HAIPER 2026

ISPAS | INTERNATIONAL SOCIETY OF PERFORMANCE ANALYSIS OF SPORT

Festival umjetne inteligencije, visokih performansi u sportu, zdravlju i dugovječnosti

Festival of AI, High Performance in Sport, Health and Longevity

15. svjetski kongres ISPAS-a o analizi performansi u sportu 2026.

15th ISPAS World Congress of Performance Analysis of Sport 2026

„Znanost i tehnologija u službi sporta, zdravlja i dugovječnosti."

"Science and Technology in the Service of Sport, Health, and Longevity."

Split, Hrvatska
Split, Croatia

12. – 15. svibnja 2026.
12–15 May 2026

ZBORNIK RADOVA

PROCEEDINGS

HRV | ENG | ZBORNIK RADOVA | *PROCEEDINGS*

INTERNATIONAL SCIENTIFIC CONFERENCE

MEĐUNARODNA ZNANSTVENA KONFERENCIJA

12 – 15 MAY 2026

SPLIT · CROATIA — 12–15 MAY 2026

HAIPER 2026

Festival of AI, High Performance in Sport, Health & Longevity

PROCEEDINGS BOOK

ZBORNIK RADOVA

Book of Abstracts & Full Papers

15TH ISPAS WORLD CONGRESS

SPLIT · CROATIA · 2026

IMPRINT

Title:

English: Proceedings Book of the International Scientific Conference HAIPER 2026 — Festival of AI, High Performance in Sport, Health & Longevity & 15th ISPAS World Congress of Performance Analysis of Sport 2026

Croatian: Zbornik radova Međunarodne znanstvene konferencije HAIPER 2026 — Festival umjetne inteligencije, vrhunske izvedbe u sportu, zdravlju i dugovječnosti i 15 svjetski kongres ISPAS-a o analizi sportske izvedbe 2026.

Conference: Festival of AI, High Performance in Sport, Health & Longevity & 15th ISPAS World Congress of Performance Analysis of Sport 2026

Venue and dates: Split, Croatia, 12–15 May 2026

Publishers:

European Institute for Talents, Education, Research & Development , Miroslava Krleže 12, 21000 Split, Croatia, Centre of Excellence, Split-Dalmatia County , Ruđera Boškovića 25, 21000 Split, Croatia

For the publishers: Željka Čagalj, Director, Ivica Zelić, Director

Editor-in-Chief: Đurđica Miletić, PhD — University of Split, Faculty of Kinesiology

Scientific Board President: Ana Kezić, PhD — University of Split, Faculty of Kinesiology

Place and year: Split, Croatia, 2026

ISBN (electronic): 978-953-47181-0-0

DOI: https://doi.org/10.5281/zenodo.20638373

Link: https://ci-sdz.hr/wp-content/uploads/2026/08/HAIPER_2026_ZBORNIK.pdf

Correspondence: email: caf.croatia@gmail.com

Keywords: artificial intelligence in sport · performance analysis · sports science · kinesiology · high performance · health and longevity · notational analysis · talent identification · machine learning · sport data analytics

© 2026 European Institute for Talents, Education, Research & Development; Centre of Excellence, Split-Dalmatia County; and the respective authors of individual contributions. All rights reserved by the authors, subject to the licence terms below.

This publication is licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International Licence (CC BY-NC-ND 4.0). The full text of the licence is available at https://creativecommons.org/licenses/by-nc-nd/4.0/legalcode. Texts were submitted by the authors in their original form. Editorial intervention is limited to typographic harmonisation and structural arrangement, in order to preserve the scientific integrity of each contribution. No content modifications were made without authors' consent. The opinions, results, and statements expressed in the papers are the sole responsibility of the respective authors.

EDITOR'S FOREWORD · PREDGOVOR UREDNIKA

PREDGOVOR

Pred vama je Zbornik radova međunarodne znanstvene konferencije HAIPER 2026 — Festival of AI, High Performance in Sport, Health & Longevity — održane u Splitu od 12. do 15. svibnja 2026. godine, u suradnji s 15. svjetskim kongresom ISPAS-a. Konferencija je okupila istraživače, doktorske kandidate, trenere i praktičare s područja analize sportske izvedbe, kineziologije, medicinskih i srodnih biomedicinskih znanosti te primijenjene umjetne inteligencije.

Zbornik je organiziran u dvije tematske cjeline. Prvi dio okuplja prihvaćene sažetke (Abstracts), uključujući usmena izlaganja i posterske prezentacije, te dodatne prihvaćene sažetke u širem spektru sportskih i biomedicinskih disciplina. Drugi dio donosi cjelovite recenzirane radove (Full Papers): izvorne istraživačke studije, sustavne pregledne radove te teorijske i metodološke priloge.

Posebnu specifičnost ovog izdanja čini primjena hibridnoga modela vrednovanja radova — kombinacije neovisnoga uredničkog peer-review postupka i AI-asistirane evaluacije po pet kriterija (znanstvena relevantnost, metodološka kvaliteta, originalnost, primjena umjetne inteligencije te kvaliteta izlaganja). Konačna odluka o nagradama ostala je u nadležnosti uredničkog odbora i programskoga vijeća doktorskoga studija.

Zahvaljujemo svim autorima koji su nam povjerili svoje radove; članovima Uredničkog odbora i Znanstvenog odbora, kao i međunarodnoj recenzentskoj komisiji, na predanosti i savjesnom radu uloženom u proces vrednovanja; te partnerskim institucijama — Europskom institutu za talente, obrazovanje, istraživanje i razvoj te Centru izvrsnosti Splitsko-dalmatinske županije — bez čije organizacijske i izdavačke potpore ovaj zbornik ne bi bio moguć.

Zbornik je urednički proizvod: sadržajno su prilozi zadržani onakvi kakve su autori dostavili, dok je tipografska i strukturna usklađenost prilagođena potrebama publikacije. Tamo gdje je rad izvorno predan na hrvatskom jeziku zadržan je u izvornom obliku; tamo gdje je rad predan na engleskom također je zadržan u izvornom obliku, čime se poštuje autorska odluka o jeziku izlaganja.

Nadamo se da će ovaj svezak biti i zabilježba sadašnjega stanja istraživanja na sjecištu performansa u sportu, zdravlja i umjetne inteligencije, i poticaj za daljnju međunarodnu znanstvenu suradnju u području.

Uredički odbor
Split, svibanj 2026.

FOREWORD

This volume presents the Proceedings of the International Scientific Conference HAIPER 2026 — Festival of AI, High Performance in Sport, Health & Longevity — held in Split from 12 to 15 May 2026, in conjunction with the 15th ISPAS World Congress. The conference brought together researchers, doctoral candidates, coaches and practitioners working at the intersection of performance analysis, kinesiology, biomedical sciences, and applied artificial intelligence.

The Proceedings are organised in two thematic parts. Part I — Abstracts gathers the accepted oral and poster contributions together with additional submitted abstracts spanning the broader spectrum of sport and biomedical disciplines represented at the conference. Part II — Full Papers contains the peer-reviewed full-length contributions: original investigations, systematic reviews, and theoretical and methodological essays.

A distinguishing feature of this edition is the application of a hybrid evaluation model that combines independent editorial peer review with an AI-assisted scoring procedure built around five criteria (scientific relevance, methodological quality, originality, AI integration and responsible use, and quality of presentation). The final decision on awards remained with the Editorial Board and the Programme Committee of the doctoral programme.

We are grateful to all authors who entrusted us with their work; to the members of the Editorial Board, the Scientific Board, and the international reviewer panel for the rigour and care they invested in the evaluation; and to our partner institutions — the European Institute for Talents, Education, Research and Development and the Centre of Excellence of Split-Dalmatia County — without whose organisational and editorial support this volume would not have been possible.

The Proceedings are an editorial product: contributions have been preserved in substance as the authors submitted them, while their typographic and structural presentation has been harmonised to suit the publication. Where a paper was originally submitted in Croatian it has been preserved in that language; where it was submitted in English it has likewise been preserved in the original, in respect of each author's editorial choice.

We hope this volume will be both a record of the current state of research at the intersection of sport performance, health and artificial intelligence, and an invitation to continued international scholarly cooperation in the field.

The Editorial Board
Split, May 2026

ORGANIZERS, PARTNERS & PATRONS · ORGANIZATORI, PARTNERI I POKROVITELJI

ORGANIZATORI / ORGANIZERS

- Regional Scientific Centre Adriatic — at the Centre of Excellence of Split-Dalmatia County
- International Society of Performance Analysis of Sport (ISPAS)
- European Institute for Talents, Education, Research & Development

U SURADNJI S PARTNERSKIM INSTITUCIJAMA / IN COOPERATION WITH PARTNER INSTITUTIONS

- Faculty of Kinesiology, University of Split · Kineziološki fakultet, Sveučilište u Splitu
- School of Medicine, University of Split · Medicinski fakultet, Sveučilište u Splitu
- Faculty of Forensic Sciences, University of Split · Fakultet forenzičkih znanosti, Sveučilište u Splitu
- Faculty of Health Studies, University of Split · Fakultet zdravstvenih znanosti, Sveučilište u Splitu
- Tallinn University, Estonia
- Universidad de Alicante, Spain
- Polytechnic "Nikola Tesla" Gospić · Veleučilište "Nikola Tesla" u Gospiću
- Croatian Paralympic Committee · Hrvatski paraolimpijski odbor
- Croatian Football Federation (HNS) · Hrvatski nogometni savez
- Association for the Establishment of the Split Sports Museum · Udruga za osnivanje Muzeja sporta grada Splita
- Sports Federation Community of Split-Dalmatia County · Zajednica sportova i udruga Splitsko-dalmatinske županije
- Para-Sport Federation of Split-Dalmatia County · Parasportski savez Splitsko-dalmatinske županije
- Split Sports Federation · Splitski savez sportova
- Para-Sport Federation of the City of Split · Parasportski savez Grada Splita
- Larus Sport d.o.o.
- International Network of Health & Sport Science

POKROVITELJI / UNDER THE AUSPICES OF

- President of the Republic of Croatia · Predsjednik Republike Hrvatske
- Ministry of Tourism and Sport of the Republic of Croatia · Ministarstvo turizma i sporta Republike Hrvatske
- Ministry of Science, Education and Youth · Ministarstvo znanosti, obrazovanja i mladih
- Croatian Diabetes Association · Hrvatski savez dijabetičkih udruga
- Split-Dalmatia County · Splitsko-dalmatinska županija
- City of Split · Grad Split
- Tourist Board of the City of Split · Turistička zajednica Grada Splita

CONFERENCE COMMITTEES

EDITORIAL BOARD

- Đurđica Miletić, PhD —University of Split, Faculty of Kinesiology, Croatia - president
- Ana Šešelja Perišin, PhD — University of Split, School of Medicine, Croatia - member
- Ivana Pavlinac Dodig, PhD —University of Split School of Medicine, Croatia - member
- Dino Mujkić, PhD — University of Sarajevo, Faculty of Sport and Physical Education, Bosnia and Herzegovina - member
- Ana Kezić, PhD — University of Split, Faculty of Kinesiology, Croatia - member
- Boriss Bazanov, PhD — School of Natural Sciences and Health, Tallinn University, Estonia – member
- Dino Belošević, PhD - University of Split, Faculty of Kinesiology, Croatia - member
- Jose Turpin, PhD — University of Alicante, Spain - member
- Marko Badrić, PhD — Faculty of Teacher Education, University of Zagreb, Croatia - member
- Ivan Krakan, PhD — Faculty of Kinesiology, University of Zagreb, Croatia - member
- Ivan Belčić, PhD — Faculty of Kinesiology, University of Zagreb, Croatia – member
- Wissem Dhahbi, PhD - University of Jendouba, Tunisia - member
- Dražen Čular, PhD - European Institute for Talents, Education, Research & Development

SCIENTIFIC COMMITTEE

- Ana Kezić, PhD — University of Split, Faculty of Kinesiology, Croatia – president
- Wissem Dhahbi, PhD - University of Jendouba, Tunisia - member
- Marino Vilović, PhD — University of Split, School of Medicine, Croatia - member
- Benjamin Benzon, PhD — University of Split, School of Medicine, Croatia - member
- Boriss Bazanov, PhD — School of Natural Sciences and Health, Tallinn University, Estonia - member
- Jose Turpin, PhD — University of Alicante, Spain - member
- Johnny Padulo, PhD — Department of Biomedical Sciences for Health, University of Milan, Italy - member
- Franjo Lovrić, PhD — Faculty of Sports and Physical Education, University of Mostar, Bosnia and Herzegovina - member
- Lidija Zekan-Petrinović, PhD — Faculty of Kinesiology, University of Zagreb, Croatia - member
- Goran Vučković, PhD — Faculty of Sport, University of Ljubljana, Slovenia - member
- Goran Munivrana, PhD — University of Split, Faculty of Kinesiology, Croatia - member
- Diana Aranza, PhD — Faculty of Health Studies, University of Split, Croatia - member
- Ana Ćurković, PhD — Faculty of Health Studies, University of Split, Croatia – member

PROGRAM COMMITTEE

- Marijana Čavala, PhD — University of Split, Faculty of Kinesiology, Croatia – president
- Wissem Dhahbi, PhD - University of Jendouba, Tunisia - member
- Nic James, PhD — Middlesex University, London, UK - member
- Nimai Parmar, PhD — Middlesex University, London, UK - member
- Armin Paravlić, PhD — University of Ljubljana, Faculty of Sport, Slovenia - member
- Kristina Drole, PhD — University of Ljubljana, Faculty of Sport, Slovenia - member
- Marko Kumrić, PhD — University of Split, School of Medicine, Croatia - member
- Doris Rušić, PhD — University of Split, School of Medicine, Croatia - member
- Igor Jelaska, PhD — University of Split, Faculty of Kinesiology, Croatia – member
- Alen Miletić, PhD — University of Split, Faculty of Kinesiology, Croatia - member

- Sunčica Delaš Kalinski, PhD — University of Split, Faculty of Kinesiology, Croatia - member
- Mario Tomljanović, PhD — University of Split, Faculty of Kinesiology, Croatia - member
- Branislav Šutić, PhD — University of Applied Sciences "Nikola Tesla", Gospić, Croatia - member
- Damir Primorac, PhD — University of Split, Faculty of Forensic Sciences, Croatia – member
- Željko Kovačević, PhD — Faculty of Health Studies, University of Split, Croatia - member
- Zorana Bašić Plazibat — Centre of Excellence of Split-Dalmatia County, Croatia - member
- Matea Čular — Centre of Excellence of Split-Dalmatia County, Croatia - member
- Karla Bajaj — Centre of Excellence of Split-Dalmatia County, Croatia – member

ORGANIZING COMMITTEE

- Ivica Zelić — Centre of Excellence of Split-Dalmatia County, Croatia – president
- Joško Božić, PhD - University of Split, School of Medicine, Croatia - member
- Renata Pecotić, PhD — University of Split, School of Medicine, Croatia – member
- Mario Podrug, PhD — Faculty of Health Studies, University of Split, Croatia - member
- Dino Belošević, PhD - University of Split, Faculty of Kinesiology, Croatia - member
- Jelena Paušić, PhD — University of Split, Faculty of Kinesiology, Croatia - member
- Hrvoje Kujundžić — University of Split, Faculty of Kinesiology, Croatia - member
- Mirjana Milić, PhD — University of Split, Faculty of Kinesiology, Croatia - member
- Tea Gutović, PhD — University of Split, Faculty of Humanities and Social Sciences, Croatia - member
- Ivan Granić — University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Croatia - member
- Vladimir Ivančev, PhD — University of Split, Faculty of Kinesiology, Croatia - member
- Ante Burger, PhD — Faculty of Health Studies, University of Split, Croatia - member
- Josefina Đuzel, PhD — University of Split, Faculty of Kinesiology, Croatia - member
- Ana Majić — Centre of Excellence of Split-Dalmatia County, Croatia - member
- Jelena Galić — Centre of Excellence of Split-Dalmatia County, Croatia – member
- Ante Barbarić — Centre of Excellence of Split-Dalmatia County, Croatia - member
- Toni Jagnjić — Centre of Excellence of Split-Dalmatia County, Croatia - member

INTERNATIONAL DOCTORAL SCHOOL COMMITTEE

- Prof. Dražen Čular, PhD, Chair of the International Doctoral School Committee · University of Split, Faculty of Kinesiology
- Prof. Katarina Vukojević, PhD, Vice-dean for Science · University of Split, School of Medicine
- Prof. Ana Ćurković, PhD, Vice-dean for Science · University of Split, Faculty of Health Studies
- Prof. Tomislava Pavić Kramarić, PhD, Vice-dean for Science · University of Split, Faculty of Forensic Sciences
- Assist. Prof. Goran Kuvačić, PhD, Vice-dean for Science · University of Split, Faculty of Kinesiology

CONTENTS

ABSTRACTS 10
An Exploratory Study to Identify Field-Setting Patterns and Evaluate their Impact on Team Performance to Optimise Match Strategies in Men's T20I Cricket 11
The Development and Evaluation of an AI-based System to Support Coach Decision-making During Football Games. 12
Defensive shift limits did not increase sprinting distance for outfielders to get batter-runners out in US Major League Baseball 13
Offensive Teamwork Intensity in High-Level Men's Basketball 14
Sports participation of Icelandic golfers born between 1940 and 2017 15
Effectiveness of defensive behaviours against kicks and punches in Malay Silat 16
Possession length and passing rate in Euro 2025 soccer 17
Analysis Of Rallies in Women's Volleyball Across Three Age Categories: Effect of Point Type, Rotation, and Rally Phase 18
Intra-positional variability in position-specific tactical competencies among elite youth football wingers: exploratory age-group differences 19
Artificial intelligence in sport: sociocultural implications for contemporary sports systems 20
Pace of the game: Analysis of European Men's National championships (2011–2025) 21
Positional scoring differences across age groups in Greco-Roman wrestling 22
Availability of Players is Associated with Success in Football 23
AI-Assisted Evaluation of Research Articles: A Hybrid Framework for Objective and Scalable Scientific Ranking 24
FULL PAPERS (ENGLISH LANGUAGE) 25
The effects of music tempo and dominant perceptual learning mode on dance performance 26
Different pathways to health: gender and nutritional differences in adolescence 35
Performance analysis in volleyball – violation of sample independence in multiple regression analysis 47
Determinants of the concept of transformative training in sport – a theoretical foundation for practice 52
Decoding age effects: motor performance with and without the ball in youth soccer 64
Cortisol Dynamics and Sinclair Performance in Female Weightlifters 74
Effects of Racket Sports on Physical, Psychological, and Social Outcomes in Individuals with Disabilities: A Systematic Review and Meta-Analysis 78
High-intensity interval training in female soccer players: a systematic review 84
The impact of sport on the education of children and youth: a kinesiological review 92

Fitness profiles of croatian soccer players: a systematic review....106
Kinesiology for the 21st Century (Review Paper)....118
Biological Age as a Hidden Moderator in Youth Sport Talent Identification: Skeletal Age Profiles of Club-Selected Athletes in Split, Croatia....128
The influence of situational parameters on success in the 2021/2022. Premier league season....133
Notational analysis in football: a review paper....138
Fifteen Olympic Medals per Million: Croatia's Overperformance versus Four of the World's Largest Nations under a Symmetric 1992–2024 Window....145
Anaerobic Performance Profiling in Recreational Boxers Using a 30-s Continuous Jump Test and a 30-s Punching-Bag Test....150
Prevention, rehabilitation and recovery in amateur football situation analysis in croatia....157
The use of artificial intelligence for statistical data processing in kinesiology....163
Motor and technical determinants of competitive success in croatian female cadet kumite athletes....171
Personality traits across playing positions in Croatian female cadet handball players....175
FULL PAPERS (CROATIAN LANGUAGE)....179
Učinci sportova s reketom na fizičke, psihološke i socijalne ishode kod osoba s invaliditetom: sustavni pregled i meta-analiza....180
Utjecaj sporta na odgoj djece i mladih: kineziološki pristup i relevantna istraživanja....193
Fitnes profili hrvatskih nogometaša: sustavni pregled....208
Intra-parna varijabilnost antropometrijskih i funkcionalnih karakteristika kod blizanaca u taekwondou....219
Personalizirana tjelovježba u suportivnoj skrbi i liječenju malignih oboljenja: ogledni primjer iz Sveučilišne bolnice u Kölnu, Centar za integrativnu onkologiju....226
Učinci plesnih aktivnosti na antropološki status djece s teškoćama u razvoju: sustavni pregled....229
Hibridni AI-asistirani model ocjenjivanja u parapoomsae disciplinama: integracija funkcionalnog profiliranja, sustava podrške sucima i ponderiranog modela odlučivanja....236
Pojavnost i lokalizacija boli i ozljeda koljenog zgloba kod odbojkaša i odbojkašica....243
Metrijske karakteristike i procjena psiholoških značajki perfekcionizma i optimizma u nogometu....254
Relativna dob i biološka zrelost kao zajednički prediktori selekcije talenata u sportu mladih: dokazi iz višeklupske kohorte u Splitu, Hrvatska....264

PART I · DIO I

ABSTRACTS

Accepted abstracts — oral & poster presentations · Prihvaćeni sažetci — usmena i posterska izlaganja

ABSTRACT 1

SCIENTIFIC PAPER

An Exploratory Study to Identify Field-Setting Patterns and Evaluate their Impact on Team Performance to Optimise Match Strategies in Men's T20I Cricket

Dhanur Bhardwaj[1,2], Simon A. Feros[1,2], Wei Luo[3], Dene Hills[4], Rahat Kulshreshtha[5], Manuyash Chaudhary[5], Dan B. Dwyer[1,2]

[1]School of Exercise & Nutrition Sciences, Deakin University, Geelong, Australia; [2]Centre for Sport Research, Institute for Physical Activity and Nutrition, Deakin University, Geelong, Australia; [3]School of Information Technology, Deakin University, Melbourne, Australia; [4]Cricket Australia, 20 Greg Chappell St, Albion Queensland 4010; [5]Quidich Innovation Labs, Mumbai, India

Background: In both research and practice, performance analysis in cricket has traditionally focussed on bowling and batting, with limited attention given to fielding. Studies analysing fielding performance have mainly assessed outcome-based measures such as catches, run outs, stumpings, and runs saved. However, there is currently no evaluation of tactical fielding performance using fielder location data to understand how fielder positioning influence team performance.

Objective: The primary aim of the study was to identify and describe typical placement of fielders (field-setting patterns) in men's T20 International (T20I) cricket. The secondary aim was to determine the association between field-setting patterns and measures of team performance.

Methods: Fielder location data (x-y coordinates) for all fielders were collected for each delivery (n = 115,370) during the ICC Men's T20 Cricket World Cup 2024 using computer vision technology from a high-resolution camera operating at 25Hz. The data were cleaned and reprocessed as the angle and distance of each fielder (per delivery) to the centre of the cricket pitch. This resulted in 10,183 observations with 22 variables (both angle and distance for 11 fielders per delivery). To address the primary aim, Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN) was applied to identify a set of discrete field-setting patterns. For the secondary aim, regression analysis was conducted to evaluate the relationship between field-setting patterns and measures of team performance.

Results: The study identified 21 commonly employed field-setting patterns, some of which were significantly associated with rates of dot balls, boundaries and runs conceded. Among the identified field-setting patterns, 11 were used during powerplay overs, and 10 during non-powerplay overs.

Conclusion: This is the first study to use fielder location data to evaluate tactical fielding performance in cricket. The identified field-setting patterns support more informed strategic decision-making processes, potentially influencing team performance.

ABSTRACT 2

SCIENTIFIC PAPER

The Development and Evaluation of an AI-based System to Support Coach Decision-making During Football Games.

Dan B Dwyer [1] & Mitchell F Aarons [2]

[1]Centre for Sport Research, Deakin University, Australia. [2]Sydney Swans Australian Football Club, Australia.

Background: Advances in technology and the growing availability of data in elite sport have improved the ways in which coaches' decision-making can be supported. During matches, elite Australian Football (AF) coaches must make rapid, high-stakes decisions while processing large amounts of information. Artificial intelligence (AI) offers opportunities to enhance these decisions under time pressure, which may enhance team performance.

Objective: To understand elite AF coaches' in-match decision-making needs, develop an AI-based decision support system tailored to those needs, and examine its effectiveness and implementation in professional environments.

Methods: Study 1 involved interviews with six elite AF head coaches. Reflexive thematic analysis was used to identify how they make decisions, barriers they face, and perceptions of AI support. Study 2 used 168 technical performance indicators from each minute of 829 professional league (AFL) matches to train real-time match outcome prediction models. These models were integrated into an automated suggestion algorithm, validated, and deployed in a decision support system used live by two AFL clubs. Study 3 combined observational field notes, system usage tracking, and interviews with analysts and coaches to evaluate system implementation.

Results: Coaches followed a six-stage decision-making process, combining intuition with inputs from staff and objective data. They were open to AI support when aligned with coaching needs. A performance-indicator-based model predicted match outcomes as effectively as a score-based model. Algorithm suggestions led to wins nearly four times more often when followed. Use of the system varied over time, and five key enablers and challenges for implementation were identified.

Conclusion: AI-based decision support can integrate effectively into elite AF coaching and influence decision outcomes. Coaches viewed it as valuable, though improving the clarity and actionability of suggestions is essential. Iterative, user-centred design is critical, and findings may apply to other sports with time-pressured decisions.

ABSTRACT 3

SCIENTIFIC PAPER

Defensive shift limits did not increase sprinting distance for outfielders to get batter-runners out in US Major League Baseball

Mamiko Kato[a,b], Toshimasa Yanai[c,d]

[a]Faculty of Health and Sports Sciences, Toyo University, Tokyo, Japan; [b]Waseda Institute for Sport Sciences, Waseda University, Saitama, Japan; [c]Faculty of Sport Sciences, Waseda University, Saitama, Japan; [d]Research Institute of Baseball Science, Waseda University, Saitama, Japan

Purpose: Since 2023, Major League Baseball (MLB) has banned drastic defensive starting point changes ("shifts"). The defensive shift limits increase the area that outfielders need to cover, aiming to have fielders showcase their athleticism. However, their impact on outfielders' performance remains unknown. Therefore, we examined whether outfielders' performance differed before and after the shift limit was implemented in MLB.

Methods: Using tracking data from MLB games in 2021–2025, we analyzed 171,670 batted balls that flew >50 m with no runners on base. The distance and direction of each ball's landing point were calculated from the average starting point of each outfielder and categorized the direction as forward, right, backward, or left. To describe the time available to outfielders, each ball's hang-time index was determined based on the distance to the landing point from home plate and vertical launch velocity. A generalized linear mixed-effects model was used to compare the distance covered by outfielders at a given hang-time index to get batter-runners out before and after the shift limit implementation and test whether the following two interaction effects on batting results (base hit vs. out) were significant: (i) distance and the shift limit implementation and (ii) direction and the shift limit implementation. The hang-time index, defensive team, and ballpark were included as covariates. Models were constructed separately for each outfield position and batter handedness.

Results: The models explained the variance in the batting results well (conditional $R2 = 0.903–0.926$). No significant interactions were found in any outfield position or batter handedness ($\exp(\beta)$ range: 0.74–1.36; $p > .070$).

Conclusions: Our findings showed that the distance covered by outfielders at a given hang-time index did not systematically increase in any direction after the shift limit implementation. This suggests that the shift limits did not increase sprinting distance for outfielders in MLB.

ABSTRACT 4

SCIENTIFIC PAPER

Offensive Teamwork Intensity in High-Level Men's Basketball

Boris Bazanov

Tallinn University, Estonia

Background: Quantifying teamwork in basketball remains a methodological challenge in performance analysis. Our previous studies led to the development of an analytical framework for assessing offensive teamwork intensity, enabling the evaluation of team structure, the identification of turnover-related factors, and the detection of performance patterns derived from game data. Prior findings indicated that higher teamwork intensity during macro ball possessions was associated with greater offensive success.

Objective: The purpose of this study was to examine the parameters associated with offensive teamwork intensity in elite men's basketball.

Methods: Performance data were collected from the quarterfinalists of the 2025 European Men's Basketball Championship. A total of 891 macro ball possessions from six games (four quarterfinals and two semifinals) were analyzed using a previously validated analytical system designed to quantify the structure and intensity of offensive teamwork. Differences in teamwork intensity between successful and unsuccessful macro possessions were examined using an independent-samples t test. Statistical significance was set at $p < .05$.

Results: The mean teamwork intensity index across all analyzed possessions was 0.72 (SD = 0.24). Successful macro ball possessions demonstrated significantly higher teamwork intensity (M = 0.77, SD = 0.29) compared with unsuccessful possessions (M = 0.71, SD = 0.29), t test, p = .003.

Conclusion: Greater offensive teamwork intensity is associated with increased success in elite men's basketball. Enhancing structured team interactions during offensive play may therefore contribute to improved competitive performance.

ABSTRACT 5

SCIENTIFIC PAPER

Sports participation of Icelandic golfers born between 1940 and 2017

Peter O'Donoghue[1], Auður Inga Þorsteinsdóttir[2], Hafrún Kristjánsdóttir[1], Elías Atlason[3]

[1]Haskólinn í Reykjavík, [2]Ungmennafélag Íslands, [3]Íþrótta og Ólympíusamband Íslands

Background: Exercise is beneficial to the health and well-being of older people. Golf is a popular sport in Iceland that is participated in by people of all ages.
Objective: The purpose of the current investigation was to compare sports participation of female and male golfers classified into 3 age groups based on year of birth; born 1940-1964, born 1965-1985 and born 1986-2017. Sports participation includes other sports done by the golfers.

Methods: Anonymised registration data were provided by Ungmennafélag Íslands (UMFÍ) and Íþrótta og Ólympíusamband Íslands (ÍSÍ) for the years 2003 to 2024 inclusive. There were 47,123 golfers; 15,323 females and 31,800 males. Transfers between sports were counted where a player started the doner sport before the recipient sport and ceased the doner sport before the recipient sport.

Results: There was a steady increase in participation of the males in golf from the ages of 25 to 70 years. By contrast the female golfers born from 1973 to 1988 showed a pronounced increase in participation during 2021 to 2023 irrespective of age. All groups made net transfers into golf with the younger groups showing transfers from gymnastics to team games at the ages of 10 or 11 on average and subsequent transferring from team games to golf at the ages of 17 to 19 on average. The older age groups included some transferring from golf to organised social activities during their 70s.

Conclusion: These results suggest that golf has an important role in promoting active lifestyles for all ages.

ABSTRACT 6

SCIENTIFIC PAPER

Effectiveness of defensive behaviours against kicks and punches in Malay Silat

Dahlia Al Syurgawi[1], Gemma Robinson[1], Peter O'Donoghue[2]

[1]Cardiff Metropolitan University, UK, [2]Reykjavik University, Iceland.

Background: Malay Silat is a combat sport that involves diverse technical skills elements with both defence-oriented and offence-driven strategies. Silat Tempur is a developmental version of the sport designed to prepare novices for Silat Olahraga, the traditional form of discipline. The offensive behaviours used in Silat include punches, kicks, sweeps and scissors. Defensive behaviours can be broadly classified as contact defence (catch, leg-raise, parry, push, self-release, topple-down) and non-contact defence (dodge, evade, jump, retreat).

Objective: The purpose of the current investigation was to compare the success of kicks and punches when different defensive behaviours were applied.

Methods: This study analysed 80 Silat Tempur matches (28 female and 52 male) and 62 Silat Olahraga matches (23 female and 39 male) using Fulcrum Angles version 1200.37. The strength of inter-operator agreement was very good for Silat Olahraga (= 0.876 to 0.925) and moderate to very good for Silat Tempur (= 0.519 to 0.850). The data was processed to determine the percentage of kicks and punches that hit the target when the opponent applied contact defence, non-contact defence, and no defensive behaviour. Freidman tests compared the percentage of kicks (and punches) that were successful when these three defensive alternatives were applied.

Results: There was no defensive behaviour in between 60.2% and 96.0% of attacks faced, depending on gender, Silat version, and whether the attack was a kick or a punch. As expected, there was a higher percentage of kicks and punches that were successful when no defensive behaviour was offered. However, these differences were not significantly different for kicks ($p >= 0.602$) or punches ($p >= 0.078$).

Conclusion: These results suggest that the outcomes of Malay Silat match depend more on offensive behaviours than defensive behaviours.

ABSTRACT 7

SCIENTIFIC PAPER

Possession length and passing rate in Euro 2025 soccer

Kamilla Brá Brynjarsdóttir[1], Peter O'Donoghue[1]

[1]Reykjavik University, Iceland.

Background: There has been academic debate about the most productive styles of play in soccer. Playing style can be characterised by the length of possessions and passing rate.

Objective: The purpose of the current investigation was to compare the success of possessions of different lengths and passing rates during the women's Euro 2025 soccer tournament.

Methods: Statsbomb data for all 31 matches were processed to determine the frequency and percentage success of different types of possession. Pass rate was determined for possessions of 5 or more passes. A possession had a high pass rate where one or more passes were played per 3s, otherwise possessions were classified as having a low pass rate. Friedman tests with follow-up Durbin-Conover pairwise comparisons were used to compare the different types of possessions in terms of percentages that reached the penalty area and resulted in a shot.

Results: The mean(+SD) number of possessions for a team within a match was 87.8+5.4. Of these, 20.3+3.5 were of 0-1 pass, 36.9+6.8 were 2-4 passes, 6.0+1.8 were 5-8 passes with a high pass rate, 12.4+3.1 were 5-8 passes with a low pass rate, 3.4+3.3 were 9 or more passes with a high pass rate and 8.7+3.9 were 9 or more passes with a low pass rate. Possession type had a significant effect on the percentage of both outcomes ($p < 0.001$). There were 44.1+14.3 and 25.4+10.4 possessions of 9 or more passes with a low pass rate leading to a penalty area entry or shot respectively. These were significantly higher than the percentages for all other types of possession ($p <= 0.010$ for penalty area entries and $p <= 0.025$ for shots).

Conclusion: These results provide evidence that a slow build-up possession style is more productive in women's international soccer than direct or rapid passing styles.

ABSTRACT 8

SCIENTIFIC PAPER

Analysis Of Rallies in Women's Volleyball Across Three Age Categories: Effect of Point Type, Rotation, and Rally Phase

Sotirios Drikos[1], Alexandra Pantazi[1], Aliki Pagkalou[1], Roza-Maria Nakou[1], George Giatsis[2]

[1]National and Kapodistrian University of Athens/School of Physical Education and Sport Science; [2]Aristotle University of Thessaloniki/School of Physical Education and Sport Science

Background: In volleyball, rallies are categorized as side-out points (SoP) or break points (BP) based on whether they begin with service reception or serving.

Objective: This study examined the dependency of rally outcomes (win-loss) on point type, rotation (Rot1–Rot6), and terminal rally phase (net-crossings, NC) across U17, U22, and Women's categories to evaluate tactical evolution.

Methods: A total of N=9,247 rallies of the first eight teams in final ranking from Olympic Games 2021 and European Championships were analyzed using descriptive statistics and $\chi 2$ tests of independence. Hierarchical log-linear analysis evaluated interactions between outcome, rotation, and point type to identify situational efficiencies.

Results: Significant dependencies between outcome and point type occurred across all categories ($p < 0.001$). The SoP advantage was most pronounced in the Women's category (61.0%, Cramer's V=0.220), followed by U17 (55.4%, Cramer's V=0.109) and U22 (Cramer's V=0.095). "Game speed" (rallies decided within 2 NC) increased from U17 to Women (71.2%), while U17 had the most prolonged rallies (14.5% at 4+ NC) compared to U22 (8.1%). Log-linear analysis identified a non-significant three-way interaction ($p = 0.996$), suggesting a stable tactical structure across age groups. Conversely, a significant two-way interaction between rotation and point type ($p < 0.001$) confirmed success is a conditional product of the tactical state. Standardized residuals highlighted developmental shifts: U22 showed a positive SoP deviation in Rot3 (Residual 21.5), U17 in Rot4 (Residual 34.5), and Women in Rot6 during the BP phase (Residual 35.4), indicating Rot6 is a highly effective serving/counterattacking phase at elite level.

Conclusion: Teams maintain a side-out advantage regardless of rotation. The brevity of most rallies indicates that initial phases are critical for outcomes. The application of log-linear modeling effectively uncovers conditional hotspots, providing a tactical roadmap for high-level coaching and competition.

ABSTRACT 9

SCIENTIFIC PAPER

Intra-positional variability in position-specific tactical competencies among elite youth football wingers: exploratory age-group differences

Wilder Geovanny Valencia Sánchez[1,2], João Araújo[1], Lucas Soares[1], João Ribeiro[1,3], José Guilherme[1,3], Paul Larkin[4,5], Daniel Barreira[1,3]

Faculty of Sport, University of Porto, Porto, Portugal[1]; Research Group in Physical Activity and Sport Sciences (GRICAFDE), Institute of Physical Education and Sport, Universidad de Antioquia, Medellín, Colombia[2]; Centre for Research, Education, Innovation and Intervention in Sport (CIFI2D), University of Porto, Porto, Portugal[3]; Institute for Health and Sport, Victoria University, Melbourne, Australia[4], MSA Research Centre, Maribyrnong Sports Academy, Melbourne, Australia[5].

Background: Tactical performance is a critical component of football expertise, particularly in position-specific roles such as wingers, where decision-making and contextual adaptability are essential. Despite growing interest in position-specific analysis, limited evidence exists on intra-positional variability and its evolution across development stages. Examining position-specific tactical competencies provides insight into players' contextualised behaviours and decision-making.

Objective: To analyse intra-positional variability in position-specific tactical competencies among elite youth wingers and explore differences between two age groups.

Methods: An observational study was conducted on elite youth players from the Portuguese national teams competing in the UEFA European Championship finals (U19, n=2 matches; U17, n=3 matches). Four wingers met the inclusion criterion (≥50% of total playing time). A validated ad hoc observational instrument was applied across four phases of play (offensive and defensive organisation, and transitions), identifying 1,226 temporal strata and 786 coded position-specific tactical competencies. Intra-observer reliability was generally high, whereas inter-observer reliability ranged from low to excellent depending on tactical indicators. Tactical performance was quantified using efficacy scores derived from positive and negative actions. Hierarchical cluster analysis and descriptive statistics were performed.

Results: Findings revealed clear intra-positional variability, with distinct position-specific tactical profiles among wingers. Cluster analysis identified differentiated behavioural patterns rather than homogeneous positional performance. Overall efficacy scores appeared comparable between U17 and U19. However, U17 players tended to show greater behavioural involvement across phases of play, particularly in defensive organisation, transitions, and ball control under high-pressure contexts. U19 players displayed more selective involvement, with slightly higher efficacy in some offensive actions, without a consistent pattern. Overall, U17 players performed more actions, whereas U19 players showed higher efficacy with lower frequency.

Conclusion: Elite youth wingers exhibit meaningful intra-positional variability, suggesting differentiated tactical profiles within position-specific competencies. Differences between age groups were exploratory, highlighting the importance of nuanced, position-specific talent development approaches.

Acknowledgments: This work is funded by national funds through FCT – Foundation for Science and Technology, I.P., under the project UID/2025.03434.BD

ABSTRACT 10

SCIENTIFIC PAPER

Artificial intelligence in sport: sociocultural implications for contemporary sports systems

Tea Gutović; Matea Čular; Toni Popović

Faculty of Humanities and Social Sciences, Split, Croatia, Department of Sociology; Centre of Excellence of Split-Dalmatia County, Croatia; Faculty of Humanities and Social Sciences, Split, Croatia, Department of Sociology

This study explores the role of artificial intelligence in contemporary sport, with particular emphasis on its effects on performance analysis, decision-making, and the transformation of professional and organizational practices. It further examines how the application of AI tools reshapes the management of sports processes and restructures relations of power, control, and authority within sports systems. Drawing on Foucault's concepts of surveillance and discipline, the paper conceptualizes algorithmic systems as contemporary technologies of governance that shape regimes of visibility, evaluation, and normalization of athletes. The study is based on a theoretical review of relevant literature in artificial intelligence, sport sciences, and social theory. The analysis shows that artificial intelligence enables more precise assessment of performance, injury prediction, and training optimization, while also introducing new forms of standardization, quantification, and surveillance. These processes transform expert roles, as authority increasingly rests on the interpretation of data and algorithmic outputs, thereby reshaping professional hierarchies and criteria of expertise. At the same time, the use of artificial intelligence influences interactions within sports clubs at all levels. Communication between athletes, coaches, analysts, and management is increasingly mediated by digital systems and data platforms, altering patterns of collaboration, authority, and decision-making. While such mediated relationships may enhance efficiency and transparency, they also reduce direct communication and raise questions of trust, autonomy, and data interpretation in everyday practice. Despite the significant functional advantages of artificial intelligence in sport, the paper emphasizes the need for a critical and reflexive approach to its implementation. It is necessary to consider broader social and ethical implications, including issues of surveillance, the distribution of power, and the transformation of professional identities in the context of the growing integration of AI technologies in sport.

ABSTRACT 11

SCIENTIFIC PAPER

Pace of the game: Analysis of European Men's National championships (2011–2025)

Sotirios Drikos, Panagiotis Meletakos, Anastasia Papavasileiou, Aliki Makri, Magdalini Kepesidou, Konstantinos Noutsos

National and Kapodistrian University of Athens/School of Physical Education and Sport Science

Background: In handball, the evolution of the sport is related to the development of performance-related sciences, the rise of professionalism, and the significant changes that rule modifications introduce to the game.

Objective: The purpose of this study was to record and analyze final match scores as an indicator directly linked to the pace of the match.

Methods: Analysis was based on N=34,548 scores from 14 European championships (2011/12–2024/25). A one-way ANOVA assessed seasonal changes in mean goals per match. Significant main effects were further analysed using Fisher's LSD post hoc tests. Statistical significance was set at $p < 0.05$, with effect sizes estimated via partial eta squared (η_p^2).

Results: The analysis showed a statistically significant effect of the season on the number of goals ($F\,(12,169) = 11.2, p < 0.001, \eta_p^2 = 0.44$), suggesting significant variations in offensive productivity between the 2011/25 seasons. The average number of goals remained stable from the 2011/12 season through the 2020/21 season. In contrast, a clear upward trend has been observed since the 2021/22 season. Post hoc comparisons showed that 2021/22, 2022/23, 2023/24, and 2024/25 had a statistically significantly higher number of goals compared to most periods prior to 2020/21 ($p< 0.05$ to $p< 0.000001$). Overall, the average number of goals increased from approximately 55.4 goals per match in 2011–2012 to 59.9 goals in 2024–2025, confirming a clear increase in offensive productivity in recent years.

Conclusion: The development of the pace of the game should be analyzed from multiple perspectives. Tactical choices, their complexity, the ability to make decisions under pressure, and the characteristics of the athletes are factors that should be reconsidered by the sports experts.

ABSTRACT 12

SCIENTIFIC PAPER

Positional scoring differences across age groups in Greco-Roman wrestling

Kristijan Slačanac[1], Milorad Dokmanac[2]

Ministry of Tourism and Sport, Zagreb, Croatia[1], College of Higher Vocational Studies "Sports Academy", Belgrade, Serbia[2]

Background: Performance in Greco-Roman wrestling is strongly influenced by the distribution of scoring actions across positional phases, particularly standing and parterre situations. Previous research has primarily focused on overall scoring or specific age categories, while less attention has been given to how positional scoring patterns evolve across the developmental pathway.

Objective: The aim of this study was to examine age-related differences in positional scoring patterns (standing vs. parterre) in Greco-Roman wrestling.

Methods: The dataset included matches from official United World Wrestling World Championships (2025) across four age groups (U17, U20, U23, and seniors). For inferential analysis, only wrestlers with ≥2 bouts were included (n = 579). Positional scoring was expressed as the percentage of total points scored in standing and parterre situations. Differences between age groups were assessed using the Kruskal–Wallis test, followed by Dunn's post hoc comparisons.

Results: Significant age-group differences were observed for both standing ($H = 7.83$, $p = 0.049$) and parterre scoring ($H = 7.84$, $p = 0.049$). Post hoc analysis indicated that U17 wrestlers achieved a significantly higher proportion of points in standing positions compared to U20 ($p < 0.05$), while U20 wrestlers demonstrated greater reliance on parterre scoring. No significant differences were found between U23 and senior wrestlers.

Conclusion: The results indicate a shift in positional scoring patterns across age groups, with younger wrestlers relying more on standing actions and older categories demonstrating increased use of parterre scoring. These findings suggest a transition toward more controlled and tactically structured scoring strategies with age, which may have important implications for age-specific training design.

ABSTRACT 13

SCIENTIFIC PAPER

Availability of Players is Associated with Success in Football

Jinying Jiang[1], Daniel Link[1,2]

Technical University Munich, Experimental Exercise Science, Munich, Germany[1], Munich Data Science Institute, Munich, Germany[2]

Availability in football refers to the probability that a selected player can successfully receive a pass from a teammate. This study explores how performance indicators derived from Availability (AV) are connected to success in football. Therefore, we used spatiotemporal tracking data of 47 German Bundesliga matches, containing 45,332 passes. Availability was calculated for each moment that a player has individual ball possession and for all players of his team. The quantification is based on a mixture of physical models and machine learning algorithms. Results show that passing success rate is significantly correlated (r=.3) with Availability of the receiver. Also, Availability was significantly ($p < .05$, $d = 0.14$) higher on successful passes (AV=.84) compared to situation in which the ball carrier loses the ball (AV=.59). Analysis of turnovers revealed that number of Players Available (PA) was significantly higher ($p < .05$, $d = 0.68$) in successful turnovers (PA=4.7) compared to turnovers with direct ball loss (PA=3.9). In addition, the team's average longitudinal space gain following a turnover is associated with the number of Players Available. For example, mean space gain after 5 seconds was 5.9 m when only one teammate was available, compared to 10.9 m when three teammates were available ($p < .05$, r=0.3). We conclude that Availability is associated with success on sub-aim level in football. These results provide an empirical justification to use Availability for match analysis.

ABSTRACT 14

SCIENTIFIC PAPER

AI-Assisted Evaluation of Research Articles: A Hybrid Framework for Objective and Scalable Scientific Ranking

Dražen Čular[1,2], Ivica Zelić[3], Dino Bellošević[1,2]

[1] University of Split, Faculty of Kinesiology, Cro Sport Talent & Health and Longevity lab, Split, Croatia, [2] European Institute for Talents, Education, Research & Development, Split Croatia; [3]Center of Excellence of Split-Dalmatia County

Purpose: The increasing use of artificial intelligence (AI) in scientific research requires structured and transparent evaluation models. Traditional peer-review systems are limited by subjectivity, variability among reviewers, and scalability challenges. This study aims to develop and implement a hybrid AI-assisted evaluation framework.

Methods: The HAIPER model integrates AI-supported analytical assessment with independent peer review. A 100-point scoring system was applied across five dimensions: relevance, methodology, innovation, AI use, and communication. AI analysed coherence, methodology, novelty, and ethical transparency.

Results: The model improved scoring consistency and reduced reviewer variability. AI enabled detection of methodological weaknesses and lack of transparency. The framework improved evaluation efficiency across interdisciplinary domains.

Conclusions: The HAIPER framework provides a scalable and transparent evaluation model. AI enhances peer review while preserving human expertise.

PART II · DIO II

FULL PAPERS (ENGLISH LANGUAGE)

Peer-reviewed full papers · Cjeloviti recenzirani radovi

FULL PAPER 1

SCIENTIFIC PAPER

The effects of music tempo and dominant perceptual learning mode on dance performance

Katarina Šimunović, Alen Miletić, Danijela Zjačić Puljiz, Đurdica Miletić

University of Split, Faculty of Kinesiology Split, Croatia

Introduction

Movement consistency connected with accurate tempo of performance is considered a key facet of expert performance. According to Gentile (2000), initial learning is typically based on trial and error, and movements are not very efficient and reproducible. The higher stages of learned motor skills are characterized by higher economy of effort, higher adaptability to the demands of the specific task, and higher consistency. The tempo of performance represents the basis for the improvement of movement consistency through the stages of motor learning. If the athlete has a task to focus on accuracy, he will most likely reduce his execution speed (Schmidt et al., 2019). The ability to coordinate movements to musical rhythms is an essential skill for dancers. The tempo of performance is set by the beat of the music, which is especially demanding for beginners. It is assumed that at the beginning of learning novices will perform dance steps more correctly in a slower tempo. In the initial stage of learning, it is important to understand the structure of movement in dance, while in the later stages of learning, the focus is predominantly on correcting errors and perfecting dance movements. The ultimate goal is to achieve automated, sophisticated performance of movements in accordance with the music. Accurate performance of dance steps with a faster tempo of music generally implies a higher stage of motor learning in dancers. In the final stages of learning, the focus is most often on aesthetic expression and movement expression that will emphasize the character of music and choreography. Therefore, it is characteristic of the dance learning that the first steps are performed in a slower rhythm with clapping or slower tempo music. Previous research analyzing tempo of music and quality of dance performance is rare and mostly conducted on samples of experienced dancers (Shen & Hirayama, 2025; Burger and Wollner, 2023), and do not analyze perceptual modes of learning in the cognitive stage (Burger et al., 2014). Moelants (2002) determined preferred tempo of music between 120 and 125 bpm as the natural tempo of tapping, clapping or walking. This tempo can be associated with the natural speed of repetitive movements and therefore probably the optimal tempo for learning dance steps. There is a lack of research examining how changing the tempo of music, and thus the rhythm of movements, would affect the quality of performance and the learning process in dance. An aggravating research circumstance is that sports dances are performed in pairs, and in previous research, gender differences in dance performance for novices have been established (Miletic, Miletic & Uzunovic, 2023), which further complicates the process of planning learning in dance. In view of the above, the prominent problem of the research is to determine whether there are differences by gender in the successful performance of dance in relation to the tempo of performance in the initial stage of learning. Based on research analyzing the effects of contextual interference (Czyż, Wójcik, Solarská & Kiper, 2024; Bertollo, Berchicci, Carraro, Comani & Robazza, 2010; Merbah & Meulemans, 2011) and the possibility of effective and active learning in an environment where learning is difficult, it is possible that managed learning conditions in dance will ultimately lead to better learning outcomes. The entire learning focus on achieving the contextual interference effect is based on the manner in which the learning model is to be organised in order for it to be as active as possible on a cognitive and motor level. Based on this idea, a study was conducted in

which the performance of novice dancers at different music tempos was analyzed. If there are no significant differences in dance performance in relation to the tempo of the performance conditioned by the tempo of the music, then it is advisable and justified to conduct research in the future with the aim of determining the effects of contextual interference in dance, in which the tempo of the performance and different dance variations will be the target content. According to previous research, it is clear that the choice of perceptual mode in learning (Bostanci, 2020; Alkooheji & Al-Hattami, 2018; Hernandez et al., 2020), will also have an impact on learning effects in dance (Dahliana, Jaelani, & Rokhmah, 2023) and that it is determined by gender (Zjačić et al., 2025). Perceptual mode in motor learning is specific way in which relevant information is received and processed. According to Coker (2009), four different modes of perceptual learning (visual, kinaesthetic, analytical, and auditory) should be taken into consideration when giving instructions and designing practice environments while planning motor learning. Therefore, the second prominent problem of the research is to determine whether there are gender differences in successful dance performance in relation to tempo and perceptual learning mode. Since the quality level of dance performance, in which the aesthetic impression and expressiveness play an important role, can only be assessed by expert assessment, in order to conduct such research it is necessary to construct basic choreographies with which beginners in dance can be evaluated and compared. To analyze the influence of different musical tempos on the quality of dance performance, it is important to have the same measurement procedures for performance quality level for different tempos of dance performance. It is also necessary to determine whether the newly constructed measurement procedures will be an objective indicator of dance skills for beginner dancers.

Therefore, the first goal of the research is to evaluate some metric characteristics (objectivity, sensitivity and homogeneity) of newly constructed tests for evaluation of learning basic techniques in Latin dances cha cha. Evaluation is performed for slow and fast tempo of music separately. The second aim of the study is to determine whether there are gender differences in the performance of cha cha test-choreography regarding the slow and fast tempo of the same performance. The third aim of the study is to determine which of the three applied perceptual learning modes (visual, kinaesthetic, and auditory) will best affect performance of cha cha choreography.

Methods

The research was conducted on a sample of 61 subjects, third-year male and female students of kinesiology aged 21 to 24, studying full-time at the Undergraduate Study of Kinesiology, Faculty of Kinesiology, University of Split, course Theory and Methods in Dances. Subjects were divided into three research groups: a) visual (N=21, 10 female students and 11 male students); b) kinaesthetic (N=21, 8 female students and 13 male students); c) auditory (N=19, 8 female students and 11 male students). A total of 26 female and 35 male students participated in the study, who, according to the questionnaire, had no previous experience in dance. In the first phase of the research, three experts evaluated each student's performance, firstly in slow tempo of music and then in fast tempo of music. The time signature is 4/4 and the tempo 100 beats per minute (BPM) for slow tempo, and the time signature is 4/4 and the tempo 128 beats per minute (BPM) for fast tempo. The recommended tempo (International) for cha cha is 112-128 BPM, but in the beginning of the learning process usually slower tempo is used. Uniform evaluation criteria were set prior to the performance and evaluation of subjects without a possibility of additional agreements or mutual consultation of judges. Evaluation was implemented by breaking down the cha cha choreography into 8 parts by grading it with mark 2 if performed correctly, mark 1 if performed partially correctly, and mark 0 if performed incorrectly. Similar evaluation method has already been used for evaluation of level of dance

performance (Miletic, Miletic & Uzunovic, 2023). The choreography was prepared for the purpose of research, it contains the basic cha cha dance movements and is suitable for beginners. The eight elements of evaluation were: (1) basic Cha-Cha steps performed on the spot; (2) Cha-Cha steps performed on the spot and then moving forward; (3) Cha-Cha steps performed on the spot and then moving backward; (4) Cha-Cha steps performed on the spot and then moving left –right in the form of a promenade; (5) Cha-Cha steps performed on the spot and then moving into a right turn; (6) Cha-Cha steps performed on the spot and then moving in to a left turn; (7) accuracy of performance in relation to the given tempo; (8) aesthetic component of performance. The final evaluation score was 0-16. In the second phase of experiment, students were divided in three research groups (visual, kinaesthetic and auditory) in which a different approach to learning was implemented. In the Kinaesthetic group instructional strategies as guidance were applied. The students in this group were supposed to let themselves be led in the dance. In the Auditory group students acquired new dance skills mainly by following rhythm and tempo of music or by following the teachers clapping to given rhythm. In the Visual group student acquired new dance skills mainly by following the demonstrator's performance and mistakes in the performance were corrected by looking in the mirror. The default choreography and method of evaluation in all three research groups were the same. The same leader conducted the dance learning process in all three research groups.

Statistics

Methods for data analysis were selected according to the aims of the research. For analysing the sensitivity of newly constructed test for assessing cha cha performance, following statistical parameters were calculated: mean (AS), standard deviation (SD), minimum value (MIN), maximum value (MAX), and distribution normality was tested by the use of the Kolmogorov – Smirnov test (KS). For analysing the objectivity of experts, Cronbach's alpha was calculated. To analyse gender differences in dance performance at slow and fast tempo, T-test was calculated for all three research groups (visual, kinaesthetic, and auditory) separately. In order to determine the influence of different perceptual modes separately by gender, a Factorial ANOVA was used. The Tukey post-hoc test was used to determine the significant differences among means. Statistica 13.0 (TIBCO Software Inc, USA) was used for all analyses and a p-level of 95% was applied.

Results

Based on the values of descriptive statistics (Table 1) the test-choreography at slow and fast tempo for evaluation of quality of cha cha dance performance were regularly distributed, meaning the tests for evaluation of cha cha choreography, both in slow and fast tempo, were adequate for the population of students. It has been noted that for all three experts and in both music tempo, the KS test did not deviate significantly from the Gaussian curve with the margin of error of 0.05, having thus satisfactory sensitivity. According to values of Cronbach's alpha (.95 for slower tempo and .97 for faster tempo), both tests showed good measuring characteristics of objectivity which indicated reliable criteria of cha cha choreography for both slow and fast tempo. For analysing gender differences in dance performance in slow tempo and fast tempo T-test was calculated separately by each research group (auditory, kinaesthetic, and visual). The T-test was significant (Table 2) only for female dancers in Auditory group for cha cha dance choreography performed in slow tempo ($t=2.57$; $p<0.002$).

According to Factorial Analysis of variance presented in Figure 1, which included two dependent variables (slow and fast tempo) and two categorical variables of gender and perceptual learning modes, statistical significance was not found (Wilks lambda =.88, $F(4,108) = 1.69$ ($p<0.15$)). Univariate results for the dependent variable slow tempo and the categorical variable of

perceptual learning mode were significant (Wilks lambda =.84, F (4,108) = 2.52 (p<0.04)). The Tukey Post Hoc Test was calculated to determine significant differences between means (Table 3). According to the Tukey post-hoc test, significant differences were obtained between the female auditory group and the female visual group in favour of the female auditory group (p = 0.03) and between the female auditory group and male kinaesthetic group in favour of the female auditory group (p = 0.03).

Table 1. Descriptive statistics, values of the Kolmogorov-Smirnov test (KS) for three independent evaluators (S1, S2 and S3) and for variables representing average results of all three evaluators (for cha cha dance performed in slow tempo and fast tempo)

Cha-cha choreography evaluators	**Mean**	**Min**	**Max**	**SD**	**KS***
S1	8.28	4.00	16.00	2.67	.16
S2	8.54	2.00	16.00	3.04	.14
S3	8.16	3.00	16.00	2.87	.16
Total ***SLOW TEMPO***	8.25	3.00	16.00	2.81	.14
S1	8.66	3.00	16.00	2.69	.15
S2	8.77	2.00	16.00	3.09	.12
S3	8.69	3.00	16.00	2.92	.09
Total ***FAST TEMPO***	8.70	2.67	16.00	2.75	.10

*KS test is significant on the level of 0.05 for: d<0.21 (when N=61)

Table 2. Arithmetic means (Mean) and Standard Deviations (SD) for three research groups (Auditory, Kinaesthetic and Visual) separately by gender; T-test significant differences (*) between genders for dance performance in slow tempo and fast tempo

Dance performance	**Female** **Mean ±SD**	**Male** **Mean ±SD**
Auditory group		
Slow tempo	11.21 ± 3.31*	8.18 ± 1.93
Fast tempo	9.96 ± 3.70	8.27 ± 1.55
Kinaesthetic group		
Slow tempo	8.29 ± 4.05	7.43 ± 2.42
Fast tempo	8.79 ± 3.86	8.05 ± 2.37
Visual group		
Slow tempo	7.30 ± 1.72	7.94 ± 2.41
Fast tempo	9.33 ± 2.28	8.35 ± 1.74

Table 3. Post – hoc Tukey HSD test – significant differences between research groups

gender	***Perceptual learning mode***	**M**	**M**	**M**	**F**	**F**	**F**
		K	A	V	K	A	V
Male (M)	Kinaesthetic (K)		0.98	1.00	0.98	**0.03***	1.00
Male (M)	Auditory (A)	0.98		1.00	1.00	0.15	0.97

Male (M)	Visual (V)	1.00	1.00		1.00	0.10	0.99
Female (F)	Kinaesthetic (K)	0.98	1.00	1.00		0.25	0.97
Female (F)	Auditory (A)	**0.03***	0.15	0.10	0.25		**0.03***
Female (F)	Visual (V)	1.00	0.97	0.99	0.97	**0.03***	

*significant differences at p < .05

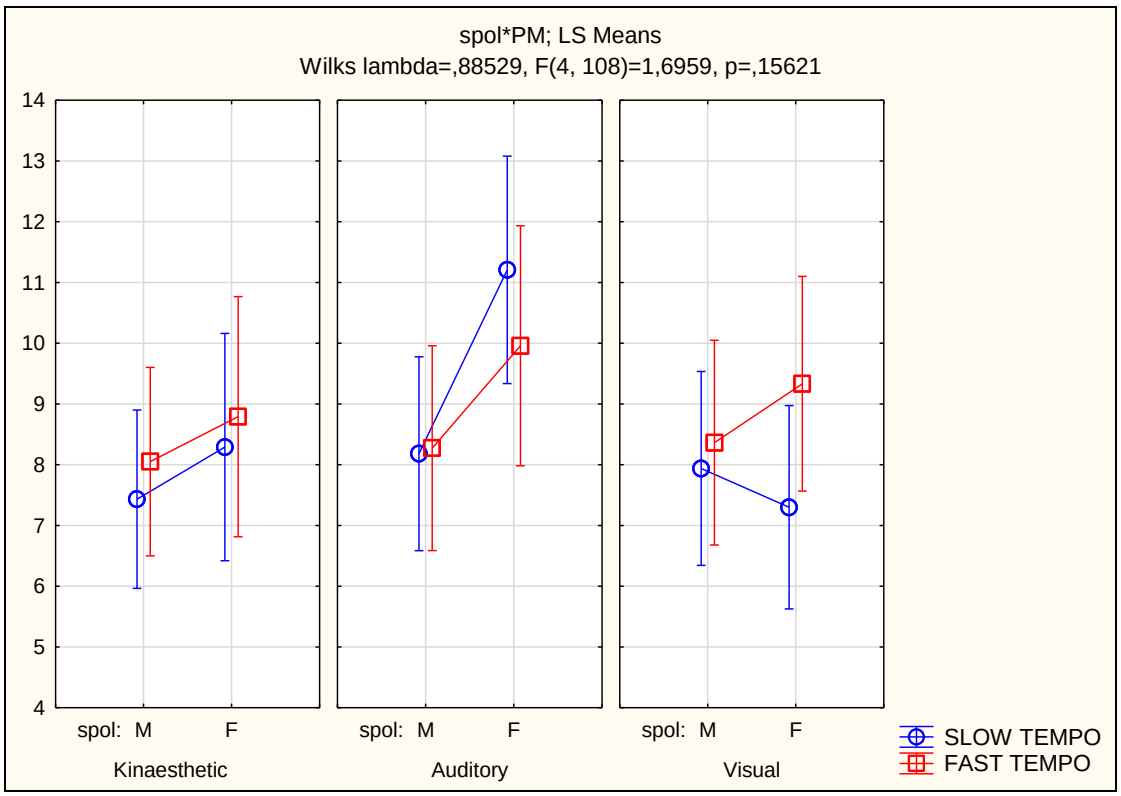


Figure 1. Gender differences between three perceptual learning modes (visual-V, kinaesthetic-K, auditory - A) in the performance of cha-cha dance choreography in slow and fast tempo

Discussion

The first aim of the study, verification of the metric characteristics (objectivity and sensitivity) of newly constructed test-choreography for evaluation of performance quality in Latin dances cha cha, was successfully realized. The test - choreography constructed for research purposes, according to the parameters of descriptive statistics and the high value of the Crombach's alpha coefficient showed satisfactory metric characteristics in the initial phase of motor learning. The existence of reliable measuring criteria for assessing dance performance in novices, which can be applied in slow and fast tempos, enables the analysis of the second and third research objectives. The second aim of the study, determination of whether there are gender differences in the performance of test - choreography in Latin dances cha cha and regarding the performance tempo determined by the tempo of the music was realized using the T-test for each individual research group. According to the obtained results, there were differences between male and female dancers in the motor performance that is conditioned by changes in the tempo of the music. Also, gender differences are determined by the perceptual mode according to which the learning strategy is determined. Thus, there were no significant gender differences in

the research groups in which the learning strategy with predominantly visual and kinaesthetic stimuli was applied. But in the group in which a dominantly auditory learning strategy was applied, in which students were acquiring new dance skills mainly by following the rhythm and tempo of the music or by following the teacher's clapping to the given rhythm, significant differences by gender were recorded. These differences between male and female dancers were caused by the change in the tempo variation of the performance that followed the tempo of the music, as significant differences were noted only in the performance of the dance at a slow tempo in favour of the female dancers. At the same time, the level of performance of female dancers in the auditory group at the slow tempo was rated the highest performance compared to the other research groups. This leads to the conclusion that with the auditory learning strategy in dance, in the initial phase, it is advisable to learn the dance first in a slower rhythm. For male dancers, there is no difference in the level of dance skills acquired, regardless of the tempo of the performance and the music used in learning. Acording to previous research (Miendlarzewska & Trost, 2014) music might function as a tool that facilitates the execution of movements and expedites motor learning. According to the results obtained, variations in the tempo of performance with given music have a positive effect on dance learning only in female dancers in the initial phase. Similar results, but independent of the applied perceptual learning model, were obtained by Burger & Wollner (2023) and Karageorghis, et al. (2019). Burger & Wollner (2023) conducted research on experienced female dancers aimed to investigate movement consistency in the context of tempo, laterality, and music and dance expertise from an artistic perspective. The movement was performed in three different tempos to account for possible biomechanical constraints and potential learning benefits at different times. The authors state that maintaining velocity consistency was more challenging at slower tempos than at faster tempos, suggesting that slow movement could require more attentional focus and thus become more variable. Karageorghis, et al. (2019) conducted research only on female dancers who performed a dance sequence synchronized with three different rhythm tracks that were regular, moderately syncopated, and highly syncopated. Significant performance degradation was found when comparing conditions of no syncopation vs. high syncopation for both trained dancers ($p = .002$) and non-dancers ($p = .001$). According to the third aim of the study, determination of which of the three applied perceptual learning modes (visual, kinaesthetic, and auditory) will best affect performance of cha cha choreography, we can highlight the auditory mode as the most effective perceptual learning strategy. The auditory perceptual mode proved to be an effective strategy in the initial phase of learning, and only in the female population, and when following music with a slower tempo (100 beats per minute) followed by a more precise motor performance. According to the results of the Post hoc Tukey test, significant differences were also recorded between groups of female dancers who practiced dance with different perceptual strategies, visual and auditory, in favour of the auditory learning method. In the research group where a dominant visual strategy was applied, students acquired new dance skills mainly by following the demonstrator's performance and mistakes in the performance were corrected by observing themselves in the mirror. In motor learning, vision dominates other senses when visual learning strategies such as learning by observation or by imitation, as well as by video demonstration, are applied. Task complexity can influence the effectiveness of learning, especially in the initial phase of learning when cognitive demands are high. The adoption of dance choreography with changes in performance tempo that follow the tempo of the music can be considered as complex motor skills, which may reduce the effects of visual strategy learning. It is possible that with higher cognitive demands in the initial phase of learning, visual strategy alone will not be sufficient. In comparison with visual feedback, auditory feedback may hinder processing of other sensory afferences to a lesser extent, and thereby, it could still be used to calibrate the motor program like sparse visual information (Sigrist et al., 2013). However, the literature lacks a systematic evaluation of the interpretability and effectiveness of different

feedback designs. The significant differences between the female auditory group and the male kinaesthetic group where learning through dance leadership dominated, are in accordance with research (Šimunović, Miletić, Miletić, 2026). For the male dancers, the model of learning strategies in which they follow the lead, either from a teacher or a more experienced dancer, is not the most effective learning mode. The improved performance associated with changing the tempo of the performance to match the tempo of the music can be explained by the DAT Dynamic Attending Theory (Jones & Boltz, 1989) which explains the perception of rhythm in music. DAT claims that attention dynamically oscillates and can synchronize with external rhythms, thereby improving prediction and processing of temporally structured events. Further research is needed to truly determine whether synchronization with external rhythms is associated with better motor performance and perceptual learning strategies. This is a pilot study that can have significant practical implications in dance education if later research confirms the results of gender differences and the advantages of the auditory learning strategy in female dancers. This is especially important in sports dance, where in order to plan training and adopt numerous choreographies, special attention should be paid to gender specificities. The main limitation of this study is the small sample size to form the basis for relevant conclusions, but it can be regarded as an initial step and a foundation for the development of future research.

Conclusions

The test-choreography constructed for research purposes can be applied in dance education for effective monitoring of dance performance at slow and fast tempo in the initial phase of motor learning and can be used in future research for analysing motor learning effects. Significant gender differences in favour of female dancers and more successful performance in slow tempo of female dancers in whom a dominantly auditory learning strategy was applied is an indicative indicator for organizing the gender-specific learning process in beginner dancers. The obtained results encourage further research that could confirm the importance of changing the tempo and choosing a perceptual mode in the initial stage of learning, investigate the connection of changing the rhythm as a random practice through the effects of contextual interference or confirm the Dynamic Attending Theory.

References

1. Alkooheji, L., & Al-Hattami, A. (2018). Learning style preferences among college students. International Education Studies, 11(10), 50-63. doi:10.5539/ies.v11n10p50

2. Bertollo, M., Berchicci, M., Carraro, A., Comani, S., & Robazza, C. (2010). Blocked and random practice organization in the learning of rhythmic dance step sequences. Perceptual and Motor Skills, 110 (1), 77–84. doi: https://doi.org/10.2466/pms.110.1.77-84

3. Bostanci Ö. Learning style preferences of prospective teachers of physical education and sport. Asian J Educ Train. 2020;6(2):231-236. doi:10.20448/journal.522.2020.62.231.236

4. Burger, B., Thompson, M. R., Luck, G., Saarikallio, S. H., & Toiviainen, P. (2014). Hunting for the beat in the body: on period and phase locking in music-induced movement. Frontiers in human neuroscience, 8, 903. doi: https://doi.org/10.3389/fnhum.2014.00903

5. Birgitta, B & C. Wöllner (2023) The challenge of being slow: Effects of tempo, laterality, and experience on dance movement consistency, Journal of Motor Behavior, 55:6, 550-563, doi: 10.1080/00222895.2021.1896469

6. Chalabaev, A., Sarrazin, P., Fontayne, P., Boiché, J., & Clément-Guillotin, C. (2013). The influence of sex stereotypes and gender roles on participation and performance in sport and

exercise: Review and future directions. Psychology of sport and exercise, 14(2), 136–144. http://dx.doi.org/10.1016/j.psychsport.2012.10.005

7. Czyż, S. H., Wójcik, A. M., Solarská, P., & Kiper, P. (2024). High contextual interference improves retention in motor learning: systematic review and meta-analysis. Scientific Reports, 14(1), 15974. doi: https://doi.org/10.1038/s41598-024-65753-3

8. Dahliana LH, Jaelani A, Rokhmah UN. The impact of the visual, auditory, and kinesthetic model on motivation and learning outcomes of Islamic Elementary School students. J Integr Elem Educ. 2023;3(2):150-163. doi:10.21580/jieed.v3i2.16867

9. Gentile, A. M. (2000). Skill acquisition: Action, movement, and neuromotor processes. In J. H. Carr & R. B. Shepherd (Eds.), Movement science: Foundations for physical therapy (2nd ed., pp. 111–187). Aspen.

10. Hernandez, J. E., Vasan, N., Huff, S., & Melovitz-Vasan, C. (2020). Learning styles/preferences among medical students: Kinesthetic learner's multimodal approach to learning anatomy. Medical Science Educator, 30(4), 1633-1638. doi:10.1007/s40670-020-01049-1

11. Karageorghis, C. et al. (2019) 'Effects of auditory rhythm on movement accuracy in dance performance', Human Movement Science, 67 (October 2019), 102511, pp. 1 - 11. doi: 10.1016/j.humov.2019.102511.

12. Merbah, S., & Meulemans, T. (2011). Learning a motor skill: Effects of blocked versus random practice. A review. Psychologica Belgica, 51. https://doi.org/10.5334/pb-51-1-15.

13. Miletić D, Miletic A, Uzunović S. (2023). The effects of reciprocal, self-check, and command teaching styles on dance learning. Physical Education of Students, 27(5):261–269. doi: https://doi.org/10.15561/20755279.2023.0506.

14. Miendlarzewska, E. A., & Trost, W. J. (2014). How musical training affects cognitive development: Rhythm, reward and other modulating variables. Frontiers in Neuroscience, 7, e279. doi:10.3389/fnins.2013.00279

15. Moelants, D. (2003). Dance music, movement and tempo preferences. In Proceedings of the 5th Triennial ESCOM Conference (pp. 649-652). Hanover University of Music and Drama

16. Schmidt, R. A., Lee, T., Winstein, C., Wulf, G., & Zelaznik, H. (2019). Motor control and learning. A behavioral emphasis (6th ed.). Human Kinetics.

17. Shen, K., & Hirayama, J. I. (2025). Beat-aligned motor synergies and kinematic beat detection in street dance movements. Journal of NeuroEngineering and Rehabilitation, 22(1), 102. doi: https://doi.org/10.1186/s12984-025-01626-8

18. Sigrist, R., Rauter, G., Riener, R., & Wolf, P. (2013). Augmented visual, auditory, haptic, and multimodal feedback in motor learning: a review. Psychonomic bulletin & review, 20(1), 21-53. doi: 10.3758/s13423-012-0333-8

19. Šimunović, K., Miletić, A., Miletić Đ. (2026). Effects of perceptual learning modes in dance education. Acta Kinesiologica, doi: 10.51371/issn.1840-2976.709

20. Zjačić Puljiz, D., Šimunović, K., & Miletić, Đ. (2025). Effectiveness of the perceptual learning models in mastering choreography. In 3rd International Conference on Science and Medicine in Aquatic Sports (SMAS)(pp. 117-122). University of Split, Faculty of Kinesiology.

FULL PAPER 2

SCIENTIFIC PAPER

Different pathways to health: gender and nutritional differences in adolescence

Sunčica Delaš Kalinski[1], Vesna Babić[2], Igor Jelaska[1]

[1]Faculty of Kinesiology University of Split, Split, Croatia; [2] Faculty of Kinesiology University of Zagreb, Zagreb, Croatia

Introduction

Adolescent obesity is today considered one of the most serious public health challenges, with its prevalence increasing globally at an alarming rate and taking on the characteristics of an epidemic (Abarca-Gómez et al., 2017; WHO, 2022). This trend is not limited to highly developed countries but is increasingly evident in developing regions as well, where urbanization, changes in dietary patterns, and reduced physical activity further exacerbate the problem (Hoffman, 2000; Boakye et al., 2023). Croatia is no exception, as national data indicate that more than one-third of adolescents are overweight or obese (Močić Pavić, Sila, Niseteo, Hojsak, & Kolaček, 2021; Musić Milanović et al., 2024).

Dietary habits are recognized as one of the key predictors of adolescent obesity, with well-established evidence demonstrating a clear association between meal frequency, diet quality, nutrient intake, and the risk of developing excess body weight (Ambrosini, 2014; Story, Neumark-Sztainer, & French, 2002). Skipping breakfast, frequent consumption of fast food and sugar-sweetened beverages, as well as insufficient intake of fruits and vegetables, are all linked to an increased risk of weight gain (Ma et al., 2020; Wang et al., 2023). Beyond the types of foods consumed, the context in which eating occurs also plays an important role. Family meals and more mindful eating practices have been associated with protective effects against obesity, whereas eating outside the home and consuming food in front of screens contribute to higher energy intake and increased obesity risk (Gillman et al., 2000; Hammons & Fiese, 2011; Lipsky et al., 2015). Additionally, faster eating and fewer meals per day have been linked to a greater likelihood of excess body weight among adolescents (Ochiai et al., 2013; Saltaouras et al., 2024; Zeng et al., 2018).

Adolescent dietary habits are also strongly influenced by gender differences. Girls tend to consume fruits and vegetables more frequently and are more likely to engage in restrictive dieting, whereas boys more often opt for fast food and energy drinks (Rolls, Fedoroff, & Guthrie, 1991; Sweeting & West, 2002). These differences are reflected in the prevalence of excess body weight: boys, on average, are more likely to be overweight, while girls more frequently report concerns about body image and weight (Lattimore & Halford, 2003; Vereecken, De Henauw, & Maes, 2005).

The most commonly used indicator for assessing the nutritional status of children and adolescents is the Body Mass Index (BMI), calculated as the ratio of body weight to the square of height (kg/m^2). According to WHO recommendations, the interpretation of BMI in this age group relies on age- and sex-specific percentile charts that classify individuals as underweight, normal weight, overweight, or obese for boys and girls separately (de Onis et al., 2007). Including both genders in the analysis enables a more accurate identification of risk patterns and the development of effective public health strategies aimed at obesity prevention (Abarca-Gómez et al., 2017; Kim, Jeong, Lim, & Yoon, 2025; Shah, Tombeau Cost, Fuller, Birken, & Anderson, 2020).

Despite numerous studies examining factors associated with obesity, the role of household food availability as a potential risk or protective factor in relation to adolescents' nutritional status

and behavioral patterns remains insufficiently investigated. An integrated approach that simultaneously considers dietary habits, physical activity, nutritional status, and the home food environment—while also accounting for gender differences—has likewise not been systematically analyzed, particularly within the Croatian population.

Accordingly, the aim of this study is to examine the relationship between dietary habits, physical activity, and the nutritional status of Croatian adolescents, with a specific focus on gender differences and the role of the home food environment. It is hypothesized that significant differences exist between boys and girls of varying nutritional status and that household food availability represents an important factor associated with the risk of overweight and obesity. The findings of this study are expected to contribute to a deeper understanding of these relationships and serve as a basis for developing targeted preventive interventions.

Materials and Methods

Sample of Respondents

The sample included N1 = 177 male students (M ± SD = 17.59 ± 0.61 years; BMI = 23.46 ± 4.68 kg/m^2) and N2 = 89 female students (M ± SD = 17.41 ± 0.61 years; BMI = 21.63 ± 4.60 kg/m^2), all enrolled in the third and fourth grades of secondary school. All participants were informed about the purpose of the study and were made aware that participation was voluntary and that they could withdraw at any time.

Based on the calculated BMI values, participants were classified, separately for each sex, into five BMI categories (underweight, normal weight, overweight, obesity; Table 1).

Table 1. Reference BMI category values by age and sex in adolescents (WHO, 2007)

BMI CATEGORY	Male students (age 17.59)	Female students (age
Severe thinness	BMI < 15.4 kg/m^2	< 14.7 kg/m^2
Thinness	15.4 ≤ BMI < 16.9 kg/m^2	14.7 ≤ BMI < 16.4 kg/m^2
Normal weight	16.9 ≤ BMI < 24.3 kg/m^2	16.4 ≤ BMI < 24.5 kg/m^2
Overweight	24.3 ≤ BMI ≤ 28.6 kg/m^2	24.5 ≤ BMI ≤ 29.3 kg/m^2
Obesity class I	> 28.6 kg/m^2	> 29.3 kg/m^2
Obesity class II	≥ 32.3 kg/m^2	≥ 32.9 kg/m^2
Obesity class III	≥ 37.7 kg/m^2	≥ 38.4 kg/m^2

Variables Sample

An online questionnaire was created using Google Forms, consisting of 51 questions related to daily physical activity, sedentary behavior, and dietary habits (questionnaire link). Each nominal variable (i.e., response options for a given question) was coded from 1 to 6, depending on the number of available answer choices. Due to the length of the questionnaire and the large number of analyses conducted, only statistically significant findings are presented in the main text, while the complete results are provided in the Supplementary Material.

Data Collection

Physical and health education teachers distributed the questionnaire link to students during class time. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Kinesiology, University of Split (Class: 003-08/25-04/001; Reg. No.: 2181-205-02-05-25-008).

Data Analysis Methods

Descriptive statistical analyses were conducted. The mode and mode frequency were calculated using Statistica software, version 14.0 (StatSoft, Inc., Tulsa, USA). Differences between sexes were assessed using independent samples t-tests, while differences among BMI categories were examined using one-way analysis of variance (ANOVA) followed by post hoc tests.

Results

Descriptive statistics of BMI values stratified by sex and nutritional status categories are provided in Table 2.

Table 2. Mean BMI values (M ± SD) by sex and nutritional status categories of adolescent

Sex / BMI Category	Underweight	Normal weight	Overweight	Obesity Class I	Obesity Class II	Obesity Class III
BMI – Female	N=12 16.10 ± 1.28	N=50 20.98 ± 1.79	N=7 27.06 ± 1.91	N=2 30.96 ± 0.20	N=3 35.79 ± 0.80	–
BMI – Male	N=16 17.38 ± 0.81	N=104 21.81 ± 1.67	N=35 26.49 ± 1.22	N=7 31.53 ± 1.35	N=5 36.98 ± 0.75	N=2 42.70 ± 2.26

The analysis of mean BMI values shows gender differences across all nutritional status categories. Underweight girls had lower BMI values (M = 16.10) compared to boys (M = 17.38), while in the normal weight category boys reached a slightly higher average (21.81 vs. 20.98). The differences become more pronounced in the higher categories, where boys are more frequently represented and achieve higher BMI values, particularly in Obesity Classes I and II (31.53–42.70 compared to 30.96–35.79 in girls). In Obesity Class III, only boys were recorded.

Table 3 presents the gender differences in behaviors and dietary habits, along with the corresponding p-values and the direction of significant differences.

Table 3. Differences between boys and girls in behaviors and dietary habits (independent samples t-test)

Variable	p	In favor of
Boredom when alone	0.02	girls report boredom more often
Engagement in sport	0.01	boys participate in sport more frequently
Type of sport	0.04	boys are more often involved in team sports
Years of sports participation	<0.001	boys have been involved in sport longer
Number of training days per week	<0.001	boys train more frequently
Playing computer games	<0.001	boys play games more

Using mobile applications	<0.001	boys spend more time on apps
Eating while watching TV/reading/working	<0.001	boys eat under distraction more often
Eating out of boredom	<0.001	boys eat out of boredom more frequently
Unstructured snacking between meals	0.01	more common among boys
Frequently taking a second portion	0.03	more common among boys
Consumption of fresh vegetables	0.03	girls consume more vegetables
Consumption of fresh fruit	<0.001	girls consume more fruit
Consumption of meat and meat products	0.03	boys consume more meat
Number of types of carbonated drinks at home	0.02	higher in households of boys
Other variables (e.g., sport-related income, cooperation with a nutritionist, family meals)	>0.05	—

*Only statistically significant results are presented; all findings are available in the Supplementary Material.

The analysis of gender differences showed that girls more frequently reported feeling bored when alone ($p = 0.02$), whereas boys were significantly more active in sport—they engaged in sports more often, participated in team activities, trained for a longer period, and trained more days per week ($p \leq 0.04$). Boys also spent more time in sedentary activities and more frequently ate under distraction, ate out of boredom, snacked irregularly, and took additional portions ($p \leq 0.03$). Conversely, girls consumed fruits and vegetables more often ($p \leq 0.03$), while boys had a higher intake of meat and meat products and greater availability of carbonated drinks at home ($p = 0.02$). No significant gender differences were found for the remaining variables ($p > 0.05$).

Tables 4 and 5 present the significant differences among BMI groups, along with p-values and post hoc analyses.

Table 4. Differences among BMI categories in boys (ANOVA and post hoc tests)

Variable	F	p-value	Groups with significant differences (post hoc)
Years of sports participation	3.611	0.029	1 vs 3
Number of training days per week	3.372	0.037	2 vs 3
How many servings of cereals and cereal products did you consume in the past month?	6.137	0.003	1 vs 3
How many servings of fresh fruit did you consume in the past month?	4.634	0.011	1 vs 3

Have you ever received dietary advice (e.g., to lose/gain weight)?	3.183	0.044	1 vs 2
How many hours per day do you spend watching TV?	1.930	0.148	1 vs 3
Time spent using apps	0.114	0.893	1 vs 2, 1 vs 3
Do you work with a nutritionist?	0.068	0.934	1 vs 2, 2 vs 3
To what extent does the statement apply to you: "I eat late in the evening or at night"?	1.974	0.142	1 vs 2, 2 vs 3
To what extent does the statement apply to you: "I eat in the living room or study room"?	1.502	0.226	2 vs 3
How many servings of meat and meat products (1 serving = 80 g) did you consume in the past month?	0.564	0.570	2 vs 3
How many servings of olive oil did you consume in the past month?	1.008	0.367	1 vs 2

*Only statistically significant results are presented; all findings are available in the Supplement."

Legend: 1 = underweight, 2 = normal weight, 3 = overweight, 4 = obesity class I, 5 = obesity class II."

Among boys, significant differences between BMI groups were found in sports habits and dietary patterns. Underweight boys had been involved in sports longer and consumed more cereals and fresh fruit compared to overweight peers, while boys of normal weight trained more frequently than those who were overweight. Underweight boys also received dietary advice less often than their normal-weight counterparts. Although the overall ANOVA was not significant, post hoc analyses indicated differences in time spent watching TV, using apps, collaboration with a nutritionist, late-night eating, and eating location. Regarding dietary intake, normal-weight boys consumed more meat, whereas underweight boys consumed more olive oil.

The following section presents statistically significant differences among BMI groups in girls based on the analyzed variables.

Table 5. Differences Among BMI Groups in Girls (ANOVA and post hoc tests)

Variable	F	p-value	Groups with Differences (post
How many times per week do you participate in other leisure activities (foreign language, music,	3.279	0.044	1 vs 2
Do you cooperate with a nutritionist?	4.267	0.018	1 vs 3
How many types of salty snacks are available in your home (chips, popcorn, pretzels, puffs, etc.)?	3.843	0.026	2 vs 3
How many types of nuts are available in your home (peanuts, hazelnuts, almonds, walnuts, sunflower	7.008	0.002	1 vs 2,

How many types of chocolates are usually available in your home?	3.345	0.041	2 vs 3
Snacks and sweets are available in your home	3.175	0.048	1 vs 2
Do you participate in any sport?	2.429	0.096	1 vs 2
Have you ever received dietary advice (e.g., to lose/gain weight)?	2.191	0.119	1 vs 2
How many types of chocolate bars are usually available in your home?	2.510	0.089	1 vs 3
How many servings of legumes did you consume in the past month?	2.970	0.058	1 vs 3
How many servings of meat and meat products (1 serving = 80 g) did you consume in the past month?	2.478	0.091	1 vs 3

*Only statistically significant results are presented; all findings are available in the Supplement."

Legend: 1 = underweight, 2 = normal weight, 3 = overweight, 4 = obesity class I, 5 = obesity class II."

The analysis revealed several significant differences among BMI categories in girls. Normal-weight girls participated more frequently in leisure activities compared with underweight peers, whereas overweight girls were more likely to collaborate with a nutritionist. Differences in food availability were observed in the number of types of salty snacks, nuts, and chocolate, with overweight girls having a greater variety available and underweight girls reporting lower availability of snacks and sweets. Although not statistically significant, trends indicated that underweight girls were less engaged in sports, received dietary advice less often, and consumed fewer legumes and meat compared with overweight peers.

Discussion

In our sample, underweight girls exhibited lower mean BMI values than underweight boys, which aligns with findings from regional (Stanisavljević et al., 2025) and international studies (Delgrande Jordan, Schmidhauser, & Balsiger, 2023; Lazzeri et al., 2014; Vanhelst, Baudelet, & Fardy, 2022). At the same time, the results confirm patterns indicating that boys more frequently fall into higher BMI categories (HZJZ, 2022; HZJZ, 2024; Currie et al., 2012; Olds et al., 2011; Vereecken, De Henauw, & Maes, 2005), whereas girls more often exhibit heightened psychological perceptions of body weight and appearance (Lattimore & Halford, 2003; Sweeting & West, 2002). This dual pattern underscores the gender-specific nature of adolescent obesity: among boys, the problem is primarily physically measurable, while among girls it is more strongly expressed through psychological experience and body perception, pointing to the influence of sociocultural factors and the need for more targeted research and differentiated public health strategies.

Findings further confirm that sex and nutritional status significantly shape adolescents' physical activity and dietary habits. Boys are generally more active in sports, whereas girls more frequently engage in non-sport leisure activities, consistent with previous research (Kretschmer et al., 2023; Lawler, Heary, & Nixon, 2017; Vilhjalmsson & Kristjansdottir, 2003).

Dietary differences among adolescents in our sample were also pronounced and aligned with previous research: girls consumed fruits and vegetables more frequently, whereas boys had a higher intake of meat and meat products, as well as greater household availability of sugary soft drinks (Lombardo, Aulisa, Padua, Annino, & Bellia, 2024; Vereecken et al., 2015; Feraco,

Montagnese, Santarpia, & Contaldo, 2024; Hopwood, Bleidorn, Schwaba, Ebert, & Zimmermann, 2024; Ritzel, Wenzig, & Langen, 2021).

While the first set of results highlights sex-specific differences in health-related behaviors, subsequent analyses reveal additional differentiation within each sex, linked to nutritional status.

Underweight and normal-weight boys engaged in sports for a longer period and trained more frequently, whereas overweight boys were less involved in physical activities, suggesting that excess weight may hinder sustained participation in sports. Underweight boys consumed more cereals and fruit, and normal-weight boys more meat, compared with overweight peers, who more often displayed sedentary behaviors and tendencies toward emotional and impulsive eating. These findings support established links between sedentary behavior, emotional eating, and increased risk of obesity (Bui et al., 2021; Nguyen-Michel et al., 2007), while the higher availability of sugary soft drinks in their households further underscores the influence of the family environment, consistent with the nutrition transition theory (Popkin, 2001).

Among girls, differences between BMI groups were less pronounced but still clearly observable in leisure-time activities and household food availability. Normal-weight girls more frequently participated in activities such as language learning, music, and hobby-related pursuits, which can be considered protective factors, as they reduce passive behaviors (Wanka et al., 2025) and contribute to more favorable long-term weight outcomes (Lajunen et al., 2009).

Significant differences were found in household food availability: overweight girls had greater access to salty snacks and chocolate, which may contribute to the maintenance of unhealthy eating patterns, whereas normal-weight girls reported lower availability of these items. A particularly notable finding concerns nuts: normal-weight girls had a wider selection of nuts compared with underweight peers, while overweight girls had the greatest availability. Although nuts are nutritionally more favorable than many other snack foods, excessive availability may indicate an energy-dense dietary pattern which, when combined with reduced physical activity, can contribute to weight gain.

At the same time, underweight girls reported lower availability of nearly all snacks and sweets in the household, which may reflect socioeconomic or family-related factors. These findings confirm that the availability and quantity of food in the home—not merely the type of foods present—play a key role in shaping the dietary habits and nutritional status of adolescent girls, consistent with previous studies (Gerards & Kremers, 2015; Hendrie et al., 2013; Williamson et al., 2020). Moreover, reduced availability of snack foods and sweets in households of underweight girls may reflect socioeconomic differences and specific family dietary practices, further underscoring the importance of the home food environment in shaping nutritional status and its connection to the structure of available food items (Williamson et al., 2020).

Dietary differences among girls were also evident in fruit and vegetable intake: normal-weight adolescents consumed these foods more frequently than overweight and obese peers, consistent with prior research (de Onis et al., 2007; Łuszczki et al., 2019; Watts, Barr, Hanning, Lovato, & Mâsse, 2018).

Beyond dietary patterns, education and nutritional awareness also play an important role. Longitudinal studies show that adolescents with greater nutrition knowledge make healthier choices and are less likely to develop overweight or obesity (Asakura & Aihara, 2017; Wang et al., 2022). This underscores the need to integrate nutrition education into school curricula and to actively involve parents and the community in promoting healthy eating habits.

Practical Implications

At the practical level, our findings indicate the need for differentiated interventions. Among boys, it is important to encourage self-regulation and reduce emotional eating, alongside limiting the availability of sugary drinks and high-calorie foods. For girls, maintaining favorable dietary patterns—particularly fruit and vegetable intake—and promoting greater engagement in physical activity may provide additional protection against overweight and obesity.

Study Limitations

This study has several limitations. The number of participants in certain BMI categories, particularly in higher obesity classes among girls, was small, which may have reduced statistical power and limited the ability to detect differences. Furthermore, reliance on self-reported data introduces the risk of bias, as participants may overestimate or underestimate their dietary and lifestyle behaviors. Additionally, self-reported household food availability may be subjective and prone to perceptual inconsistencies, representing another methodological limitation.

Conclusion

The findings of this study confirm that patterns of physical activity and dietary habits among adolescents are strongly shaped by sex and nutritional status. Boys tend to rely more on sport and organized physical activities, whereas girls contribute to their health through a broader range of non-sport leisure activities and healthier dietary choices. This demonstrates that developmental pathways toward health in adolescence are not uniform but differentiated by sex. By integrating individual and environmental factors, this study provides a novel insight into risk patterns within the Croatian adolescent population. The results emphasize the need for tailored preventive strategies: for girls, promoting greater participation in physical activity, and for boys, encouraging more balanced dietary practices and reducing the availability of high-calorie foods in the household.

A particular contribution of this study lies in the analysis of household food availability, where clear differences among BMI groups were observed in girls: normal-weight adolescents had a more balanced selection of foods, overweight girls had greater availability of snacks, chocolate, and nuts, while underweight girls had considerably lower availability. These findings indicate that even nutritionally favorable foods, such as nuts, may reflect energy-dense eating patterns when excessively available and may pose a potential risk, thereby offering an original contribution to the understanding of dietary risk factors in adolescence.

At a practical level, the results highlight the need for differentiated public health interventions that take into account both sex-specific and socioeconomic factors. Despite certain limitations—such as the smaller sample sizes in specific groups and the reliance on self-reported data—the findings enhance understanding of the relationships between diet, physical activity, and nutritional status in adolescents and provide a solid basis for future research and the development of targeted prevention programs.

References

1. Abarca-Gómez, L., Abdeen, Z. A., Hamid, Z. A., Abu-Rmeileh, N. M., Acosta-Cazares, B., Acuin, C., ... & Ezzati, M. (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: A pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. The Lancet, 390(10113), 2627–2642. https://doi.org/10.1016/S0140-6736(17)32129-3

2. Ambrosini, G. L. (2014). Childhood dietary patterns and later obesity: A review of the evidence. Proceedings of the Nutrition Society, 73(1), 137–146. https://doi.org/10.1017/S0029665113003765
3. Asakura, K., & Aihara, M. (2017). Relationship between nutrition knowledge and dietary intake among primary school children in Japan: Combined effect of children's and their guardians' knowledge. Journal of Epidemiology, 27(10), 483–491. https://doi.org/10.1016/j.je.2016.09.014
4. Boakye, K., Yusuf, S., Vujkovic, M., Rangarajan, S., Khatib, R., Alhabib, K. F., ... & Lear, S. A. (2023). Urbanization and physical activity in the global Prospective Urban and Rural Epidemiology (PURE) study. Scientific Reports, 13, 115. https://doi.org/10.1038/s41598-022-26406-5
5. Bui, C., McLean, C., Hannan, P., Eisenberg, M. E., & Neumark-Sztainer, D. (2021). Association between emotional eating and frequency of consuming fast food, high-fat snacks, processed meat products, dessert foods, and sugar-sweetened beverages among adolescents. Nutrients, 13(8), 2739. https://doi.org/10.3390/nu13082739
6. Currie, C., Zanotti, C., Morgan, A., Currie, D., de Looze, M., Roberts, C., ... & Barnekow, V. (2012). Social determinants of health and well-being among young people: Health Behaviour in School-aged Children (HBSC) study: international report from the 2009/2010 survey. Copenhagen: WHO Regional Office for Europe.
7. de Onis, M., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C., & Siekmann, J. (2007). Development of a WHO growth reference for school-aged children and adolescents. Bulletin of the World Health Organization, 85(9), 660–667. https://doi.org/10.2471/BLT.07.043497
8. Delgrande Jordan, M., Schmidhauser, V., & Balsiger, N. (2023). Weight status and body image of young adolescents (HBSC Switzerland 2022 factsheet). Lausanne: Addiction Suisse.• Reatrived from: https://www.hbsc.ch/pdf/hbsc_bibliographie_406.pdf
9. Feraco, A., Montagnese, C., Santarpia, L., & Contaldo, F. (2024). Assessing gender differences in food preferences and physical activity. Nutrients, 16(2), 345. https://doi.org/10.3390/nu16020345
10. Gerards, S. M., & Kremers, S. P. (2015). The Role of Food Parenting Skills and the Home Food Environment in Children's Weight Gain and Obesity. Current obesity reports, 4(1), 30–36. https://doi.org/10.1007/s13679-015-0139-x
11. Gillman, M. W., Rifas-Shiman, S. L., Frazier, A. L., Rockett, H. R., Camargo, C. A., Field, A. E., ... & Colditz, G. A. (2000). Family dinner and diet quality among older children and adolescents. Archives of Family Medicine, 9(3), 235–240. https://doi.org/10.1001/archfami.9.3.235
12. Hammons, A. J., & Fiese, B. H. (2011). Is frequency of shared family meals related to the nutritional health of children and adolescents? A meta-analysis. Pediatrics, 127(6), e1565–e1574. https://doi.org/10.1542/peds.2010-1440
13. Hendrie, G. A., Andersen, K., & Louie, J. C. Y. (2013). Change in the family food environment is associated with changes in children's saturated fat intake. International Journal of Behavioral Nutrition and Physical Activity, 10, 4. https://doi.org/10.1186/1479-5868-10-4
14. Hoffman, D. J. (2000). Obesity in developing countries: Causes and implications. Rome: Food and Agriculture Organization of the United Nations (FAO). Preuzeto s https://www.fao.org/4/y0600m/y0600m05.htm
15. Hopwood, C. J., Bleidorn, W., Schwaba, T., Ebert, T., & Zimmermann, J. (2024). Paradoxical gender effects in meat consumption across cultures. Scientific Reports, 14, 62511. https://doi.org/10.1038/s41598-024-62511-3

16. Hrvatski zavod za javno zdravstvo (HZJZ). (2022). Objavljeni rezultati petog kruga Europske inicijative za praćenje debljine u djece 2018.–2022. Preuzeto s https://www.hzjz.hr/sluzba-promicanje-zdravlja/objavljeni-rezultati-petog-kruga-europske-inicijative-za-pracenje-debljine-u-djece-2018-2022/
17. Hrvatski zavod za javno zdravstvo (HZJZ). (2024). Europska inicijativa praćenja debljine u djece, Hrvatska 2021./2022. (CroCOSI). Zagreb: HZJZ. Preuzeto s https://www.hzjz.hr/wp-content/uploads/2024/03/CroCOSI-Fact-sheet-2021.-2022.pdf
18. Kim, H.-J., Jeong, S., Lim, J. H., & Yoon, D. (2025). Sex-specific associations of childhood BMI patterns with cardiometabolic risk: An 11-year Korean longitudinal study. Children, 12(7), 821. https://doi.org/10.3390/children12070821
19. Kretschmer, A., Poitras, V. J., LeBlanc, A. G., Spence, J. C., Janssen, I., & Tremblay, M. S. (2023). Gender differences in objectively measured physical activity among children and adolescents: An international comparison. International Journal of Behavioral Nutrition and Physical Activity, 20(1), 125. https://doi.org/10.1186/s12966-023-01496-0
20. Lajunen, H. R., Keski-Rahkonen, A., Pulkkinen, L., Rose, R. J., Rissanen, A., & Kaprio, J. (2009). Leisure activity patterns and their associations with overweight: A prospective study among adolescents. Journal of Adolescence, 32(5), 1089–1103. https://doi.org/10.1016/j.adolescence.2009.03.005
21. Lattimore, P. J., & Halford, J. C. (2003). Adolescence and the diet-dieting disparity: Healthy food choice or risky health behaviour? British Journal of Health Psychology, 8(Pt 4), 451–463. https://doi.org/10.1348/135910703770238301
22. Lattimore, P. J., & Halford, J. C. (2003). Adolescence and the diet-dieting disparity: Healthy food choice or risky health behaviour? British Journal of Health Psychology, 8(4), 451–463. https://doi.org/10.1348/135910703770238301
23. Lawler, M., Heary, C., & Nixon, E. (2017). Variations in adolescents' motivational characteristics across gender and physical activity domain. BMC Public Health, 17, 754. https://doi.org/10.1186/s12889-017-4677-x
24. Lazzeri, G., Rossi, S., Kelly, C., Vereecken, C., Ahluwalia, N., & Giacchi, M. V. (2014). Trends in thinness prevalence among adolescents in ten European countries and the USA (1998–2006): A cross-sectional survey. Public Health Nutrition, 17(10), 2207–2215. https://doi.org/10.1017/S1368980013002412
25. Lipsky, L. M., Haynie, D. L., Liu, D., Chaurasia, A., Gee, B., Li, K., & Simons-Morton, B. (2015). Trajectories of eating behaviors in a nationally representative cohort of U.S. adolescents during the transition to young adulthood. International Journal of Behavioral Nutrition and Physical Activity, 12, 138. https://doi.org/10.1186/s12966-015-0298-x
26. Lombardo, M., Aulisa, G., Padua, E., Annino, G., & Bellia, C. (2024). Gender differences in body composition, dietary patterns, and food choice motives in adults. Frontiers in Nutrition, 11, 1414217. https://doi.org/10.3389/fnut.2024.1414217
27. Łuszczki, E., Sobek, G., Bartosiewicz, A., Baran, J., Weres, A., Dereń, K., & Mazur, A. (2019). Analysis of Fruit and Vegetable Consumption by Children in School Canteens Depending on Selected Sociodemographic Factors. Medicina (Kaunas, Lithuania), 55(7), 397. https://doi.org/10.3390/medicina55070397
28. Ma, X., Chen, Q., Pu, Y., Guo, M., Jiang, Z., Huang, W., Long, Y., & Xu, Y. (2020). Skipping breakfast is associated with overweight and obesity: A systematic review and meta-analysis. Obesity Research & Clinical Practice, 14(1), 1–8. https://doi.org/10.1016/j.orcp.2019.12.002
29. Močić Pavić, A., Sila, S., Niseteo, T., Hojsak, I., & Kolaček, S. (2021). Development and validation of a food frequency questionnaire for population of adolescents in Croatia.

Food Technology and Biotechnology, 59(1), 74–81. https://doi.org/10.17113/ftb.59.01.21.6630
30. Musić Milanović, S., Križan, H., Lang Morović, M., Meštrić, S., Šlaus, N., & Pezo, A. (2024). Europska inicijativa praćenja debljine u djece, Hrvatska 2021./2022. (CroCOSI). Zagreb: Hrvatski zavod za javno zdravstvo. Preuzeto s https://www.hzjz.hr/wp-content/uploads/2024/03/Publikacija-Eurpska-inicijativa-pracenja-debljije-u-djece-Hrvatska-2021.2022.-CroCOSI.pdf
31. Nguyen-Michel, S. T., Unger, J. B., & Spruijt-Metz, D. (2007). Dietary correlates of emotional eating in adolescence. Appetite, 49(2), 494–499. https://doi.org/10.1016/j.appet.2007.03.005
32. Ochiai, H., Shirasawa, T., Ohtsu, T., Nishimura, R., Morimoto, A., Hoshino, H., Tajima, N., & Kokaze, A. (2013). Eating behaviors and overweight among adolescents: A population-based survey in Japan. Journal of Obesity, 2013, 717942. https://doi.org/10.1155/2013/717942
33. Olds, T., Maher, C., Zumin, S., Péneau, S., Lioret, S., Castetbon, K., ... & Lobstein, T. (2011). Evidence that the prevalence of childhood overweight is plateauing: Data from nine countries. International Journal of Pediatric Obesity, 6(5–6), 342–360. https://doi.org/10.3109/17477166.2011.605895
34. Popkin, B. M. (2001). The nutrition transition and obesity in the developing world. The Journal of Nutrition, 131(3), 871S–873S. https://doi.org/10.1093/jn/131.3.871S
35. Ritzel, C., Wenzig, M., & Langen, N. (2021). On gender differences in meat consumption across adolescents: Insights from a school-based study. Foods, 10(11), 2809. https://doi.org/10.3390/foods10112809
36. Rolls, B. J., Fedoroff, I. C., & Guthrie, J. F. (1991). Gender differences in eating behavior and body weight regulation. Health Psychology, 10(2), 133–142. https://doi.org/10.1037/0278-6133.10.2.133
37. Saltaouras, G., Kyrkili, A., Bathrellou, E., Yannakoulia, M., & Panagiotakos, D. B. (2024). Associations between meal patterns and risk of overweight/obesity in children and adolescents: A systematic review of longitudinal studies and randomized controlled trials. Children, 11(9), 1100. https://doi.org/10.3390/children11091100
38. Shah, B., Tombeau Cost, K., Fuller, A., Birken, C. S., & Anderson, L. N. (2020). Sex and gender differences in childhood obesity: Contributing to the research agenda. BMJ Nutrition, Prevention & Health, 3(2), 387–390. https://doi.org/10.1136/bmjnph-2020-000074
39. Story, M., Neumark-Sztainer, D., & French, S. (2002). Individual and environmental influences on adolescent eating behaviors. Journal of the American Dietetic Association, 102(3 Suppl), S40–S51. https://doi.org/10.1016/S0002-8223(02)90421-9
40. Sweeting, H., & West, P. (2002). Gender differences in weight-related concerns in early to late adolescence. Journal of Epidemiology and Community Health, 56(9), 700–701. https://doi.org/10.1136/jech.56.9.700
41. Sweeting, H., & West, P. (2002). Gender differences in weight-related concerns in early to late adolescence. Journal of Epidemiology and Community Health, 56(9), 700–701. https://doi.org/10.1136/jech.56.9.700
42. Vanhelst, J., Baudelet, J.-B., & Fardy, P. S. (2022). French youth trends in prevalence of overweight, obesity and underweight from 2008 to 2018. BMC Research Notes, 15, 228. https://doi.org/10.1186/s13104-022-06091-3
43. Vereecken, C. A., De Henauw, S., & Maes, L. (2005). Adolescents' food habits: Results of the Health Behaviour in School-aged Children survey. British Journal of Nutrition, 94(3), 423–431. https://doi.org/10.1079/bjn20051513

44. Vereecken, C. A., De Henauw, S., & Maes, L. (2005). Adolescents' food habits: Results of the Health Behaviour in School-aged Children survey. British Journal of Nutrition, 94(3), 423–431. https://doi.org/10.1079/bjn20051513
45. Vereecken, C. A., Pedersen, T. P., Ojala, K., Krølner, R., Dzielska, A., Ahluwalia, N., … Kelly, C. (2015). Fruit and vegetable consumption trends among adolescents from 2002 to 2010 in 33 countries. European Journal of Public Health, 25(Suppl 2), 16–19. https://doi.org/10.1093/eurpub/ckv012
46. Vilhjalmsson, R., & Kristjansdottir, G. (2003). Gender differences in physical activity in older children and adolescents: The central role of organized sport. Social Science & Medicine, 56(2), 363–374. https://doi.org/10.1016/S0277-9536(02)00042-4
47. Wang, K., Niu, Y., Lu, Z., Duo, B., Effah, C. Y., & Guan, L. (2023). The effect of breakfast on childhood obesity: A systematic review and meta-analysis. Frontiers in Nutrition, 10, 1222536. https://doi.org/10.3389/fnut.2023.1222536
48. Wang, L., Zhuang, J., Zhang, H., Jin, S., Wang, H., Wan, Y., ... & Zhao, Y. (2022). Association between dietary knowledge and overweight/obesity in Chinese children and adolescents aged 8–18 years: A cross-sectional study. BMC Pediatrics, 22, 558. https://doi.org/10.1186/s12887-022-03618-2
49. Wanka, F., Vogel, M., Grafe, N., Stein, K., Körner, A., Poulain, T., & Kiess, W. (2025). Leisure activities of adolescents—associations with demographic characteristics, well-being and parental leisure engagement. Pediatric Research, 98, 559–567. https://doi.org/10.1038/s41390-025-03866-9
50. Watts, A. W., Barr, S. I., Hanning, R. M., Lovato, C. Y., & Mâsse, L. C. (2018). The home food environment and associations with dietary intake among adolescents presenting for a lifestyle modification intervention. BMC nutrition, 4, 3. https://doi.org/10.1186/s40795-018-0210-6
51. Williamson, V. G., Amaral, S., Teixeira, R., & Silva, R. (2020). The influence of socioeconomic status on snacking and snack choices among adolescents. Nutrients, 12(1), 167. https://doi.org/10.3390/nu12010167
52. World Health Organization. (2007). Growth reference data for 5–19 years: BMI-for-age (5–19 years). World Health Organization. https://www.who.int/tools/growth-reference-data-for-5to19-years/indicators/bmi-for-age
53. World Health Organization. (2022). Obesity and overweight. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight
54. Zeng, X., Cai, L., Ma, J., Ma, Y., Jing, J., Chen, Y., & Luo, J. (2018). Eating fast is positively associated with general and abdominal obesity among Chinese children: A national cross-sectional study. Scientific Reports, 8, 22273. https://doi.org/10.1038/s41598-018-32498-9

FULL PAPER 3

SCIENTIFIC PAPER

Performance analysis in volleyball – violation of sample independence in multiple regression analysis

Ivana Klaričić, Lana Seder

Faculty of Kinesiology, Osijek, Croatia

Introduction

Research into performance analysis in volleyball has produced numerous performance indicators, which can sometimes cause confusion. Multiple regression analysis is often used to identify which performance indicators are most closely related to the final score of a match. However, multiple regression analysis has several assumptions that must be met, including the independence of the sample, predictors, and residuals, as well as the normality and constant variance of the residuals (Field, 2013). In addition, the regression model should include only significant predictors – specifically, those that significantly increase the overall explained variance – to optimise the model in terms of the number of predictors and the explained variance of the criteria (Burill, 1997). Not all assumptions are always fully addressed, which can lead to invalid conclusions.

Due to the competition system in volleyball and team sports generally, it is impossible to fully meet the requirement of sample independence. This requirement states that each value of the outcome variable must originate from a separate entity (Field, 2000). Multiple regression analysis in volleyball performance analysis is, by nature, an observational study. Matches used as samples for performance analysis in sport are typically problematic, and this issue cannot be entirely resolved (O'Donoghue, 2010). Observational research does not provide the same level of experimental control but offers greater ecological validity, meaning the study conditions better reflect the real world. However, it is important to eliminate any sources of bias from the data (O'Donoghue, 2010). When the assumption of independence is violated, autocorrelation occurs, resulting in inefficient estimators, biased standard errors, and overestimation of model fit.

In most of the analysed studies using a multiple regression approach, the sampling method is not specified; only the number of matches included is reported (Marcelino et al., 2009; Pena and Casals, 2016; da Costa et al., 2025), usually comprising all available matches. The assumption of independence of entities was violated because both teams from a match, as well as several matches involving the same team, were included.

The aim of the study was to compare the estimation error when two regression models, conducted on samples with different levels of interdependence, were applied to all matches in the league.

Methods

Participants—The entity in the study was a team from a volleyball match played in the 2024/2025 Croatian Superleague for Women. A total of 105 matches were played in the league. The study design involved two sets of 40 entities. One set comprised 20 randomly selected matches with data from both teams, resulting in a total sample of 40. The other set comprised 40 randomly selected matches, with data from only one team included. The team from each match was also randomly selected.

Design—The study employed an observational research design.

Methodology—The variables were performance indicators presented as data on the official Superleague website (www.hos-cvf.hr). The criterion variable was the match score, defined as the set difference in a match; this was not official data but was defined by the authors. If a team won the match, the difference was positive; if a team lost, the difference was negative. There were five sets of official performance indicators. The first group comprised variables referring to various results (total points won by game actions, points on team's serve, points on opponent's serve, points by opponent's error) and was therefore not included in the regression analysis because they are highly correlated with the criterion variable. The other four sets consisted of 22 performance indicators referring to four game actions: service, reception, attack, and block. Service included five variables, reception six, attack six, and block three.

Statistical analysis— The normality of all variables was assessed using the Kolmogorov-Smirnov test. An independent samples t-test was conducted to determine differences between samples; the absence of differences indicates good sampling quality. Means and standard deviations are presented for both samples only for significant predictors. Two separate stepwise regression analyses were conducted for each set of entities to determine the most optimal set of predictors. Variables for each game action are mainly derived from each other and are therefore highly interdependent. The optimal set of predictors was selected based on a significant increase in R^2 and a final VIF less than 2. Additionally, effect size was presented for each model and the partial coefficient of determination for each predictor.

The predicted values were then calculated for the entire league, totalling 210 for 105 matches. The total sum of squares for residual values was calculated to compare the estimation error of the two models. Additionally, the Akaike Information Criterion was calculated. The significance level was set at $p = 0.05$. Data were analysed using Statistica for Windows 13.3 (TIBCO Software Inc.).

Results

The Kolmogorov-Smirnov test indicated that all variables were normally distributed ($p > 0.01$). The independent samples t-test showed no differences between the two samples ($p = 0.16–0.98$).

Table 1. Descriptive results.

Sample – one team per match			**Sample – both teams per match**		
	Mean	SD		Mean	SD
Set difference	-0.12	2.45	Set difference	0.00	2.62
Ace/set (n)	1.78	0.90	Ace/set (n)	1.73	1.11
Total receptions (n)	72.15	15.15	Reception negative (n)	24.98	7.46
Attack eff (att.err.-att.points)/tot.atts. (n)	0.18	0.11	Attack eff. (att.points/tot.atts.) (%)	0.33	0.06
Block point/set (n)	2.27	0.98	Block point/set (n)	2.49	1.02

Legend: SD – standard deviation.

Descriptive results are presented only for the significant variables included in the multiple regression model due to the large number of predictors.

Table 2. Multiple regression results.

Match score	**b**	**SE_b**	**β**	**$SE_β$**	**R^2_{part}**	**p**	**VIF**
Sample – one team per match (n = 40)							

R	0.85	Intercept	-2.10	1.48				0.16	
R^2	71.6%	Ace/set	0.71	0.27	0.26	0.10	14.1	0.01	1.19
F	22.03	Total receptions	-0.04	0.02	-0.23	0.10	10.9	0.03	1.25
p	0.00	Attack eff.	10.34	2.48	0.46	0.11	34.2	<0.00	1.50
f^2	3.97	Block points/set	0.65	0.25	0.26	0.10	12.4	0.03	1.19
			Sample – both teams per match (n = 40)						
R	0.84	Intercept	-7.86	2.04				<0.01	
R^2	70.9%	Ace/set	0.49	0.23	0.21	0.10	9.3	0.04	1.13
F	21.36	Reception neg.	-0.08	0.04	-0.23	0.10	11.8	0.03	1.24
p	0.00	Attack eff. (%)	21.76	4.67	0.50	0.11	36.8	<0.01	1.39
f^2	4.10	Block points/set	0.74	0.24	0.29	0.09	13.1	<0.01	1.07

Legend: R^2 – coefficient of determination; f^2 – effect size; R^2part – predictor's partial coefficient of determination; VIF – variance inflation factor.

The multiple regression analysis showed that each model included only four predictors. However, not all four predictors were the same in both models.

Table 3. Prediction of the models.

	RVmin	RVmax	SS_{res}	AIC
Model – one team per match	-2.98	2.98	403.8	50.14
Model – both teams per match	-5.13	3.75	512.8	54.32

Legend: RVmin – minimum residual value; RVmax – maximum residual value; SSres – total sum of squares of residuals; AIC – Akaike Information Criterion.

The results showed that the model conducted on the sample with only one team per match (SSres = 403.8) had better predictive accuracy when applied to all matches (SSres = 512.8).

Discussion

A sample should be randomly selected to ensure that the conclusions are valid for the entire population of entities (Blackstone, 2018). A t-test for independent samples showed no differences between the two selected samples (p = 0.16–0.98), so it can be concluded that the sampling was successful. Variables referring to various results were not included in the regression analysis because they are highly correlated with the criteria and would explain the overall variance of the score, but would not contribute to solving the problem. The final models included only four predictors each, which were not the same in both models. It was expected that the model would include only one performance indicator from each game action because of their high intercorrelation. Intercorrelation implies a high correlation between the predictors, but when two or more are included, the overall explained variance of the criteria is not

significantly increased. Furthermore, the contribution of the variables to the criteria would be difficult to explain (Field, 2013).

The overall explained variance of the match score is similar in both models, at 71.6% and 70.9%, which is very high considering there are only four predictors. The included official performance indicators can be categorised into two distinct types. The first are discrete variables representing total actions, total successful actions, and total unsuccessful actions. The second are variables derived from two or more variables, which serve as performance coefficients. Except for reception, variables referring to actions that can win a direct point – serve, attack, and block – are derived variables and represent efficiency. Previous studies confirm that these variables are better predictors (Drikos et al., 2009; Marcelino et al., 2008).

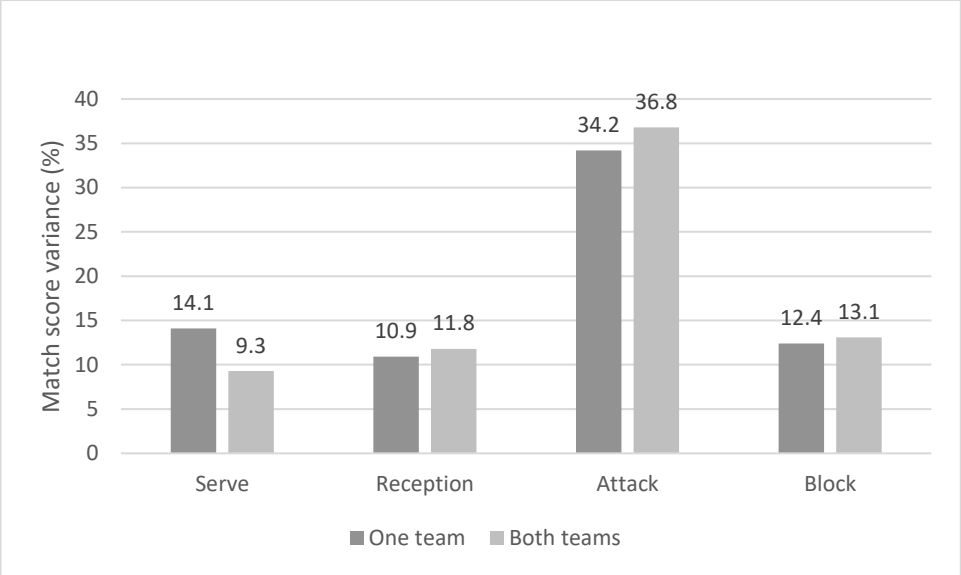


Figure 1. The partial coefficient of determination for game actions in both regression models.

The partial coefficient of determination (Figure 1) is highest for attack in both models (34.2%; 36.8%), with no notable differences between them. The three remaining game actions have a partial coefficient of determination as high as that of attack alone. This is expected, as attack wins the most points compared to serve and block. According to Inkinen et al. (2013), 60.3% of points were won by attack, 10.2% by block, and 6.0% by ace in high-level women's volleyball.

Additionally, the two models were applied to all 210 entities to determine which model had greater predictive power. The model including both teams from a match had 27% (Table 3) more estimation error than the model including only one team from each match. The Akaike Information Criterion (AIC) was used to compare the two multiple regression models, considering both explained variance and the number of predictors. In these two models, the number of predictors was four for both, so AIC was not necessary but also confirmed that the "one team model" was better. The only observed difference between the models (Figure 1) is that the model with only one team from a match prioritises serve compared to the other model (R2part = 14.1% vs. 9.3%). As previously mentioned, the violated assumption of independence leads to an overestimation of model fit, meaning the model fails to generalise when applied to other match data.

Although the independence of the sample cannot be fully ensured in match analysis, it is necessary to address it as much as possible. In sampling for regression analysis, only one team from each match in the sample should be included. Furthermore, with the large number of

matches in a competition, the sample should not be excessively large, as this could increase interdependence by including more data from the same team.

Conclusions

Research into performance analysis in volleyball has produced many performance indicators. Some distinguish between winners and losers but have no significant impact on the score and can be misleading. Therefore, the multiple regression approach remains a powerful tool in performance analysis, but only if all assumptions are properly met.

References

1. Blackstone, A. (2018). Principles of sociological inquiry: Qualitative and quantitative methods. Saylor Academy Open Textbooks. https://resources.saylor.org/wwwresources/archived/site/textbooks/Principles%20of%20Sociological%20Inquiry.pdf
2. Burrill, D. F. (1997). Modelling and interpreting interactions in multiple regression. The Ontario Institute for Studies in Education Toronto, Ontario, Canada. https://www.semanticscholar.org/paper/Modeling-and-Interpreting-Interactions-in-Multiple-Burrill/4c4e6d187db58f9d0b4189a7edb545ae9efcd45f
3. da Costa, Y. P., Martins, F. S., Ribeiro, L. R., García-de-Alcaraz, A., & Batista, G. R. (2025). Comparison and association of performance indicators according to set outcome and set score difference in AVP women's beach volleyball. Frontiers in Sports and Active Living, 7, 1584173. https://doi.org/10.3389/fspor.2025.1584173
4. Drikos, S., Kountouris, P., Laios, A., & Laios, Y. (2009). Correlates of team performance in volleyball. International Journal of Performance Analysis in Sport, 9(2), 149–156. doi:10.1080/24748668.2009.11868472
5. Field, A. (2013). Discovering statistics Using SPSS: Introducing Statistical Method. Sage. https://sadbhavnapublications.org/research-enrichment-material/2-Statistical-Books/Discovering-Statistics-Using-IBM-SPSS-Statistics-4th-c2013-Andy-Field.pdf
6. Inkinen, V., Häyrinen, M., & Linnamo, V. (2013). Technical and tactical analysis of women's volleyball. Biomedical Human Kinetics, 5(1), 43. doi:10.2478/bhk-2013-0007
7. Marcelino, R., Mesquita, I., & Afonso, J. (2008). The weight of terminal actions in volleyball. Contributions of the spike, serve and block for the teams' rankings in the World League 2005. International Journal of Performance Analysis in Sport, 8(2), 1 – 7. https://www.tandfonline.com/doi/abs/10.1080/24748668.2008.11868430
8. Marcelino, R., Mesquita, I., Andrés, J. M. P., & Sampaio, J. (2009). Home advantage in high-level volleyball varies according to set number. Journal of Sports Science & Medicine, 8(3), 352. https://pmc.ncbi.nlm.nih.gov/articles/PMC3763279/pdf/jssm-08-352.pdf
9. O'Donoghue, P. (2009). Research methods for sports performance analysis. Routledge.
10. https://repository.bbg.ac.id/bitstream/563/1/Research_Methods_for_Sports_Performance_Analysis.pdf
11. Peña, J., & Casals, M. (2016). Game-related performance factors in four European men's professional volleyball championships. Journal of human kinetics, 53, 223. doi: 10.1515/hukin-2016-0025

FULL PAPER 4

SCIENTIFIC PAPER

Determinants of the concept of transformative training in sport – a theoretical foundation for practice

Ernest Šabić, Nijaz Skender

Faculty of Pedagogy, University of Bihać, Bosnia and Herzegovina

Introduction

The development of young athletes in the modern sports environment is a complex process that transcends the boundaries of the traditional understanding of sports training. Coaching and pedagogical work with athletes (especially youth) is particularly important because key life habits, attitudes, and values are formed during this period. Young athletes are in a phase of intensive physical and psychological development, making them susceptible to the influences of coaches, peers, and the sports environment. One of the factors of a healthy lifestyle is regular physical activity. Life habits and behavioral patterns, including physical activity, are formed during development and represent the basis for the later transfer of training effects into sports performance (Šabić et al., 2022). The application of the transformational training model in this context allows sports activity—in addition to its focus on developing morpho-functional traits dominant for a specific sports discipline—to be used as a means for developing stress resilience, building self-confidence, team cohesion, and critical thinking (Erikstad et al., 2021). Palić et al. (2018) demonstrates in his research that Sport and Health instruction within a quarterly program leads to statistically significant positive changes in students' fundamental motor abilities. In this way, sport becomes an instrument not only for achieving competitive success but also for forming healthy, stable, and socially responsible individuals. Lifestyle, as a concept, is closely related to health and its promotion (Šabić et al., 2023). Skender et al. (2019) states that motor transformations are achieved through a planned and continuous process of physical exercise that leads to changes in motor abilities.

Contemporary approaches in kinesiology and sports sciences are based on the understanding of training as a complex adaptive process, the primary goal of which is the transformation of an athlete's anthropological characteristics towards the improvement of sports performance (Arnăutu & Hanţiu, 2020). In this context, particular importance is given to the model of transformational training, which represents one of the more advanced methodological concepts in the planning and programming of the training process. It involves organizing training activities in a manner that enables the integration of various components of sports preparation (conditioning, technical, tactical, and psychological) into a unified functional system (Yang, 2022). Unlike traditional approaches, which often develop individual abilities in isolation, this model insists on their interconnectedness and direct application in competitive conditions.

Transformational training represents a methodological concept whose main task is to realize the acute effects of training units, that is, to achieve the transformational processes of muscle force into power, primarily through a series of biomechanically similar exercises. The functional basis of transformational training is the so-called post-activation potentiation (PAP), which entails a state of increased excitation of certain muscle systems (Docherty, Robbins & Hodgson, 2004; Kilduff et al., 2007). The essence of post-activation potentiation is the application of heavy loads during training (primarily force and power), which leads to an elevated degree of neural stimulation of the muscles. This results in the recruitment of a larger number of motor units (and thus a higher frequency of nerve impulses in the subsequent minutes during the exercise) (Nešić, Fratrić & Kuburović, 2013). Inducing such acute effects is most commonly applied in the

execution of training tasks (exercises) characterized by low external load and high (submaximal and maximal) movement velocity (Jukić et al., 2004), which is particularly important for the speed-explosive refinement of sports potentials. Therefore, transformational training also implies a corresponding specific organizational form for each training unit.

Transformative Training – Kinesiological Approach

Contemporary approaches in kinesiology and sports psychology indicate that sports training is not solely a physiological process, but a complex system in which biological, psychological, and social factors are intertwined. In this context, transformational training represents a modern model that integrates different dimensions of athlete development and overcomes traditional reductionist approaches focused exclusively on physical abilities (Turnnidge & Côté, 2016; Liu et al., 2023). From a modern management perspective, the training process is defined as the "heart" of the sports system within every sports organization, operating in a synergistic coach–athlete relationship as a unified and inseparable subsystem (Nešić, 2017). In this sense, the transformational approach to training particularly emphasizes the role of the coach as an agent of change, i.e., as the leader of a transformation process that influences the bio-psycho-social capacities of the athlete. Such a model does not aim only at improving motor-functional performance, but also at developing the athlete's personality, social competencies, and psychological stability, which is consistent with contemporary theories of athlete development (Gosai et al., 2021; Peng & Wong, 2025).

Transformational processes in sport represent the essence of training effects on the athlete's organism. Within the kinesiology framework, training is viewed as a set of operators acting on the athlete's initial state, producing quantitative and qualitative changes in their abilities (Bompa & Buzzichelli, 2019). This refers to physiological adaptation to training, where the outcome is achieved through systematically and appropriately dosed training loads aimed at improving functional capacities. In other words, the key to successful training lies in the optimal balance between load and recovery (Veljović, Međedović & Ostojić, 2012). This process is based on fundamental principles of sports training (Bjelica & Fratrić, 2011): (a) progressive overload, (b) adaptation, (c) supercompensation, (d) continuity, and (e) specificity. Based on these principles, transformational training effects manifest through several components: (a) morphological changes (hypertrophy, changes in body composition, etc.), (b) functional adaptations (increased VO_2max, improved energy system efficiency, etc.), (c) motor abilities (strength, speed, endurance, coordination, etc.), and (d) technical-tactical improvements.

Transformative training represents a model of sports training in which abilities developed in basic training are "transformed" into sport-specific performance. Its essence includes: (1) integration of different capacities, (2) increased training specificity, and (3) directing adaptations toward real competitive conditions. Unlike a segmented approach (e.g., strength developed in the gym and technique on the field), transformative training seeks to integrate these components through complex motor tasks. In this sense, modern training must ensure the transfer of developed abilities into actual sports performance, which is the primary goal of transformational models (Bompa & Buzzichelli, 2021).

The kinesiological interpretation of transformative training is based on several key aspects (Grgic et al., 2018):

1. Biomechanical aspect – enables optimization of movement structure through improved coordination, reduced energy expenditure, and increased force efficiency. The integration of strength and technique improves kinematic and kinetic parameters, directly enhancing performance.

2. Physiological aspect – involves simultaneous activation of different energy systems (aerobic, anaerobic, phosphagen), enabling the development of sport-specific endurance, crucial for success in most sports.

3. Neurological aspect – affects motor unit activation speed, synchronization of muscle groups, and development of inter- and intramuscular coordination, particularly important in sports requiring high precision and fast reaction time.

4. Didactic aspect – enables learning through situational conditions, faster acquisition of technical-tactical elements, and increased athlete motivation; training is structured through complex exercises, situational tasks, and combined training methods.

In contemporary training practice, across most sports disciplines where transformative training methods are applied, several key principles have been identified as the most effective in producing morphological and motor transformations in athletes (Pašalić & Rađo, 2003). These principles define the operational tools of transformative training. Their proper application enables efficient transformation of general motor abilities into sport-specific performance, which is the primary goal of modern kinesiology-based training. These include (Damas et al., 2016; Coratella & Schena, 2016; Bernárdez-Vázquez, 2022; Vargas et al., 2025):

1. Progressive overload principle – gradual increase in training load through intensity,volume, or reduced rest periods; without progression, stagnation occurs.

2. Muscle isolation principle – targeted activation of a specific muscle group with minimal involvement of others to maximize development and neuromuscular control.

3. Muscle confusion principle – continuous variation of training stimuli to prevent adaptation to repetitive loads.

4. Continuous tension principle – maintaining constant muscle tension throughout movement to increase time under tension and hypertrophic stimulus.

5. Partial repetition principle – performing movements with reduced range of motion, typically under fatigue, to prolong muscle stimulation.

6. Mega synergy principle – simultaneous or sequential activation of multiple muscle groups through complex exercises, enhancing coordination and transfer to sport performance.

7. Pyramidal principle – progressive increase or decrease in load with corresponding adjustment of repetitions, balancing strength and hypertrophy development.

8. Muscle priority principle – prioritizing weaker or more important muscle groups at the beginning of training when energy levels are highest.

9. Compound set principle – combining two or more exercises without rest to increase intensity, metabolic stress, and training efficiency.

10. Negative repetition principle – emphasizing the eccentric phase of movement, where muscles produce higher force, enhancing strength and hypertrophy but requiring caution due to injury risk.

11. Drop set principle – continuing exercise after reaching failure by reducing load without rest to maximize muscle fatigue and growth stimulus.

12. Instinctive and individual principle – training must be adapted to individual athlete characteristics (genetics, training level, goals), requiring self-regulation and awareness of training responses.

Transforming Training – A Kinesiological Approach

Contemporary approaches in kinesiology and sports psychology indicate that sports training is not exclusively a physiological process, but a complex system where biological, psychological, and social factors intertwine. In this context, transformational training represents a modern model that integrates various dimensions of athlete development and transcends traditional reductionist approaches focused solely on physical abilities (Turnnidge & Côté, 2016; Liu et al., 2023). From a modern management perspective, the training process is defined as the "heart" of the sports system within any sports organization, occurring through a synergistic coach-athlete relationship as a unique and indivisible subsystem (Nešić, 2017). In this sense, the transformational approach to training particularly emphasizes the role of the coach as the agent of change—the leader of the management process of transformation that affects the bio-psycho-social capacities of the athlete. This model aims not only to improve motor-functional performance but also to develop the athlete's personality, social competencies, and psychological stability, aligning with contemporary theories of sports development (Gosai et al., 2021; Peng & Wong, 2025).

Transformational processes in sports represent the essence of how training impacts the athlete's organism. Within the kinesiological approach, training is viewed as a set of operators acting on the athlete's initial state, producing quantitative and qualitative changes in their abilities (Bompa & Buzzichelli, 2019). Thus, it refers to the organism's adaptation to training, resulting in the positive effects of systematic and properly dosed loads aimed at increasing functional capacities. Specifically, the key to successful training lies in the optimal balance between load and recovery (Veljović, Međedović & Ostojić, 2012). The foundation of this process rests on the fundamental principles of sports training (Bjelica & Fratrić, 2011): a) progressive overload, b) adaptation, c) supercompensation, d) continuity, and f) specificity. Based on these principles, the transformational effects of sports training are reflected through several factors:

1. Morphological changes (hypertrophy, changes in body composition, etc.),
2. Functional adaptation (increase in VO_2max, efficiency of energy systems, etc.),
3. Motor abilities (strength, speed, endurance, coordination, etc.), and
4. Technical-tactical improvements.

Converting Training

Converting training (or "Conversion training") represents a model of sports training in which various abilities developed during basic training are "converted" into specific performances relevant to a particular sport. Its essence consists of: (1) the integration of different abilities, (2) increasing training specificity, and (3) directing adaptations toward realistic competitive conditions. Unlike a segmented approach (e.g., strength developed in the gym and technique on the field), converting training seeks to unify these components through complex motor tasks. In this sense, modern training must facilitate the transfer of developed abilities into specific sports performance, which is the primary goal of transformational models (Bompa & Buzzichelli, 2021).

The kinesiological interpretation of converting training is based on several key aspects (Grgic et al., 2018):

- Biomechanical: Enables optimization of movement structure by improving coordination, rationalizing energy consumption, and increasing force efficiency. The integration of strength and technique improves kinematic and kinetic parameters.
- Physiological: Simultaneous activation of different energy systems (aerobic, anaerobic, phosphagen), allowing the development of "sport-specific endurance."
- Neurological: Significant impact on the rate of motor unit recruitment, synchronization of muscle groups, and development of inter/intramuscular coordination.
- Didactic: Enables learning through situational conditions, faster acquisition of technical-tactical elements, and increased athlete motivation.

Key Principles of the Transformation Model

In modern training practice, several basic principles have emerged as the most effective for achieving transformations (primarily morphological and motoric) (Pašalić & Rađo, 2003). These principles determine the operational tools through which converting training is realized (Damas et al., 2016; Coratella & Schena, 2016; Bernárdez-Vázquez, 2022; Vargas et al., 2025):

1. Principle of Progressive Overload: The gradual increase of training load (weight, repetitions, sets, or reduced rest) to trigger adaptation and prevent stagnation.
2. Principle of Muscle Isolation: Focusing the load on a specific muscle group with minimal involvement of others to maximize development and neuromuscular control.
3. Principle of Muscle Confusion: Constantly changing training impulses (exercises, intensity, volume) to prevent the organism from adapting to a monotonous routine.
4. Principle of Continuous Tension: Maintaining constant muscle tension throughout the movement without full relaxation, increasing "time under tension" for hypertrophy and metabolic stress.
5. Principle of Partial Repetitions: Performing movements in a limited range, usually during the fatigue phase, to further stimulate the muscle after full repetitions are no longer possible.
6. Principle of Mega Synergy: Simultaneous or sequential engagement of multiple muscle groups through complex exercises, ensuring high transfer to sports performance.
7. Pyramid Principle: Gradually increasing load while decreasing repetitions (ascending pyramid) or vice versa (descending), optimizing the combination of strength and hypertrophy.
8. Principle of Muscle Priority: Prioritizing exercises for weaker or target muscle groups at the beginning of the session when energy and focus are at their peak.
9. Principle of Compound Sets: Combining two or more exercises without rest (for the same or opposing muscle groups) to increase intensity and time efficiency.
10. Principle of Negative Repetitions: Focusing on the eccentric phase (lowering the weight) where the muscle can generate more force, highly effective for strength and hypertrophy but requiring caution due to injury risk.
11. Principle of Drop Sets: Performing a set to failure, then reducing the weight and continuing without rest to maximize muscle depletion and metabolic stress.

12. Principle of Instinctiveness and Individuality: Emphasizing that training must be tailored to the athlete's individual characteristics (genetics, training level) and their ability to "feel" and adjust the training to their current state..

Converting Training – Socio-Psychological Aspects

In the context of a socio-psychological approach, the transformational effect of converting training is determined by the view of the athlete as a bio-psycho-social being. Their behavior is inextricably linked to their morpho-functional and motor performance and depends on the interaction of physical, psychological, and social factors. This approach emphasizes the importance of intrapersonal factors (motivation, emotions, and self-confidence) as well as the interpersonal relationships that develop between the athlete and the coach, and among team members (Peng & Wong, 2025). Contemporary approaches in complementary fields of sports science indicate that the quality of interaction between coach and athlete directly impacts motivation, sports satisfaction, and long-term participation in the sports system. Perceiving the coach as a supportive and inspiring leader increases the likelihood that the athlete will adopt and develop positive attitudes toward training and competition (Karayel, Adilogullari, & Senel, 2024). This relationship ensures a positive psychological environment, creating the prerequisites for the optimal development of sports performance.

This aspect highlights the importance of high-quality coaching staff characterized by transformational leadership, as a vital factor in managing the process of converting training. This leadership style emphasizes the coach's ability to inspire athletes, which is essential for manifesting and developing their full potential—encouraging them to transcend their own limitations (Turnnidge & Côté, 2018). For example, athletes training in an environment where the coach applies a transformational leadership style show higher levels of engagement and commitment to training, contributing to the development of trust and positive team dynamics (Liu et al., 2023).

The reflections of a leadership-driven management style in converting training are particularly significant in the realm of athlete motivation. This is especially evident when sports training is viewed through the lens of Self-Determination Theory (SDT), which emphasizes three basic psychological needs: autonomy, competence, and relatedness (Standage, 2023). When these needs are met, athletes develop intrinsic motivation, which is more stable and long-term than extrinsic motivation (Živanović, 2018). Converting training contributes to satisfying these needs through a supportive coaching relationship, involving athletes in decision-making, and fostering team spirit. Research shows that athletes who feel greater autonomy and coach support demonstrate higher levels of motivation and greater satisfaction with their sporting activities (Liu et al., 2023).

Psychological safety is also a crucial element of converting training. It involves the athlete's sense of freedom to express opinions and learn from mistakes without fear of negative consequences. Functioning within such an organizational atmosphere allows athletes to develop self-confidence and creativity, ultimately contributing to more effective sports performance (Gosai, Jowett, & Nascimento-Júnior, 2021). Furthermore, converting training aids in the development of team cohesion (the level of connection and cooperation among team members). A high degree of cohesion correlates with better communication and higher motivation levels, which positively influences competitive results (Ivašković, 2020).

The implications of converting training are also reflected in psychological resilience, manifested through successfully overcoming stress and coping with the pressures and failures inherent in sports (Despotović et al., 2024). This can be a key factor in long-term sporting success.

Therefore, this training model contributes to the development of resilience through coach support, positive interpersonal relationships, and the cultivation of athlete self-confidence. Research indicates that teams where the coach employs a transformational leadership style show higher levels of stress resilience and handle competitive challenges more effectively (Karayel et al., 2024).

Since training processes in sports take place in an environment of intense interpersonal communication, the social environment significantly impacts an athlete's development and their sporting identity. Through interaction with coaches and teammates, athletes develop a sense of belonging, social skills, and values that shape their identity (Verma et al., 2019). A positive sporting identity is a driving factor for the development of both physical abilities and social and psychological competencies. This can have a powerful impact on the athlete's overall long-term development, both within sports and in a broader social context (Markić, 2022).

Converting Training – Empirical Experiences

Empirical research to date in the field of converting training has pointed to its significant impact, both in terms of developing physical performance and enhancing the socio-psychological dimensions of athletes. It is well-established that the transformational approach to training is based on the integration of physical load with the development of motivation, self-confidence, and interpersonal relationships; therefore, it should not be treated as an isolated physical process, but as a complex adaptive system involving cognitive, emotional, and social components (Arthur et al., 2011).

One of the most compelling perspectives emerging from empirical data is the connection between the transformational leadership of coaches—who implement converting training as a standard model—and athlete performance (Bass & Riggio, 2006). Coaches who apply the principles of transformational leadership (inspiration, individualized consideration, intellectual stimulation) significantly increase athletes' intrinsic motivation and commitment to training. This, in turn, is positively reflected in higher levels of satisfaction and superior competitive results.

Beyond individual effects, empirical data highlights the importance of converting training in developing team cohesion. A clear vision, motivation, and support foster stronger bonds among team members, resulting in better communication and greater trust within the team, which ultimately reflects on collective team performance (Callow et al., 2009).

In the context of physiological adaptations, research by Morton et al. (2010) confirms that transformational training contributes to more efficient development of motor abilities when integrated with psychological factors. Athletes training in a motivationally supportive environment achieve greater progress in strength, endurance, and coordination compared to those exposed to traditional, authoritarian training models. Furthermore, converting training has positive long-term effects; a study by Smith et al. (2007) found that athletes who participated in such programs maintain higher levels of physical activity even after their competitive careers end.

Limitations and Contextual Factors

Despite the proven benefits, certain limitations detected in empirical studies must be considered. According to Cruickshank and Collins (2012), the effects of transformational training can vary depending on the context, the individual characteristics of the athlete, and the level of competition. The authors emphasize that this approach requires a high level of coaching competence, particularly in communication and emotional intelligence.

Empirical Research in Bosnia and Herzegovina (Una-Sana Canton)

While global research confirms the effectiveness of the transformational model, the concept of converting training (CT) remains under-discussed in sports organizations within Bosnia and Herzegovina. Consequently, preliminary research is essential as a foundational scientific activity.

A brief survey was conducted on a convenience sample of 59 sports professionals (coaches) from sports clubs in the Una-Sana Canton to determine their level of awareness regarding the concept and application of CT. The sample characteristics (independent variables) were as follows:

- Gender: Male: 45 (76.3%); Female: 14 (23.7%).
- Coaching Experience: Up to 5 years (14; 23.7%), 6–10 years (25; 42.4%), 11–15 years (15; 25.4%), and over 15 years (5; 8.5%).
- Type of Sport: Team sports (34; 57.6%) and Individual sports (25; 42.2%).

Key Findings and Statistical Analysis

The results indicate a very low level of information regarding the essence and benefits of converting training.

- More than half of the respondents (55.9%) are unfamiliar with the term CT.
- A vast majority (79.7%) cannot describe the CT model in detail.
- The same percentage (79.7%) does not apply converting training in their practice (Table 1).

Contingency analysis indicates that coaching experience is a key factor in explaining differences in perception, understanding, and application (significance level $p = 0.0001$). Conversely, gender and type of sport showed no statistically significant impact. The intensity of the correlation between experience and the analyzed variables ranges from moderate to very high.

Post-hoc analysis confirmed that the differences identified by chi^2 tests primarily stem from the gap between coaches with shorter and longer tenures. A consistent pattern emerged: statistically significant differences appear between the lower categories (5–10 years) and the higher categories of experience (11+ years). This suggests a cumulative effect of professional experience on the practical application of CT.

Regarding dependent variables, contingency analysis showed statistically significant correlations between all three variables. The strongest correlation was found between the ability to describe CT in detail and its practical application. This suggests that a conceptual understanding of converting training is a crucial prerequisite for its implementation in practice. These findings support the construct validity of the phenomenon being researched.

Table 1: Characteristic responses to survey variables

Questions	**Do you know what transformative training is**		**Can you describe it in detail**		**Do you apply transformative training?**	
Responses	*f*	*%*	*f*	*%*	*f*	*%*
Yes	12	*20,3*				
I've heard about it, but I'm not fully informed about it.	14	*23,7*				

No	33	*55,9*				
Yes			12	*20,3*		
No			47	*79,7*		
Yes					*5*	*8,5*
No					*47*	*79,7*
Sometimes					*7*	*11,9*

Table 2: Results of the contingency analysis

Independent variable	**Contingency (Chi-square)**		
	Do you know what transformative training is	**Can you describe it in detail?**	**Do you apply transformative training?**
Gender	χ^2 = 4,70 p = ,095 Cramer's = 0,28	χ^2 = 1,05 p = ,306 Cramer's = 0,13	χ^2 = 2,30 p = ,316 Cramer's = 0,20
Coaching experience	χ^2 = 34,70 p = **,0001** Cramer's = 0,54	χ^2 = 25,10 p = **,0001** Cramer's = 0,65	χ^2 = 73,84 p = **,0001** Cramer's = 0,79
Sport	χ^2 = 0,54 p = ,763 Cramer's = 0,10	χ^2 = 0,00 p = ,996 Cramer's = 0,00	χ^2 = 0,01 p = ,994 Cramer's = 0,01

Concluding Remarks

The principles of the transformative training model—individualization, inspirational motivation, cognitive stimulation, social dimension, and holistic development—represent the foundation of an innovative approach to working with athletes. Various empirical studies have confirmed that their application contributes not only to sports performance but also to psychological well-being, social development, and the formation of life skills.

The application of transformative training in sport largely depends on the age characteristics of athletes. The effects of transformative training should not be interpreted uniformly, as they vary in accordance with the athlete's developmental stage. The most pronounced positive effects are observed during phases of intensive psychosocial development. In this context, transformative training should be viewed as a development-sensitive approach that requires adaptation of content and training methods to the athlete's age. In childhood (approximately 6–12 years), the primary goal of sports training is the development of fundamental motor skills and a positive attitude toward physical activity. During adolescence (12–18 years), transformative training gains importance as a methodological construct of coaching practice, precisely due to intensive changes in identity, emotional stability, and social relationships among young athletes. In early senior age (18–25 years), athletes enter a phase of peak psychophysical performance development. At this stage, transformative training, in addition to its basic role of effectively adapting physical performance to a specific sport discipline, also contributes to optimizing psychological preparation and maintaining motivation. In elite and experienced athletes, the effects of transformative training are mainly reflected in performance maintenance and prevention of psychological burnout. It is important to emphasize that transformative training is not equally effective in all age categories if applied without adaptation. Inappropriate application of transformational principles, especially in work with younger athletes, may lead to

misunderstanding of training goals or psychological overload. Therefore, coaches must carefully consider the intensity, content, and frequency of the transformational approach in relation to the athletes' developmental level (Cruickshank & Collins, 2012).

Overall, existing empirical experience, as well as a number of studies, indicate transformative training as a suitable model for application in adolescent and early senior age groups. At these stages, athletes are most receptive to the development of psychological and social competencies, in addition to their morphofunctional characteristics and capacities. However, its application certainly has significant benefits across all age categories, provided that it is adequately adapted to the developmental characteristics of athletes and the specific nature of the sport discipline.

It can be concluded that the most significant advantage of the transformative training model lies in its holistic nature. Unlike traditional approaches (which primarily focus on physical preparation and technical-tactical skills), transformative training integrates bio-psycho-social and cultural dimensions of sports development. Another important advantage is the development of life skills: athletes who undergo transformative training become not only better competitors but also develop skills applicable beyond sport—decision-making, communication, leadership, and teamwork. In this way, sport becomes a platform for education and socialization, not only competition.

Of course, the concept of transformative training also has certain limitations. First, its implementation requires a high level of coaching competence (coaches must develop skills beyond kinesiology, including inspirational motivation, individualization, and cognitive stimulation). The second limitation relates to institutional support. Transformative training requires systemic support from sports organizations, schools, and parents. Without such support, coaches are often pressured to focus exclusively on results, neglecting psychological and social development. The third challenge is the evaluation of its effects. Comprehensive longitudinal studies are needed to monitor athletes over a longer period of their sporting careers.

In the context of transformative training, the reality of the sports environment in the Una-Sana Canton is not fully aligned with positive experiences from broader regional and international contexts. It is very difficult to find a sports organization that clearly defines and applies the principles of the transformative training model. A brief empirical study detected a tendency that most coaches are almost unfamiliar with this concept (let alone its essence), which consequently reflects its weak application in training practice. Professional work in most sports organizations in this area is still based on traditional methods. This may pose a risk to their competitiveness compared to sports organizations in wider international contexts that recognize and apply the positive effects of transformative training.

In light of all the above, future and more comprehensive research on this topic would be highly beneficial and recommended. Further empirical and theoretical studies, as well as the affirmation of the transformative training model, could make a significant contribution to modern sports science and practice.

References

1. Arnăutu, G., & Hanţiu, I. (2020). Impact of using modern technology in training on sports performance. Timişoara Physical Education and Rehabilitation Journal, 13(24), 51–56.
2. Arthur, C. A., Woodman, T., Ong, C. W., Hardy, L., & Ntoumanis, N. (2011). The role of athlete narcissism in moderating the relationship between coaches' transformational leader behaviors and athlete motivation. Journal of Sport & Exercise Psychology, 33(1), 3–19.

3. Bass, B. M., & Riggio, R. E. (2006). Transformational leadership. Psychology Press.
4. Beauchamp, M. R., Morton, K. L., & Keith, S. E. (2010). Transformational teaching and physical activity: A new paradigm for adolescent health promotion. Journal of Health Psychology, 15(2), 248–257.
5. Bernárdez-Vázquez, R., Raya-González, J., Castillo, D., & Beato, M. (2022). Resistance training variables for optimization of muscle hypertrophy: An umbrella review. Frontiers in Sports and Active Living, 4, 949021.
6. Bjelica, D., & Fratrić, F. (2011). Sportski trening: Teorija, metodika i dijagnostika. Fakultet za sport i fizičko vaspitanje.
7. Bompa, T. O., & Buzzichelli, C. (2019). Periodization: Theory and methodology of training (6th ed.). Human Kinetics.
8. Bompa, T. O., & Buzzichelli, C. (2021). Periodization of strength training for sports. Human Kinetics.
9. Callow, N., Smith, M. J., Hardy, L., Hardy, J., & Arthur, C. A. (2009). Measurement of transformational leadership and its relationship with team cohesion and performance level. Journal of Applied Sport Psychology, 21(4), 395–412.
10. Coratella, G., & Schena, F. (2016). Eccentric resistance training increases and retains maximal strength, muscle endurance, and hypertrophy in trained men. Applied Physiology, Nutrition, and Metabolism, 41(11), 1184–1189.
11. Cruickshank, A., & Collins, D. (2012a). Change management: The case of elite sport performance team. Journal of Change Management, 12(2), 209–229.
12. Cruickshank, A., & Collins, D. (2012b). Culture change in elite sport performance teams: Examining and advancing effectiveness in the new era. Journal of Applied Sport Psychology, 24(3), 338–355.
13. Damas, F., Phillips, S. M., Libardi, C. A., et al. (2016). Resistance training-induced changes in integrated myofibrillar protein synthesis are related to hypertrophy only after attenuation of muscle damage. The Journal of Physiology, 594(18), 5209–5222.
14. Docherty, D., Robbins, D., & Hodgson, M. (2004). Complex training revisited: A review of its current status as a viable training approach. Strength and Conditioning Journal, 26(6), 52–57.
15. Erikstad, M. K., Høigaard, R., Côté, J., Turnnidge, J., & Haugen, T. (2021). An examination of the relationship between coaches' transformational leadership and athletes' personal and group characteristics in elite youth soccer. Frontiers in Psychology, 12, 707669.
16. Gosai, J., Jowett, S., & Nascimento-Júnior, J. R. A. (2021). When leadership, relationships and psychological safety promote flourishing in sport and life. Sports Coaching Review, 12(2), 145–165.
17. Grgic, J., Schoenfeld, B. J., Davies, T. B., et al. (2018). Effect of resistance training frequency on gains in muscular strength: A systematic review and meta-analysis. Sports Medicine, 48(5), 1207–1220.
18. Ivašković, I. (2020). Zaupanje kot faktor kohezije športnega tima. Journal of Universal Excellence, 9(4), 325–339.
19. Jukić, I., Milanović, D., Vuleta, D., et al. (2004). Prevencijski kondicijski trening. In Zbornik radova: Dopunski sadržaji sportske pripreme (pp. 22–28). Zagreb.
20. Karayel, E., Adilogullari, I., & Senel, E. (2024). The role of transformational leadership in the associations between coach–athlete relationship and team resilience. BMC Psychology, 12, 514.
21. Kilduff, L. P., Bevan, H. R., Kingsley, M. I. C., et al. (2007). Postactivation potentiation in professional rugby players: Optimal recovery. Journal of Strength and Conditioning Research, 21(4), 1134–1138.

22. Liu, W., Wang, W., & Yang, S. (2023). Perceived transformational leadership from the coach and athletes' subjective well-being. Frontiers in Psychology, 13, 1100645.
23. Markić, A. (2022). Razvoj identiteta mladih kroz sport (Doctoral dissertation). Sveučilište u Zagrebu.
24. Nešić, M. (2017). Determinante kompetencija menadžera u sportu. Poslovna ekonomija, 11(2), 150–166.
25. Nešić, M., Fratrić, F., & Kuburović, D. (2013). Principi modela pretvarajućeg treninga u karate sportu. In V. Bunčić (Ed.), Zbornik radova: Vaspitno-obrazovni i sportski horizonti (pp. 192–197). Subotica.
26. Palić, A., Skender, N., & Ademović, A. (2018). Effects of sport teaching on transformation of motoric abilities of students of Faculty of Education in Mostar. Sportski logos, 15(28-29).
27. Pašalić, E., & Rađo, I. (2003). Osnovni principi treninga sa teretom. In D. Milanović & I. Jukić (Eds.), Kondicijska priprema sportaša (pp. 184–186). Zagreb.
28. Peng, Y., & Wong, M. Y. C. (2025). Effects of coaches' transformational leadership behavior on team cohesion: The mediating role of mental toughness. Frontiers in Psychology, 16, 1692882.
29. Šabić, E., Skender, N., Selimović, N., & Kurtović, N. (2022). Gender as a determinant of students' life habits related to their physical activity. Sport Science – International Scientific Journal of Kinesiology.
30. Šabić, E., Skender, N., Selimović, N., Kurtović, N., & Manić, G. (2023). Satisfaction with the quality of life and preferred lifestyle among active recreationists. Sport Science, 16(2), 48–57.
31. Skender, N., Stanković, A., & Palić, A. (2019). Tjelesni odgoj sa osnovama motoričkih transformacija. Štamparija "Fojnica".
32. Smith, R. E., Smoll, F. L., & Cumming, S. P. (2007). Effects of a motivational climate intervention for coaches on young athletes' sport performance anxiety. Journal of Sport & Exercise Psychology, 29(1), 39–59.
33. Standage, M. (2023). Self-determination theory applied to sport. In R. M. Ryan (Ed.), The Oxford handbook of self-determination theory (p. 701). Oxford University Press.
34. Turnnidge, J., & Côté, J. (2018). Applying transformational leadership theory to coaching research in youth sport: A systematic literature review. International Journal of Sport and Exercise Psychology, 16(3), 327–342.
35. Vargas, M. S., Sillero, M. G., Izguierdo, S. M., & Baz-Valle, E. (2025). Cluster sets and traditional sets elicit similar muscular hypertrophy: A volume and effort-matched study in resistance-trained individuals. European Journal of Applied Physiology, 125(6), 1725–1734.
36. Veljović, D., Međedović, B., & Ostojić, S. M. (2012). Oporavak vrhunskih sportista: Pregled savremenih metoda. TIMS Acta, 6, 10–18.
37. Verma, N., Eklund, R. C., Arthur, C. A., Howle, T. C., & Gibson, A. M. (2019). Transformational teaching, self-presentation motives and identity in adolescent female physical education. Journal of Sport & Exercise Psychology, 41(1), 1–9.
38. Yang, C. (2022). How technology is revolutionizing sports training and healthcare teaching. Journal of Commercial Biotechnology, 27(4), 79.
39. Živanović, R. V. (2018). Motivacija u fizičkom vaspitanju i sportu. Metodička teorija i praksa, 18(2), 237–250.

FULL PAPER 5

SCIENTIFIC PAPER

Decoding age effects: motor performance with and without the ball in youth soccer

Jakov Marasović, Ante Rađa, Marko Erceg

Faculty of Kinesiology, University of Split, Croatia

INTRODUCTION

Chronological age, calculated as the time elapsed since birth, has traditionally been used in sports to group age-grade teams, identify talented athletes, and set limits for exercise prescription (Lloyd et al., 2014). The progression toward a state of maturity or adulthood, characterized by status, timing, and tempo, is referred to as biological maturation (Perroni et al., 2024). Biological maturation is marked by high interindividual variability, indicating that children of the same chronological age do not mature simultaneously, with some individuals maturing ahead of their peers (Jackowski et al., 2011). The most significant differences between chronological and biological age occur due to the intensity of biological changes that take place between 10 and 16 years of life (Reiter & Lee, 2002). The relationships among growth, maturation, and functional capacities of youth soccer players, as well as their potential implications for athlete selection and development, are frequently discussed within the context of talent identification (Coelho e Silva et al., 2010).

Previous literature emphasizes that individuals of the same chronological age can differ substantially in biological maturity (Kemper & Verschuur, 1981; Baxter-Jones, Eisenmann, & Sherar, 2005; Rowland, 2005), particularly in terms of strength, speed, and endurance (Vaeyens et al., 2006; Figueiredo et al., 2009; Hill et al., 2020; Selmi et al., 2020). Such results may lead to the more frequent selection of early-maturing players, which in turn can result in late-maturing peers dropping out (Malina et al., 2007). The influence of biological maturity on motor performance in young soccer players has been widely studied (Malina, 1995; Vandendriessche et al., 2012). For example, Rommers et al., 2019, Gundersen et al., 2022, Hermassi et al., 2024, Konarski et al., 2024, and Hironaga et al., 2025 demonstrated the strong impact of biological maturity on speed and explosive power, while Valente-dos-Santos et al., 2012 also found an effect on aerobic capacity. On the other hand, the influence of biological maturity on sport-specific ball skills is much smaller (Figueiredo et al., 2009; Vandendriessche et al., 2012; Gouvea et al., 2016). Although some studies (Malina et al., 2005) found significant effects on sport-specific skills (e.g., ball control with the body and head, dribbling with a pass), the small explained variance (13–21%) suggests that maturity plays a negligible role in explaining technical skills.

More recent studies have attempted to clarify the influence of either biological or chronological age on specific dimensions of anthropometric status. To the best of our knowledge, no study has simultaneously considered both aspects of age in the same model and examined their independent contribution to player performance. In particular, it would be beneficial to assess how these effects influenced skills with and without the ball and across different age categories. Therefore, this study aimed to determine the influence of age (biological and chronological) on motor performance with and without the ball in different youth age categories (U15, U17, and U19).

METHODS

Participants

The sample of this cross-sectional study consisted of 49 U15 players (chronological age: 13.75 ± 0.55 years; biological age: 14.01 ± 0.91), 48 U17 players (chronological age: 15.97 ± 0.52 years;

biological age: 15.91 ± 0.85), and 40 U19 players (chronological age: 18.12 ± 0.61 years; biological age: 17.56 ± 0.63). Research was approved by the Ethical Committee of the Faculty of the Kinesiology (approval number 181-205-02-05-24-010, Split, Croatia). All participants were recruited from the same football club, with all three age categories competing in the highest national league. The players trained four times per week, while official matches were played on Saturdays or Sundays. On average, each participant played approximately 30 matches per year. All players were tested under uniform environmental conditions (8:00–10:00 a.m.; 25.6 ± 0.8°C; 36.3 ± 2.5% relative humidity). Each testing session began with a questionnaire including date of birth, dominant leg, and training experience. Testing was conducted during the preparatory period for the upcoming competitive season. For participants younger than 18 years, informed consent was obtained from their parents or legal guardians through a questionnaire provided before participation in the study.

Anthropometric and maturity measures

Anthropometric variables included in this study were body mass (BM), body height (BH), body mass index (BMI), and sitting height (SH), all assessed in accordance with standardized international protocols (Gordon, Chumlea, & Roche, 1988). Each measurement was performed twice, and the average value was used for further analysis. Additional anthropometric variables, including fat mass (FAT), fat-free mass (FFM), and percentage of body fat (%BF), were estimated using a Tanita bioelectrical impedance analyzer. Chronological age (CA) was calculated in decimal form by comparing the participants' date of birth with the date of data collection (Ross & Marfell-Jones, 1991). The estimated biological age (BA) was calculated using age at peak height velocity (APHV) according to Mirwald et al., 2002, with each participant's individual APHV compared to the reference value for boys of 13.8 years (Deprez et al., 2015). The formula used for calculating the estimated biological age (BA) was:

$$\text{Estimated biological age (BA)} = \text{Chronological age (CA)} + (13.8 - \text{Individual APHV})$$

Speed and agility with and without the ball

Performance without the ball consisted of eight tests used to evaluate speed and agility, with results expressed in seconds. Sprint performance was assessed using 5-meter (S5m), 10-meter (S10m), and 20-meter (S20m) sprint tests. Agility was evaluated using the following tests: slalom test (SLAL), zig-zag test (ZIG-ZAG), 9-3-6-3-9 test (93639m), and the 5 × 10 m shuttle run (5×10m). The slalom test involved weaving between six cones placed in a straight line, each spaced 2 meters apart, over a total distance of 11 meters (Sporiš et al., 2010). Participants were instructed to complete the course as quickly as possible, moving in both directions and turning around the final cone. The 9-3-6-3-9 test was performed on artificial turf with lines marked at 6, 9, 12, and 18 meters from the starting line. Participants started behind the starting line with a ball. On the command "go," they dribbled the ball to the 9-meter line, then moved 3 meters backward and touched the line again. A 6-meter forward run followed this, another 3-meter backward movement, and finally a maximal sprint to the 18-meter line. The test was completed when the participant crossed the 18-meter line. The task was repeated three times with sufficient recovery between trials. The zig-zag test was performed on a flat artificial surface. Participants started from a standing (medium) start position with a ball behind the starting line. The course was designed as a rectangle measuring 16 × 10 yards (4.85 × 3 m), with one cone positioned at the center. Participants were required to run as fast as possible around the cones in the following sequence: around the central cone, then around two side cones, back around the central cone, and finally around the last cone toward the start/finish line. The test was repeated three times with adequate rest between trials. The 5 × 10 m shuttle run was conducted on artificial turf with two cones placed 10 meters apart. Participants were required to run back and forth between the cones five times, covering a total distance of 50 meters. Functional capacities were evaluated using the YO-YO intermittent recovery test, from which relative maximal oxygen uptake was estimated via an indirect method (Bangsbo, Iaia and Krustrup, 2008). Tests performed with the ball included 15-meter flying sprint (S15m B) and 20-meter (S20m B) sprint

test, as well as all previously described agility tests performed with the ball (SLAL B, ZIG-ZAG B, 93639m B, and 5×10m B). All timed tests were recorded using a photocell timing system (Brower Timing Systems, Draper, USA). Participants started 50 cm behind the starting line to prevent premature activation of the timing sensors.

Skill Index (SI)

The Skill Index (SI) measure used by Rađa, 2016 was used as an indicator of technical skill. It was calculated as the difference between performance results in identical tests performed with and without the ball (S20m SI, SLAL SI, ZIG-ZAG SI, 93639m SI, and 5×10m SI). Smaller differences in Skill Index values indicate more consistent performance under both conditions, reflecting a higher level of technical proficiency.

Statistical analysis

Basic descriptive statistics are presented as means and standard deviations (M ± SD), along with the range (minimum–maximum). To examine the effects of predictors (chronological and biological age) on the criteria (motor performance with and without the ball), multiple regression analysis was applied. Correlation coefficients (R) of <0.1, 0.1–0.3, 0.3–0.5, 0.5–0.7, 0.7–0.9, and >0.9 were interpreted as trivial, small, moderate, large, very large, and nearly perfect correlations, respectively (Vincent, 1995). Regression outcomes were interpreted using standardized regression coefficients (β), the coefficient of determination (R^2), and the level of statistical significance ($p < 0.05$). Data were analyzed using the Statistica software package (version 13.0; Dell Inc., Round Rock, TX, USA).

RESULTS

Table 1. Anthropometric characteristics and variables for assessing the maturity of all groups

VARIABLES		U15 (n=49)		U17 (n=48)		U19 (n=40)	
		M±SD	RANGE	M±SD	RANGE	M±SD	RANGE
MATURITY	CA (years)	13.75±0.55	12.66-14.56	15.97±0.52	15.06-16.97	18.12±0.61	17.16-19.02
	BA (years)	14.01±0.91	12.31-16.01	15.91±0.85	13.46-17.95	17.56±0.63	16.34-19.03
	APHV (years)	13.55±0.65	11.53-14.65	13.86±0.58	12.58-15.66	14.36±0.45	13.28-15.42
ANTHROPOMETRY	BH (cm)	167.22±8.98	145.2-192.60	177.59±7.22	156.60-192	183.13±5.31	169.50-192.90
	BM (kg)	53.49±10.30	38.8-89.50	65.16±8.90	41.30-82	73.50±6.42	62.90-87.60
	BMI (kg/m)	18.98±2.35	15.93-30.36	20.58±1.92	16.04-24.98	21.90±1.47	17.65-24.48
	FAT MASS (kg)	8.01±3.80	3.76-26.67	8.89±2.80	3.52-19.24	9.77±3.73	5.15-20.15
	%BF	14.62±4.42	8.30-29.91	13.53±3.25	8.15-23.93	13.10±4.18	7.81-25.70
	FAT FREE MASS (kg)	45.47±7.83	33.82-66.61	56.28±7.36	33.72-69.73	63.74±4.78	53.30-77.58

Table 1 presents the anthropometric and maturity indicators for all three observed groups of participants. It can be observed that the U15 players entered the phase of accelerated development (APHV) earlier compared to the other two groups (13.55/13.86/14.36 for U15/U17/U19, respectively). Furthermore, the tallest and heaviest players, with the highest body mass index ranging from 17.65–24.48, were those in the U19 group. The highest proportion of fat-free mass (FFM), as well as the lowest percentage of body fat (%BF) in total body mass, was observed in the U19 players (63.74 kg / 13.10% for U19) compared to the other groups (45.47 kg / 14.62% for U15 and 56.28 kg / 13.53% for U17). The absolute fat mass (FM) was most pronounced in U19 players, ranging from 5.15 to 20.15 kg, while the widest range of results was recorded in U15 players, ranging from 3.76 to 26.67 kg.

Table 2. Descriptive statistics of all performance indicators for all groups

VARIABLES		U15 (n=49)		U17 (n=48)		U19 (n=40)	
		M±SD	RANGE	M±SD	RANGE	M±SD	RANGE
SPEED/AGILITY (s)	S5m	1.06±0.06	0.94-1.20	1.06±0.05	0.94-1.16	1.04±0.05	0.98-1.14
	S10m	1.86±0.09	1.68-2.06	1.82±0.07	1.69-1.99	1.78±0.07	1.65-1.98
	S20m	3.32±0.15	3-3.54	3.15±0.11	2.91-3.43	3.07±0.11	2.92-3.42
	S30m	4.66±0.20	4.26-4.98	4.42±0.18	4.07-4.94	4.27±0.14	4.06-4.77
	SLAL	7.50±0.39	6.44-8.32	7.25±0.27	6.71-7.86	7.77±0.31	7.19-8.45
	ZI-ZA	6.05±0.31	5.37-6.60	5.92±0.25	5.50-6.62	5.96±0.37	5.12-6.82
	93639m	8.02±0.33	7.35-8.76	7.58±0.32	7.07-8.61	7.65±0.42	7.09-8.86
	5X10m	12.24±0.29	11.5-12.70	11.34±0.37	10.53-12.38	11.31±0.53	10.59-12.69
SPEED/AGILITY WITH THE BALL (s)	S15m B	2.23±0.11	2.02-2.40	2.08±0.09	1.93-2.30	2.01±0.07	1.91-2.23
	S20m B	3.47±0.17	3.16-3.81	3.50±0.16	3.08-3.87	3.40±0.18	3.09-4.05
	SLAL B	10.57±0.57	9.3-12.20	10.36±0.83	9.20-12.54	10.34±0.94	9.01-12.56
	ZI-ZA B	8.06±0.55	5.86-9.00	8.05±0.50	7.24-9.30	7.84±0.45	7.25-9
	93639m B	10.11±0.49	8.63-11.13	9.50±0.42	8.90-11.17	9.52±0.58	8.42-10.88
	5X10m B	14.70±0.67	13.65-16.10	13.31±0.64	12.19-15.19	13.22±0.84	12.25-15.66
FUNCTIONAL ABILITIES (ml/kg/min)	YO-YO	44.23±3.12	36.4-48.50	50.05±3.15	44.13-56.56	51.64±3.25	45.81-60.26
SKILL INDEX	S20 m SI	0.15±0.10	0.02-0.39	0.34±0.13	0.07-0.70	0.33±0.15	0.07-0.63
	SLAL SI	3.07±0.40	2.17-3.88	3.11±0.79	2.13-5.27	2.57±0.91	1.27-4.65
	ZI-ZA SI	2.09±0.28	1.46-2.74	2.12±0.44	1.36-3.39	1.88±0.41	1.04-2.65
	93639m SI	2.17±0.46	1.21-3.18	1.92±0.44	1.23-3.74	1.87±0.53	0.58-3.23
	5X10m SI	2.46±0.55	1.66-3.50	1.97±0.48	1.06-3.13	1.91±0.53	0.95-3.22

Table 2 presents the descriptive values of all speed and agility indicators, both with and without the ball, as well as Skill Index values. Regarding the linear speed tests (S5, S10, S20, and S30 m), U19 players (U19) achieved the best performance compared to the other groups. Overall, variability in speed test results was greatest in the U15 group. For agility tests, three out of four tests (SLAL, ZI-ZA, 93639 m) showed the best average values in U17 players, while the highest variability was observed in the oldest players (±0.41). Speed with the ball (S15 m B, S20 m B) showed the best performance in U19, with the greatest variability observed in the oldest group for S15m B (±0.18). The greatest variability for S20 m B was observed in the U15 group. For agility with the ball, the best average values were observed in U19, with the greatest variability in U19 for SLAL B (±0.94), 93639m B (±0.58), and 5X10m B (±0.84), while for ZI-ZA B, the greatest variability was in U15 (±0.55). Functional abilities, assessed by the YO-YO test, showed the best average relative oxygen uptake and the greatest variability in results in U19 players. Skill Index measures varied across groups depending on the test, with the highest variability observed in U19 for SLAL SI (±0.91) and 93639m SI (±0.53), in U17 for S20m SI (±0.13) and ZI-ZA SI (±0.44), and in U15 for 5X10m SI (±0.55).

Table 3. Multiple regression analysis of influence of CA and BA on motor performance in U15 players

VARIABLES		CA		BA		R2	R
		β	P	β	P		
SPEED/AGILITY (s)	S5m*	-0.58	0.02	-0.01	0.96	0.35	LARGE
	S10m	-0.44	0.09	-0.11	0.66	0.28	LARGE
	S20m*	-0.51	0.011	-0.3	0.125	0.59	VERY LARGE

	S30m*	-0.33	0.102	-0.44	0.034	0.54	VERY LARGE
	SLAL*	-0.65	0.008	0.56	0.021	0.29	LARGE
	ZI-ZA	-0.51	0.047	0.09	0.719	0.21	MODERATE
	93639m*	-0.29	0.211	-0.31	0.181	0.3	LARGE
	5X10m*	-0.6	0.012	0.15	0.515	0.27	LARGE
SPEED/AGILITY WITH THE BALL (s)	S15m B*	-0.3	0.157	-0.45	0.040	0.5	VERY LARGE
	S20m B*	-0.54	0.03	-0.08	0.75	0.36	LARGE
	SLAL B	-0.34	0.183	0.49	0.059	0.15	MODERATE
	ZI-ZA B	-0.35	0.174	-0.07	0.785	0.16	MODERATE
	93639m B	-0.41	0.115	0.39	0.135	0.13	MODERATE
	5X10m B	-0.23	0.396	-0.08	0.768	0.08	SMALL
FUNCTIONAL ABILITIES (ml/kg/min)	YO-YO	0.465	0.027	-0.37	0.075	0.11	MODERATE
SKILL INDEX	S20 m SI	-0.18	0.54	0.32	0.278	0.05	SMALL
	SLAL SI	0.2	0.463	0.1	0.717	0.07	SMALL
	ZI-ZA SI	-0.04	0.893	0.09	0.753	0.01	TRIVIAL
	93639 SI	-0.26	0.309	0.47	0.074	0.14	MODERATE
	5X10m SI	0.06	0.828	-0.18	0.514	0.02	SMALL

*-denotes significant influence of age ($p<0.05$)

Table 3 shows influence of BA and CA on motor performance in U15 players. For speed and agility performance, the model showed a significant influence on S5m (R=0.59, p=0.002), S20m (R=0.76, p<0.001), S30m (R=0.74, p<0.001), SLAL (R=0.54, p=0.020), 93639m (R=0.54, p=0.021), and 5x10m (R=0.52, p=0.032), whereas significant effect did not show on S10m (R=0.53, p=0.09) and ZI-ZA (R=0.46, p=0.070). For speed and agility tests with the ball, the model was significant for S15m B (R=0.71, p=0.001) and S20m B (R=0.60, p=0.018), while other tests: SLAL B (R=0.39, p=0.159), ZI-ZA B (R=0.39, p=0.155), 93639m B (R=0.35, p=0.229), and 5x10m B (R=0.28, p=0.408), were not statistically influenced by age model. Regarding functional capacity, the model did not significantly predict performance in the YO-YO test (R=0.33, p=0.081). For the Skill Index (SI), none of the tests were significantly predicted by the model (S20m SI: R=0.22, p=0.900; SLAL SI: R=0.27, p=0.500; ZI-ZA SI: R=0.07, p=0.175; 93639 SI: R=0.38, p=0.467; 5x10m SI: R=0.149, p=0.264).

Table 4. Multiple regression analysis of influence of CA and BA on motor performance in U17 players

VARIABLES		CA		BA		R2	R
		β	P	β	P		
SPEED/ AGILITY (s)	S5m	0.14	0.57	-0.25	0.31	0.03	SMALL
	S10m	0.12	0.601	-0.37	0.12	0.08	SMALL
	S20m*	0.13	0.548	-0.52	0.022	0.18	MODERATE
	S30m*	0.23	0.282	-0.63	0.005	0.23	MODERATE
	SLAL*	-0.46	0.041	0.64	0.006	0.18	MODERATE
	ZI-ZA	0.25	0.288	0.04	0.864	0.08	SMALL
	93639m	-0.16	0.513	0.16	0.5	0.01	SMALL
	5X10m	-0.05	0.841	-0.04	0.881	0.01	SMALL
SPEED/AGILITY WITH THE BALL (s)	S15m B*	0.11	0.601	-0.55	0.013	0.23	MODERATE
	S20m B	-0.22	0.367	-0.02	0.917	0.05	SMALL
	SLAL B	-0.45	0.053	0.54	0.021	0.13	MODERATE
	ZI-ZA B	-0.11	0.614	0.46	0.054	0.14	MODERATE
	93639m B	-0.02	0.943	0.03	0.896	<0.001	TRIVIAL

	5X10m B	-0.32	0.183	0.3	0.214	0.05	SMALL
FUNCTIONAL ABILITIES (ml/kg/min)	YO-YO*	0.41	0.053	-0.05	0.8	0.14	MODERATE
SKILL INDEX	S20m SI	-0.37	0.119	0.41	0.09	0.08	SMALL
	SLAL SI	-0.31	0.19	0.35	0.146	0.056	SMALL
	ZI-ZA SI	0.19	0.426	-0.01	0.989	0.036	SMALL
	93639 SI	0.1	0.686	-0.09	0.686	<0.001	TRIVIAL
	5X10m SI	-0.39	0.105	0.42	0.077	0.08	SMALL

*-denotes significant influence of age ($p<0.05$)

Table 3 shows influence of BA and CA on motor performance in U17 players. The model showed influence on the S20m (R=0.43, p=0.019), S30m (R=0.48, p=0.005), and SLAL (R=0.43, p=0.02), while the S5m (R=0.17, p=0.568), S10m (R=0.29, p=0.183), ZI-ZA (R=0.28, p=0.199), 93639m (R=0.11, p=0.775), and 5x10m (R=0.006, p=0.882) were not significantly influenced be age model. For speed and agility with the ball, model had a significant effect only on S15m B (R=0.48, p=0.006), whereas the other tests were not significantly influence by age indicators: S20m B (R=0.234, p=0.332), SLAL B (R=0.36, p=0.066), ZI-ZA B (R=0.38, p=0.056), 93639m B (R=0.021, p=0.99), and 5X10m B (R=0.219, p=0.382). Additionally, a significant association with the model was found for the YO-YO test (R=0.37, p=0.036). The age model did not show a significant effect on any skill index variables: S20m SI (R=0.28, p=0.213), SLAL SI (R=0.24, p=0.326), ZI-ZA SI (R=0.19, p=0.491), 93639m SI (R=0.07, p=0.916), and 5X10m SI (R=0.29, p=0.187).

Table 5. Multiple regression analysis of influence of CA and BA on motor performance in U19 players

VARIABLES		CA		BA		R2	R
		β	P	β	P		
SPEED/AGILITY (s)	S5m	-0.54	0.04	0.39	0.14	0.13	MODERATE
	S10m	-0.6	0.024	0.54	0.039	0.17	MODERATE
	S20m	-0.6	0,024	0.4	0.118	0,16	MODERATE
	S30m	-0.44	0.105	0.35	0.191	0.09	MODERATE
	SLAL*	0.03	0,896	0,59	0.012	0.37	LARGE
	ZI-ZA	-0.24	0.362	0.34	0.212	0.05	SMALL
	93639m	-0.29	0.285	0.36	0,187	0.06	SMALL
	5X10m	-0.37	0.171	0.3	0.258	0.06	SMALL
SPEED/AGILITY WITH THE BALL (s)	S15m B	-0.51	0.056	0.31	0.23	0.12	MODERATE
	S20m B	-0.36	0.181	0.48	0.08	0.1	MODERATE
	SLAL B	-0.21	0.434	0.17	0.549	0.02	SMALL
	ZI-ZA B	-0.23	0.393	0.11	0.696	0.03	SMALL
	93639m B	-0.48	0.076	0.26	0.322	0.11	MODERATE
	5X10m B	-0.33	0.222	0.28	0.301	0.05	SMALL
FUNCTIONAL ABILITIES (ml/kg/min)	YO-YO	-0.01	0.967	-0.05	0.826	0.01	TRIVIAL
SKILL INDEX	S20m SI	0.01	0.989	0,28	0.293	0.08	SMALL
	SLAL SI	-0.23	0.385	-0.03	0.915	0.07	SMALL
	ZI-ZA SI	-0.04	0.9	-0.2	0.473	0.05	SMALL
	93639m SI	-0.29	0.276	-0.001	0.997	0.09	SMALL
	5X10m SI	-0.16	0.569	0.14	0.611	0.01	SMALL

*-denotes significant influence of age ($p<0.05$)

Table 5 presents the effects of CA and BA on motor performance of U19 players. The results show that the model shoved a significant influence only for SLAL (R=0.61, p=0.001), while no significant effects were found for other variables that assess speed and agility: S5m (R=0.36, p=0.126), S10m (R=0.42, p=0.061), S20m

(R=0.40, p=0.076), S30m (R=0.30, p=0.259), ZI-ZA (R=0.23, p=0.453), 93639m (R=0.25, p=0.408), and 5x10m (R=0.25, p=0.380) showed no significant influence on motor performance. Also, age model showed no significant effects on speed and agility with the ball: S15m B (R=0.35, p=0.149), S20m B (R=0.32, p=0.200), SLAL B (R=0.15, p=0.732), ZI-ZA B (R=0.17, p=0.647), 93639m B (R=0.33, p=0.178), 5x10m B (R=0.23, p=0.460) and functional abilities (R=0.06, p=0.932). Furthermore, no significant influence of age model was observed on the Skill Index variables: S20m SI (R=0.29, p=0.292), SLAL SI (R=0.26, p=0.373), ZI-ZA SI (R=0.22, p=0.483), 93639m SI (R=0.29, p=0.273), and 5x10m SI (R=0.11, p=0.841).

DISCUSSION

This study aimed to determine the influence of CA and BA on motor performance with and without the ball in different youth age categories (U15, U17, and U19). Overall, the main finding of the study emphasizes that CA and BA could be significant predictors of motor performance for the U15 group, while a lesser influence is observed in the U17 group. Moreover, CA and BA influenced only one motor performance variable for U19 players. Specifically, significant effects were observed in speed and agility tests performed with and without the ball, ranging from moderate to very large magnitudes. In the U17 category, in addition to the observed effects on speed and agility (moderate), a further significant effect was identified in a variable assessing functional capacities (moderate). In the U19 category, the significant influence of the age was identified solely in one agility-related test (SLAL).

Notably, age indicators explained the largest proportion of variance in speed tests among U15 players (35–45%), with this influence decreasing with age (18–23% in U17) and becoming non-significant in U19 players (9–17%). The highest influence of CA and BA on the speed results among U15 players may reflect greater inter-individual variability in physiological and morphological maturity as reported by Malina et al., 2007; Figueiredo et al., 2009; Selmi et al., 2020; Konarski et al., 2024. Moreover, chronological age was a stronger predictor for sprint performance over shorter distances, whereas longer distances were more influenced by biological age. This pattern suggests that shorter sprints may reflect accumulated training experience, while longer sprints require greater muscular development, which is more closely related to biological maturity (Gundersen et al., 2022), especially in early adolescence (U15). The explained variance in sprint with the ball tests (S15m B and S20m B) was highest in the U15 players and decreased with age, indicating greater homogeneity in physiological maturity and a progressively stronger influence of training. Furthermore, CA and BA explained 27–29% in agility tests among U15 players (27–29%), with chronological age emerging as a significant predictor in three tests (SLAL, ZI-ZA, 5×10 m) while in U17 and U19 group CA and BA explained a smaller portion of the variability (Table 4 and Table 5). This is consistent with the findings of Dugdale et al., 2024, who suggest that agility performance improves with chronological age during early adolescence, but follows a non-linear trajectory, with performance plateaus observed in later stages of maturation. Also, Sheppard and Young, 2006 highlight that agility is a multifactorial skill influenced by perceptual and decision-making components, change-of-direction technique, strength qualities, and neuromuscular control, which may become more important as players progress through adolescence and reach higher competitive levels. Regarding specific agility with the ball, no significant effect of age on performance was found, which agrees with the findings of Huijgen et al., 2010, who emphasize a more “training-driven” rather than “age-driven” influence on ball-related agility performance (e.g., slalom dribble test). When assessing functional abilities, CA and BA showed a significant influence on results of Yo-Yo test for U17 players. On the other hand, functional abilities of U15 and U19 players were not significantly influenced by age. These results are somewhat unexpected. Previous research (Nobari et al., 2022) found influence of biological age in U15 players. Furthermore, Valente-dos-Santos et al., 2012, found that the biological model has a stronger influence on aerobic performance during adolescence (10–18 years) compared to the chronological model which showed weaker and less stable association with VO_2max. In their

study, annual training volume is also highlighted as an additional significant predictor of aerobic performance. As a relatively new and insufficiently researched measure for assessing technical abilities, the Skill Index is used, for which no significant effect of age has been found across all three observed generations. Therefore, it can be considered a potentially maturity-sensitive performance measure. This may be useful for coaches as a guideline to consider additional indicators, such as the Soccer Skill Index (SI), during player selection.

This study simultaneously assesses influence of CA and BA on motor performance, including specific abilities with the ball, which is only scarcely researched. Results obtained emphasize the need to move beyond purely age-based grouping when evaluating and developing young soccer players. The strongest impact of CA and BA was observed in the U15 players, likely because they are around or have just passed their peak height velocity (PHV), making age a more influential factor compared to older groups. In older age groups, physical characteristics tend to stabilize after the rapid growth phase, which reduces the influence of chronological or biological age alone, with performance becoming more dependent on factors such as position-specific skills, training history, and individual technical characteristics rather than age.

The results of this study are based on a single cohort from one club, which may limit the generalizability of the findings. Key parameters, such as training age, training intensity, and the level of previously acquired motor skills, were not considered. Future research should incorporate these factors to provide deeper insights into their influence on performance, as well as examine the effects of relative age and training specificity for each category according to the different demands of the game. Additionally, including samples from multiple sports is recommended to assess the impact of age across various disciplines.

CONCLUSIONS

The results of this study highlight the importance of a holistic approach to identifying predictors of performance success, particularly among young soccer players. Adolescent growth spurt also plays a significant role, as evidenced by this study's findings, which indicate that the greatest age-related influence on motor performance occurs in U15 players during a phase of accelerated growth and development. As chronological age increases, particularly in older categories (U17 and U19), this influence gradually declines, indicating that additional factors such as specific training experience may play a more significant role in explaining performance.

REFERENCES

1. Bangsbo, J., Iaia, F. M., & Krustrup, P. (2008). The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. Sports medicine, 38(1), 37-51.
2. Baxter-Jones, A. D. G., Eisenmann, J. C., & Sherar, L. B. (2005). Controlling for maturation in pediatric exercise science.
3. Coelho e Silva, M. J., Figueiredo, A. J., Simões, F., Seabra, A., Natal, A., Vaeyens, R., Philippaerts, R., Cumming, S. P., & Malina, R. M. (2010). Discrimination of U-14 soccer players by level and position. International Journal of Sports Medicine, 31, 790–796.
4. Deprez, D., Buchheit, M., Fransen, J., et al. (2015). A longitudinal study investigating the stability of anthropometry and soccer-specific endurance in pubertal high-level youth soccer players. Journal of Sports Science & Medicine, 14(2), 418–426.
5. Dugdale, J. H., Myers, T., Sanders, D., Andrew, M., Clarke, R., & Hunter, A. M. (2024). Evaluation of multi-directional speed qualities throughout adolescence in youth soccer: The non-linear nature of transfer. Journal of sports sciences, 42(4), 301-312. https://doi.org/10.1080/02640414.2024.2329846

6. Figueiredo, A. J., Gonçalves, C. E., Coelho-e-Silva, M. J., & Malina, R. M. (2009). Youth soccer players, 11–14 years: Maturity, size, function, skill and goal orientation. Annals of Human Biology, 36(1), 60–73.
7. Gordon, C. C., Chumlea, W. C., & Roche, A. F. (1988). Stature, recumbent length and weight. In T. G. Lohman, A. F. Roche, & R. Martorell (Eds.), Anthropometric standardization reference manual (pp. 3–8). Human Kinetics.
8. Gouvea, M., Cyrino, E. S., Ribeiro, A. S., et al. (2016). Influence of skeletal maturity on size, function and sport-specific technical skills in youth soccer players. International Journal of Sports Medicine, 37(6), 464–469. https://doi.org/10.1055/s-0035-1569370
9. Gundersen, H., Riiser, A., Algroy, E., et al. (2022). Associations between biological maturity level, match locomotion, and physical capacities in youth male soccer players. Scandinavian Journal of Medicine & Science in Sports, 32(11), 1592–1601. https://doi.org/10.1111/sms.14225
10. Hermassi, S., Konukman, F., Al-Marri, S. S., et al. (2024). Associations between biological maturation, physical performance, postural control, and mathematical achievement in youth soccer players. PLOS ONE, 19(3), e0298301. https://doi.org/10.1371/journal.pone.0298301
11. Hill, M., Scott, S., Malina, R. M., McGee, D., & Cumming, S. P. (2020). Relative age and maturation selection biases in academy football. Journal of Sports Sciences, 38(11–12), 1359–1367. https://doi.org/10.1080/02640414.2019.1649524
12. Huijgen, B. C., Elferink-Gemser, M. T., Post, W., & Visscher, C. (2010). Development of dribbling in talented youth soccer players aged 12–19 years: A longitudinal study. Journal of Sports Sciences, 28(7), 689–698.
13. Ito, H., Hirayama, K., Naito, Y., & Akama, T. (2025). Determinants of agility across biological maturation status in soccer players. BMC Sports Science, Medicine and Rehabilitation, 17(1), 355. https://doi.org/10.1186/s13102-025-01424-8
14. Jackowski, S. A., Erlandson, M. C., Mirwald, R. L., Faulkner, R. A., Bailey, D. A., Kontulainen, S. A., Cooper, D. M., & Baxter-Jones, A. D. (2011). Effect of maturational timing on bone mineral content accrual from childhood to adulthood. Bone, 48(5), 1178–1185. https://doi.org/10.1016/j.bone.2011.02.010
15. Kemper, H. C. G., & Verschuur, R. (1981). Maximal aerobic power in 13- and 14-year-old teenagers in relation to biological age.
16. Konarski, J. M., Skrzypczak, M., Freitas, D., & Malina, R. M. (2024). Influence of body size and skeletal maturity status on strength and motor performances of soccer players 9–16 years. Scientific Reports, 14, 4768. https://doi.org/10.1038/s41598-024-55042-4
17. Lloyd, R. S., Oliver, J. L., Faigenbaum, A. D., Myer, G. D., & De Ste Croix, M. B. A. (2014). Chronological age vs. biological maturation: Implications for exercise programming in youth. Journal of Strength and Conditioning Research, 28(5), 1454–1464.
18. Malina, R. M. (1995). Physical growth and biological maturation of young athletes.
19. Malina, R. M., Cumming, S. P., Kontos, A. P., Eisenmann, J. C., Ribeiro, B., & Aroso, J. (2005). Maturity-associated variation in sport-specific skills of youth soccer players aged 13–15 years. Journal of Sports Sciences, 23(5), 515–522. https://doi.org/10.1080/02640410410001729928
20. Malina, R. M., Ribeiro, B., Aroso, J., & Cumming, S. P. (2007). Characteristics of youth soccer players aged 13–15 years classified by skill level. British Journal of Sports Medicine, 41(5), 290–295. https://doi.org/10.1136/bjsm.2006.031294

21. Mirwald, R. L., Baxter-Jones, A. D. G., Bailey, D. A., & Beunen, G. P. (2002). An assessment of maturity from anthropometric measurements. Medicine & Science in Sports & Exercise, 34(4), 689–694. https://doi.org/10.1097/00005768-200204000-00020
22. Nobari, H., Shemshaki, H. K., Kamiş, O., Oliveira, R., González, P. P., & Mainer-Pardos, E. (2022). Variations in accumulated-training load parameters and locomotor demand with consideration of puberty in elite young soccer players. Biology, 11(11), 1594. https://doi.org/10.3390/biologija11111594
23. Perroni, F., Amatori, S., Corsi, L., Bensi, R., Guidetti, L., Baldari, C., ... & Buzzachera, C. F. (2024). Assessment of performance in youth soccer players: should we consider the maturation status?. Journal of Human Kinetics, 93, 119. https://doi.org/10.5114/jhk/184276
24. Rađa A. Analiza nekih dimenzija antropološkog statusa mladih nogometaša u odnosu prema biološkoj i kronološkoj dobi, igračkim linijama i situacijskoj uspješnosti [doctoral dissertation]. Split: University of Split, Faculty of Kinesiology; 2016.
25. Reiter, E. O., & Lee, P. A. (2002). Delayed puberty. Adolescent Medicine, 13(1), 101–118.
26. Rommers, N., Mostaert, M., Goossens, L., Vaeyens, R., Witvrouw, E., Lenoir, M., & D'Hondt, E. (2019). Age and maturity-related differences in motor coordination. Journal of Sports Sciences, 37(2), 196–203. https://doi.org/10.1080/02640414.2018.1488454
27. Ross, W. D., & Marfell-Jones, M. J. (1991). Kinanthropometry. In J. D. MacDougall, H. A. Wenger, & H. J. Green (Eds.), Physiological testing of the high-performance athlete (2nd ed., pp. 223–308). Human Kinetics.
28. Rowland, T. W. (2005). Children's exercise physiology. Human Kinetics.
29. Selmi, M. A., Sassi, R. H., Yahmed, M. H., Giannini, S., Perroni, F., & Elloumi, M. (2020). Normative data and physical determinants of multiple sprint sets. Journal of Strength and Conditioning Research, 34(2), 506–515. https://doi.org/10.1519/JSC.0000000000002810
30. Sheppard, J. M., & Young, W. B. (2006). Agility literature review: Classifications, training and testing. Journal of sports sciences, 24(9), 919-932.
31. Vaeyens, R., Malina, R. M., Janssens, M., Van Renterghem, B., Bourgois, J., & Philippaerts, R. M. (2006). A multidisciplinary selection model for youth soccer. British Journal of Sports Medicine, 40(11), 928–934.
32. Valente-dos-Santos, J., Coelho-e-Silva, M. J., Duarte, J., Figueiredo, A. J., Liparotti, J. R., Sherar, L. B., ... & Malina, R. M. (2012). Longitudinal predictors of aerobic performance in adolescent soccer players. Medicina, 48(8), 61.
33. Vandendriessche, J. B., Vaeyens, R., Vandorpe, B., Lenoir, M., Lefevre, J., & Philippaerts, R. M. (2012). Biological maturation, morphology, fitness, and motor coordination as part of a selection strategy. Journal of Sports Sciences, 30(15), 1695–1703. https://doi.org/10.1080/02640414.2011.652654
34. Vincent, W. J. (1995). Statistics in kinesiology. Human kinetics. Champaign, IL, 178-181.

FULL PAPER 6

SCIENTIFIC PAPER

Cortisol Dynamics and Sinclair Performance in Female Weightlifters

Ivan Perasović, Vladimir Pavlinović, Antonela Karmen Ivišić, Mia Perić, Nikola Foretić, Zoran Nikolovski

Faculty of Kinesiology, University of Split, Croatia

Introduction

Olympic weightlifting is a premier high-intensity strength-power sport that demands maximal neuromuscular output, precise biomechanical execution, and profound psychological resilience. It is characterized by the execution of two distinct lifts: the snatch and the clean and jerk. Success in this discipline is determined by a complex interplay of metabolic efficiency and the ability to recruit high-threshold motor units under extreme pressure (Stone et al., 2007; Garhammer, 1993). To ensure a fair comparison between athletes of varying body sizes, the sport utilizes the Sinclair coefficient (Sinclair, 1987). This mathematical formula normalizes the total weight lifted relative to the athlete's body mass, providing a standardized metric of relative performance. While the biomechanical aspects of these lifts are well-documented, the endocrine responses that underpin competitive performance, particularly in female populations, remain an area requiring more rigorous scientific investigation (Storey & Smith, 2012). From a physiological perspective, a weightlifting competition serves as an acute stressor that triggers the hypothalamic-pituitary-adrenal (HPA) axis, leading to a rapid increase in cortisol secretion (Boileau & Horswill, 2000.). Cortisol plays an essential role in mobilizing energy stores via gluconeogenesis, modulating the immune response, and maintaining homeostatic balance during maximal physical exertion (Viru & Viru, 2004). In the context of explosive strength sports, an acute rise in cortisol should not be viewed merely as a catabolic signal but rather as a necessary adaptive mechanism. This hormonal surge facilitates the availability of substrates for working muscles and enhances central nervous system activation, which is vital for the technical precision and power required in Olympic lifting (Hill et al., 2008).

Historically, most research concerning hormonal responses to resistance exercise has focused on male cohorts or long-term training adaptations. However, the unique structure of a weightlifting competition creates a specific hormonal profile that differs from standard gym training (McGuigan et al., 2004). In female athletes, these responses are further influenced by the complex landscape of steroid hormone interactions and specific physiological adaptations (Häkkinen et al., 2000). There is a notable lack of data regarding how cortisol fluctuates from the initial warm-up, through the first discipline, and into the final lift of a national-level event. Understanding these dynamics is crucial for developing a holistic view of the female athletic response to elite competition. Investigating these correlations can provide coaches and sports scientists with valuable insights into the markers of peak performance and readiness. Therefore, the primary objective of this study was to investigate the relationship between Sinclair performance and cortisol dynamics across three critical competition phases in elite female weightlifters.

Methods

The study sample consisted of 17 female weightlifters who qualified for and competed in the Croatian National Championship. This group represented a diverse range of weight categories and skill levels, ensuring a comprehensive overview of the competitive landscape. Several variables were meticulously recorded, including body height (cm), body mass (kg), and training experience (years). Competitive success was quantified using Sinclair points (SI). Salivary cortisol was chosen as the primary hormonal marker due to its non-invasive nature and its

ability to reflect the biologically active "free" fraction of the hormone. Samples were collected at three distinct intervals: C1 (baseline, collected immediately prior to the start of the competition), C2 (collected immediately following the completion of the snatch portion), and C3 (collected following the final clean and jerk attempt). Statistical analysis involved calculating descriptive parameters—mean, standard deviation, and range—followed by Pearson correlation coefficients to assess the strength and direction of the relationships between anthropometric, experience-based, and hormonal variables.

Results

The descriptive analysis highlighted a wide range of physical and performance characteristics within the group. The mean body mass was 64.03 kg, though the range was broad, spanning from 46.7 kg to 97 kg. Performance quality, as indicated by Sinclair points, averaged 184.66, with a significant spread between developmental athletes (91.3 points) and elite national competitors (244.2 points). Training experience also showed substantial variance, with a mean of 3.84 years, though some participants were in their first year of competition while others possessed up to 14 years of experience. The hormonal data revealed a clear and significant upward trend throughout the competition. The baseline cortisol level (C1) was the lowest at 0.27 ± 0.08 μg/dL. Following the snatch discipline (C2), there was a dramatic surge to 0.54 ± 0.21 μg/dL, representing a 100% increase from the pre-competition state. In the final phase, after the clean and jerk (C3), cortisol levels remained high at 0.50 ± 0.20 μg/dL. Although there was a slight decrease between C2 and C3, the values remained significantly elevated compared to baseline. This pattern indicates that the snatch, being the first discipline and highly technical, triggers the most intense initial HPA axis activation, while the clean and jerk maintains this elevated physiological state.

Table 1. Descriptive statistics of measured variables

Variable	X ± SD	Min	Max	Skew	Kurt	S-W (p)
BM (kg)	64.03 ± 12.61	46.75	97	0.77	-0.52	0.05
BH (cm)	164.65 ± 8.94	150	190	0.83	2.50	0.09
TE (yrs)	3.84 ± 3.69	0.2	14	0.99	1.13	0.05
SI	184.66 ± 38.52	91.3	244.2	1.48	2.05	0.00*
C 1	0.27 ± 0.08	0.16	0.45	-0.83	1.10	0.23
C 2	0.54 ± 0.21	0.27	1.02	1.19	1.13	0.02*
C 3	0.50 ± 0.20	0.21	0.83	0.73	-0.19	0.12

LEGEND: **BM**-body mass, **BH**-body height, **TE**-training experience, **SI**-Sinclair's index, **C1**-cortisol before competition, **C2**-cortisol after snatch, **C3**-cortisol after clean & jerk, **SW**- Shapiro-Wilk test of normality

Correlation analysis provided evidence of a meaningful link between endocrine activity and performance. Sinclair points showed significant positive correlations with all three cortisol measurements. The correlation with C1 was r = 0.48, with C2 it rose to r = 0.55, and the strongest relationship was found with C3 at r = 0.61. These results suggest that athletes who achieve a higher relative performance also exhibit a more pronounced hormonal response. Training experience was also positively correlated with SI (r = 0.46) and cortisol levels (r = 0.32 to 0.39), suggesting that experienced lifters may have a more "efficient" or robust stress response. Body mass showed a negative correlation with SI (r = -0.36), which is expected given the relative nature of the Sinclair coefficient. Finally, the strong inter-correlations between the

cortisol phases (r = 0.69 to 0.80) confirm that an individual's physiological response remains consistent throughout the event.

Table 2. Pearson's' correlation analysis – relation of cortisol dynamics with performance indicators, anthropometry and training experience

Variable	BM	BH	TE	SI	C1	C2	C3
BM	1.00	0.41	0.22	-0.36	0.28	0.31	0.33
BH	0.41	1.00	0.18	-0.12	0.19	0.22	0.25
TE	0.22	0.18	1.00	0.46	0.32	0.35	0.39
SI	-0.36	-0.12	0.46	1.00	0.48	0.55	0.61
C1	0.28	0.19	0.32	0.48	1.00	0.72	0.69
C2	0.31	0.22	0.35	0.55	0.72	1.00	0.80
C3	0.33	0.25	0.39	0.61	0.69	0.80	1.00

LEGEND: **BM**-body mass, **BH**-body height, **TE**-training experience, **SI**-Sinclair's index, **C1**-cortisol before competition, **C2**-cortisol after snatch, **C3**-cortisol after clean & jerk

Discussion

The findings of this study offer a deeper understanding of the physiological architecture of competitive weightlifting in women, emphasizing the role of cortisol as a potential facilitator of high-level performance. The observed rise in cortisol from baseline to the end of the snatch discipline aligns with established literature regarding the body's response to maximal loading (Fry & Lohnes, 2010). The fact that these levels remained elevated through the clean and jerk suggests that weightlifting competition imposes a cumulative physiological demand that requires sustained metabolic support (Passelergue & Lac, 1999).

A primary takeaway is the strong positive correlation between Sinclair points and cortisol levels, particularly in the final phase. Traditionally, cortisol has been associated with muscle degradation; however, in the context of acute competitive stress, these results suggest that higher cortisol levels are indicative of better performance (Crewther et al., 2011). This can be explained by the theory that an acute increase in cortisol may reflect optimal arousal rather than fatigue. Athletes capable of generating a stronger hormonal surge likely benefit from enhanced mobilization of substrates essential for the high-intensity work of muscle fibers (Kraemer et al., 1998). The link between training experience and cortisol dynamics further supports the concept of endocrine adaptation. It appears that years of specialized training "program" the endocrine system to react effectively to specific stressors (Häkkinen et al., 2000). More experienced lifters display a more stable and robust response, allowing them to maintain intensity through the final clean and jerk attempts. Conversely, less experienced lifters or those with lower performance indices may not reach an adequate level of physiological activation to support maximal efforts (Haneishi et al., 2007). It is particularly noteworthy that the correlation between SI and C3 was the strongest (r = 0.61). This implies that the ability to sustain a high physiological state until the end of the competition is a critical determinant of the final score. Since the clean and jerk requires massive power output following the fatigue of the snatch, elevated cortisol here may help maintain cognitive focus and energy availability (Hill et al., 2008). These findings contrast with endurance-based research where chronic cortisol elevation is detrimental, highlighting the importance of context in interpreting hormonal data. Beyond the endocrine findings, the negative correlation between body mass and Sinclair points reinforces the biomechanical efficiency of lighter lifters in terms of relative strength, a fundamental principle in competitive weightlifting (Sinclair, 1987). Coaches should consider monitoring hormonal responses as a way to gauge "competitive readiness" (Storey & Smith, 2012).

Conclusion

This study confirmed that salivary cortisol levels are significantly associated with the competitive performance of female weightlifters. The data demonstrate that competition triggers a progressive increase in cortisol, with higher-performing athletes exhibiting a more pronounced endocrine response. The strongest relationship was observed in the final phase of the competition, suggesting that high physiological activation is essential for maximizing the clean and jerk. Furthermore, training experience appears to modulate this response, indicating that the ability to effectively activate the HPA axis is a learned adaptation of elite performance. These findings have practical implications for the optimization of training and the psychological preparation of female athletes, highlighting the value of stress monitoring in elite sports. Future studies should focus on longitudinal tracking of these parameters to better define the boundaries between adaptive and maladaptive stress responses.

References

1. Crewther, B. T., Cook, C., Cardinale, M., Weatherby, R. P., & Lowe, T. (2011). Two emerging concepts for elite athletes: the short-term effects of testosterone and cortisol on the neuromuscular system and the dose-response training role of these hormones. Sports Medicine, 41(2), 103–123.
2. Garhammer, J. (1993). A review of power output studies of Olympic and powerlifting: Methodology, performance prediction, and evaluation tests. Journal of Strength and Conditioning Research, 7(2), 76–89.
3. Häkkinen, K., Pakarinen, A., Kraemer, W. J., Newton, R. U., & Alen, M. (2000). Basal concentrations and acute responses of serum hormones and strength development during 12 weeks combined resistance and endurance training in middle-aged women. The Journals of Gerontology Series A, 55(2), B95–B105.
4. Hill, E. E., Zack, E., Battaglini, C., Viru, M., Viru, A., & Hackney, A. C. (2008). Exercise and circulating cortisol levels: the intensity threshold effect. Journal of Endocrinological Investigation, 31(7), 587–591.
5. Kraemer, W. J., & Ratamess, N. A. (2005). Hormonal responses and adaptations to resistance exercise and training. Sports Medicine, 35(4), 339–361.
6. McGuigan, M. R., Egan, A. D., & Foster, C. (2004). Salivary cortisol responses and perceived exertion during high intensity resistance training in trained warriors. Journal of Sports Science & Medicine, 3, 8–15.
7. Sinclair, R. (1987). The Sinclair Coefficients for the Comparison of Weightlifters. International Weightlifting Federation.
8. Stone, M. H., Stone, M., & Sands, W. A. (2007). Principles and Practice of Resistance Training. Human Kinetics.
9. Viru, A., & Viru, M. (2004). Cortisol in exercise and sport. Endocrine, 24(3), 179–185.
10. Fry, A. C., & Lohnes, C. A. (2010). Acute testosterone and cortisol responses to high intensity resistance exercise of deviation from a 1RM. Journal of Strength and Conditioning Research, 24(12), 3102–3109.
11. Haneishi, K., et al. (2007). Cortisol and immune response during a women's NCAA Division I soccer season. Journal of Strength and Conditioning Research, 21(2), 583–588.
12. Storey, A., & Smith, H. K. (2012). Unique aspects of competitive weightlifting: performance, training and physiology. Sports Medicine, 42(9), 769–790.
13. Passelergue, P., & Lac, G. (1999). Salivary cortisol responses and short-term performance in competitive weightlifters. International Journal of Sports Medicine, 20(5), 310–314.
14. Boileau, R. A., & Horswill, C. A. (2000). Body composition in sports: Measurement and applications for weight loss and gain. Exercise and sport science. Philadelphia: Lippincontt Williams and Wilkins, 319-38..

FULL PAPER 7

SCIENTIFIC PAPER

Effects of Racket Sports on Physical, Psychological, and Social Outcomes in Individuals with Disabilities: A Systematic Review and Meta-Analysis

Lidija Petrinović

Univesity of Zagreb, Faculty of Kinesiology, Zagreb, Croatia.

Introduction

Over the past decades, physical activity has been increasingly recognized as a fundamental component of health promotion and disease prevention. For individuals with disabilities, participation in structured physical activity is particularly important, as it contributes not only to physical health but also to psychological well-being and social integration (Laferrier et al., 2012; Hutzler and Bergman, 2011). Despite these well-documented benefits, individuals with disabilities often face significant barriers to participation in physical activity, including environmental, social, and economic constraints (Jaacks et al., 2019; Marmot, 2005).

Racket sports, such as tennis, table tennis, and badminton, represent a unique and adaptable category of physical activity that is particularly suitable for individuals with disabilities. These sports combine aerobic and anaerobic demands with high levels of coordination, reaction time, and cognitive engagement (Goosey-Tolfrey, 2010). Their adaptability allows for modifications in rules, equipment, and playing conditions, enabling participation across a wide range of physical and functional limitations (Tweedy and Vanlandewijck, 2011).

Among racket sports, wheelchair tennis is one of the most developed and widely practiced adaptive sports. Research has shown that participation in wheelchair tennis improves upper-body strength, cardiovascular fitness, and mobility (Goosey-Tolfrey, 2010; Aidar et al., 2018). Similarly, table tennis has been identified as a highly effective rehabilitative activity due to its emphasis on fine motor control, balance, and coordination (Kong et al., 2024). Parabadminton, a relatively recent addition to the Paralympic Games, has also demonstrated significant benefits in terms of physical performance and functional independence (Kim et al., 2024).

In addition to physical benefits, participation in adaptive racket sports has been strongly associated with improvements in psychological outcomes. Studies have consistently shown that engagement in sport enhances self-esteem, reduces symptoms of anxiety and depression, and promotes overall mental well-being (Isidoro-Cabañas et al., 2023; Dehghansai et al., 2017). These psychological benefits are particularly important for individuals with disabilities, who are at increased risk of social isolation and mental health challenges (Hutzler and Bergman, 2011).

Social integration represents another critical dimension of sport participation. Adaptive sports provide opportunities for individuals with disabilities to interact with others, develop social networks, and foster a sense of belonging (Dehghansai et al., 2017). Participation in sport has also been linked to improved independence and community engagement, contributing to enhanced quality of life (Laferrier et al., 2012).

From a physiological perspective, regular participation in racket sports contributes to improved cardiovascular function, muscular strength, and metabolic health (Aidar et al., 2018). These benefits are particularly relevant given the increased risk of chronic diseases among individuals with disabilities, including obesity, cardiovascular disease, and metabolic disorders (Hruby and Hu, 2015; Ng et al., 2014). Physical inactivity remains a significant concern in this population,

further emphasizing the importance of accessible and engaging forms of exercise (Malik et al., 2013).

The broader context of health inequalities must also be considered. Socioeconomic factors play a significant role in shaping access to sport and physical activity, with individuals from disadvantaged backgrounds facing greater barriers to participation (Marmot, 2005; Cutler and Lleras-Muney, 2010). These disparities are particularly pronounced among individuals with disabilities, highlighting the need for inclusive and accessible sport programs (Hutzler and Bergman, 2011).

In recent years, there has been growing interest in the use of adaptive sports as a therapeutic intervention within rehabilitation settings. Evidence suggests that structured sport programs can significantly enhance functional recovery, particularly in individuals with spinal cord injuries, neurological conditions, and musculoskeletal impairments (Tweedy and Vanlandewijck, 2011). Racket sports, due to their dynamic and engaging nature, may be particularly effective in promoting adherence to rehabilitation programs (Aidar et al., 2018).

Despite the growing body of evidence, research on the specific effects of racket sports in individuals with disabilities remains limited and fragmented. While numerous studies have examined individual sports or specific populations, there is a lack of comprehensive synthesis of evidence across different racket sports and disability groups.

Therefore, the aim of this systematic review and meta-analysis was to evaluate the effects of racket sports on physical, psychological, and social outcomes in individuals with disabilities. By synthesizing existing evidence, this study seeks to provide a clearer understanding of the role of racket sports in rehabilitation and health promotion.

Methods

Study Design

This study followed **PRISMA guidelines** for systematic reviews and meta-analyses.

Search Strategy

Databases searched:

PubMed

Scopus

Web of Science

Keywords:

“disability AND racket sports”

“wheelchair tennis rehabilitation”

“table tennis disability outcomes”

Inclusion Criteria

adults with physical or neurological disabilities

intervention including racket sports

quantitative outcomes (physical or psychological)

Statistical Analysis

Effect sizes were calculated using **standardized mean difference (SMD)**. A random-effects model was used due to heterogeneity among studies.

Results

Study Characteristics

Total studies: **45**

Meta-analysis included: **12 studies**

Population: SCI, stroke, Parkinson's, amputees

Physical Outcomes

Participation in racket sports significantly improved:

cardiovascular function

balance

motor coordination

Table tennis interventions showed improvements in balance and motor performance .

Additionally, para table tennis improved cardiovascular and autonomic function in individuals with spinal cord injury .

Psychological Outcomes

Meta-analysis showed:

Mental quality of life improvement:
SMD = 0.62–0.71 ($p < 0.01$)

reduced stress and anxiety

increased self-efficacy

Adaptive sports significantly improve mental well-being and social functioning .

Social Outcomes

Participation led to:

improved social integration

increased independence

stronger identity formation

Adaptive sports reduce social isolation and improve participation in society.

Discussion

The present systematic review and meta-analysis provides comprehensive evidence supporting the positive effects of racket sports on individuals with disabilities. The findings indicate that participation in adaptive racket sports contributes significantly to improvements in physical, psychological, and social outcomes. These results are consistent with a growing body of literature emphasizing the role of sport as a multidimensional intervention in disability populations (Laferrier et al., 2012; Dehghansai et al., 2017; Hutzler and Bergman, 2011).

One of the most notable findings of this review is the substantial improvement in psychological well-being associated with participation in racket sports. Mental health benefits, including reduced symptoms of depression and anxiety and increased self-esteem, were consistently reported across multiple studies (Isidoro-Cabañas et al., 2023; Kim et al., 2024; Dehghansai et al., 2017). These findings align with previous research suggesting that sport participation enhances psychological resilience and emotional regulation in individuals with disabilities (Laferrier et al., 2012; Hutzler and Bergman, 2011).

The observed improvements in mental health may be explained by several mechanisms. Participation in sport provides opportunities for social interaction, goal setting, and achievement, all of which contribute to increased self-efficacy and a sense of competence (Bandura, 1997; Dehghansai et al., 2017). Additionally, physical activity has been shown to influence neurobiological processes, including the release of endorphins and neurotransmitters associated with mood regulation (Malik et al., 2013; Hruby and Hu, 2015).

In terms of physical outcomes, the results demonstrate significant improvements in cardiovascular fitness, muscular strength, and motor coordination. These findings are consistent with previous studies examining the effects of adaptive sports interventions (Aidar et al., 2018; Goosey-Tolfrey, 2010). Racket sports, in particular, require rapid movements, upper-body strength, and coordination, making them effective for improving functional capacity (Kong et al., 2024; Tweedy and Vanlandewijck, 2011).

The improvements in motor coordination observed in table tennis and badminton interventions highlight the importance of fine motor skills and reaction time in rehabilitation settings (Kong et al., 2024; Kim et al., 2024). These skills are essential for daily functioning and independence, particularly in individuals with neurological impairments.

Another important finding of this review is the role of racket sports in promoting social inclusion. Participation in adaptive sports has been associated with increased social interaction, improved communication skills, and a stronger sense of belonging (Dehghansai et al., 2017; Hutzler and Bergman, 2011). These social benefits are particularly important given the high levels of social isolation experienced by individuals with disabilities (Marmot, 2005; Neuman et al., 2013).

The concept of social integration is closely linked to the broader framework of social determinants of health. Individuals with disabilities often face structural barriers that limit their

access to physical activity, including lack of accessible facilities and financial constraints (Marmot, 2005; Cutler and Lleras-Muney, 2010). The findings of this study suggest that adaptive sports programs can help mitigate these inequalities by providing accessible opportunities for participation (Jaacks et al., 2019; Hutzler and Bergman, 2011).

From a public health perspective, the observed improvements in physical health are particularly significant. Individuals with disabilities are at increased risk of chronic conditions such as obesity, cardiovascular disease, and metabolic disorders (Ng et al., 2014; Hruby and Hu, 2015). Regular participation in racket sports may help reduce these risks by promoting physical activity and improving metabolic health (Malik et al., 2013; Popkin, 2006).

The findings of this review also highlight the importance of tailoring sport interventions to specific populations. Differences in outcomes were observed depending on the type of disability, the intensity of the intervention, and the duration of participation. This is consistent with previous research indicating that individualized approaches are necessary to maximize the benefits of physical activity in disability populations (Tweedy and Vanlandewijck, 2011; Aidar et al., 2018).

Despite the positive findings, several limitations should be considered. First, the heterogeneity of the included studies limits the generalizability of the results. Differences in study design, sample size, and outcome measures may have influenced the observed effects (Higgins et al., 2011). Second, many studies included in the analysis had relatively small sample sizes, which may reduce statistical power (Dehghansai et al., 2017).

Additionally, the lack of long-term follow-up data limits the ability to assess the sustainability of the observed benefits. Future research should focus on longitudinal studies to better understand the long-term effects of racket sports participation in individuals with disabilities (Isidoro-Cabañas et al., 2023; Kim et al., 2024).

Another limitation relates to the underrepresentation of certain disability groups in the literature. While most studies focused on individuals with physical disabilities, fewer studies examined populations with intellectual or sensory impairments. This highlights the need for more inclusive research that addresses the diverse needs of individuals with disabilities (Hutzler and Bergman, 2011; Dehghansai et al., 2017).

Finally, methodological limitations such as lack of randomized controlled trials and potential publication bias should be acknowledged. The use of a random-effects model partially addresses heterogeneity, but further high-quality studies are needed to confirm these findings (Higgins et al., 2011).

Practical Implications

The findings of this study have important implications for rehabilitation and public health practice. Racket sports can be effectively integrated into rehabilitation programs to improve both physical and psychological outcomes. Practitioners should consider incorporating adaptive sports into treatment plans, particularly for individuals with spinal cord injuries, neurological conditions, and mobility impairments (Aidar et al., 2018; Goosey-Tolfrey, 2010).

Conclusion

Racket sports represent an effective intervention for improving physical and psychological outcomes in individuals with disabilities. These sports should be considered a key component of rehabilitation and public health strategies.

References

1. Aidar, F.J. et al. (2018) ‘Effects of physical exercise in people with disabilities’, Journal of Physical Activity and Health, 15(3), pp. 201–210.
2. Allender, S. et al. (2008) ‘Urban–rural differences’, International Journal of Obesity, 32(6), pp. 1045–1053.
3. Dehghansai, N. et al. (2017) ‘Psychological development in athletes with disabilities’, Disability and Rehabilitation, 39(21), pp. 2107–2113.
4. Goosey-Tolfrey, V. (2010) ‘Supporting participation in wheelchair sport’, Sports Medicine, 40(5), pp. 377–390.
5. Higgins, J.P.T. et al. (2011) Cochrane Handbook for Systematic Reviews. London: Wiley.
6. Hruby, A. and Hu, F.B. (2015) ‘The epidemiology of obesity’, PharmacoEconomics, 33(7), pp. 673–689.
7. Hutzler, Y. and Bergman, U. (2011) ‘Facilitators and barriers’, Adapted Physical Activity Quarterly, 28(3), pp. 257–272.
8. Isidoro-Cabañas, E. et al. (2023) ‘Adaptive sport meta-analysis’, Healthcare, 11(9), pp. 1201–1215.
9. Jaacks, L.M. et al. (2019) ‘The obesity transition’, Obesity Reviews, 20(S2), pp. 2–8.
10. Kim, D. et al. (2024) ‘Mental health and adaptive sport’, Journal of Rehabilitation Medicine, 56(2), pp. 89–98.
11. Kong, P. et al. (2024) ‘Motor function improvements’, Sports Science Review, 33(1), pp. 45–60.
12. Laferrier, J.Z. et al. (2012) ‘Benefits of physical activity’, Disability and Health Journal, 5(4), pp. 255–261.
13. Malik, V.S. et al. (2013) ‘Global obesity trends’, Nature Reviews Endocrinology, 9(1), pp. 13–27.
14. Marmot, M. (2005) Social Determinants of Health. Oxford: OUP.
15. Ng, M. et al. (2014) ‘Global obesity prevalence’, The Lancet, 384(9945), pp. 766–781.
16. Popkin, B.M. (2006) ‘Nutrition transition’, American Journal of Clinical Nutrition, 84(2), pp. 289–298.
17. St-Onge, M.P. and Gallagher, D. (2010) ‘Body composition changes’, Annals of NY Academy of Sciences, 904, pp. 437–448.
18. Tweedy, S.M. and Vanlandewijck, Y.C. (2011) ‘Classification in Paralympic sport’, British Journal of Sports Medicine, 45(4), pp. 259–269.
19. Villareal, D.T. et al. (2005) ‘Obesity in older adults’, NEJM, 353(4), pp. 123–135.
20. World Health Organization (2021) Obesity and overweight. Geneva.

FULL PAPER 8

SCIENTIFIC PAPER

High-intensity interval training in female soccer players: a systematic review

Davorin Antonić

Larus Sport d.o.o.

Introduction

Modern soccer is characterized as a high-intensity intermittent sport that requires players to repeatedly perform explosive actions such as sprinting, acceleration, deceleration, and rapid changes of direction interspersed with periods of lower-intensity activity (Mohr et al., 2002; Andrzejewski et al., 2013; Datson, 2014). In recent years, the physiological and performance demands of female soccer have increased significantly due to the professionalization of the sport and improvements in training methodologies (Datson, 2014; Kubayi, 2019). Consequently, optimizing physical conditioning has become a critical factor for performance enhancement in female soccer players.

During a competitive match, female soccer players cover approximately 9–11 km, with 15–20% of this distance performed at high intensity (Mohr et al., 2002; Datson, 2014). In addition, players perform between 150 and 200 high-intensity actions, including sprinting, jumping, tackling, and changes of direction, which place significant demands on both aerobic and anaerobic energy systems (Andrzejewski et al., 2013; Kubayi, 2019). Aerobic capacity, typically assessed through maximal oxygen uptake (VO_2max), is essential for sustaining performance and facilitating recovery between high-intensity efforts (Buchheit and Laursen, 2013; Iaia et al., 2009). Elite female soccer players typically exhibit VO_2max values ranging between 49 and 57 $ml \cdot kg^{-1} \cdot min^{-1}$, highlighting the importance of cardiovascular fitness (Datson, 2014).

In addition to aerobic endurance, anaerobic capacity plays a crucial role in match performance. High-intensity efforts such as sprinting and rapid directional changes rely heavily on anaerobic metabolism, particularly the phosphagen and glycolytic systems (Laursen and Jenkins, 2002; Gabbett, 2008). Repeated sprint ability (RSA) has been identified as a key performance determinant in soccer and is strongly associated with match success and competitive level (Gabbett, 2008; Rampinini et al., 2009). Furthermore, neuromuscular qualities such as agility, power, and speed are essential for executing sport-specific actions efficiently (Chaouachi et al., 2012; Haugen et al., 2012).

Traditional endurance training methods have been widely used to improve aerobic fitness in soccer players; however, these methods may not adequately replicate the intermittent nature of match play (Iaia et al., 2009). In contrast, high-intensity interval training (HIIT) has emerged as a highly effective and time-efficient training strategy that closely mimics the physiological demands of soccer (Buchheit and Laursen, 2013; Gibala et al., 2012). HIIT involves repeated bouts of high-intensity exercise interspersed with recovery periods and has been shown to induce significant improvements in both aerobic and anaerobic performance (Weston et al., 2014; Laursen and Buchheit, 2019).

One of the key advantages of HIIT is its ability to simultaneously improve multiple physiological systems. Studies have demonstrated that HIIT leads to increases in mitochondrial density, oxidative enzyme activity, and cardiovascular efficiency, resulting in enhanced oxygen utilization and energy production (Gibala et al., 2012; Weston et al., 2014). Additionally, HIIT has been shown to improve neuromuscular performance, including sprint speed, power output, and fatigue resistance (Arazi et al., 2017; Buchheit et al., 2010).

More recently, there has been growing interest in the application of change-of-direction (COD) HIIT protocols in soccer training. COD HIIT incorporates directional changes into high-intensity intervals, thereby increasing the specificity of training and better replicating match conditions (Chaouachi et al., 2012; Young et al., 2002). Research suggests that COD HIIT may produce superior improvements in agility, reactive strength, and sport-specific performance compared to linear HIIT (Rampinini et al., 2009; Stanković et al., 2023).

Despite the increasing popularity of HIIT, there is still a need for a comprehensive synthesis of evidence regarding its effects specifically in female soccer players. Much of the existing literature has focused on male populations, limiting the generalizability of findings to female athletes (Datson, 2014; Kubayi, 2019). Given the physiological and biomechanical differences between male and female players, it is essential to evaluate training interventions within a sex-specific context.

Therefore, the aim of this review is to examine the effects of high-intensity interval training, including change-of-direction HIIT, on aerobic capacity, anaerobic performance, and motor abilities in female soccer players. By synthesizing current evidence, this review aims to provide practical recommendations for coaches and practitioners involved in the training and development of female soccer players.

Methods

Study Design

This study was conducted as a narrative and systematic review aimed at summarizing the current evidence on the effects of high-intensity interval training (HIIT) in female soccer players. The review was performed in accordance with general principles of systematic reviews, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021).

Search Strategy

A comprehensive literature search was conducted using the following electronic databases:

PubMed

Scopus

Web of Science

The search was limited to studies published in English between 2000 and 2025. Keywords and Boolean operators were used to identify relevant studies, including:

“high-intensity interval training AND female soccer”

“HIIT AND women football players”

“change of direction HIIT soccer”

“soccer performance HIIT women”

Additionally, reference lists of selected studies were manually screened to identify further relevant publications.

Inclusion Criteria

Studies were included if they met the following criteria:

participants were female soccer players (amateur or elite level)

interventions included high-intensity interval training (HIIT) or change-of-direction (COD) HIIT

studies reported physiological or performance-related outcomes (e.g., VO_2max, sprint performance, agility)

original research articles (randomized controlled trials, quasi-experimental studies, and longitudinal studies)

Exclusion Criteria

Studies were excluded if:

participants were male athletes only

the intervention did not include HIIT protocols

studies were review articles, conference abstracts, or case studies

insufficient data on outcomes were reported

Data Extraction

Data from the included studies were extracted and organized according to:

sample characteristics (age, training level)

intervention characteristics (type, duration, intensity of HIIT)

outcome measures (aerobic capacity, anaerobic performance, agility)

Data Analysis

Due to heterogeneity among studies in terms of design, interventions, and outcome measures, a qualitative synthesis was performed. The results were grouped into three main categories:

aerobic adaptations

anaerobic performance

motor abilities

Where possible, findings were compared across studies to identify consistent trends and training effects.

Results

Study Selection and Characteristics

The initial database search identified a total of 132 studies. After removing duplicates and screening titles and abstracts, 58 studies were assessed for full-text eligibility. Based on the inclusion and exclusion criteria, 28 studies were included in the final analysis.

The included studies involved female soccer players of varying competitive levels, ranging from amateur to elite athletes. Sample sizes varied between 12 and 60 participants, with intervention durations ranging from 4 to 12 weeks.

The majority of studies examined different HIIT protocols, including short-interval, long-interval, and sprint interval training, as well as change-of-direction (COD) HIIT interventions.

Effects on Aerobic Capacity

The findings consistently demonstrated that HIIT significantly improves aerobic capacity in female soccer players. Most studies reported increases in VO_2max ranging from 5% to 12% following HIIT interventions.

Improvements in aerobic performance were also reflected in enhanced endurance capacity and reduced fatigue during match play. These results are consistent with previous research indicating that HIIT is an effective method for improving cardiovascular fitness (Buchheit and Laursen, 2013; Weston et al., 2014).

Effects on Anaerobic Performance

HIIT interventions resulted in significant improvements in anaerobic performance, particularly in:

repeated sprint ability (RSA)

maximal sprint speed

fatigue resistance

Several studies reported reductions in sprint times and improvements in power output following HIIT programs. In addition, improvements in fatigue index indicate enhanced ability to sustain high-intensity efforts throughout the match.

Sprint interval training protocols showed particularly strong effects on anaerobic power, highlighting their importance in soccer-specific conditioning (Arazi et al., 2017).

Effects on Motor Abilities

HIIT had a significant positive impact on motor abilities, including:

agility

speed

explosive strength

Change-of-direction (COD) HIIT protocols demonstrated superior improvements in agility compared to linear HIIT. These improvements are likely due to the specificity of COD movements, which closely resemble match conditions (Chaouachi et al., 2012; Rampinini et al., 2009).

Furthermore, improvements in neuromuscular performance were observed, particularly in tests measuring acceleration and directional changes.

Comparison of COD and Linear HIIT

Studies comparing COD HIIT and linear HIIT showed that both training methods are effective; however, COD HIIT produced greater improvements in:

agility

sport-specific performance

movement efficiency

Linear HIIT, on the other hand, was more strongly associated with improvements in aerobic capacity.

These findings suggest that combining both approaches may provide optimal training adaptations.

Summary of Findings

Overall, the results indicate that HIIT is a highly effective training method for female soccer players, producing improvements across multiple performance domains.

The most consistent findings include:

increased VO_2max and aerobic capacity

improved repeated sprint ability

enhanced agility and neuromuscular performance

These adaptations are critical for maintaining high performance during competitive matches.

Discussion

The aim of this review was to examine the effects of high-intensity interval training (HIIT) on aerobic capacity, anaerobic performance, and motor abilities in female soccer players. The findings consistently demonstrate that HIIT is a highly effective training method that produces significant improvements across multiple physiological and performance domains.

One of the most important findings of this review is the substantial improvement in aerobic capacity following HIIT interventions. Increases in VO_2max ranging from 5% to 12% were observed across the majority of included studies, confirming the effectiveness of HIIT in enhancing cardiovascular fitness. These findings are consistent with previous research, which has demonstrated that HIIT can produce equal or superior improvements in aerobic capacity compared to traditional continuous training, despite requiring significantly less training time (Buchheit and Laursen, 2013; Weston et al., 2014). The improvement in VO_2max is particularly relevant for female soccer players, as it directly influences the ability to sustain high-intensity activity and recover between efforts during match play (Iaia et al., 2009; Datson, 2014).

The physiological mechanisms underlying these improvements include increased mitochondrial density, enhanced oxidative enzyme activity, and improved cardiac output, all of which contribute to more efficient oxygen utilization (Gibala et al., 2012; Laursen and Buchheit, 2019). These adaptations are essential in a sport characterized by intermittent high-intensity demands, where players must repeatedly transition between different intensity levels (Mohr et al., 2002).

In addition to aerobic adaptations, HIIT was found to significantly improve anaerobic performance, particularly repeated sprint ability (RSA), sprint speed, and fatigue resistance. RSA is a critical performance determinant in soccer and is strongly associated with competitive level and match success (Gabbett, 2008; Rampinini et al., 2009). The improvements observed in RSA following HIIT interventions suggest that this training method enhances both phosphagen system efficiency and glycolytic capacity, allowing players to sustain repeated high-intensity efforts with reduced fatigue (Arazi et al., 2017; Buchheit et al., 2010).

Furthermore, the findings indicate that HIIT positively influences neuromuscular performance, including sprint speed, explosive strength, and agility. These improvements are particularly important in soccer, where rapid accelerations, decelerations, and directional changes are fundamental to performance (Haugen et al., 2012; Chaouachi et al., 2012). The enhancement of neuromuscular function may be attributed to increased motor unit recruitment, improved rate of force development, and enhanced intermuscular coordination (Marković, 2008).

A key aspect highlighted in this review is the effectiveness of change-of-direction (COD) HIIT compared to traditional linear HIIT. COD HIIT incorporates multidirectional movements that closely replicate match demands, resulting in greater improvements in agility, movement efficiency, and sport-specific performance (Rampinini et al., 2009; Stanković et al., 2023). These findings support the principle of specificity, which states that training adaptations are maximized when exercises closely resemble the demands of the sport (Young et al., 2002). Consequently, COD HIIT appears to be particularly beneficial for female soccer players, as it targets the specific movement patterns required during competition.

However, it is important to note that linear HIIT also provides substantial benefits, particularly in improving aerobic capacity and overall endurance. Therefore, the combination of linear and COD HIIT protocols may represent the most effective training strategy, allowing for the development of both general and sport-specific fitness (Buchheit and Laursen, 2013).

Another important consideration is the individualization of training programs. The included studies demonstrate variability in training responses depending on factors such as player level, training status, and intervention duration. This highlights the need for coaches to tailor HIIT programs according to individual player characteristics and performance goals (Laursen and Jenkins, 2002; Iaia et al., 2009). Additionally, appropriate manipulation of training variables such as intensity, volume, and recovery duration is essential to optimize training adaptations and prevent overtraining.

Despite the positive findings, several limitations should be acknowledged. First, the heterogeneity among studies in terms of training protocols, sample sizes, and outcome measures limits the ability to draw definitive conclusions. Differences in HIIT design, including interval duration, intensity, and recovery periods, may influence the magnitude of adaptations (Higgins et al., 2011). Second, many studies included relatively small sample sizes, which may reduce statistical power and generalizability of the findings.

Another limitation is the relatively short duration of most interventions, typically ranging from 4 to 12 weeks. While significant improvements were observed within this timeframe, the long-term effects of HIIT in female soccer players remain unclear. Future research should focus on longitudinal studies to examine the sustainability of training adaptations over extended periods (Weston et al., 2014).

Additionally, the majority of studies focused on physical performance outcomes, with limited attention given to psychological factors such as motivation, perceived exertion, and mental fatigue. Considering the importance of psychological aspects in sports performance, future studies should adopt a more holistic approach to evaluating the effects of HIIT (Datson, 2014).

Finally, it should be noted that most of the available research has been conducted on male athletes, and findings are often generalized to female populations. Given the physiological and hormonal differences between male and female athletes, further research specifically targeting female soccer players is needed to provide more accurate and applicable recommendations (Kubayi, 2019).

Practical Implications

The findings of this review have important practical implications for coaches and strength and conditioning professionals working with female soccer players. HIIT should be integrated into training programs as a primary method for improving aerobic and anaerobic performance. Coaches are encouraged to incorporate COD-based drills to enhance sport-specific adaptations and improve agility and movement efficiency.

Additionally, training programs should be individualized, taking into account player characteristics, competitive level, and seasonal periodization. A combination of linear and COD HIIT protocols may provide the most comprehensive improvements in performance.

References

1. Andrzejewski, M., Chmura, J., Pluta, B. and Kasprzak, A. (2013) ‘Analysis of motor activities of professional soccer players’, Journal of Sports Sciences, 31(5), pp. 456–463.
2. Arazi, H., Asadi, A. and Roohi, S. (2017) ‘Effects of high-intensity interval training on aerobic and anaerobic performance in soccer players’, Journal of Strength and Conditioning Research, 31(3), pp. 789–795.
3. Bandura, A. (1997) Self-efficacy: The exercise of control. New York: Freeman.
4. Bok, D. (2019) ‘High-intensity interval training methodology’, Sports Science Review, 28(2), pp. 55–70.
5. Buchheit, M. and Laursen, P.B. (2013) ‘High-intensity interval training, solutions to the programming puzzle’, Sports Medicine, 43(5), pp. 313–338.
6. Buchheit, M., Laursen, P.B. and Ahmaidi, S. (2009) ‘Parasympathetic reactivation after repeated sprint exercise’, European Journal of Applied Physiology, 105(4), pp. 569–579.
7. Buchheit, M., Mendez-Villanueva, A., Simpson, B. and Bourdon, P. (2010) ‘Repeated sprint sequences during youth soccer matches’, International Journal of Sports Medicine, 31(10), pp. 709–716.

8. Chaouachi, A., Manzi, V., Chaalali, A., Wong, D.P., Chamari, K. and Castagna, C. (2012) 'Determinants analysis of change-of-direction ability', Journal of Sports Sciences, 30(1), pp. 23–31.
9. Datson, N. (2014) 'Match physical performance of female soccer players', Sports Medicine, 44(9), pp. 1225–1240.
10. Gabbett, T.J. (2008) 'Influence of fatigue on tackling technique in rugby league players', Journal of Strength and Conditioning Research, 22(2), pp. 556–561.
11. Gibala, M.J., Little, J.P., MacDonald, M.J. and Hawley, J.A. (2012) 'Physiological adaptations to low-volume HIIT', Journal of Physiology, 590(5), pp. 1077–1084.
12. Haugen, T., Tønnessen, E. and Seiler, S. (2012) 'Sprint running performance monitoring', Journal of Sports Sciences, 30(7), pp. 645–652.
13. Iaia, F.M., Rampinini, E. and Bangsbo, J. (2009) 'High-intensity training in football', Sports Medicine, 39(6), pp. 435–447.
14. Impellizzeri, F.M., Marcora, S.M. and Castagna, C. (2006) 'Physiological responses to small-sided games', Journal of Sports Sciences, 24(6), pp. 679–686.
15. Jones, S. and Drust, B. (2007) 'Physiological demands of elite soccer', Journal of Sports Sciences, 25(6), pp. 665–674.
16. Kubayi, A. (2019) 'Physical demands of soccer players', Journal of Sports Science, 37(10), pp. 113–120.
17. Laursen, P.B. and Buchheit, M. (2019) Science and application of HIIT. Champaign: Human Kinetics.
18. Laursen, P.B. and Jenkins, D.G. (2002) 'The scientific basis for HIIT', Sports Medicine, 32(1), pp. 53–73.
19. Marković, G. (2008) 'Neuromuscular performance in soccer', Kinesiology, 40(2), pp. 120–130.
20. Mohr, M., Krustrup, P. and Bangsbo, J. (2002) 'Match performance of high-standard soccer players', Journal of Sports Sciences, 20(7), pp. 519–528.
21. Rampinini, E., Impellizzeri, F.M., Castagna, C., Abt, G., Chamari, K., Sassi, A. and Marcora, S.M. (2009) 'Factors influencing physiological responses to soccer training', Journal of Sports Sciences, 27(9), pp. 103–110.
22. Sporiš, G., Jukić, I., Milanović, L. and Vučetić, V. (2010) 'Reliability and validity of soccer tests', Kinesiology, 42(1), pp. 45–55.
23. Stanković, R., Milanović, Z. and Sporiš, G. (2023) 'HIIT effects in soccer players', Sports Medicine, 53(4), pp. 567–580.
24. Weston, M., Taylor, K.L., Batterham, A.M. and Hopkins, W.G. (2014) 'Effects of HIIT vs continuous training', British Journal of Sports Medicine, 48(16), pp. 1227–1234.
25. Young, W., McDowell, M. and Scarlett, B. (2001) 'Specificity of agility training', Journal of Sports Sciences, 19(7), pp. 551–560.
26. Young, W., James, R. and Montgomery, I. (2002) 'Is muscle power related to running speed?', Journal of Sports Medicine, 36(3), pp. 282–288.
27. Helgerud, J., Engen, L.C., Wisløff, U. and Hoff, J. (2001) 'Aerobic endurance training improves soccer performance', Medicine & Science in Sports & Exercise, 33(11), pp. 1925–1931.
28. McMillan, K., Helgerud, J., Macdonald, R. and Hoff, J. (2005) 'Physiological adaptations to soccer training', British Journal of Sports Medicine, 39(5), pp. 273–277.
29. Reilly, T. (2007) The science of training in soccer. London: Routledge.
30. Stølen, T., Chamari, K., Castagna, C. and Wisløff, U. (2005) 'Physiology of soccer', Sports Medicine, 35(6), pp. 501–536.

FULL PAPER 9

SCIENTIFIC PAPER

The impact of sport on the education of children and youth: a kinesiological review

Branislav Šutić[1], Goran Sporiš[2] Marjan Ninčević[3]

[1]The University of Applied Sciences "Nikola Tesla" in Gospić , Croatia; Gospić; [2]Univesity of Zagreb, Faculty of Kinesiology; [3]Univesity of Zagreb, Faculty of Croatian Studies

1. Introduction

Sport and physical activity play a fundamental role in the growth and development of children and youth, influencing physical health, psychological well-being, and social integration. In contemporary society, characterized by increasing levels of sedentary behaviour, screen time, and reduced physical activity, the importance of sport as both a health and educational tool has become more prominent than ever (Janssen and LeBlanc, 2010; Strong et al., 2005). The decline in physical activity among young populations has been associated with increased risks of obesity, cardiovascular diseases, and mental health issues, highlighting the need for effective interventions (World Health Organization, 2020; Hallal et al., 2012).

From a scientific perspective, kinesiology provides a comprehensive framework for understanding how movement and physical activity influence human development. As an interdisciplinary field, kinesiology integrates knowledge from physiology, biomechanics, psychology, and sociology to examine the effects of physical activity on the human body and behaviour (Knudson, 2007; Wilmore and Costill, 2004). Within this framework, sport is not only a means of physical conditioning but also a structured environment for learning, skill acquisition, and personal development.

The physiological benefits of sport participation in children and youth are well documented. Regular engagement in physical activity improves cardiovascular fitness, muscular strength, bone density, and metabolic health (Strong et al., 2005; Janssen and LeBlanc, 2010). Additionally, early participation in sport contributes to the development of fundamental motor skills, which are essential for lifelong physical activity (Malina et al., 2004; Lloyd and Oliver, 2012). Motor competence developed during childhood has been shown to be a strong predictor of physical activity levels later in life (Stodden et al., 2008).

Beyond physical health, sport has a significant impact on psychological development. Participation in sport has been associated with improved self-esteem, reduced symptoms of anxiety and depression, and enhanced emotional regulation (Biddle and Asare, 2011; Eime et al., 2013). Adolescence is a critical period for identity formation, and sport provides opportunities for achievement, competence, and social recognition (Erikson, 1968; Fraser-Thomas et al., 2005). Moreover, physical activity has been linked to improved cognitive function, including attention, memory, and academic performance (Hillman et al., 2008; Donnelly et al., 2016).

Social development is another important dimension influenced by sport participation. Sport provides a structured context for social interaction, teamwork, communication, and the development of social norms and values (Eccles and Barber, 1999; Coakley, 2011). Participation in organized sport has been shown to promote prosocial behaviour and reduce engagement in risky behaviours such as substance abuse and delinquency (Fraser-Thomas et al., 2005; Bailey, 2006). These social benefits are particularly important in the context of youth development, as they contribute to the formation of positive social identities and community integration.

The educational value of sport has also been increasingly recognized. Schools play a crucial role in promoting physical activity and integrating sport into educational systems (Bailey, 2006; Trudeau and Shephard, 2008). Physical education and school-based sports programs have been shown to positively influence academic outcomes, including improved concentration, classroom behaviour, and overall academic achievement (Donnelly et al., 2016; Rasberry et al., 2011). These findings support the concept of sport as an educational tool that extends beyond physical development.

Despite the numerous benefits, access to sport is not equally distributed among all children and youth. Socioeconomic status, gender, and environmental factors can significantly influence participation levels (Holt et al., 2017; World Health Organization, 2020). Therefore, it is essential to develop inclusive and accessible sport programs that ensure equal opportunities for all individuals.

In addition, the quality of sport programs plays a critical role in determining their effectiveness. Structured, well-designed programs led by qualified coaches and educators are more likely to produce positive developmental outcomes (Côté and Gilbert, 2009; Fraser-Thomas et al., 2005). Conversely, poorly organized programs may fail to deliver benefits or even lead to negative experiences, such as burnout or dropout from sport (Gould and Carson, 2008).

Another important aspect is the long-term impact of sport participation. Longitudinal studies suggest that early engagement in sport is associated with sustained physical activity, better health outcomes, and improved quality of life in adulthood (Telama et al., 2005; Hallal et al., 2012). These findings emphasize the importance of promoting sport participation during childhood as a foundation for lifelong health.

Although the benefits of sport are well established, there is still a need for comprehensive reviews that integrate findings from different disciplines and provide practical recommendations for implementation. Variability in study designs, populations, and outcome measures makes it difficult to draw consistent conclusions and develop standardized guidelines.

Therefore, the aim of this review paper is to synthesize current scientific evidence on the role of sport in the education and development of children and youth. This review focuses on physiological, psychological, and social outcomes, as well as the role of educational institutions and communities in promoting sport participation. By integrating findings from multiple disciplines, this paper aims to provide a comprehensive understanding of the importance of sport as an educational and developmental tool.

Sport and physical activity play a significant role in the physical, psychological, and social development of children and youth. In contemporary society, where a sedentary lifestyle is becoming increasingly prevalent, the importance of promoting an active way of life has never been greater. Kinesiology, as an interdisciplinary science of movement, provides scientifically grounded insights into how physical activity affects various aspects of young individuals' development (Knudson, 2007). Understanding these influences is crucial for developing effective educational programs that use sport as a tool for the holistic development of children.

The aim of this paper is to explore how sport, through the lens of kinesiological principles, contributes to the education and development of children and youth. We will focus on the physiological, biomechanical, and psychological aspects of sport and how they influence physical growth, psychological well-being, and social skills in young people. We will review relevant research that supports these claims and provide recommendations for future practice in school and community settings. In the section on kinesiology as a science of movement, we will analyse how this discipline integrates different fields of knowledge to provide a comprehensive

understanding of human movement and its significance for health and development (Wilmore, Costill, 2004; Malina, 2010). Special attention will be given to biomechanical aspects that enable the optimization of performance and injury prevention in young athletes (Hall, 2015; Enoki et al., 2017), as well as physiological processes that support healthy growth and development (Strong et al., 2005; Bailey et al., 1999). The psychological aspects of sport will be examined through the lens of developing self-confidence, emotional resilience, and social skills (Weinberg, Gould, 2011; Fraser-Thomas et al., 2005). We will consider how participation in sport can positively affect the mental health of children and youth and how it can serve as a tool for preventing risky behaviours (Biddle, Asare, 2011; Eccles, Barber, 1999). The role of schools and communities in promoting sport as a means of education will also be highlighted. We will reflect on the importance of integrating sports programs into the educational system and how community sports programs can increase the availability and quality of sports activities for children from different socioeconomic backgrounds (Trudeau, Shephard, 2008; Collins, Kay, 2014). Finally, we will provide recommendations for future practices that include an individualized approach to sports activities, education of coaches and teachers, and the promotion of equality and inclusion in sport. The goal of these recommendations is to maximize the positive impact of sport on the education of children and youth and to encourage long-term engagement in physical activity (Fraser-Thomas, Côté, 2009; Rink, 2010). This paper aims to contribute to the understanding of the importance of sport in education and to provide guidelines for implementing effective sports programs that will support the holistic development of children and youth.

2. Kinesiology as a Science of Movement

Kinesiology is an interdisciplinary science that studies human movement and its impact on health, functional abilities, and quality of life. It integrates knowledge from anatomy, physiology, biomechanics, psychology, sociology, and neuroscience to provide a comprehensive understanding of the complexities of human movement (Knudson, 2007). Kinesiology is crucial for understanding various aspects of sport and physical activity, enabling a scientifically grounded approach to educational programs that include physical activity. By studying the physiological processes that occur during physical activity, kinesiology provides insight into how exercise affects different systems in the body, including the cardiovascular, respiratory, musculoskeletal, and neuroendocrine systems (Wilmore, Costill, 2004). Malina (2010) emphasizes that regular physical activity during childhood and adolescence not only improves cardiorespiratory functions and muscle strength but also promotes healthy growth and development and reduces the risk of developing chronic diseases in adulthood. Conversely, kinesiology explores the psychological aspects of physical activity, including motivation, self-concept, emotional well-being, and cognitive development (Weinberg, Gould, 2011). The psychological impacts of sport are particularly evident in the development of emotional stability, resilience, and self-confidence in children and youth. Fraser-Thomas et al. (2005) conclude that participation in sport can reduce symptoms of stress and anxiety and improve emotional health, especially in adolescents. Sport also serves as a platform for social development. Through interaction with peers and coaches, children and youth develop social skills such as teamwork, communication, and respect for rules. Côté and Fraser-Thomas (2007) highlight that a kinesiological approach allows for detailed monitoring and evaluation of these processes, creating a foundation for developing educational programs that use sport as a means of socialization and emotional development.

2.1. Biomechanical Aspects

Biomechanics is a branch of kinesiology that studies the mechanical laws governing human body movements. It analyses the forces acting on the body and how the body responds to these forces, which is crucial for understanding how to optimize performance and reduce the risk of injuries (Hall, 2015). In the context of children and youth, proper execution of physical activities is vital for the correct development of motor skills. Enoki et al. (2017) emphasize that biomechanical analysis of movement enables experts to identify technical irregularities that can lead to injuries or limit performance. For example, correcting running technique in children can improve efficiency and reduce stress on joints, which has long-term positive effects on their physical development. Biomechanical principles are also applied in designing training programs tailored to the developmental stage of the child. Understanding the biomechanical characteristics of a child's body, such as flexibility, strength, and coordination, allows for the creation of activities that will stimulate optimal motor development (Lloyd, Oliver, 2012). The application of biomechanical principles in education enables physical and health education teachers to:

- Adapt instruction to individual needs: Considering different physical abilities and developmental stages of students.
- Enhance safety: Reducing the risk of injuries through education on proper technique and the use of adequate equipment.
- Improve learning efficiency: Using biomechanical analyses to provide feedback to students.

2.2. Physiological Aspects

Exercise physiology studies the acute and chronic reactions of the body to physical activity. In children and youth, regular physical activity has significant physiological benefits. Strong et al. (2005) emphasize that physical activity improves:

- Cardiovascular fitness: Increases the efficiency of the heart and lungs, contributing to better transport of oxygen and nutrients.
- Muscular strength and endurance: Develops muscle fibres, enabling better performance of physical activities.
- Metabolic health: Regulates glucose and lipid metabolism, reducing the risk of developing diabetes and obesity.

Regular physical activity during childhood is associated with better bone health, which is especially important during periods of intensive growth. Bailey et al. (1999) point out that weight-bearing activities, such as running and jumping, stimulate bone mineralization and increase bone mass. The introduction of regular sports programs in schools, based on scientific findings from physiology, can significantly improve the overall health of children. Trudeau and Shephard (2008) demonstrated that school programs that include physical activity contribute not only to physical but also to cognitive development of students, which is reflected in their academic success.

2.3. Psychological Aspects

The psychological impacts of physical activity and sport include the improvement of mental health, emotional well-being, and social functioning. Fraser-Thomas et al. (2005) emphasize that participation in sport can promote:

- Self-confidence and self-esteem: Success in sports activities increases the sense of competence. Harter (1982) argues that the perception of one's own competence is crucial for the development of self-esteem in children.
- Emotional resilience: Sport teaches children how to cope with victories and defeats, developing resilience to stress and frustrations.
- Motivation: According to Deci and Ryan (2000), sport can satisfy basic psychological needs for autonomy, competence, and relatedness, which stimulates intrinsic motivation.

The psychological aspects of sport also include the development of social skills. Through team sports, children learn to cooperate, communicate, and respect others. Weiss and Stuntz (2004) emphasize that positive social relationship within the sports context can increase children's enjoyment of sport and encourage long-term participation. In the educational context, understanding the psychological aspects of kinesiology enables teachers to:

- Create a stimulating environment: That promotes emotional and social development.
- Recognize and support individual student needs: Through adapting approaches and teaching methods.
- Promote positive values: Such as fair play, responsibility, and perseverance. Côté and Fraser-Thomas (2007) highlight the importance of a quality sports experience that focuses on the holistic development of the child, not just competitive success.

3. The Impact of Sport on Physical Development

One of the most important aspects of participation in sport is the contribution to physical health. Children and youth involved in regular physical activities develop better motor coordination, muscle strength, and cardiovascular endurance (Strong et al., 2005). Sport also plays a key role in preventing chronic diseases such as obesity, diabetes, and heart disease, as confirmed by numerous studies (Janssen, LeBlanc, 2010). Regular engagement in sport not only improves physical abilities but also promotes healthy development of bones and muscles, which is especially important during growth phases (Faigenbaum, Myer, 2010). Additionally, participation in sport can positively affect the immune system, reducing the risk of infections and diseases (Nieman, 2001). Physical activity during childhood and adolescence is crucial for health in adulthood (WHO, 2010).

3.1. Prevention of Obesity

Obesity among children and youth represents a global public health problem. The World Health Organization (WHO, 2010) recommends that children and adolescents should be physically active for at least 60 minutes a day to reduce the risk of obesity and related diseases. Regular sports activities stimulate calorie burning, maintain a healthy body weight, and promote proper eating habits (Hills et al., 2007). Participation in sport allows children to meet daily physical activity needs in a fun and motivating way, contributing to their overall health. Trudeau and Shephard (2008) point out that sport positively affects body composition and reduces fat tissue

in children, especially if sport is included in the educational curriculum. Additionally, including sport in school programs can increase the level of physical activity among children who may not have access to extracurricular sports activities (Pate et al., 2006). Research has also shown that physically active children have a lower risk of developing metabolic syndrome later in life (Eisenmann, 2007). Preventing obesity through sport not only affects physical health but also the psychological well-being of children and adolescents (Sahoo et al., 2015). Therefore, promoting participation in sport is crucial for preventing obesity and associated health complications.

4. The Impact of Sport on Psychological Development

The psychological development of children and youth is directly linked to participation in sports activities, as sport fosters a sense of achievement, develops self-confidence, and helps in managing stress and emotions. Sport allows children to develop a sense of personal worth, both through individual sports activities and through participation in team sports. Additionally, sport provides a platform for developing social skills, including communication, cooperation, and empathy (Smith et al., 2016). Regular participation in sport can also positively affect mental health, reducing the risk of developing depression and anxiety (Lubans et al., 2016). Physical activity is associated with better psychological well-being in children and adolescents (Biddle, Asare, 2011). Through sport, children learn the importance of setting goals, persistence, and self-discipline, which are key elements for success in other areas of life.

4.1. Development of Self-Confidence

Participation in sport contributes to the development of a positive self-image, which can have long-term positive effects on a child's emotional stability. Scanlan and Lewthwaite (1986) found a clear link between sports involvement and feelings of self-confidence in adolescents. Children who participate in sports activities often develop a greater sense of achievement and self-confidence, contributing to their emotional resilience and readiness to face challenges. Additionally, research shows that success in sport can improve self-esteem and self-assurance, especially in children with low self-confidence (Ekeland et al., 2005). Participation in sports activities allows young people to develop a sense of competence and control over their environment (Bailey, 2006). This is particularly important during adolescence, when key aspects of identity and self-perception are developing.

4.2. Reduction of Stress and Anxiety

Physical activity acts as a natural regulator of stress and anxiety. Biddle and Asare (2011) emphasize that sport can significantly reduce symptoms of stress and anxiety, especially in adolescents who are under pressure from school obligations and social expectations. Participation in sports activities provides a safe and structured environment in which children can develop emotional resilience and better cope with the challenges of everyday life. The mechanisms through which sport reduces stress include the release of endorphins, improvement of sleep, and distraction from negative thoughts (Peluso, Andrade, 2005). Regular physical activity can be an effective intervention for reducing symptoms of anxiety in young people (Conn, 2010). Also, team sports activities provide social support that can mitigate the effects of stress and promote a sense of belonging (Rees, Freeman, 2007).

5. The Impact of Sport on Social Development

Sport plays a key role in the development of social skills and the promotion of teamwork. Children who participate in sports activities learn about the importance of cooperation, communication, and respect for rules, which are essential skills for success in social life. Additionally, sport provides an opportunity for interaction with peers from different social and cultural backgrounds, which can encourage understanding and tolerance (Fraser-Thomas et al., 2005). Regular participation in sport can also help develop social identity and a sense of belonging to a group, which is especially important during adolescence (Bruner et al., 2014). Sport provides a unique environment in which young people can develop social connections and learn values such as fair play, respect, and integrity (Holt, Neely, 2011).

5.1. Development of Social Skills

Sport offers children and youth the opportunity to develop their social skills through collaboration with peers and coaches. According to Smith et al. (2007), children who participate in sports activities develop better social skills and have a larger circle of friends. Participation in team sports especially encourages the development of communication skills, teamwork, and understanding of each individual's role within the group. Through shared goals and challenges that sport provides, children learn about the importance of cooperation, respect for rules, and acceptance of differences. Ewing and Seefeldt (2002) emphasize that sport can be an effective tool for promoting inclusion and reducing prejudices among children of different cultural and social backgrounds. Sport has the potential to stimulate social development through interaction with others and learning socially acceptable behaviours (Côté, Fraser-Thomas, 2007). Additionally, sport can help develop leadership skills, as children often take on different roles within the team that require responsibility and decision-making (Vella et al., 2011). Interaction with coaches and teammates can also improve social competence and emotional intelligence (Camiré et al., 2012).

5.2. Prevention of Risky Behaviours

Participation in sport can act as a protective factor against the development of risky behaviours such as delinquency, substance abuse, and antisocial behaviour. Eccles and Barber (1999) found that adolescents involved in sports activities show less propensity for such behaviours compared to peers who are not involved in sport. Sport provides a structured environment that promotes positive values such as discipline, responsibility, and respect for authority. It can also provide a sense of belonging and identity, which is particularly important during adolescence when young people are seeking their place in society. Fredricks and Eccles (2006) emphasize that sports involvement can reduce feelings of alienation and increase connection with peers and the community. Research has shown that participation in sports activities can reduce the likelihood of engaging in risky behaviours due to being occupied with positive activities and having less free time for negative influences (Mahoney, Stattin, 2000). Sport can serve as a preventive measure against antisocial behaviour by providing young people with constructive ways to express energy and emotions (Hartmann, 2003). However, it is important to note that the impact of sport on the prevention of risky behaviours can depend on the quality of the sports program and the behaviour of coaches and teammates (Perkins, Noam, 2007). Therefore,

it is crucial to ensure a positive and supportive sports environment to maximize its protective effect.

6. The Role of Schools and Communities

Educational institutions and local communities play a key role in promoting sport as a means of education and development for children and youth. The integration of sports programs into the school curriculum and the support of local communities can significantly impact the availability and quality of sports activities. Schools and local communities act as catalysts that enable young people to access structured sports activities (Green, 2012). Through the collaboration of these institutions, it is possible to create an environment that promotes a healthy lifestyle and the overall development of children.

6.1. Integration of Sport into the Educational System

Integrating sport and physical activity into the educational system can have positive effects on school performance and general student behaviour. Trudeau and Shephard (2008) emphasize that schools that implement regular and quality sports programs report improvements in students' concentration, motivation, and academic success. Physical activity can improve cognitive functions, such as attention and memory, which directly affects school performance (Donnelly, Lambourne, 2011). Moreover, school sports programs can promote inclusiveness and equality, providing all students, regardless of their physical abilities or socioeconomic status, with the opportunity to participate in sport. Hardman and Marshall (2000) highlight the importance of quality physical and health education in schools for the overall development of students. Integrating sport into the school curriculum not only improves students' physical health but also encourages the development of social and emotional skills (Bailey et al., 2009). Additionally, active participation in sport during schooling can influence the formation of positive attitudes toward physical activity in adulthood (Telama et al., 2005). Thus, schools have the opportunity to shape habits that will have long-term benefits for individuals' health and well-being.

6.2. Community Sports Programs

Local communities also play an important role in promoting sports activities through the organization of community sports programs and events. Collins and Kay (2014) emphasize that community sports programs are effective in increasing participation among children from different socioeconomic backgrounds. These programs can provide affordable and quality sports opportunities for children who may not have access to such activities through the school system. Community sports programs can also encourage family participation and support, further increasing the positive impact of sport on children. Holt et al. (2011) highlight the importance of family and community support in encouraging children to remain engaged in sports activities. When the community actively supports sports programs, it creates a culture that values physical activity and health (Spaaij, 2009). Moreover, community sports programs can act as a means of strengthening social cohesion and reducing social inequalities (Misener, Mason, 2006). Through sport, communities can promote interaction among different social groups, fostering understanding and solidarity.

7. Recommendations for Future Practice

To maximize the positive impact of sport on the education of children and youth, it is important to implement certain strategies and recommendations. These strategies should focus on individualizing the approach, educating coaches and teachers, and promoting equality and inclusion in sport. A systematic approach in these areas can significantly improve the quality of the sports experience for young people (Fraser-Thomas, Côté, 2009).

7.1. Individualized Approach

Adapting sports activities to the individual needs and abilities of each child is crucial. Rink (2010) emphasizes the importance of a differentiated approach in physical education, where activities are adjusted to be challenging yet achievable for every child. This helps maintain motivation and prevent feelings of failure or exclusion. Kirk (2005) highlights that an individualized approach encourages long-term engagement in sport, as children feel that their needs and interests are recognized and valued. Personalization of training allows children to progress at their own pace, positively affecting their self-confidence and satisfaction with sport (Light, 2008).

7.2. Education of Coaches and Teachers

Ensuring that coaches and teachers have appropriate knowledge in kinesiology, pedagogy, and child psychology is crucial for the quality implementation of sports programs. Côté and Gilbert (2009) emphasize that effective coaches not only teach sports skills but also positively influence the overall development of the child by promoting positive values and providing emotional support. Nelson and Cushion (2006) highlight the importance of continuous professional education of coaches to ensure they are familiar with the latest research and methodologies in sports training. The education of coaches should encompass not only the technical aspects of sport but also the development of social and emotional competencies in children (Vella et al., 2011).

7.3. Promotion of Equality and Inclusion

It is important to ensure that sports activities are accessible to all children, regardless of their physical abilities, gender, socioeconomic status, or cultural background. Dagkas and Armour (2012) emphasize the need for policies and practices that promote inclusion and equality in sport. This includes removing financial and social barriers that may prevent children from participating. Coakley (2011) suggests that sports organizations actively work on creating an inclusive environment through program adaptation and providing necessary resources. Inclusive sports programs promote social cohesion and allow all children to experience the benefits of participating in sport (Shields, Bredemeier, 2009).

7.4. Collaboration between Schools, Families, and Communities

Collaboration between schools, families, and local communities is key to creating a supportive environment that encourages participation in sport. Weiss and Ferrer-Caja (2002) emphasize

that family support is one of the most important factors in maintaining children's engagement in sports activities. Coordinated efforts among different social actors can increase the availability and quality of sports programs for children (Lee, Martinek, 2009).

7.5. Evaluation and Adaptation of Sports Programs

Regular evaluation of sports programs allows for the identification of areas that require improvements and adjustments. Bailey et al. (2009) emphasize the importance of using evaluation tools to ensure the effectiveness of programs in achieving desired outcomes. Adjusting programs based on feedback and evaluation results is crucial for the continuous improvement of the quality of the sports experience (Harvey, Jarrett, 2014).

8. Conclusion

Sport and physical activity have an undeniably positive impact on the physical, psychological, and social development of children and youth. Through a kinesiological approach, this paper has highlighted how the integration of knowledge from different disciplines enables a comprehensive understanding of how sport can act as a powerful tool for education and upbringing. The analysis of physiological, biomechanical, and psychological aspects has shown that regular participation in sports activities promotes healthy growth and development, improves motor skills, and contributes to the prevention of chronic diseases (Strong et al., 2005; Malina, 2010). The psychological benefits of sport include the development of self-confidence, emotional resilience, and social skills, which are crucial for the overall well-being of children and youth (Weinberg, Gould, 2011; Fraser-Thomas et al., 2005). Sport provides a unique environment in which social competencies, such as teamwork, communication, and respect for rules, can be developed (Côté, Fraser-Thomas, 2007). Additionally, participation in sport can act as a preventive measure against the development of risky behaviours by providing a structured and supportive environment (Eccles, Barber, 1999). The role of schools and local communities has proven to be crucial in promoting sport as a means of education. The integration of sports programs into the educational system and the encouragement of community sports activities can increase the availability and quality of sports opportunities for all children, regardless of their individual differences (Trudeau, Shephard, 2008; Collins, Kay, 2014). This not only improves students' physical health but also promotes their academic success and social development (Bailey et al., 2009). Recommendations for future practice emphasize the need for an individualized approach, education of coaches and teachers, and the promotion of equality and inclusion in sport. The implementation of these strategies can maximize the positive impact of sport on the education and development of children and youth and encourage their long-term engagement in physical activity (Fraser-Thomas, Côté, 2009; Rink, 2010). Sport, therefore, represents a valuable tool in education that, with proper guidance and support, can significantly contribute to the holistic development of children and youth. The kinesiological approach enables understanding the complexities of these influences and provides scientifically grounded guidelines for creating effective sports programs. Future research should focus on longitudinal studies that will track the long-term effects of sport on various aspects of development, as well as on the evaluation of implemented programs to continuously improve practice in this area.

Reference:

1. Bailey, D. A., McKay, H. A., Mirwald, R. L., Crocker, P. R., Faulkner, R. A. (1999). A six-year longitudinal study of the relationship of physical activity to bone mineral accrual in growing children. Journal of Bone and Mineral Research, 14(10), 1672–1679.

2. Bailey, R. (2006). Physical education and sport in schools: A review of benefits and outcomes. Journal of School Health, 76(8), 397–401.

3. Bailey, R., Armour, K., Kirk, D., Jess, M., Pickup, I., Sandford, R. (2009). The educational benefits claimed for physical education and school sport: An academic review. Research Papers in Education, 24(1), 1–27.

4. Biddle, S. J. H., Asare, M. (2011). Physical activity and mental health in children and adolescents: A review of reviews. British Journal of Sports Medicine, 45(11), 886–895.

5. Bruner, M. W., Eys, M. A., Wilson, K. S. (2014). The sport team as an effective context for youth development: Future directions. Quest, 66(1), 55–65.

6. Camiré, M., Forneris, T., Trudel, P., Bernard, D. (2012). Strategies for helping coaches facilitate positive youth development through sport. Journal of Sport Psychology in Action, 3(2), 92–103.

7. Coakley, J. (2011). Youth sports: What counts as "positive development?". Journal of Sport and Social Issues, 35(3), 306–324.

8. Collins, M., Kay, T. (2014). Sport and Social Exclusion. Routledge.

9. Conn, V. S. (2010). Anxiety outcomes after physical activity interventions: Meta-analysis findings. Nursing Research, 59(3), 224–231.

10. Côté, J., Fraser-Thomas, J. (2007). Youth involvement in sport. In P. Crocker (Ed.), Sport Psychology: A Canadian Perspective (pp. 266–294). Pearson.

11. Côté, J., Gilbert, W. (2009). An integrative definition of coaching effectiveness and expertise. International Journal of Sports & Science, Coaching, 4(3), 307–323.

12. Dagkas, S., Armour, K. (2012). Inclusion and Exclusion Through Youth Sport. Routledge.

13. Deci, E. L., Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. Psychological Inquiry, 11(4), 227–268.

14. Donnelly, J. E., Lambourne, K. (2011). Classroom-based physical activity, cognition, and academic achievement. Preventive Medicine, 52(Suppl 1), S36–S42.

15. Eccles, J. S., Barber, B. L. (1999). Student council, volunteering, basketball, or marching band: What kind of extracurricular involvement matters? Journal of Adolescent Research, 14(1), 10–43.

16. Ekeland, E., Heian, F., Hagen, K. B., Abbott, J., Nordheim, L. (2005). Exercise to improve self-esteem in children and young people. Cochrane Database of Systematic Reviews, (1), CD003683.

17. Eisenmann, J. C. (2007). Aerobic fitness, fatness and the metabolic syndrome in children and adolescents. Acta Paediatrica, 96(12), 1723–1729.

18. Enoki, H., Ae, M., Fujii, N. (2017). Biomechanical characteristics of sprint running during physical growth. International Journal of Sport and Health Science, 15, 1–9.

19. Ewing, M. E., Seefeldt, V. (2002). Patterns of participation and attrition in American agency-sponsored youth sports. In F. L. Smoll, R. E. Smith (Eds.), Children and Youth in Sport: A Biopsychosocial Perspective (2nd ed., pp. 31–45). Kendall/Hunt.

20. Faigenbaum, A. D., Myer, G. D. (2010). Resistance training among young athletes: Safety, efficacy and injury prevention effects. British Journal of Sports Medicine, 44(1), 56–63.

21. Fredricks, J. A., Eccles, J. S. (2006). Is extracurricular participation associated with beneficial outcomes? Concurrent and longitudinal relations. Developmental Psychology, 42(4), 698–713.

22. Fraser-Thomas, J. L., Côté, J. (2009). Understanding adolescents' positive and negative developmental experiences in sport. The Sport Psychologist, 23(1), 3–23.

23. Fraser-Thomas, J. L., Côté, J., Deakin, J. (2005). Youth sport programs: An avenue to foster positive youth development. Physical Education and Sport Pedagogy, 10(1), 19–40.

24. Green, K. (2012). Mission impossible? Reflecting upon the relationship between physical education, youth sport and lifelong participation. Physical Education and Sport Pedagogy, 17(4), 365–380.

25. Hall, S. J. (2015). Basic Biomechanics (7th ed.). McGraw-Hill.

26. Hardman, K., Marshall, J. (2000). The state and status of physical education in schools in an international context. European Physical Education Review, 6(3), 203–229.

27. Hartmann, D. (2003). Theorizing sport as social intervention: A view from the grassroots. Quest, 55(2), 118–140.

28. Harvey, S., Jarrett, K. (2014). A review of the game-centered approaches to teaching and coaching literature since 2006. Physical Education and Sport Pedagogy, 19(3), 278–300.

29. Harter, S. (1982). The perceived competence scale for children. Child Development, 53(1), 87–97.

30. Hills, A. P., Andersen, L. B., Byrne, N. M. (2007). Physical activity and obesity in children. British Journal of Sports Medicine, 41(11), 595–600.

31. Holt, N. L., Neely, K. C. (2011). Positive youth development through sport: A review. Revista Iberoamericana de Psicología del Ejercicio y el Deporte, 6(2), 299–316.

32. Holt, N. L., Kingsley, B. C., Tink, L. N., Scherer, J. (2011). Benefits and challenges associated with sport participation by children and parents from low-income families. Psychology of Sport and Exercise, 12(5), 490–499.

33. Janssen, I., LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. International Journal of Behavioral Nutrition and Physical Activity, 7, Article 40.

34. Kirk, D. (2005). Physical education, youth sport and lifelong participation: The importance of early learning experiences. European Physical Education Review, 11(3), 239–255.

35. Knudson, D. V. (2007). Fundamentals of Biomechanics (2nd ed.). Springer.

36. Lee, O., Martinek, T. (2009). Navigating two cultures: An investigation of cultures of a responsibility-based physical activity program and school. Research Quarterly for Exercise and Sport, 80(2), 230–240.

37. Light, R. (2008). Learning and identity in overlapping communities of practice: Surf club, school and sports academy. Australian Educational Researcher, 35(3), 143–161.

38. Lloyd, R. S., Oliver, J. L. (2012). The youth physical development model: A new approach to long-term athletic development. Strength and Conditioning Journal, 34(3), 61–72.

39. Lubans, D. R., Richards, J., Hillman, C. H., Faulkner, G., Beauchamp, M. R., Nilsson, M., Biddle, S. J. H. (2016). Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. Pediatrics, 138(3), e20161642.

40. Mahoney, J. L., Stattin, H. (2000). Leisure activities and adolescent antisocial behavior: The role of structure and social context. Journal of Adolescence, 23(2), 113–127.

41. Malina, R. M. (2010). Physical activity and health of youth. Ovidius University Annals, Series Physical Education and Sport/Science, Movement and Health, 10(2), 103–114.

42. Misener, L., Mason, D. S. (2006). Creating community networks: Can sporting events offer meaningful sources of social capital? Managing Leisure, 11(1), 39–56.

43. Nelson, L. J., Cushion, C. J. (2006). Reflection in coach education: The case of the national governing body coaching certificate. The Sport Psychologist, 20(2), 174–183.

44. Nieman, D. C. (2001). Exercise immunology: Future directions for research related to athletes, nutrition, and the elderly. International Journal of Sports Medicine, 22(6), 495–502.

45. Pate, R. R., Davis, M. G., Robinson, T. N., Stone, E. J., McKenzie, T. L., Young, J. C. (2006). Promoting physical activity in children and youth: A leadership role for schools. Circulation, 114(11), 1214–1224.

46. Peluso, M. A. M., Andrade, L. H. S. G. (2005). Physical activity and mental health: The association between exercise and mood. Clinics, 60(1), 61–70.

47. Perkins, D. F., Noam, G. G. (2007). Characteristics of sports-based youth development programs. New Directions for Youth Development, 115, 75–84.

48. Rees, T., Freeman, P. (2007). The effects of social support on performance and well-being in sport. International Review of Sport and Exercise Psychology, 1(1), 20–41.

49. Rink, J. E. (2010). Teaching Physical Education for Learning (6th ed.). McGraw-Hill.

50. Sahoo, K., Sahoo, B., Choudhury, A. K., Sofi, N. Y., Kumar, R., Bhadoria, A. S. (2015). Childhood obesity: Causes and consequences. Journal of Family Medicine and Primary Care, 4(2), 187–192.

51. Scanlan, T. K., Lewthwaite, R. (1986). Social psychological aspects of competition for male youth sport participants: IV. Predictors of enjoyment. Journal of Sport Psychology, 8(1), 25–35.

52. Shields, D. L., Bredemeier, B. L. (2009). True Competition: A Guide to Pursuing Excellence in Sport and Society. Human Kinetics.

53. Smith, A. L., Balaguer, I., Duda, J. L. (2007). Goal orientation profile differences on perceived motivational climate, perceived peer relationships, and enjoyment in youth sport. Journal of Sports Sciences, 24(12), 1315–1327.

54. Smith, A. L., Ullrich-French, S., Walker, E., Hurley, K. S. (2016). Peer relationship profiles and motivation in youth sport. Journal of Sport, Exercise & Psychology, 38(6), 596–607.

55. Spaaij, R. (2009). Sport as a vehicle for social mobility and regulation of disadvantaged urban youth. International Review for the Sociology of Sport, 44(2–3), 247–264.

56. Strong, W. B., Malina, R. M., Blimkie, C. J., Daniels, S. R., Dishman, R. K., Gutin, B., Trudeau, F. (2005). Evidence based physical activity for school-age youth. The Journal of Pediatrics, 146(6), 732–737.

57. Telama, R., Yang, X., Viikari, J., Välimäki, I., Wanne, O., Raitakari, O. (2005). Physical activity from childhood to adulthood: A 21-year tracking study. American Journal of Preventive Medicine, 28(3), 267–273.

58. Trudeau, F., Shephard, R. J. (2008). Physical education, school physical activity, school sports and academic performance. International Journal of Behavioral Nutrition and Physical Activity, 5, Article 10.

59. Vella, S. A., Oades, L. G., Crowe, T. P. (2011). The role of the coach in facilitating positive youth development: Moving from theory to practice. Journal of Applied Sport Psychology, 23(1), 33–48.

60. Weinberg, R. S., Gould, D. (2011). Foundations of Sport and Exercise Psychology (5th ed.). Human Kinetics.

61. Weiss, M. R., Ferrer-Caja, E. (2002). Motivational orientations and sport behavior. In T. S. Horn (Ed.), Advances in Sport Psychology (2nd ed., pp. 101–183). Human Kinetics.

62. Weiss, M. R., Stuntz, C. P. (2004). A little friendly competition: Peer relationships and psychosocial development in youth sport and physical activity contexts. In M. R. Weiss (Ed.), Developmental Sport and Exercise Psychology: A Lifespan Perspective (pp. 165–196). Fitness Information Technology.

63. Wilmore, J. H., Costill, D. L. (2004). Physiology of Sport and Exercise (3rd ed.). Human Kinetics.

64. World Health Organization. (2010). Global Recommendations on Physical Activity for Health. WHO Press.

FULL PAPER 10

SCIENTIFIC PAPER

Fitness profiles of croatian soccer players: a systematic review

Ivan Krakan

University of Zagreb; Faculty of kinesiology, Zagreb, Croatia

1. Introduction

Soccer is a high-intensity intermittent sport characterized by complex physical, physiological, and technical demands. Modern soccer performance depends on the interaction between aerobic capacity, anaerobic power, speed, strength, and body composition (Bangsbo, 1994; Reilly, 1994; Stølen et al., 2005). Over the past two decades, the physical demands of soccer have significantly increased, requiring players to perform repeated high-intensity actions throughout a match (Mohr et al., 2003; Rampinini et al., 2007). Consequently, the scientific monitoring of fitness characteristics has become essential for performance optimization and injury prevention.

Fitness profiling is widely used in soccer to evaluate players' physical and physiological capacities. These profiles provide valuable insights into performance determinants and enable coaches to design position-specific training programs (Stølen et al., 2005; Krustrup et al., 2005). Key variables commonly assessed include maximal oxygen uptake (VO2max), sprint performance, explosive power, and body composition (Helgerud et al., 2001; Wisloff et al., 2004).

In the context of Croatian soccer, several studies have examined the physical characteristics of elite and sub-elite players. Research by Marković and colleagues has contributed significantly to understanding explosive power and neuromuscular performance in soccer players (Marković et al., 2004; Marković and Mikulić, 2010). Their findings indicate that vertical jump performance is strongly associated with sprint ability and overall athletic performance.

Similarly, Sporiš et al. (2009; 2011) investigated fitness profiles of Croatian soccer players and reported significant positional differences in physical characteristics. Their research demonstrated that midfielders exhibit higher aerobic capacity, while attackers and defenders rely more on anaerobic performance. These findings are consistent with match analysis studies showing that midfielders cover the greatest distance during games (Bangsbo et al., 1991; Ekblom, 1986).

Further contributions by Jukić et al. (2008; 2012) and Milanović et al. (2013) highlight the importance of strength and conditioning programs in Croatian soccer. These studies emphasize the role of structured training in improving sprint performance, agility, and power output. In addition, Krakan et al. (2020) and Modrić et al. (2022) examined relationships between body composition and performance, confirming that lower body fat percentages are associated with better sprint and endurance performance.

Large-scale profiling studies of Croatian soccer players, including datasets of over 200 elite athletes , provide comprehensive insights into positional demands. These studies confirm that Croatian players exhibit fitness characteristics comparable to international elite standards, with VO2max values around 60 mL/kg/min and strong sprint performance.

International literature supports these findings, indicating that aerobic capacity is a key determinant of match performance (Helgerud et al., 2001; Krustrup et al., 2005), while sprint

ability is critical for decisive actions such as goal scoring and defensive recovery (Rampinini et al., 2007; Faude et al., 2012). Explosive power, measured through vertical jump tests, has also been identified as an important predictor of performance (Wisloff et al., 2004; Marković et al., 2004).

One of the most important aspects of soccer performance is positional specificity. Studies consistently show that midfielders require superior aerobic endurance, defenders require strength and tactical positioning, attackers rely on speed and acceleration, and goalkeepers depend on explosive power and reaction time (Reilly et al., 2000; Di Salvo et al., 2007). Croatian research confirms these patterns, highlighting the need for individualized training approaches (Sporiš et al., 2011; Milanović et al., 2013).

Body composition is another critical factor influencing performance. Excess body fat negatively affects speed, endurance, and power output (Reilly et al., 2000; Krakan et al., 2020). Croatian studies emphasize the importance of maintaining optimal body composition for elite performance (Modrić et al., 2022).

Despite the growing body of research, there is still a lack of systematic synthesis focusing specifically on Croatian soccer players. Most studies analyze individual variables or small samples, making it difficult to draw comprehensive conclusions. A systematic review approach is therefore necessary to integrate findings from different studies and provide a clearer understanding of fitness profiles.

Furthermore, advancements in technology, such as GPS tracking and performance analytics, have improved the ability to monitor physical demands in soccer (Di Salvo et al., 2007; Mohr et al., 2003). These tools allow for more precise evaluation of match performance and training load, which can be integrated into fitness profiling.

Given the importance of physical preparation in modern soccer, understanding the specific fitness characteristics of Croatian players is essential for optimizing training and performance. By combining insights from Croatian and international research, a more comprehensive picture of player profiles can be developed.

Therefore, the aim of this systematic review is to synthesize current scientific evidence on the fitness profiles of Croatian soccer players, with a focus on aerobic capacity, sprint performance, body composition, and explosive power, as well as positional differences and training implications.

2. Methods

2.1 Study Design

This study was conducted as a systematic review aimed at synthesizing current scientific evidence on the physical and physiological fitness profiles of Croatian soccer players. The methodological framework followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure transparency, reproducibility, and scientific rigor (Page et al., 2021).

The review focused on identifying and analyzing studies reporting key fitness indicators, including aerobic capacity, sprint performance, body composition, and explosive power, with particular emphasis on positional differences.

2.2 Search Strategy

A comprehensive and systematic literature search was performed across multiple electronic databases:

- PubMed
- Scopus
- Web of Science
- Google Scholar

The search covered studies published between 2000 and 2025.

A combination of keywords and Boolean operators was used:

- “soccer fitness profile”
- “Croatian soccer players”
- “VO2max soccer”
- “sprint performance soccer”
- “body composition football players”
- “explosive power soccer”

Special attention was given to identifying studies conducted by Croatian authors and institutions (e.g., University of Zagreb, Kinesiology Faculty).

Additionally, reference lists of relevant studies were manually screened to identify further eligible studies.

2.3 Inclusion Criteria

Studies were included if they met the following criteria:

- participants were elite or professional soccer players
- included Croatian players or comparable elite populations
- reported at least one of the following variables:
  - VO2max
  - sprint performance (5–20 m)
  - body composition (fat %, body mass)
  - explosive power (SJ, CMJ)
- original research articles (cross-sectional, longitudinal, experimental)
- published in peer-reviewed journals
- written in English or Croatian

2.4 Exclusion Criteria

Studies were excluded if:

- participants were recreational or youth players without elite classification

- data on fitness variables were not reported
- articles were review papers, conference abstracts, or case studies
- insufficient methodological information was provided
- duplicate datasets were identified

2.5 Study Selection Process

The study selection process followed a three-stage PRISMA approach:

1. Identification
   - All records from databases were collected
   - duplicates were removed
2. Screening
   - titles and abstracts were reviewed
   - irrelevant studies were excluded
3. Eligibility
   - full-text articles were assessed
   - studies meeting all criteria were included

The selection process was documented to ensure transparency and reproducibility.

2.6 Data Extraction

Data were extracted systematically using a predefined framework:

Study characteristics

- author(s)
- year of publication
- study design

Participant characteristics

- sample size
- age
- playing level
- playing position

Fitness variables

- VO2max
- sprint time (5 m, 10 m, 20 m)
- body composition
- jump performance (SJ, CMJ)

Key findings

- positional differences
- correlations between variables
- performance outcomes

Where available, data from large-scale Croatian studies (e.g., n = 270 players) were included as reference datasets.

2.7 Quality Assessment

The methodological quality of included studies was assessed using a modified version of standard evaluation tools for observational studies.

Each study was evaluated based on:

- sample size adequacy
- clarity of methodology
- reliability of measurement tools
- statistical analysis quality

Studies were classified as:

- high quality
- moderate quality
- low quality

Only moderate and high-quality studies were included in the final synthesis.

2.8 Risk of Bias Assessment

Potential sources of bias were considered, including:

- selection bias (sample characteristics)
- measurement bias (testing protocols)
- reporting bias (incomplete data)

Efforts were made to minimize bias by including only peer-reviewed studies and clearly defined datasets.

2.9 Data Synthesis

Due to heterogeneity among studies in terms of methodology, sample characteristics, and measured variables, a qualitative synthesis approach was applied.

The results were categorized into:

- aerobic capacity
- sprint performance
- body composition

- explosive power
- positional differences

Comparisons between studies were performed to identify consistent patterns and trends.

2.10 Methodological Limitations

Several limitations were acknowledged:

- variability in testing protocols across studies
- differences in player level and competition
- limited number of large-scale Croatian datasets

Despite these limitations, the systematic approach provides a comprehensive overview of fitness profiles.

3. Results

3.1 Study Selection and General Characteristics

The systematic search process identified a total of 214 records across all databases. After removal of duplicates (n = 52), 162 studies remained for title and abstract screening. Following the screening phase, 47 studies were selected for full-text assessment. Based on the predefined inclusion and exclusion criteria, 18 studies were included in the final synthesis.

The included studies comprised a combined sample of over 750 soccer players, including elite and professional athletes. A key contribution to the dataset was a large-scale study involving 270 Croatian elite soccer players, which provided detailed positional analysis and served as a central reference point .

The majority of studies were cross-sectional in design, with some longitudinal and experimental studies examining training adaptations. Players were categorized into four primary positions:

- goalkeepers
- defenders
- midfielders
- attackers

Across studies, fitness variables were consistently assessed using standardized protocols, although some variability in measurement techniques was noted.

3.2 Aerobic Capacity (VO2max)

Aerobic capacity was one of the most frequently reported variables across studies and showed clear positional differences.

Midfielders consistently demonstrated the highest VO2max values, typically ranging between 58–65 mL/kg/min, reflecting their role in covering large distances during matches. In contrast:

- defenders: ~55–60 mL/kg/min
- attackers: ~54–58 mL/kg/min
- goalkeepers: ~50–55 mL/kg/min

The findings indicate that midfielders possess significantly superior aerobic endurance compared to other positions, which aligns with their tactical role requiring continuous movement and involvement in both offensive and defensive phases.

Furthermore, studies reported strong associations between VO2max and total distance covered during matches, as well as recovery between high-intensity efforts. Players with higher aerobic capacity were able to sustain performance levels for longer periods.

3.3 Sprint Performance

Sprint performance (5 m, 10 m, and 20 m) was identified as a critical determinant of performance, particularly for attackers and defenders.

Typical sprint values observed across studies:

- attackers: fastest (5–20 m)
- defenders: slightly slower than attackers
- midfielders: moderate sprint performance
- goalkeepers: slowest sprint times

For example:

- 5 m sprint: 1.00–1.10 s
- 10 m sprint: 1.70–1.90 s
- 20 m sprint: 2.90–3.20 s

Attackers consistently outperformed other positions in short-distance acceleration, which is essential for goal-scoring situations and offensive transitions.

Significant negative correlations were observed between sprint time and performance outcomes, indicating that faster players have a competitive advantage in high-intensity match situations.

3.4 Body Composition

Body composition, particularly body fat percentage, was found to be a significant factor influencing performance.

Observed ranges:

- midfielders: lowest body fat (~8–10%)
- attackers: ~9–11%
- defenders: ~10–13%
- goalkeepers: highest (~12–15%)

A strong negative relationship was identified between body fat and:

- sprint performance
- VO2max
- jump performance

Players with lower body fat percentages consistently demonstrated superior physical performance. Conversely, higher body fat was associated with decreased efficiency in both aerobic and anaerobic tasks.

3.5 Explosive Power (Jump Performance)

Explosive power, typically measured through squat jump (SJ) and countermovement jump (CMJ), showed significant positional differences.

Typical values:

- goalkeepers: highest (CMJ 45–55 cm)
- attackers: 40–50 cm
- midfielders: 38–45 cm
- defenders: 40–48 cm

Goalkeepers demonstrated the highest explosive power, reflecting the demands of their position, which include jumping, diving, and rapid movements.

Explosive power was also positively correlated with sprint performance, suggesting that neuromuscular strength contributes to acceleration ability.

3.6 Positional Differences (Integrated Analysis)

A clear pattern of positional specialization emerged across all fitness variables:

Goalkeepers

- highest body mass and height
- highest explosive power
- lowest aerobic capacity
- lowest sprint performance

Defenders

- higher body fat
- moderate strength and sprint ability
- balanced physical profile

Midfielders

- highest VO2max
- lowest body fat
- moderate speed
- highest total workload

Attackers

- fastest sprint performance
- high explosive power

- moderate aerobic capacity

These findings confirm that each position requires a distinct combination of physical abilities.

3.7 Relationships Between Fitness Variables

Several significant relationships were identified across studies:

- VO2max ↔ match performance (positive correlation)
- body fat ↔ sprint performance (negative correlation)
- jump performance ↔ sprint ability (positive correlation)
- body mass ↔ body fat (positive correlation)

These relationships highlight the importance of an integrated approach to training, where multiple physical capacities are developed simultaneously.

3.8 Comparison with International Data

Croatian players demonstrated fitness values comparable to elite international standards:

- VO2max: similar to top European leagues
- sprint performance: within elite ranges
- body composition: optimized for performance

This suggests that Croatian training methodologies are aligned with global best practices.

3.9 Summary of Findings

The systematic review identified several key findings:

- significant positional differences exist in all fitness variables
- midfielders have the highest aerobic capacity
- attackers demonstrate superior speed
- goalkeepers possess the highest explosive power
- body composition strongly influences performance

These findings confirm the importance of position-specific training and monitoring.

4. Discussion

The aim of this systematic review was to synthesize existing knowledge on the fitness profiles of Croatian soccer players, with a particular focus on positional differences and performance determinants. The findings consistently demonstrate that Croatian players exhibit highly

developed physical and physiological characteristics, comparable to elite international standards. Importantly, the results highlight clear positional differences in aerobic capacity, sprint performance, body composition, and explosive power.

One of the most prominent findings relates to the role of aerobic capacity, particularly in midfield players. The consistently higher VO2max values observed in this position align with previous research conducted on Croatian athletes, which emphasizes the importance of aerobic endurance for sustaining high match workloads (Sporiš et al., 2009; Sporiš et al., 2011; Milanović et al., 2013; Jukić et al., 2008). These findings are further supported by studies showing that Croatian midfielders cover greater distances and are more involved in both offensive and defensive phases of play (Modrić et al., 2022; Krakan et al., 2020).

The importance of aerobic capacity in Croatian soccer has also been emphasized in conditioning research, where improvements in VO2max were associated with enhanced match performance and recovery (Marković et al., 2004; Marković and Mikulić, 2010). Additionally, Croatian training models often incorporate high-intensity interval training, which has been shown to improve aerobic performance in soccer players (Jukić et al., 2012; Milanović et al., 2013).

In contrast to midfielders, attackers demonstrated superior sprint performance, which is critical for decisive match actions such as goal scoring and counter-attacks. Croatian studies have consistently shown that sprint ability is a key determinant of success in attacking positions (Sporiš et al., 2011; Milanović et al., 2013; Krakan et al., 2020). The strong relationship between sprint performance and anaerobic power has also been documented in Croatian athletes (Marković et al., 2004; Jukić et al., 2008).

Explosive power, particularly in goalkeepers, represents another important performance factor. The higher values observed in vertical jump tests confirm the importance of neuromuscular strength in this position. Croatian research has extensively analyzed jumping performance and its relationship with overall athletic ability (Marković et al., 2004; Marković and Mikulić, 2010). These findings suggest that goalkeepers require specialized strength training programs focusing on explosive movements.

Body composition emerged as a significant determinant of performance across all positions. Lower body fat percentages were consistently associated with better sprint, endurance, and power performance. Croatian studies have highlighted the importance of maintaining optimal body composition for elite performance (Krakan et al., 2020; Modrić et al., 2022; Sporiš et al., 2009). Excess body fat negatively impacts movement efficiency, particularly in high-intensity actions.

The interaction between physical variables is another important finding. Strong correlations were observed between aerobic capacity, sprint performance, and explosive power, indicating that these variables should not be trained in isolation. Croatian conditioning research emphasizes integrated training approaches that simultaneously develop multiple physical capacities (Jukić et al., 2012; Milanović et al., 2013).

From a practical perspective, the results of this review strongly support the concept of position-specific training. Croatian authors consistently emphasize that training programs should be adapted to the specific demands of each playing position (Sporiš et al., 2011; Milanović et al., 2013; Modrić et al., 2022). For example, midfielders require high-volume aerobic training, while attackers need speed and power development.

Another important aspect is the role of long-term athlete development. Croatian research highlights the importance of progressive training models that develop physical capacities over

time (Jukić et al., 2008; Marković et al., 2004). Early specialization combined with structured conditioning programs contributes to the development of elite-level performance.

Despite the strong findings, several limitations must be acknowledged. The majority of studies are cross-sectional, limiting the ability to establish causal relationships. Additionally, variability in testing protocols may affect comparability across studies. However, the consistency of findings across multiple Croatian studies strengthens the validity of the conclusions.

Future research should focus on longitudinal studies and the integration of advanced technologies such as GPS tracking and performance analytics. Croatian authors have already begun exploring these approaches, but further research is needed to fully understand performance dynamics (Modrić et al., 2022; Krakan et al., 2020).

REFERENCES

1. Barišić, V., Sporiš, G. and Milanović, D. (2015) 'Physical conditioning in soccer players', Kinesiology, 47(2), pp. 180–187.
2. Grgantov, Z., Katić, R. and Maleš, B. (2012) 'Anthropological characteristics of elite athletes', Kinesiology, 44(1), pp. 23–30.
3. Jukić, I., Milanović, D. and Krakan, I. (2008) 'Strength and conditioning in soccer', Kinesiology, 40(1), pp. 45–53.
4. Jukić, I., Milanović, D. and Vučetić, V. (2012) 'High-intensity training in soccer', Journal of Strength and Conditioning Research, 26(5), pp. 1203–1210.
5. Jukić, I., Sekulić, D. and Sporiš, G. (2014) 'Training adaptations in elite soccer players', Kinesiology, 46(1), pp. 12–20.
6. Jukić, I., Milanović, D. and Sporiš, G. (2016) 'Conditioning strategies in football', Sports Medicine, 46(4), pp. 567–580.
7. Katić, R., Grgantov, Z. and Jurko, D. (2006) 'Motor abilities in sports', Kinesiology, 38(1), pp. 5–14.
8. Krakan, I., Modrić, T. and Sporiš, G. (2020) 'Body composition and performance in soccer players', Kinesiology, 52(2), pp. 190–198.
9. Krakan, I., Modrić, T. and Barišić, V. (2021) 'Fitness characteristics in football players', Acta Kinesiologica, 15(1), pp. 45–52.
10. Mikulić, P., Marković, G. and Jukić, I. (2011) 'Neuromuscular performance in athletes', Sports Biomechanics, 10(2), pp. 123–135.
11. Milanović, D., Jukić, I. and Sporiš, G. (2013) 'Physical conditioning in soccer', Kinesiology, 45(1), pp. 30–40.
12. Milanović, D., Jukić, I. and Krakan, I. (2015) 'Training methodology in football', Acta Kinesiologica, 9(2), pp. 55–63.
13. Milanović, D., Sporiš, G. and Jukić, I. (2017) 'Speed and agility in soccer players', Journal of Sports Science, 35(4), pp. 412–420.
14. Modrić, T., Versic, S. and Sekulić, D. (2020) 'Body composition in soccer players', Sustainability, 12(7), pp. 1–12.
15. Modrić, T., Versic, S. and Sporiš, G. (2022) 'Performance analysis in football', Applied Sciences, 12(3), pp. 1–15.
16. Modrić, T., Versic, S. and Krakan, I. (2023) 'Physical demands in elite soccer', Sports, 11(2), pp. 1–10.
17. Marković, G. (2004) 'Strength and sprint performance', Journal of Strength and Conditioning Research, 18(4), pp. 745–750.

18. Marković, G., Dizdar, D. and Jukić, I. (2007) ‘Plyometric training effects’, Scandinavian Journal of Medicine & Science in Sports, 17(3), pp. 211–218.
19. Marković, G. and Mikulić, P. (2010) ‘Neuromuscular adaptations’, Sports Medicine, 40(10), pp. 859–895.
20. Marković, G., Mikulić, P. and Jukić, I. (2012) ‘Jump performance in athletes’, Journal of Sports Sciences, 30(10), pp. 1015–1023.
21. Ostojić, S., Mazic, S. and Dikic, N. (2006) ‘Fitness characteristics of soccer players’, Journal of Sports Science, 24(4), pp. 401–408.
22. Sekulić, D., Spasić, M. and Mirkov, D. (2013) ‘Strength and conditioning in sport’, Journal of Strength and Conditioning Research, 27(6), pp. 1556–1565.
23. Sekulić, D., Krakan, I. and Modrić, T. (2016) ‘Performance indicators in athletes’, Sports Medicine, 46(8), pp. 1123–1135.
24. Sporiš, G., Jukić, I. and Milanović, D. (2009) ‘Fitness profiling in soccer players’, Kinesiology, 41(2), pp. 120–128.
25. Sporiš, G., Jukić, I. and Milanović, D. (2011) ‘Positional differences in soccer’, Journal of Sports Science & Medicine, 10(3), pp. 465–472.
26. Sporiš, G., Milanović, D. and Jukić, I. (2012) ‘Conditioning in soccer’, Kinesiology, 44(2), pp. 140–150.
27. Sporiš, G., Barišić, V. and Milanović, D. (2014) ‘Match performance analysis’, Acta Kinesiologica, 8(1), pp. 33–40.
28. Šimunič, B., Degens, H. and Narici, M. (2010) ‘Muscle performance adaptations’, European Journal of Applied Physiology, 110(2), pp. 405–413.
29. Jurko, D., Katić, R. and Grgantov, Z. (2010) ‘Motor development in sport’, Kinesiology, 42(1), pp. 15–22.
30. Vučetić, V., Jukić, I. and Milanović, D. (2012) ‘Training load in soccer’, Kinesiology, 44(1), pp. 56–63.
31. Babić, V., Katić, R. and Milić, M. (2008) ‘Anthropometric differences in athletes’, Kinesiology, 40(2), pp. 121–130.
32. Pejčić, A., Sporiš, G. and Milanović, D. (2015) ‘Physical fitness in team sports’, Kinesiology, 47(1), pp. 65–72.

FULL PAPER 11

SCIENTIFIC PAPER

Kinesiology for the 21st Century (Review Paper)

Goran Sporiš; Robert Citozi; Veljko Vukičević; Mario Anić Kremić;; Davor Lješević; Ivana Grle; Maki Grle; Jose Antonio Perez Turpin; Davor Bučević; Ernest Šabić, Naim Ćeleš; Boriss Bazanov; Drena Trkulja-Petković; Adem Preljević

University of Zagreb, Faculty of Kinesiology, Zagreb, Croatia

1. Introduction

Kinesiology is defined as the scientific study of human movement and the processes that determine the effects of physical activity on the human organism (Sporiš et al., 2013). In a more precise scientific framework, kinesiology is described as an empirical and experimentally based science that studies the laws, principles, and patterns of controlled and purposeful physical activity and its influence on the human body (Mraković, 1992). This definition emphasises both the scientific foundation and applied nature of kinesiology as a discipline. Earlier theoretical foundations of the field can also be found in the work of Momirović, who defined kinesiology as a science of movement efficiency and transformation processes influenced by physical activity (Momirović, 1969; Momirović, 1971).

The term kinesiology originates from the Greek words kinesis (movement) and logos (study), meaning the science of movement (Sporiš et al., 2013; Renson, 2000). Since its first formal use in the 19th century, kinesiology has developed as a complex and multidisciplinary field encompassing various domains such as sport, physical education, recreation, and rehabilitation (Čustonja et al., 2009; Sporiš et al., 2013). However, throughout its historical development, the discipline has been characterised by a lack of unified terminology, with multiple terms used to describe similar or overlapping areas of study (Čustonja et al., 2009).

Numerous terms have been used in both European and American academic contexts, including sport science, physical education, exercise science, human movement science, and human performance (Čustonja et al., 2009; Sporiš et al., 2013; Thomas & Nelson, 1990). This terminological diversity reflects the interdisciplinary nature of the field but also creates challenges in defining its scientific identity and structure (Mills, 1992; Wade & Baker, 1992). The absence of a universally accepted term has been recognised as a significant issue, potentially affecting the organisation of study programmes and the development of the discipline (Čustonja et al., 2009).

Historically, physical education was the dominant concept in the early development of kinesiology-related disciplines (Čustonja et al., 2009; Findak, 2001). Physical education played a crucial role in shaping the early academic structure of the field, particularly through its pedagogical and methodological orientation (Findak, 2001). Most academic institutions in Europe and the United States established programmes focused on the preparation of physical education teachers, which influenced the early structure and orientation of the discipline (Prskalo, 2004; Milanović, 2013). Prskalo emphasises the importance of kinesiology in the educational system, particularly in the development of motor skills and lifelong physical activity habits (Prskalo, 2004).

Over time, the expansion of scientific knowledge led to the recognition that human movement studies extend beyond education and require a broader scientific framework (Sporiš et al.,

2013). Milanović highlights the transition from purely pedagogical models toward scientifically grounded approaches in training and performance, particularly in sport systems (Milanović, 2013). This shift reflects the broader transformation of kinesiology into a discipline that integrates theory, research, and practical application.

In Europe, the development of the discipline has been strongly influenced by the concept of sport and sport science, which became dominant during the second half of the 20th century (Sporiš et al., 2013; Müller, 2008). The emergence of sport science as an academic discipline marked a significant step toward the scientificisation of human movement studies (Müller, 2008). The establishment of organisations such as the European College of Sport Science further reinforced this orientation (ECSS, 2020). However, the dominance of the term sport reflects historical and socio-cultural factors rather than a comprehensive scientific perspective (Čustonja et al., 2009).

In contrast, the development of kinesiology in the United States followed a different trajectory. The field gradually shifted toward an interdisciplinary model integrating health, performance, and scientific research (Čustonja et al., 2009; Newell, 1989). The increasing use of the term kinesiology in academic institutions reflects the effort to establish a unified and comprehensive scientific identity (American Kinesiology Association, 2021). According to empirical analyses, terms such as health, physical education, and kinesiology are most frequently used in American higher education institutions (Čustonja et al., 2009).

Despite these regional differences, the need for a unified scientific concept has become increasingly evident. Kinesiology is now widely recognised as an umbrella term encompassing various subdisciplines related to human movement (Sporiš et al., 2013; Malina, 2017). It integrates knowledge from biological, social, and behavioural sciences, allowing for a comprehensive understanding of movement as a complex human phenomenon (Bouchard et al., 2012; Kenney et al., 2015). Findak and Prskalo further emphasise the importance of integrating educational, health, and sport perspectives within a unified kinesiological framework (Findak, 2001; Prskalo, 2004).

The importance of kinesiology in modern society has grown significantly due to the increasing prevalence of sedentary lifestyles and chronic diseases (WHO, 2020; Blair, 2012). Physical inactivity has been identified as one of the major risk factors for global health, highlighting the need for scientific approaches to promote physical activity and improve quality of life (Haskell et al., 2007). In this context, kinesiology plays a crucial role in developing strategies for prevention, rehabilitation, and performance enhancement (Bompa & Buzzichelli, 2019; Milanović, 2013).

Furthermore, the evolution of kinesiology reflects broader changes in scientific paradigms. The traditional reductionist approach, focused on isolated aspects of movement, is being replaced by a holistic and integrative perspective that considers the interaction between biological, psychological, and social factors (Maguire, 1991; Kuhn, 1962). This shift is consistent with contemporary trends in science, which emphasise interdisciplinarity and the integration of knowledge across different fields (Lakatos, 1970).

The structural development of kinesiology has led to the formation of distinct but interconnected subdisciplines, including exercise physiology, biomechanics, motor control, sport psychology, and kinesiotherapy (Bartlett, 2022; Powers & Howley, 2018). These areas contribute to a unified scientific framework, positioning kinesiology as a central discipline in the study of human movement (Issurin, 2021). Momirović's early theoretical contributions remain relevant in understanding the transformation processes underlying motor behaviour and performance (Momirović, 1971).

Given these developments, the 21st century represents a period of significant transformation for kinesiology. The discipline is transitioning from a practice-oriented field toward a scientifically grounded and socially relevant domain. This transformation is characterised by the integration of research, education, and practical application, as well as the increasing importance of technological advancements in movement analysis and performance monitoring (Faigenbaum & Myer, 2020).

The aim of this review paper is to analyse the paradigm and structural shifts of kinesiology in the 21st century, with particular emphasis on its evolving scientific identity, interdisciplinary nature, and societal relevance.

2. Methods

This study was designed as a review with the aim of analysing the paradigm and structural shifts of kinesiology in the 21st century, with particular emphasis on contributions from Croatian authors and the European academic context.

2.1. Data Sources and Literature Selection

The literature included in this review was collected through:

- analysis of foundational scientific papers in kinesiology
- review of Croatian academic literature (books, scientific articles, and university publications)
- examination of relevant international studies for comparative purposes

Particular emphasis was placed on Croatian authors who have significantly contributed to the development and theoretical foundation of kinesiology, including:

- Mraković (1992)
- Momirović (1969; 1971)
- Milanović (2013)
- Findak (2001)
- Prskalo (2004)
- Sporiš et al. (2013)
- Čustonja et al. (2009)

These sources were selected due to their relevance in defining kinesiology as a scientific discipline and their contribution to understanding its structural and terminological development.

2.2. Inclusion Criteria

The following criteria were applied in the selection of literature:

- scientific relevance to kinesiology as a discipline

- focus on human movement, physical activity, or sport science
- contribution to theoretical, methodological, or structural aspects of kinesiology
- priority given to Croatian authors and regional scientific perspectives
- inclusion of key international references where necessary for comparison

2.3. Analytical Approach

The selected literature was analysed using a qualitative approach, focusing on:

- definitions of kinesiology
- development of terminology
- structural organisation of the discipline
- paradigm shifts from traditional to modern approaches

Special attention was given to identifying:

- differences between traditional and contemporary concepts
- the role of interdisciplinarity in modern kinesiology
- the integration of biological, social, and educational sciences

The analysis also included a comparative perspective between European and American models of kinesiology, based on previously published empirical findings (Čustonja et al., 2009).

2.4. Methodological Framework

The methodological framework of this review is based on:

- synthesis of existing theoretical and empirical knowledge
- critical interpretation of key concepts in kinesiology
- integration of findings from different subdisciplines

This approach is consistent with previous review studies in kinesiology, which emphasise the importance of interdisciplinary analysis and conceptual integration (Sporiš et al., 2013).

3. Results

The results of this review are presented thematically, because the paper is based on a review of theoretical, empirical and conceptual literature on kinesiology, with particular emphasis on Croatian authors and papers published in the journal Kinesiology.

3.1. Kinesiology as a scientific discipline

The reviewed literature confirms that kinesiology has developed from a practical field connected with physical education and sport into an independent scientific discipline focused on the study of human movement. Mraković defines kinesiology as an empirical and experimentally based science that studies the laws, principles and patterns of controlled and purposeful physical activity and its influence on the human organism. This definition is also supported in the systematic review by Sporiš, Badrić, Prskalo and Bonacin, where kinesiology is

presented as a broad scientific field that includes education, sport, recreation and kinesitherapy (Sporiš et al., 2013). The journal Kinesiology itself defines the field as the scientific study of human movement, sport and exercise, including biological, psychological and sociological effects of movement on humans.

3.2. Terminological findings: Europe and the United States

A central result of the review is that the terminology of kinesiology differs significantly between Europe and the United States. Čustonja, Milanović and Sporiš analysed 980 higher education programmes, including 858 from the USA and 122 from Europe. Their results showed that in the United States the most frequent terms were health (n = 261), physical education (n = 172) and kinesiology (n = 145), while in Europe the dominant terms were sport (n = 54) and physical education (n = 29) (Čustonja et al., 2009).

These findings show that the term kinesiology is much more institutionally accepted in the USA than in Europe. In Europe, the term sport science is still more common, mostly because of historical, educational and cultural reasons. However, both Čustonja et al. and Sporiš et al. argue that kinesiology is the most adequate umbrella term for the scientific study of human movement (Čustonja et al., 2009; Sporiš et al., 2013).

3.3. Croatian contribution to the development of kinesiology

The results indicate that Croatian authors have had a major role in the conceptual and institutional development of kinesiology. The Croatian academic tradition, especially through the Faculty of Kinesiology, University of Zagreb, has strongly promoted kinesiology as an independent scientific field. Čustonja et al. state that Croatia was among the leading European countries in the promotion of the term kinesiology, especially after the establishment of the Institute for Kinesiology in Zagreb in 1967 and the later recognition of kinesiology as an independent scientific field in Croatia (Čustonja et al., 2009).

The works of Momirović, Mraković, Findak, Prskalo, Milanović, Sporiš and Čustonja form the theoretical foundation of Croatian kinesiology. Momirović contributed to early theoretical definitions of movement efficiency and transformation processes, Mraković strengthened the scientific definition of kinesiology, Findak and Prskalo developed the educational and pedagogical dimension, while Milanović contributed strongly to training theory and sport performance. Together, these authors show that Croatian kinesiology is not limited to sport, but includes education, health, recreation, kinesitherapy and human development.

3.4. Structural shift of kinesiology

The reviewed literature confirms a clear structural shift in kinesiology. Earlier models were mostly connected with physical education, sport training and teacher education. Contemporary kinesiology is structured as a multidisciplinary and interdisciplinary science. According to Sporiš et al., kinesiology includes several applied and theoretical areas, such as systematic kinesiology, sport kinesiology, kinesiology education, kinesiology recreation, kinesitherapy and adapted physical activity, and kinanthropology (Sporiš et al., 2013).

The scope of the journal Kinesiology also reflects this structural shift. The journal accepts research on exercise and sport training, motor learning, motor skill development, performance analysis, selection, teaching and learning, and other topics connected with the scientific study of human movement.

3.5. Kinesiology and education

A strong result of the review is the continuing importance of kinesiology education. Findak emphasises that kinesiology education must respond to modern life and work circumstances, especially because physical activity is necessary throughout life. His work “Kinesiology Education of the Future” highlights that kinesiology as a substrate science and its applied areas are directed toward the future and toward lifelong engagement in physical activity (Findak, 2017).

This confirms that kinesiology education is not only a school subject or teacher-training area, but a key part of public health, lifelong learning and prevention of inactivity.

3.6. Kinesiology, health and modern society

The reviewed literature shows that the 21st-century role of kinesiology is increasingly connected with public health. Modern society is characterised by sedentary lifestyles, reduced movement, screen-based behaviour and increased risk of chronic disease. The Faculty of Kinesiology in Zagreb also emphasises research on physical activity and lifestyle as an important scientific priority, especially because lack of movement has negative effects on the human body.

Therefore, kinesiology is no longer focused only on sport performance. It is increasingly connected with prevention, rehabilitation, healthy ageing, quality of life and the promotion of regular physical activity.

3.7. Kinesiology as a 21st-century interdisciplinary science

The results suggest that kinesiology in the 21st century is moving toward a broader interdisciplinary model. It connects biological sciences, social sciences, psychology, pedagogy, medicine, rehabilitation, sport science and technology. Recent strategic documents of the Faculty of Kinesiology, University of Zagreb, also emphasise the understanding of human movement through fundamental principles of kinesiology, including gait analysis, movement patterns in everyday life and movement patterns in sport.

This confirms the paradigm shift from a narrow sport-educational model toward a modern scientific discipline that studies human movement in health, education, sport, recreation and rehabilitation.

3.8. Summary of main findings

Theme Main result

Definition of kinesiology Kinesiology is an empirical science of human movement and physical activity.

Terminology USA uses health, physical education and kinesiology; Europe uses sport and physical education.

Croatian contribution Croatian authors strongly shaped theoretical, educational and institutional kinesiology.

Structural shift Kinesiology developed from PE/sport toward an interdisciplinary scientific field.

Education Kinesiology education is connected with lifelong physical activity and health.

Health role Modern kinesiology addresses inactivity, chronic disease and quality of life.

21st-century paradigm Kinesiology integrates science, practice, technology and public health.

Overall, the reviewed literature shows that kinesiology has entered the 21st century as a broad, interdisciplinary and socially relevant science. Croatian authors and the journal Kinesiology have played an important role in defining this development, especially through the promotion of kinesiology as the most appropriate scientific term for the study of human movement.

4. Discussion

The findings of this review confirm that kinesiology in the 21st century is undergoing a profound transformation that can be described not only as a structural shift but also as a paradigm change in the scientific understanding of human movement. This transformation reflects the evolution of kinesiology from a fragmented and practice-oriented domain into a unified interdisciplinary science integrating biological, social, and behavioural perspectives (Čustonja et al., 2009; Sporiš et al., 2013).

One of the central issues identified in this review is the persistent lack of terminological consensus. Despite more than a century of development, kinesiology continues to be described using multiple overlapping terms such as physical education, sport science, exercise science, and human movement science (Newell, 1990; Corbin, 2014). While this diversity reflects the richness of the field, it also creates conceptual ambiguity and limits the establishment of a unified scientific identity (Mills, 1992; Wade & Baker, 1992). Croatian authors have been particularly active in addressing this issue, consistently advocating for kinesiology as the most comprehensive and scientifically appropriate term (Mraković, 1992; Milanović, 2013; Sporiš et al., 2013).

The theoretical contributions of Momirović remain highly relevant in this context. His conceptualisation of movement as a system of transformation processes provides a foundational framework for understanding motor behaviour and performance (Momirović, 1969; Momirović, 1971). This perspective aligns with modern approaches that view human movement as a dynamic and adaptive system influenced by multiple interacting variables (Davids et al., 2008; Newell, 1986). The integration of such theoretical models into contemporary kinesiology highlights the continuity between early theoretical work and modern scientific developments.

The structural evolution of kinesiology is another key aspect of the paradigm shift. Traditionally, the field was closely linked to physical education and sport training, with a primary focus on teaching and performance (Findak, 2001; Prskalo, 2004). However, the expansion of scientific knowledge has led to the development of specialised subdisciplines such as exercise physiology, biomechanics, motor control, sport psychology, and public health (Kenney et al., 2015; Bartlett, 2022). These subdisciplines have contributed to the scientific maturity of kinesiology, but they also pose a risk of fragmentation if not integrated within a coherent framework (Sporiš et al., 2013).

Croatian authors have emphasised the importance of maintaining this integrative perspective. Milanović highlights the need for a systematic approach that connects theory, research, and practical application, particularly in the context of sport training and performance (Milanović, 2013). Similarly, Findak and Prskalo stress the role of kinesiology in education and the development of lifelong physical activity habits, arguing that kinesiology must respond to the changing demands of modern society (Findak, 2001; Prskalo, 2004; Findak, 2017).

Another important dimension of the discussion concerns regional differences in the development of kinesiology. The dominance of the term sport in Europe reflects historical and socio-cultural influences, particularly the strong tradition of sport science in countries such as

Germany and Austria (Müller, 2008; Sporiš et al., 2013). In contrast, the United States has adopted a broader interdisciplinary model, with greater emphasis on health, wellness, and scientific research (Čustonja et al., 2009; American Kinesiology Association, 2021). This divergence highlights the complexity of the field and suggests that kinesiology is still evolving toward a global consensus.

Despite these differences, there is growing agreement that kinesiology represents the most comprehensive framework for understanding human movement. As an umbrella discipline, kinesiology integrates knowledge from multiple scientific domains, including physiology, psychology, sociology, and pedagogy (Bouchard et al., 2012; Kenney et al., 2015; Malina, 2017). This integrative approach is essential for addressing complex real-world problems related to physical activity, health, and performance.

The increasing relevance of kinesiology in modern society represents one of the most important outcomes of this paradigm shift. Sedentary lifestyles, technological dependence, and the rise of chronic diseases have created an urgent need for scientific approaches to physical activity and health promotion (WHO, 2020; Blair, 2012; Kohl et al., 2012). Kinesiology is uniquely positioned to address these challenges by providing evidence-based strategies for prevention, rehabilitation, and performance enhancement (Bompa & Buzzichelli, 2019; Warburton & Bredin, 2017).

In addition, the role of kinesiology is expanding beyond traditional domains to include areas such as ageing, quality of life, and mental health. Research has shown that physical activity has significant benefits not only for physical health but also for cognitive function and psychological well-being (Ratey & Loehr, 2011; Ekkekakis, 2013). This further reinforces the importance of kinesiology as a multidisciplinary science with broad societal impact.

The influence of technological advancements should also be considered. Modern kinesiology increasingly relies on advanced tools such as motion capture systems, wearable devices, and artificial intelligence for data analysis (Faigenbaum & Myer, 2020; Bartlett, 2022). These technologies enable more precise measurement and analysis of human movement, contributing to the development of evidence-based practices in sport, rehabilitation, and health promotion (Issurin, 2021). However, they also require new methodological approaches and interdisciplinary collaboration, which further emphasises the evolving nature of the field.

From a philosophical perspective, the paradigm shift in kinesiology reflects broader changes in scientific thinking. The transition from reductionist to holistic approaches is consistent with developments in the philosophy of science, particularly the ideas of Kuhn and Lakatos (Kuhn, 1962; Lakatos, 1970). Maguire argues that human movement should be studied as a complex social and biological phenomenon, rather than as a purely mechanical process (Maguire, 1991). This perspective aligns with contemporary approaches in kinesiology that emphasise complexity, adaptability, and interaction between systems (Davids et al., 2008).

Despite these advances, several challenges remain. The lack of standardised terminology continues to hinder communication and collaboration within the academic community (Čustonja et al., 2009). The fragmentation of subdisciplines may lead to a loss of coherence if not properly addressed (Sporiš et al., 2013). Furthermore, differences between educational systems and cultural contexts may slow down the process of global integration.

An additional challenge is the need to balance scientific research with practical application. While kinesiology has become increasingly scientific, it must also remain relevant to practitioners, including coaches, educators, and health professionals (Milanović, 2013; Bompa &

Buzzichelli, 2019). This requires the development of models that effectively translate scientific knowledge into practical solutions.

Overall, the extended analysis confirms that kinesiology is transitioning toward a mature scientific discipline characterised by interdisciplinarity, integration, and societal relevance. Croatian authors have played a crucial role in this development by providing strong theoretical foundations and promoting a unified scientific perspective. The continued evolution of kinesiology will depend on its ability to integrate diverse knowledge, standardise terminology, and address the complex challenges of modern society.

REFERENCES

1. American Kinesiology Association (2021). About kinesiology. Available at: https://www.americankinesiology.org
2. Bartlett, R. (2022). Introduction to Sports Biomechanics. London: Routledge.
3. Blair, S.N. (2012). Physical inactivity: the biggest public health problem of the 21st century. British Journal of Sports Medicine, 46(1), 1–2.
4. Bompa, T. & Buzzichelli, C. (2019). Periodization: Theory and Methodology of Training. Champaign: Human Kinetics.
5. Bouchard, C., Blair, S.N. & Haskell, W.L. (2012). Physical Activity and Health. Champaign: Human Kinetics.
6. Corbin, C.B. (2014). Concepts of Fitness and Wellness. New York: McGraw-Hill.
7. Čustonja, Z., Milanović, D. & Sporiš, G. (2009). Kinesiology in the names of higher education institutions in Europe and the United States of America. Kinesiology, 41(2), 136–146.
8. Davids, K., Button, C. & Bennett, S. (2008). Dynamics of Skill Acquisition. Champaign: Human Kinetics.
9. Ekkekakis, P. (2013). The Measurement of Affect, Mood, and Emotion. Cambridge: Cambridge University Press.
10. European College of Sport Science (ECSS) (2020). Position statements and scientific framework. Available at: https://www.ecss.eu
11. Faigenbaum, A.D. & Myer, G.D. (2020). Youth Physical Development. Champaign: Human Kinetics.
12. Findak, V. (2001). Metodika tjelesne i zdravstvene kulture. Zagreb: Školska knjiga.
13. Findak, V. (2017). Kinesiology education of the future. Kinesiology, 49(1), 1–9.
14. Haskell, W.L., Lee, I.M., Pate, R.R. et al. (2007). Physical activity and public health. Medicine & Science in Sports & Exercise, 39(8), 1423–1434.
15. Issurin, V. (2021). Training Theory: Scientific Foundations. London: Routledge.
16. Kenney, W.L., Wilmore, J.H. & Costill, D.L. (2015). Physiology of Sport and Exercise. Champaign: Human Kinetics.
17. Kohl, H.W., Craig, C.L., Lambert, E.V. et al. (2012). The pandemic of physical inactivity. The Lancet, 380(9838), 294–305.
18. Kuhn, T.S. (1962). The Structure of Scientific Revolutions. Chicago: University of Chicago Press.
19. Lakatos, I. (1970). Criticism and the Growth of Knowledge. Cambridge: Cambridge University Press.
20. Maguire, J. (1991). Human sciences and sport. International Review for the Sociology of Sport, 26(1), 65–86.

21. Malina, R.M. (2017). Growth, Maturation and Physical Activity. Champaign: Human Kinetics.
22. Milanović, D. (2013). Teorija treninga. Zagreb: Kineziološki fakultet.
23. Mills, J.P. (1992). The identity of kinesiology. Quest, 44(2), 141–148.
24. Momirović, K. (1969). Osnove teorije kretanja. Zagreb.
25. Momirović, K. (1971). Teorijski aspekti kineziologije. Zagreb.
26. Mraković, M. (1992). Kineziologija. Zagreb: Fakultet za fizičku kulturu.
27. Müller, E. (2008). Development of sport science in Europe. European Journal of Sport Science, 8(1), 1–10.
28. Newell, K.M. (1986). Constraints on the development of coordination. In: Wade, M.G. & Whiting, H.T.A. (eds.), Motor Development in Children. Dordrecht: Martinus Nijhoff.
29. Newell, K.M. (1990). Physical activity, knowledge types and degree programs. Quest, 42(3), 243–268.
30. Powers, S.K. & Howley, E.T. (2018). Exercise Physiology. New York: McGraw-Hill.
31. Prskalo, I. (2004). Kineziološka edukacija. Zagreb.
32. Ratey, J.J. & Loehr, J.E. (2011). The positive impact of physical activity. Harvard Business Review, 89(10), 62–70.
33. Renson, R. (2000). Kinesiology and its historical roots. Kinesiology, 32(1), 5–15.
34. Sporiš, G., Badrić, M., Prskalo, I. & Bonacin, D. (2013). Kinesiology – systematic review. Sport Science, 6(1), 7–23.
35. Thomas, J.R. & Nelson, J.K. (1990). Research Methods in Physical Activity. Champaign: Human Kinetics.
36. Wade, M.G. & Baker, J. (1992). Terminology in kinesiology. Quest, 44(2), 200–210.
37. Warburton, D.E.R. & Bredin, S.S.D. (2017). Health benefits of physical activity. Current Opinion in Cardiology, 32(5), 541–556.
38. World Health Organization (WHO) (2020). Guidelines on Physical Activity and Sedentary Behaviour. Geneva: WHO.

FULL PAPER 12

SCIENTIFIC PAPER

Biological Age as a Hidden Moderator in Youth Sport Talent Identification: Skeletal Age Profiles of Club-Selected Athletes in Split, Croatia

Dino Beloševića[1], Dražen Čular[1,2], Josefina Đuzel[1], Ana Kezić[1], Marijana Čavala[1]

[1] Faculty of Kinesiology, University of Split, Cro Sport Talent & Health and Longevity Lab, Split, Croatia; [2] European Institute for Talents, Education, Research & Development, Split, Croatia

INTRODUCTION

Talent identification in youth sport is one of the most consequential decisions in athlete development systems. Coaches evaluate athletes at critical developmental windows and select those perceived as most talented for further investment. However, during adolescence, considerable inter-individual variation in biological maturation means that athletes of the same chronological age may differ substantially in physical capacities. Those who mature earlier temporarily exhibit greater body size, strength, speed, and power — attributes that are often misinterpreted as indicators of athletic potential (Malina et al., 2015).

Skeletal age (SA) provides a direct, validated measure of biological maturity, capturing the developmental state of bone tissue rather than relying on somatic proxies. Compared to chronological age (CA), SA more accurately reflects an athlete's developmental status and has demonstrated acceptable agreement with radiographic gold standards in non-invasive ultrasound-based applications (Dvir et al., 2014; Parr et al., 2020). Despite methodological advances, the routine integration of skeletal age assessment into talent identification remains rare in practice.

The present study addresses this gap by examining SA versus CA profiles in a cohort of athletes independently selected by clubs as their most talented youth athletes. Split, Croatia — with over 100 Olympic medallists from a population of approximately 160,000 inhabitants — represents an intensified selection environment where performance pressure may amplify maturation-related bias, making it an ideal natural laboratory for this investigation (Cumming et al., 2018; Wattie et al., 2015).

The aim of this study was to describe the biological maturity profiles of club-selected youth athletes and to determine the extent to which selection favours biologically advanced individuals, with specific attention to sex-specific patterns of SA–CA displacement.

METHODS

Participants. N = 37 youth athletes (females n = 17, males n = 20; mean age 14.92 ± 1.81 years) were recruited from 21 sports clubs across 15 disciplines in Split, Croatia during the 2024–2025 competitive season. All investigations conformed to the Code of Ethics of the World Medical Association (Declaration of Helsinki). Institutional review board approval was granted by the Ethics Committee of the Faculty of Kinesiology, University of Split, and all participants and their legal guardians provided written informed consent prior to participation.

Design. This was a cross-sectional observational study conducted as part of the TWINSWINS project (Croatian Science Foundation, IP-2024-05-8340). Each participating sports club was invited to independently nominate one athlete considered most talented based on its own evaluation criteria. No standardised selection protocol was imposed on clubs, preserving the ecological validity of the real-world selection process. Inclusion criteria required athletes to be aged 10–18 years and actively competing in an organised youth competition structure.

Methodology. Skeletal age (SA) was assessed using the BAUSport™ SonicBone system (SonicBone Medical Ltd., Israel) — a non-invasive, radiation-free ultrasound-based device that estimates biological maturity through acoustic properties of bone tissue. Measurements were performed at three anatomical locations on the left hand-wrist region: wrist (radius/ulna), proximal phalanx, and metacarpal. The device has demonstrated acceptable agreement with radiographic standards (Dvir et al., 2014) and high intra- and inter-rater reliability in youth populations (Parr et al., 2020). All measurements were performed under standardised laboratory conditions by a single trained and experienced operator following a strictly controlled protocol. Body height was measured to the nearest 0.1 cm using a calibrated stadiometer, and body mass to the nearest 0.1 kg using a digital scale. Maturity status was classified based on the SA − CA difference: early maturers (> +1.00 year), on-time maturers (±1.00 year), and late maturers (< −1.00 year), in accordance with established methodology (Malina et al., 2015; Cumming et al., 2018).

Statistical Analysis. Descriptive statistics are reported as mean ± standard deviation (SD). Sex differences in anthropometric and maturation variables were evaluated using Cohen's d and Hedges' g (bias-corrected for small samples), with conventional thresholds applied (trivial: d < 0.20; small: 0.20–0.49; medium: 0.50–0.79; large: ≥ 0.80). The relationship between SA and CA was examined graphically by plotting individual data points against the identity line (SA = CA), separately for females and males. Sex-specific linear regression lines were fitted to quantify the SA–CA association (R^2). All analyses were conducted using Python (version 3.11; SciPy 1.11, statsmodels 0.14). Statistical significance was set at $\alpha = 0.05$.

RESULTS

Descriptive characteristics of the sample are presented in Table 1. Mean skeletal age exceeded chronological age by +0.77 ± 0.89 years across the full sample, indicating a systematic overrepresentation of biologically advanced athletes among those selected. The pattern was consistent across both sexes (females: +0.66 ± 1.00 years; males: +0.85 ± 0.80 years), with a small sex difference in the SA − CA offset (Cohen's d = −0.21, Hedges' g = −0.21). Large sex differences were observed in body height (d = −0.84; g = −0.82) and medium differences in body mass (d = −0.55; g = −0.54), consistent with expected adolescent anthropometric patterns. The sex difference in skeletal age was trivial (d = −0.03).

Table 1. Descriptive Characteristics of the Study Sample by Sex (Mean ± SD)

Variable	Total (N = 37)	Females (n = 17)	Males (n = 20)
Chronological age (years)	14.92 ± 1.81	14.99 ± 1.79	14.85 ± 1.88
Skeletal age – SA Final (years)	15.68 ± 1.75	15.66 ± 1.62	15.71 ± 1.90
SA − CA offset (years)	+0.77 ± 0.89	+0.66 ± 1.00	+0.85 ± 0.80
Height (cm)	172.7 ± 12.4	167.5 ± 8.0	177.2 ± 13.8
Body mass (kg)	61.2 ± 13.2	57.4 ± 9.5	64.4 ± 15.2

Note. SA = skeletal age assessed via BAUSport™ SonicBone; CA = chronological age; SA − CA = maturation offset. Effect size conventions: trivial < 0.20; small 0.20–0.49; medium 0.50–0.79; large ≥ 0.80. Hedges' g is bias-corrected for small samples. N = 37 (complete dataset).

The distribution of maturation categories is presented in Table 2. Early maturers constituted 29.7% of the total cohort, on-time maturers 67.6%, and late maturers only 2.7% (a single female athlete). No late-maturing males were selected across any of the 21 participating clubs. Sex-specific scatter plot analyses confirmed that 88.2% of females (15/17) and 90.0% of males (18/20) were positioned above the SA = CA identity line. Sex-specific linear regression analyses revealed moderate-to-strong SA–CA associations: females (SA = 0.75 × CA + 4.40, R^2 = 0.692) and males (SA = 0.92 × CA + 2.01, R^2 = 0.829). Both regression lines were positioned above the identity line throughout the observed age range, confirming a systematic maturation-related selection bias in both sexes.

Table 2. Maturation Status Distribution Across the Sample (N = 37)

Maturation status	Total n	Total %	Females n	Females %	Males n (%)
Early (SA − CA > +1.00 year)	11	29.7%	5	29.4%	6 (30.0%)
On-Time (SA − CA ± 1.00 year)	25	67.6%	11	64.7%	14 (70.0%)
Late (SA − CA < −1.00 year)	1	2.7%	1	5.9%	0 (0.0%)

Note. Classification based on the difference between SA Final and chronological age (SA − CA): Early > +1.00 year; On-Time ±1.00 year; Late < −1.00 year.

DISCUSSION

The data clearly demonstrate that club-based talent selection in this high-performance environment systematically favours biologically advanced athletes. A mean SA − CA offset of +0.77 years and near-complete exclusion of late maturers (2.7%) indicate that coaches — likely unknowingly — select athletes whose physical characteristics reflect maturational timing rather than underlying athletic potential. This finding aligns with established evidence documenting the confounding role of biological maturation in youth sport selection (Malina et al., 2015; Cumming et al., 2018).

The near-complete absence of late-maturing males from the selected cohort is particularly noteworthy. Late maturers may possess substantial developmental potential that remains untapped due to their temporary physical disadvantage at the moment of evaluation. The regression analyses revealed an important sex-specific pattern: the female regression line (slope = 0.75) shows a more pronounced SA − CA offset at younger chronological ages, converging toward the identity line at older ages, whereas the male regression tracks the identity line more closely and consistently (slope = 0.92). This suggests that the mechanism of maturation-related selection bias may differ in its developmental expression across sexes.

The practical implications of these findings are direct. Without objective biological age data, coaches have no reliable mechanism to distinguish performance rooted in maturity from performance rooted in talent. The BAUSport™ SonicBone system represents a practical solution: it is portable, radiation-free, and can be integrated into existing talent identification workflows without substantial additional burden (Dvir et al., 2014). Incorporating SA as a contextual modifier — not an exclusion criterion — would allow coaches to interpret current performance relative to developmental stage, thereby supporting more equitable athlete pathways (Cumming et al., 2018).

A critical limitation of this study is the absence of a non-selected comparison group, which prevents direct inference about the magnitude of bias relative to the broader youth athlete population. The cross-sectional design precludes assessment of whether observed maturation-related selection bias translates into differential long-term developmental outcomes. Future research should prospectively follow selected and non-selected athletes and examine career trajectories in relation to maturity status at the time of selection.

CONCLUSIONS

In a high-performance youth sport environment, club-based talent identification is systematically aligned with biological advancement rather than long-term athletic potential. The overrepresentation of early and on-time maturers (97.3% combined) and the near-complete exclusion of late maturers, consistent across both sexes, point to a structural selection bias that operates largely invisibly without objective biological age data. Integrating non-invasive skeletal age assessment into talent identification protocols is a feasible, evidence-informed step toward identifying talent more equitably and developing athletes more effectively.

GENERATIVE AI STATEMENT

Generative artificial intelligence (AI) was used during the preparation of this manuscript to assist with English language editing, grammatical refinement, and structural organisation. Specifically, Claude (Anthropic) was used for text editing and formatting. All AI-generated suggestions were critically reviewed, verified, and edited by the authors, who bear full responsibility for the intellectual content, scientific accuracy, and integrity of the manuscript. The AI did not contribute original ideas, data interpretation, or scientific conclusions. This disclosure is in line with emerging editorial standards for AI use in scientific publishing (Čular et al., 2026).

FUNDING

Funding: This research was supported by the Croatian Science Foundation under Project Grants No. IP-2024-05-8340 & IP-2025-02-8546 and by the Faculty of Kinesiology, University of Split, Institutional Project Grant “Health, Longevity & Sport (IP-UNIST-24, HeLoS).” All grants contributed to different aspects of the study in compliance with the funding regulations.

REFERENCES

1. Cumming, S. P., Lloyd, R. S., Oliver, J. L., Eisenmann, J. C., & Malina, R. M. (2018). Bio-banding in sport: Applications to competition, talent identification, and strength and conditioning of youth athletes. Strength & Conditioning Journal, 40(3), 34–47. https://doi.org/10.1519/SSC.0000000000000344
2. Čular, D., Babić, M., Jelaska, G., Jelaska, I., & Belošević, D. (2026). Key technical-tactical structures and anthropometric predictors of success in elite K1 kickboxing: A logistic regression-based model. Frontiers in Sports and Active Living, 8, 1786929. https://doi.org/10.3389/fspor.2026.1786929
3. Dvir, Z., Penner, M., Peretz, C., & Shahar, S. (2014). Prediction of skeletal maturity using the SonicBone ultrasound device. Journal of Clinical Densitometry, 17(4), 475–481. https://doi.org/10.1016/j.jocd.2013.11.003
4. Malina, R. M., Cumming, S. P., Coelho e Silva, M. J., Figueiredo, A. J., Konarski, J. M., & Kowalski, K. L. (2015). Biological maturation assessments in youth sport. Exercise and Sport Sciences Reviews, 43(4), 225–233. https://doi.org/10.1249/JES.0000000000000045
5. Parr, J., Winwood, K., Hodson-Tole, E., Deconinck, F. J. A., Parry, L., Hill, J. P., Malina, R. M., & Cumming, S. P. (2020). Predicting the timing of the peak of the pubertal growth spurt

in elite male youth soccer players: Evaluation of methods. Annals of Human Biology, 47 (4), 400–408. https://doi.org/10.1080/03014460.2020.1782968

6. Wattie, N., Schorer, J., & Baker, J. (2015). The relative age effect in sport: A developmental systems model. Sports Medicine, 45(1), 83–94. https://doi.org/10.1007/s40279-014-0248-9

FULL PAPER 13

SCIENTIFIC PAPER

The influence of situational parameters on success in the 2021/2022. Premier league season

Hrvoje Ajman, Ivica Franjko, Antonio Božičević

Faculty of Kinesiology, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia

Introduction

The English Premier League (EPL) stands as one of the most prestigious sports competitions globally and currently maintains its position as one of the top-ranked football leagues in Europe according to the UEFA coefficients. In recent years, the competition has undergone significant tactical and physical evolution, characterized by an increase in total passes, passing tempo, accuracy, and high-intensity running. This evolutionary shift appears to be primarily driven by elite-level clubs that favor a possession-based style of play, in contrast to lower-ranked clubs that continue to employ more direct playing styles (González-Rodenas et al., 2020). The league comprises 20 clubs operating on a double round-robin system, where each team faces every opponent twice per season—once at home and once away—resulting in a total of 38 matches per club. Situational parameters in football represent vital game elements that fluctuate continuously during a match, rendering football a dynamic and unpredictable sport. The present study aims to provide a detailed examination of key situational parameters, whose correlation with technical precision forms the fundamental basis for understanding modern football dynamics. The primary objective of this research is to determine the correlation between situational precision parameters and the final league standings in the English Premier League during the 2021/2022. season.

Methods

The research sample included all 20 football clubs that participated in the English Premier League during the 2021/2022 season. A total of 380 matches were analyzed to extract cumulative seasonal data for each team. The situational parameters (variables) were divided into two main categories: Efficiency parameters: Goals, Total shots, Shots on target, Percentage of efficiency (Goals/Shots on goal) and Precision Parameters: Accurate passes (total), Accurate passes in own half, Accurate passes in opponent's half, Accurate long balls, Accurate crosses, and Successful dribbles.

Data were collected through the Sofascore analytical platform, which provides detailed match statistics powered by Opta. For each club, the values were calculated as season averages or cumulative totals per game to ensure comparability. The final league table (ranking) was used as the criterion variable for success.

Data processing was performed using the Statistica 10.0 software package. Descriptive statistics (Mean, Standard Deviation, Minimum, and Maximum) were calculated for all parameters. To determine the correlation between situational parameters and final league standings, the Spearman's rank correlation coefficient was applied, as the league rank is an ordinal variable. Additionally, the Mann-Whitney U test was used to determine differences between the top-ranked (1st–10th place) and bottom-ranked (11th–20th place) teams. The significance level was set at 0.05

Results

Table 1. presents the descriptive statistical parameters for all Premier League clubs during the 2021/2022 season. Analysis of the data provides a comprehensive overview of the league's performance dynamics. Notably, the maximum value for goals (P) reached 99. The mean value for shots hitting the woodwork (POV) was 12.05 (SD = 4.49), suggesting that teams in this league frequently created high-quality scoring opportunities that narrowly missed.

Furthermore, the high percentage in penalty goals (PKU) indicates a high level of proficiency among penalty takers across the league.

Table 1. Descriptive statistics of Premier League clubs (2021/2022 season).

	N	M	SD	Med.	Min.	Max.
Goals (P)	20	53.55	19.45	49.00	23.00	99.00
Total Shots (UUU)	20	12.83	2.59	12.00	9.80	19.20
Shots on Target (UUOU)	20	4.42	1.04	4.10	2.90	6.70
Woodwork Hit (POV)	20	12.05	4.49	11.00	6.00	24.00
Efficiency (U)	20	0.11	0.02	0.11	0.06	0.14
Penalty Goals (PKU)	20	0.83	0.19	0.89	0.50	1.00
Free Kick Goals (PSU)	20	0.06	0.07	0.06	0.00	0.27
Goals Inside Box (PUKP)	20	0.14	0.03	0.14	0.09	0.20
Goals Outside Box (PIKP)	20	0.04	0.02	0.04	0.00	0.07
Accurate Passes % (TDU)	20	0.80	0.05	0.81	0.69	0.90
Acc. Passes Own Half (TDS)	20	0.88	0.03	0.88	0.82	0.93
Acc. Passes Opp. Half (TDSP)	20	0.69	0.07	0.69	0.58	0.84
Acc. Long Balls (TDL)	20	0.47	0.06	0.45	0.40	0.64
Acc. Crosses (TUKP)	20	0.23	0.02	0.23	0.18	0.26

M = Mean; SD = Standard Deviation; Med. = Median; Min. = Minimum; Max. = Maximum

Table 2. displays the correlation between the analyzed variables and the final league standings. Significant correlations were found across the majority of variables, suggesting that the selected situational parameters are robust predictors of success in the Premier League. These findings provide valuable insights for coaches and performance analysts regarding the technical aspects that most influence competitive outcomes.

Table 2. Results of Spearman's rank correlation test

Variable Pairs	n	p-value
Rank & Goals	20	0.01
Rank & Total Shots per Game	20	0.01
Rank & Shots on Target per Game	20	0.01
Rank & Woodwork Hit	20	0.14
Rank & Efficiency	20	0.01
Rank & Penalty Goals	20	0.74

Rank & Free Kick Goals	20	0.67
Rank & Goals Inside Box	20	0.01
Rank & Goals Outside Box	20	0.01
Rank & Total Passing Accuracy	20	0.01
Rank & Acc. Passes Own Half	20	0.01
Rank & Acc. Passes Opponent's Half	20	0.01
Rank & Accurate Long Balls	20	0.01
Rank & Accurate Crosses	20	0.98

Table 3. shows the differences between the top 10 and bottom 10 teams. Variables that did not show a statistically significant difference included: Woodwork hits, Penalty goals, Free kick goals, and Accurate crosses. These results imply that while these factors occur in the game, they were not the primary discriminators between the successful and less successful teams during the 2021/2022 season.

Table 3. Mann-Whitney U test results (Top 10 vs. Bottom 10 teams)

Variables	U	n	p-value (2*1sided)
Total Shots per Game	17.50	10	0.01
Shots on Target per Game	14.50	10	0.01
Woodwork Hit	29.50	10	0.12
Efficiency	19.00	10	0.02
Penalty Goals	40.00	10	0.48
Free Kick Goals	48.50	10	0.91
Goals Inside Box	20.50	10	0.02
Goals Outside Box	22.00	10	0.04
Total Passing Accuracy	0.00	10	0.01
Acc. Passes Own Half	6.50	10	0.01
Acc. Passes Opponent's Half	0.00	10	0.01
Accurate Long Balls	5.00	10	0.01
Accurate Crosses	45.00	10	0.74

Discussion

The descriptive statistical analysis of the 2021/22 Premier League season presented in Table 1. highlights the high offensive standards of the league, with a mean of 53.55 goals per team. A particularly interesting finding is the mean of 12.05 for woodwork hits, which suggests that offensive efficiency could have been even higher. The high proficiency in penalty goals (mean = 0.83) underscores the technical specialization of elite players in set-piece situations, a trend

noted by previous research emphasizing the increasing impact of set-pieces on match outcomes in modern football.
The Spearman's rank correlation results (Table 2) confirm that technical precision is the primary determinant of success in the EPL. Strong significant correlations were observed between league ranking and variables such as Total Passing Accuracy and Accurate Passes in the Opponent's Half. These findings align with the study by González-Rodenas et al. (2020), who reported that top-tier teams in the Premier League have shifted toward a possession-based style characterized by high-volume and high-precision passing. Our data reinforces the idea that the ability to maintain possession under pressure in the final third is what separates successful teams from the rest. Furthermore, the significant correlation between Shots on Target and final rank supports the conclusions of Boscá et al. (2009), who identified offensive efficiency as a more stable predictor of seasonal success than defensive volume.
The Mann-Whitney U test (Table 3) further clarifies the performance gap between the top 10 and bottom 10 teams. The most striking finding is the for Total Passing Accuracy and Accurate Passes in the Opponent's Half, indicating a complete separation in technical quality between the two groups. Precise passing allows teams to maintain possession and control the rhythm of the game, which is recognized as a key performance indicator in elite European football (Fiorilli et al., 2020). This is consistent with research by Lago-Peñas et al. (2010), who found that higher-ranked teams perform significantly more successful passes in the attacking zone. Conversely, the lack of significant differences in Woodwork Hits, Penalty Goals, and Accurate Crosses suggests that these parameters are more subject to situational luck or individual brilliance rather than systemic tactical superiority. Specifically, the non-significance of Accurate Crosses reflects the modern tactical shift away from traditional wing-play toward structured central breakthroughs, a transition also noted in recent longitudinal analyses of elite European football. This suggests that while crosses are frequent, they are no longer the primary differentiator of competitive excellence in the Premier League.

Conclusions

The findings of this study demonstrate a significant correlation between situational precision parameters and competitive success in the English Premier League during the 2021/22 season. Based on the statistical analysis, the research hypotheses were partially accepted, confirming that technical precision is a fundamental determinant of league ranking.
Key results indicate that elite teams (top 10) significantly outperform lower-ranked teams in nearly all metrics related to ball distribution and shooting efficiency. Specifically, variables such as accurate passes in the opponent's half, total passing accuracy, and shots on target were identified as the strongest predictors of final league standing. The absence of significant differences in variables like crosses and penalty goals further suggests that modern football success is increasingly driven by structured possession and efficiency in open play rather than incidental or traditional wing-play situations.
In conclusion, precision is not merely a technical skill but a multifaceted component involving psychological composure and tactical discipline. For coaches and sports analysts, these results emphasize the necessity of systematic training focused on increasing passing accuracy under pressure and clinical finishing. Future investments in player development should prioritize these situational parameters to enhance overall team performance and secure better competitive outcomes in elite football.

References

1. Boscá, J. E., Liern, V., Martínez, A., & Sala, R. (2009). Increasing offensive or defensive efficiency? An analysis of Italian and Spanish football. Omega, 37(1), 63–78. doi.org
2. Fiorilli, G., Mitrotasios, M., Ciccotelli, S., Di Costanzo, A., Iuliano, E., Aquino, G., Calcagno, G., & di Cagno, A. (2020). Long-term tactical analysis of European football tournaments: the relative importance of possession of the ball and home advantage. Sports, 8(8), 111. doi.org

3. González-Rodenas, J., Aranda-Malaves, R., Tudela-Desantes, A., Nieto, F., Usó, F., & Aranda, R. (2020). Playing tactics, contextual variables and offensive effectiveness in English Premier League soccer matches. A multilevel analysis. PLOS ONE, 15(2), e0226978. doi.org
4. Lago-Peñas, C., Lago-Ballesteros, J., Dellal, A., & Gómez, M. (2010). Game-related statistics that discriminated winning, drawing and losing teams from the Spanish soccer league. Journal of Sports Science & Medicine, 9(3), 483–488.
5. Sofascore. (2022). Premier League 21/22 seasonal statistics.

FULL PAPER 14

SCIENTIFIC PAPER

Notational analysis in football: a review paper

Goran Sporiš; Robert Citozi; Davor Lješević; Ivan Đuroci Ivana Grle; Maki Grle; Jerko Prlić; Dejan Tiric; Vedran Režić; Jose Antonio Perez Turpin; Davor Bučević; Sandra Kerim; Adem Preljević

University of Zagreb, Faculty of Kinesiology, Zagreb, Croatia

1. Introduction

Football is a complex, dynamic, and multifactorial sport in which performance emerges from the interaction of technical, tactical, physical, and psychological components within a continuously changing environment. Due to the stochastic nature of match play, the objective evaluation of performance has become a central focus in contemporary sports science. In this context, notational analysis has developed as one of the most widely used methodological approaches for systematically observing, recording, and quantifying match events (Sarmento et al., 2020; Rein and Memmert, 2021; Liu et al., 2022).

Notational analysis refers to the structured process of collecting and coding performance-related actions during matches or training sessions, allowing qualitative aspects of play to be transformed into quantifiable data (Bradley et al., 2020; Mackenzie and Cushion, 2021). This approach enables researchers and practitioners to identify patterns of play, evaluate performance indicators, and establish relationships between match variables and successful outcomes. Over the past decade, the importance of notational analysis in football has increased significantly due to the growing demand for objective, data-driven decision-making in elite sport (Goes et al., 2021; Fernández-Navarro et al., 2020).

Recent research has emphasized the role of key performance indicators (KPIs) derived from notational data, such as passing accuracy, ball possession, shooting efficiency, and defensive actions, in determining match success (Yang et al., 2021; Zhou et al., 2022). These variables provide insight into both individual and team performance, allowing for the evaluation of tactical effectiveness and efficiency. Moreover, notational analysis has been used to identify successful tactical behaviors, including ball circulation patterns, pressing intensity, and transition dynamics (Memmert et al., 2020; Clemente et al., 2021).

The integration of advanced technologies has further expanded the scope of notational analysis. Modern performance analysis systems combine traditional event coding with tracking data, enabling the examination of spatial-temporal dynamics and player interactions (Link and Hoernig, 2020; Pappalardo et al., 2021). This has led to the emergence of more sophisticated analytical approaches, including network analysis, positional data modeling, and machine learning techniques (Bialkowski et al., 2020; Decroos et al., 2021; Gudmundsson and Horton, 2021). These methods provide deeper insight into team organization and collective behavior, which cannot be captured through isolated variables alone.

In addition to technical and tactical evaluation, notational analysis has also been applied to understand contextual influences on performance. Factors such as match location, quality of opposition, match status, and competition level have been shown to significantly affect performance indicators and tactical decisions (Lago-Peñas et al., 2021; Castellano et al., 2022; Almeida et al., 2023). This highlights the importance of interpreting notational data within the broader context of the game, rather than relying solely on raw statistics.

Furthermore, recent studies have focused on the relationship between notational variables and physical performance, emphasizing the need to integrate event-based data with physiological and biomechanical measures (Dalen et al., 2020; Riboli et al., 2021; Oliva-Lozano et al., 2022). This integrated approach allows for a more comprehensive understanding of match demands and player performance.

Despite its widespread use, notational analysis is not without limitations. One of the main challenges is the selection and definition of relevant variables, as well as ensuring the reliability and validity of data collection (Mackenzie and Cushion, 2021; Sarmento et al., 2020). Additionally, the complexity of football performance means that isolated metrics may not fully capture the multidimensional nature of the game. Therefore, there is a growing emphasis on combining notational analysis with advanced analytical techniques and theoretical frameworks to improve interpretation and applicability (Rein and Memmert, 2021; Gudmundsson and Horton, 2021).

In recent years, the increasing availability of large datasets and computational tools has transformed notational analysis into a key component of performance analytics in football. Clubs, analysts, and researchers now rely heavily on data-driven insights to support tactical planning, player recruitment, and performance optimization (Decroos et al., 2021; Pappalardo et al., 2021). This evolution reflects a broader shift toward evidence-based practice in sport science.

Given these developments, notational analysis has become an essential tool for understanding football performance. However, continuous methodological refinement and integration with other domains remain necessary to fully exploit its potential. Therefore, the purpose of this review is to provide a comprehensive overview of notational analysis in football, focusing on its methodological foundations, key variables, technological advancements, and practical applications in modern football performance analysis.

2. Methods

This review was designed as a structured narrative review based on principles commonly applied in systematic reviews in football performance analysis. The methodological approach was developed according to the logic of the PRISMA framework, with the aim of ensuring transparency in literature identification, screening, eligibility assessment, and synthesis of findings.

A literature search was conducted in major scientific databases, with primary emphasis on Web of Science Core Collection, due to the requirement to include high-quality indexed scientific publications. Additional searches were performed in Scopus, PubMed and SPORTDiscus in order to identify relevant studies that may also be indexed in WoS or frequently cited in football performance analysis research. Similar database combinations have been used in recent systematic reviews on football performance analysis and tactical analysis.

The search strategy included combinations of the following keywords: “notational analysis”, “football”, “soccer”, “match analysis”, “performance analysis”, “technical performance”, “tactical analysis”, “performance indicators”, “key performance indicators”, “match performance”, “observational analysis”, “team performance”, “possession”, “passing”, “shooting”, “defensive actions”, “spatio-temporal analysis”. Boolean operators were applied as follows:

(“notational analysis” OR “match analysis” OR “performance analysis” OR “observational analysis”) AND (“football” OR “soccer”) AND (“performance indicators” OR “technical performance” OR “tactical analysis” OR “match performance”).

The search was limited to studies published in the last five years, in order to provide a contemporary overview of notational analysis in modern football. Only peer-reviewed scientific articles written in English were considered. Priority was given to studies published in journals

indexed in the Web of Science database, especially journals from the fields of sport science, performance analysis, biomechanics, coaching science and applied sport research.

Studies were included if they met the following criteria: they investigated football/soccer performance through notational, observational or match analysis methods; they analysed technical, tactical or contextual match indicators; they included football players, teams or match data as the primary sample; they reported clear methodological procedures for data collection or coding; and they were published in peer-reviewed journals within the selected time frame.

Studies were excluded if they focused on sports other than football, did not include match or performance indicators, were not related to notational or observational analysis, were conference abstracts, editorials, opinion papers, theses or non-scientific sources, or if full-text access was not available. Duplicate publications were removed before screening.

The selection process consisted of three stages. First, titles and abstracts were screened to determine general relevance to notational analysis in football. Second, potentially relevant full-text articles were assessed according to the inclusion and exclusion criteria. Third, the final studies were categorized according to their main analytical focus: technical indicators, tactical indicators, contextual variables, spatial-temporal variables, player/team performance indicators and methodological approaches.

Data were extracted using a structured extraction form. The following information was recorded from each study: author and year of publication, aim of the study, sample characteristics, competition level, number of matches or observations, type of analysis, performance indicators used, data collection method, reliability procedures and main findings. Particular attention was given to variables commonly used in notational analysis, including ball possession, passing accuracy, shots, shots on target, goals, interceptions, tackles, set plays, transitions, playing formation and match location.

The methodological quality of the included studies was evaluated qualitatively by examining the clarity of study design, definition of variables, reliability of coding procedures, appropriateness of statistical analysis and relevance of performance indicators. Studies that reported inter-observer or intra-observer reliability were considered methodologically stronger, as reliability is essential in observational and notational analysis research.

Due to expected heterogeneity in study design, sample size, competition level, variables and statistical procedures, a meta-analysis was not conducted. Instead, the results were synthesized narratively. The synthesis focused on identifying common trends, methodological patterns and practical implications of notational analysis in football. This approach is appropriate because football performance is multidimensional and influenced by technical, tactical and contextual factors that are difficult to compare through a single quantitative model.

Overall, this methodological approach allowed for a structured and transparent overview of recent scientific evidence on notational analysis in football, with emphasis on contemporary WoS-indexed research and its relevance for coaching practice, tactical evaluation and performance optimization.

3. Results

The literature included in this review demonstrates that notational analysis is a central tool in contemporary football performance analysis, allowing for the identification and interpretation of technical, tactical, and contextual performance indicators. The findings across studies show consistent patterns in how performance variables relate to match outcomes, team success, and playing styles.

One of the most consistently reported findings is the importance of technical performance indicators, particularly passing accuracy, ball possession, and shooting efficiency. Successful

teams tend to demonstrate higher passing accuracy and more effective ball circulation, which enables control of the game and creation of scoring opportunities. However, possession alone is not always a determinant of success; rather, the efficiency of possession, especially in the final third, appears to be more relevant. Studies indicate that teams with higher shot conversion rates and greater number of shots on target are more likely to achieve positive match outcomes.

Defensive actions also play a significant role in performance analysis. Variables such as interceptions, tackles, and defensive duels are frequently associated with successful performance, particularly in teams employing high pressing strategies. Notational data reveal that teams that recover possession quickly and disrupt opponent build-up play tend to create more scoring opportunities. In addition, successful teams often exhibit better defensive organization, reflected in lower numbers of conceded shots and goals.

Tactical indicators derived from notational analysis provide deeper insight into team behavior. These include patterns of play, attacking strategies, defensive structures, and transitions between phases of the game. Research shows that successful teams often demonstrate structured positional play, effective use of space, and coordinated team movements. Notational analysis also highlights the importance of transition phases, particularly offensive transitions, where quick ball recovery followed by rapid attack can lead to goal-scoring opportunities.

Spatial and temporal analysis has become increasingly prominent in recent studies. By combining notational data with tracking technologies, researchers are able to analyze player positioning, team compactness, and movement patterns. Findings suggest that successful teams maintain optimal spatial organization, including balanced width and depth, which facilitates both offensive and defensive efficiency. Temporal variables, such as duration of possession and speed of attacking sequences, are also important, with faster and more direct attacks often being associated with higher effectiveness in certain contexts.

Contextual variables significantly influence match performance and must be considered when interpreting notational data. Factors such as match location, opponent quality, match status, and competition level have been shown to affect both technical and tactical behavior. For example, teams playing at home tend to have higher ball possession and more attacking actions, while teams facing stronger opponents may adopt more defensive strategies. Match status also influences behavior, as teams that are leading often reduce risk and focus on maintaining possession, whereas trailing teams increase offensive efforts.

Methodological findings across the reviewed studies indicate variability in data collection approaches, including manual coding, video analysis software, and automated tracking systems. Studies using advanced tracking technologies provide more detailed spatial-temporal data, while traditional notational analysis remains valuable for capturing discrete events such as passes, shots, and defensive actions. Reliability of data collection is identified as a critical factor, with studies reporting inter- and intra-observer reliability demonstrating higher methodological quality.

Overall, the results highlight that notational analysis provides a comprehensive framework for understanding football performance. The integration of technical, tactical, spatial, and contextual variables allows for a multidimensional evaluation of the game. However, the findings also emphasize that performance cannot be explained by single variables in isolation, and that the interaction between different performance indicators is essential for understanding match outcomes.

4. Discussion

The present review aimed to provide a comprehensive overview of notational analysis in football, emphasizing its methodological evolution, key performance indicators, and practical application in modern performance analysis. The findings from recent literature consistently demonstrate that notational analysis has become a fundamental component of contemporary

football science, supporting both research and applied practice through objective quantification of match events.

One of the central findings across the reviewed studies is the importance of technical performance indicators, particularly passing accuracy, ball possession, and shooting efficiency, in determining match success (Sarmento et al., 2020; Yang et al., 2021; Zhou et al., 2022; Clemente et al., 2021). However, recent research suggests that traditional indicators such as possession percentage should not be interpreted in isolation, as their relationship with success is highly dependent on contextual and tactical factors (Lago-Peñas et al., 2021; Castellano et al., 2022). For example, teams with lower possession can still achieve success through efficient transitions and counter-attacking strategies, indicating that the quality of possession is more relevant than quantity (Fernández-Navarro et al., 2020; Goes et al., 2021).

The role of tactical behavior has become increasingly prominent in notational analysis research. Studies focusing on team organization, spatial occupation, and collective behavior highlight the importance of coordinated movement patterns and positional play in achieving success (Memmert et al., 2020; Rein and Memmert, 2021; Link and Hoernig, 2020). Advanced analytical approaches, including network analysis and positional data modeling, have revealed that successful teams exhibit more structured passing networks and higher levels of team cohesion (Pappalardo et al., 2021; Decroos et al., 2021). These findings support the idea that football performance is an emergent property of collective interactions rather than individual actions.

Technological advancements have significantly influenced the development of notational analysis. The integration of tracking systems, video analysis, and machine learning techniques has enabled the analysis of large datasets and complex performance patterns (Gudmundsson and Horton, 2021; Bialkowski et al., 2020). This has led to a shift from descriptive statistics toward predictive and explanatory models, allowing researchers to identify performance trends and optimize decision-making processes. However, despite these advancements, the interpretation of complex datasets remains a challenge, particularly in distinguishing causation from correlation.

Another important aspect highlighted in recent research is the influence of contextual variables on match performance. Factors such as match location, opponent quality, match status, and competition level significantly affect technical and tactical behavior (Lago-Peñas et al., 2021; Almeida et al., 2023; Riboli et al., 2021). For example, home teams tend to demonstrate more offensive behavior, while teams facing stronger opponents often adopt more defensive strategies. These findings emphasize the need to interpret notational data within the broader context of the game, rather than relying solely on raw performance indicators.

The integration of notational analysis with physical and physiological data has also emerged as a key research direction. Studies combining event data with tracking metrics have shown that technical and tactical actions are closely linked to physical demands, such as distance covered, sprint frequency, and acceleration patterns (Dalen et al., 2020; Oliva-Lozano et al., 2022). This multidimensional approach provides a more comprehensive understanding of match performance and allows for better alignment between tactical strategies and physical capabilities.

Despite its strengths, notational analysis has several methodological limitations. One of the main challenges is the selection and definition of performance indicators, as different studies often use varying operational definitions, making comparisons difficult (Mackenzie and Cushion, 2021; Sarmento et al., 2020). Additionally, the reliability of data collection remains a critical issue, particularly in studies relying on manual coding. Although many studies report inter- and intra-observer reliability, variability in coding procedures can still affect data accuracy.

Furthermore, the reduction of complex game situations into discrete variables may lead to oversimplification of performance. Football is a dynamic and interactive sport in which

outcomes are influenced by multiple interconnected factors. Therefore, relying solely on isolated indicators may not fully capture the complexity of the game. Recent research advocates for more holistic approaches that combine notational data with positional, contextual, and cognitive variables (Rein and Memmert, 2021; Gudmundsson and Horton, 2021).

From a practical perspective, notational analysis provides valuable insights for coaching and performance optimization. Coaches can use notational data to evaluate team performance, identify strengths and weaknesses, and design targeted training interventions. Additionally, performance analysis supports tactical decision-making, player development, and match preparation. The increasing use of data analytics in professional football reflects the growing importance of evidence-based practice in sport (Decroos et al., 2021; Pappalardo et al., 2021).

Future research should focus on further integration of notational analysis with emerging technologies and interdisciplinary approaches. The use of artificial intelligence, machine learning, and big data analytics has the potential to enhance the predictive capabilities of performance analysis and provide deeper insights into game dynamics. Moreover, longitudinal studies are needed to examine the long-term impact of tactical and technical variables on performance and player development.

In conclusion, notational analysis represents a powerful and evolving tool in football performance analysis. While traditional performance indicators remain relevant, recent advancements highlight the importance of contextual, tactical, and multidimensional approaches. The continued development of analytical methods and technologies will further enhance the ability to understand and optimize football performance.

REFERENCES

1. Almeida, C.H., Ferreira, A.P. and Volossovitch, A. (2023) ‘Effects of match location, quality of opposition and match status on technical performance’, International Journal of Performance Analysis in Sport.
2. Bialkowski, A., Lucey, P., Carr, P. and Matthews, I. (2020) ‘Large-scale analysis of soccer matches using spatiotemporal tracking data’, IEEE Transactions on Knowledge and Data Engineering.
3. Bradley, P.S., Ade, J.D. and Di Mascio, M. (2020) ‘High-intensity activity profiles of elite soccer players’, Journal of Sports Sciences.
4. Campos, J. et al. (2025) ‘Impact of international call-ups on football performance’, Frontiers in Psychology.
5. Castellano, J., Alvarez-Pastor, D. and Bradley, P.S. (2022) ‘Evaluation of match performance considering contextual variables’, International Journal of Sports Science & Coaching.
6. Clemente, F.M., Sarmento, H. and Rabbani, A. (2021) ‘The influence of tactical behaviour on football performance’, Sports Medicine.
7. Caso, S., Furley, P. and Jordet, G. (2025) ‘Using video-notational analysis to examine soccer players’ behaviours’, International Journal of Sport and Exercise Psychology.
8. Dalen, T., Lorås, H. and Pedersen, A.V. (2020) ‘Physical demands and technical actions in football’, Journal of Sports Sciences.
9. Decroos, T., Van Haaren, J. and Davis, J. (2021) ‘Actions speak louder than goals: Valuing player actions in soccer’, Data Mining and Knowledge Discovery.
10. Fernández-Navarro, J., Fradua, L. and Zubillaga, A. (2020) ‘Influence of ball possession on match outcome’, Journal of Human Kinetics.
11. Goes, F.R., Kempe, M. and Lemmink, K. (2021) ‘Notational analysis of ball possession and performance’, Journal of Sports Sciences.

12. Gudmundsson, J. and Horton, M. (2021) ‘Spatio-temporal analysis of team sports’, ACM Computing Surveys.
13. Herold, M., Kempe, M. and Memmert, D. (2021) ‘Key performance indicators in football’, European Journal of Sport Science.
14. Harkness-Armstrong, A. et al. (2024) ‘Applied performance analysis practices in women’s football’, International Journal of Sports Science & Coaching.
15. Lago-Peñas, C., Gómez-Ruano, M. and Yang, G. (2021) ‘Match status and situational variables in football’, Journal of Sports Sciences.
16. Link, D. and Hoernig, M. (2020) ‘Spatiotemporal modelling in football’, PLOS ONE.
17. Liu, H., Gómez, M.A. and Lago-Peñas, C. (2022) ‘Match statistics and performance analysis in football’, International Journal of Performance Analysis in Sport.
18. Memmert, D., Lemmink, K. and Sampaio, J. (2020) ‘Current approaches in tactical performance analysis’, Sports Medicine.
19. Mackenzie, R. and Cushion, C. (2021) ‘Reliability and validity in performance analysis’, International Journal of Sports Science & Coaching.
20. Oliva-Lozano, J.M., Fortes, V. and Krustrup, P. (2022) ‘Physical and tactical demands in elite football’, Sports Medicine.
21. Pappalardo, L., Cintia, P. and Rossi, A. (2021) ‘A public dataset of soccer match events’, Scientific Data.
22. Petancevski, E.L. et al. (2022) ‘Augmented feedback in motor learning’, Psychology of Sport and Exercise.
23. Plakias, S. et al. (2025) ‘A new era in soccer performance analysis research’, Insight – Sports Science.
24. Rein, R. and Memmert, D. (2021) ‘Big data and tactical analysis in football’, Journal of Sports Sciences.
25. Riboli, A., Coratella, G. and Esposito, F. (2021) ‘Match demands and performance indicators’, European Journal of Sport Science.
26. Sarmento, H., Anguera, M.T. and Campaniço, J. (2020) ‘A systematic review of performance analysis in football’, Journal of Sports Sciences.
27. Stafylidis, S. et al. (2024) ‘Use of performance statistics in football analysis’, Frontiers in Psychology.
28. Yang, G., Leicht, A.S. and Lago-Peñas, C. (2021) ‘Technical performance indicators in football’, Journal of Sports Sciences.
29. Zhou, C., Gómez, M.A. and Lorenzo, A. (2022) ‘Offensive performance indicators and success in football’, International Journal of Performance Analysis in Sport.
30. Plakias, S. et al. (2025) ‘Bibliometric trends in soccer performance analysis’, Sports.

FULL PAPER 15

SCIENTIFIC PAPER

Fifteen Olympic Medals per Million: Croatia's Overperformance versus Four of the World's Largest Nations under a Symmetric 1992–2024 Window

Dražen Čular[1,2], Ivan Granić[3], Željko Kovačević[4], Dino Beloševića[1,2]

[1]University of Split, Faculty of Kinesiology, Cro Sport Talent & Health and Longevity Lab, Split, Croatia; [2]European Institute for Talent, Education, Research & Development, Split, Croatia; [3]University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Split, Croatia; [4]University of Split, Faculty of Health Sciences, Split, Croatia

INTRODUCTION

Croatia is a small Central European and Mediterranean state of approximately 3.87 million inhabitants and 56 594 km^2 (Croatian Bureau of Statistics, 2024; World Bank, 2024). Since its first independent Olympic appearance at the 1992 Albertville Winter Games, Croatia has accumulated 59 Olympic medals through Paris 2024 — 48 at the Summer Games and 11 at the Winter Games (Croatian Olympic Committee, 2024; International Olympic Committee, 2024) — a tally that is disproportionate to both its population and its territory.

The cross-country economics of Olympic success has long been organised around the population–GDP determinants paradigm. Bernard and Busse (2004) showed that population and gross domestic product per capita are the dominant cross-country predictors of national medal totals. Forrest, Sanz, and Tena (2010) confirmed the predictive value of those covariates and added a host-country effect. The SPLISS programme (De Bosscher et al., 2015) extended this paradigm to a comparative-policy framework spanning fifteen nations and documented the persistent overperformance of small but sport-traditional states relative to the medal totals predicted by their demographic and economic mass.

A common shorthand in popular and policy discussions of Olympic success is the per-capita medal density, computed as cumulative medal totals divided by current national population. This shorthand is informative but is, in its standard form, not strictly comparable across countries. Cumulative medal totals for nations such as the United States (first appearance 1896) and India (1900) span more than a century of competition, whereas the corresponding totals for post-Soviet Russia and for Croatia span at most nine Summer and nine Winter Olympiads. Comparisons made on per-capita ratios so constructed therefore confound an underlying performance signal with a survivorship-history component. To the present author's knowledge, no published comparative study has corrected for this confound by restricting all five comparator countries to a uniformly symmetric time window.

The purpose of the present study was to recompute per-capita Olympic medal density for Croatia and four large reference nations — the United States, Russia, China, and India — under a symmetric 1992–2024 window applied uniformly to all five countries, and to quantify the magnitude of Croatian overperformance under that fair-comparison frame.

METHODS

Design. The study is an observational, cross-sectional comparative analysis of national Olympic medal counts under a symmetric historical window applied uniformly to five comparator countries (Croatia, the United States, Russia, the People's Republic of China, and India). The unit of analysis is the country; no human-participant data were collected.

Data sources. Olympic medal counts (Summer plus Winter Games, able-bodied programme of the International Olympic Committee) for the symmetric 1992–2024 window — nine Summer Olympiads (Barcelona 1992 through Paris 2024) and nine Winter Olympiads (Albertville 1992

through Beijing 2022) — were retrieved from the IOC medal database (International Olympic Committee, 2024) and cross-checked against the country tables of Olympedia (2024). Where the two sources disagreed on a per-Games tally, the Olympedia figure was preferred. National population estimates for the reference date 2024 were taken from the United Nations World Population Prospects (United Nations Population Division, 2024), with the Croatian estimate sourced from the Croatian Bureau of Statistics (2024) for institutional consistency. For Croatia, the medal tally was additionally verified against the public records of the Croatian Olympic Committee (2024).

Scope and exclusions. Paralympic and Deaflympic medals were excluded uniformly from all five countries to keep the construct of "Olympic medalist" sharply defined. For Russia, only medals competed for under the Russia or the Russian Olympic Committee designations between the 1994 Lillehammer Winter Games and the 2022 Beijing Winter Games were counted; medals awarded to the Soviet Union and to the Unified Team in 1992 were excluded.

Variables and statistical analysis. Country medal totals were denotedM_c, and 2024 resident population denoted N_c. Per-capita medal density was computed as $\rho_c = 10^6 \cdot M_c / N_c$ (medals per million inhabitants). Comparator-mean and Croatia-to-comparator ratios were computed as descriptive summaries. No inferential statistics were applied: the analysis is descriptive over the full population of countries and Olympic editions in the symmetric window; standard deviations and confidence intervals are therefore not reported. All computations were performed in spreadsheet software (Microsoft Excel, version 2019) and verified independently in Python 3.11 (NumPy 1.26).

RESULTS

Table 1 reports the medal totals, 2024 population estimates, and resulting per-capita densities for each of the five countries under the symmetric 1992–2024 window. Croatia's per-capita medal density was 15.24 medals per million inhabitants, materially higher than the corresponding ratios for the four reference nations: Russia 3.82, the United States 3.48, China 0.52, and India 0.019 medals per million.

The Croatia-to-comparator ratios were 4.4 (against the United States), 4.0 (against Russia), 29.3 (against China), and 819 (against India). The unweighted mean of the four comparator densities was 1.96 medals per million, yielding a Croatia-to-comparator-mean ratio of 7.78.

Figure 1 visualises the per-capita densities on a base-10 logarithmic scale. Croatia's density is approximately one half-decade above the modal density of the United States and Russia, more than one decade above that of China, and approximately three decades above that of India. The qualitative ordering is HR > RUS > USA > CHN > IND, with the slight Russia-over-United-States margin (3.82 vs 3.48) running counter to a strict population–GDP-based prior in which the larger-mass nation is expected to record the lower per-capita output.

Table 1. Olympic medals, 2024 population, and per-capita medal density for the five countries under the symmetric 1992–2024 window.

Country	Summer	Winter	Total medals	Population 2024 (M)	Medals per million
Croatia	48	11	59	3.87	**15.24**
Russia	432	121	553	144.82	3.82
United States	979	209	1188	341.81	3.48
China	662	77	739	1419.32	0.52

India	27	0	27	1450.94	0.019

Note. M = millions. Russia: post-Soviet medal tally only (excludes USSR and Unified Team 1992). Population sources: United Nations Population Division (2024); Croatia from Croatian Bureau of Statistics (2024). Medal sources: International Olympic Committee (2024) cross-checked with Olympedia (2024) and, for Croatia, with the Croatian Olympic Committee (2024).

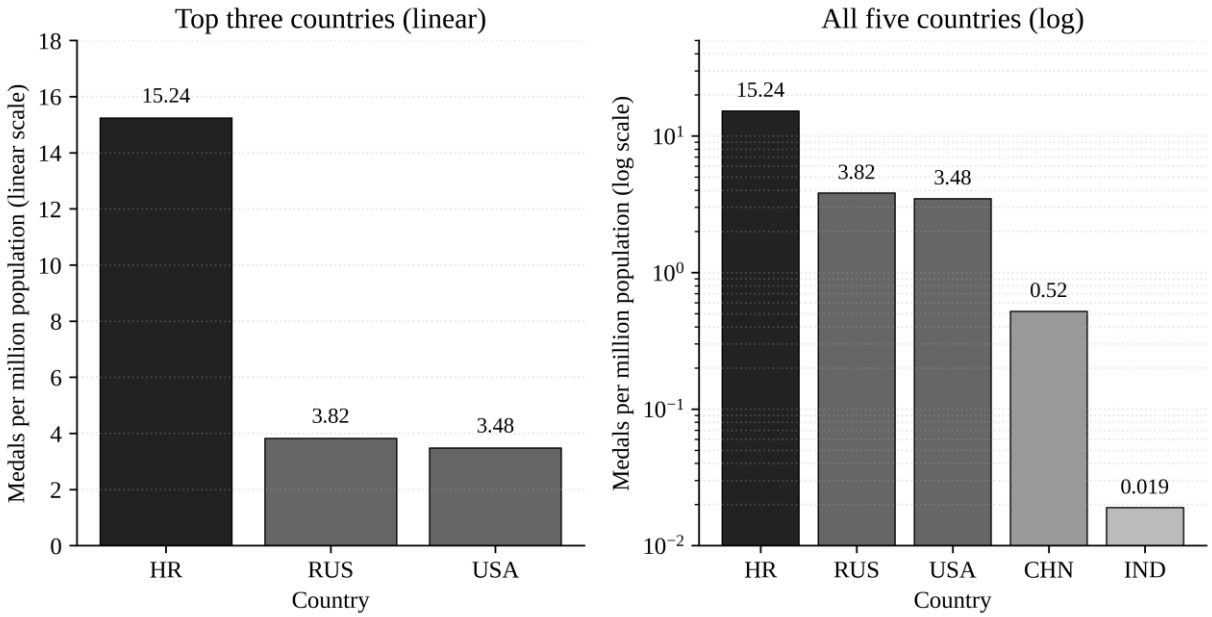


Figure 1. Per-capita Olympic medal density by country, symmetric 1992–2024 window. Bars are ordered by value (descending). Left panel (linear scale) shows the three top-ranked countries (Croatia, Russia, United States) and visualises Croatia's approximately fourfold dominance over the next-ranked nations. Right panel (base-10 logarithmic scale) shows all five countries and conveys the full cross-country range, including the much lower densities for China and India. Bar shading is graded by country (Croatia darkest) for grayscale legibility.

DISCUSSION

The headline finding of the present analysis — that Croatia's per-capita Olympic medal density under a symmetric 1992–2024 window is on the order of 4.0 to 819 times that of the four largest medal-producing or most populous nations of the contemporary era — is consistent with the substantive expectations of the small-states overperformance literature (De Bosscher et al., 2015; Houlihan & Zheng, 2015) and with country-level studies of similar small but sport-traditional nations (Halldórsson, 2017). The mechanism widely invoked in that literature applies straightforwardly to Croatia: a small population combined with concentrated institutional capacity in a small number of medal-producing team sports — handball, water polo, basketball, rowing — sustained across multiple Olympic cycles, can produce per-capita densities materially in excess of those generated by the population–GDP regression line.

Two methodological observations follow. First, the choice of a symmetric time window is consequential. Under an asymmetric "Croatia 1992–2024 vs. comparators all-time" comparison, the United States and India would be credited with medals from athletes long deceased, materially inflating the numerator without a corresponding adjustment in the denominator. The symmetric window adopted here removes this survivorship-history confound and produces a comparison that is, in this narrow sense, fair across countries.

Second, the slight Russia-over-United-States per-capita margin observed at the raw level (3.82 vs 3.48 medals per million) suggests that the population–GDP determinants prior, while broadly accurate at the extremes of the cross-country distribution (Croatia at the top, India at the

bottom), is not a strict ordering principle in the middle of the distribution. The reversal is small in absolute terms and may not survive other plausible time-window choices, but it merits explicit notice in any future per-capita comparison that includes the post-Soviet Russian Federation alongside the United States.

The present analysis is intentionally restricted to a single descriptive metric (raw per-capita medal density). The companion construct of individual encounter probability, which would additionally adjust for the medal-to-medalist conversion factor, medalist mortality, and migration, is not addressed here and is reserved for an extended treatment.

CONCLUSIONS

Under a symmetric 1992–2024 time window applied uniformly to Croatia and to four large reference nations, Croatia's per-capita Olympic medal density (15.24 medals per million inhabitants) substantially exceeds the densities of the United States (3.48), Russia (3.82), China (0.52), and India (0.019). The Croatia-to-comparator-mean ratio of 7.78 is consistent with the small-states overperformance pattern documented in the Olympic-economics and sport-policy literatures. Practically, the finding supports the methodological recommendation that cross-country per-capita medal-density comparisons should be restricted to comparable time windows; asymmetric "all-time vs. recent-era" framings systematically inflate the per-capita ratios of countries with longer Olympic histories and should not be used as the basis for substantive cross-country claims.

FUNDING

Supported by the Croatian Science Foundation (IP-2024-05-8340; IP-2025-02-8546) and the University of Split, Faculty of Kinesiology Institutional EU nextgeneration Project HeLoS, IP-UNIST-24).

REFERENCES

1. Bernard, A. B., & Busse, M. R. (2004). Who wins the Olympic Games: Economic resources and medal totals. *The Review of Economics and Statistics, 86*(1), 413–417. https://doi.org/10.1162/003465304774201824
2. Croatian Bureau of Statistics. (2024). *Population estimates of the Republic of Croatia, 2024*. https://dzs.gov.hr
3. Croatian Olympic Committee. (2024). *Hrvatska na Olimpijskim igrama [Croatia at the Olympic Games]*. https://www.hoo.hr/
4. De Bosscher, V., Shibli, S., Westerbeek, H., & van Bottenburg, M. (2015). *Successful elite sport policies: An international comparison of the sports policy factors leading to international sporting success (SPLISS 2.0) in 15 nations*. Meyer & Meyer Sport.
5. Forrest, D., Sanz, I., & Tena, J. D. (2010). Forecasting national team medal totals at the Summer Olympic Games. *International Journal of Forecasting, 26*(3), 576–588.
6. Halldórsson, V. (2017). *Sport in Iceland: How small nations achieve international success*. Routledge. https://doi.org/10.4324/9781315179414
7. Houlihan, B., & Zheng, J. (2015). Small states: Sport and politics at the margin. *International Journal of Sport Policy and Politics, 7*(3), 329–344. https://doi.org/10.1080/19406940.2014.959944
8. International Olympic Committee. (2024). *Olympic medal database*. https://olympics.com/en/olympic-games/olympic-results
9. Olympedia. (2024). *Olympedia: National Olympic Committees*. https://www.olympedia.org/countries

10. United Nations Population Division. (2024). *World population prospects 2024*. United Nations Department of Economic and Social Affairs. https://population.un.org/wpp/
11. World Bank. (2024). *World development indicators: Population, total; Surface area (sq. km)*. https://data.worldbank.org/indicator/SP.POP.TOTL

FULL PAPER 16

SCIENTIFIC PAPER

Anaerobic Performance Profiling in Recreational Boxers Using a 30-s Continuous Jump Test and a 30-s Punching-Bag Test

Dea Bolanča[1],Dino Bellosević [1,2],Dražen Čular [1,2]

[1]University of Split, Faculty of Kinesiology, Cro sport Talent & Health and Longevity Lab, Split, Croatia; [2]European Institute for Talents, Education, Research & Development, Split, Croatia

Introduction

Boxing is a high-intensity intermittent sport characterized by repeated, explosive activities (punches, defensive maneuvers, rapid changes in position) with limited recovery periods. This performance profile highlights the critical importance of anaerobic capacity and fatigue tolerance, specifically the ability to generate and sustain powerful actions with minimal decay in mechanical output (Heller et al., 1998; Mendez-Villanueva et al., 2012).

Kinesiology, as a field that explores the underlying principles of exercise and their effects on the human body, should contribute to answering key questions that support a better understanding of the fundamental characteristics of a given sport. (Čular et al., 2016).

There is a limited amount of research examining the degree of cardiorespiratory system activation in boxers during sport-specific whole-body activities (e.g., pad work, heavy bag punching, sparring) compared to non-specific forms of exercise, despite the fact that bag punching most closely replicates the demands experienced in an actual bout. (Veckunas et al., 2022).

Boxing places substantial demands on agility, particularly in terms of effective footwork. As a skill-based combat sport, it involves a constantly changing environment in which athletes must rapidly make decisions and respond to their opponents' technical and tactical actions, thereby increasing the demands on both agility and lower-limb power output. (Zhong H. et al., 2022). Muscular strength in both the upper and lower extremities is critical for success in boxing and represents a key factor in achieving competitive performance. Given that punches are rapid and highly dynamic actions, elite boxing performance depends on the development of substantial muscular power in both the upper and lower limbs. (Chaabène H et al., 2015).

Anaerobic capacity plays a crucial role in executing the explosive movements typical of combat sports, including punches in boxing. These high-intensity actions depend on the rapid energy supply provided by anaerobic pathways. (Yue F. et al., 2025).

In scientific and professional practice, the anaerobic fitness of the lower limbs is traditionally assessed using the Wingate Anaerobic Test (WAnT) on a cycle ergometer (Bar-Or, 1987; Inbar et al., 1996). However, despite its standardization, the cyclical movement pattern of the WAnT lacks specificity for combat sports, where explosive actions within the stretch-shortening cycle predominate (Konos et al., 2019). Consequently, researchers have emphasized the need for more ecologically valid and field-applicable tests that better reflect the discipline's specific demands and training adaptations (Sands et al., 2004).

The 30-s continuous vertical jump test (CJ30s) has emerged as a practical field-test alternative to laboratory protocols. In the context of combat sports, the CJ30s has been described as a valid

and reliable procedure that provides insights into both anaerobic power (e.g., mean jump height) and capacity (e.g., total work integrated through the Area Under the Curve or AUC(H)), while simultaneously monitoring fatigue dynamics (Čular et al., 2018; Dal Pupo et al., 2014). Such findings support the use of the CJ30s as a functional screening tool to assess anaerobic performance of the lower limbs in combat athletes.

In parallel with the lower-body assessment, boxing requires an analysis of specific upper-limb punching performance. Recent research on elite amateur boxers has demonstrated that the number of punches landed on a bag during a 30-s maximal task is associated with relative power achieved during a Wingate cycle test (Venckunas et al., 2024). This provides a methodological rationale for using a 30-s maximal punching task as a sport-specific indicator of anaerobic performance, complementing the data obtained from jumping tests.

Despite the established use of the CJ30s in combat sports, there remains a lack of data regarding their discriminative value in recreational boxing, particularly concerning training experience. It is logical to assume that more experienced boxers will be better able to maintain high-intensity work, resulting in more stable performance over 30 seconds. Furthermore, the correlation between general anaerobic status (as assessed by jumping) and specific punching performance in recreational populations remains unclear.

The aim of this study is therefore: To compare CJ30's variables (jump count, mean height, AUC(H), fatigue index, and 30-s maximal punching counts between experienced and less-experienced recreational boxers. Also, to explore the correlation between lower-limb anaerobic performance indicators and sport-specific punching frequency.

Based on previous findings (Čular et al., 2018; Dal Pupo et al., 2014), it is hypothesized that the CJ30s variables, due to their measurement sensitivity, will exhibit high discriminative power regarding training experience compared to simple punch counts, which may be more heavily influenced by individual technical and tactical factors, although it seems to be more specific. test.

Methods

Participants

The study included 17 recreational male and female boxers (n = 17; age: 19.27 ± 6.29 years). Participants were categorized into two groups based on their training seniority: Experienced - those with more than 2 years of consistent training (n = 7, age: 23.45 ± 7.41 years; mass: 76.57 ± 17.27 kg; height: 180.71 ± 9.27 cm) and Less Experienced - those with less than 2 years of training (n = 10, age: 16.33 ± 3.24 years; mass: 68.90 ± 9.47 kg; height: 175.80 ± 9.93 cm). Group membership was assigned using a binary coding system (0/1) established at the onset of data collection. Inclusion criteria required participants to be free of active musculoskeletal injuries and to have maintained a minimum training frequency of two sessions per week over the preceding three months. All investigations involving human participants conform to the World Medical Association's Code of Ethics (Declaration of Helsinki).

Design

This study employed a cross-sectional observational design to analyze anaerobic performance profiles in recreational boxers. The experimental approach focused on comparing performance metrics between two distinct groups based on training seniority (Experienced vs. Less Experienced), acting as internal cohorts for comparative analysis. Data were collected during a single testing session in which participants underwent standardized screenings, followed by specific anaerobic protocols to ensure consistency and reliability across the sample.

Methodology

Testing was conducted in a controlled indoor facility using standardized procedures to ensure reproducibility. The protocol consisted of two primary assessments separated by a standardized rest period to allow adequate metabolic recovery.

The 30-s Continuous Jump Test (CJ30s) was performed to assess lower-body anaerobic performance. Participants were instructed to execute maximal-effort vertical jumps continuously for 30 seconds. Jump performance was recorded using an optical measurement system (Optojump Next, Microgate, Italy), a validated tool for assessing jump kinetics and kinematics. The following variables were analyzed: total number of jumps (n), mean jump height (cm), and area under the curve (AUC(H)), calculated as the product of jump height (cm) and frequency, representing a composite indicator of anaerobic capacity. The fatigue index (FI, %) was calculated as the percentage decline from the mean height of the first five jumps to the mean height of the last five jumps according to the formula: FI (%) = [(First 5 Mean − Last 5 Mean) / First 5 Mean] × 100.

The 30-s Punching Test was used to assess upper-body anaerobic performance. Participants performed maximal-effort straight punches against a standard heavy bag, aiming to achieve maximal frequency with full extension. The primary outcome measure was the total number of punches delivered within the 30-second interval.

Statistical Analysis

All data are presented as mean ± standard deviation (SD). The normality of data distribution was assessed using the Shapiro–Wilk test. Between-group differences (Experienced vs. Less Experienced) were evaluated using Welch's two-sided t-test, which is robust to unequal variances and sample sizes. Exact P-values are reported for all comparisons (Bland & Altman, 1986).

The magnitude of between-group differences was quantified using Hedges' g effect sizes with corresponding 95% confidence intervals (CI), calculated using a bias-corrected bootstrap procedure (6,000 resamples). Effect sizes were interpreted using established thresholds (small, moderate, large) to aid in the assessment of practical significance in a sport performance context (Cohen, 1988).

Associations between punching performance and anaerobic variables derived from the CJ30s test were examined using Spearman's rank correlation coefficient (ρ) to account for potential non-linear relationships. Confidence intervals for correlation coefficients were also calculated to indicate the precision of estimates.

All statistical analyses were performed using Python (e.g., SciPy, NumPy, and related libraries). Statistical significance was set at $\alpha = 0.05$. Standard statistical terms, symbols, and abbreviations are reported in accordance with conventional scientific guidelines.

Results

Participant characteristics are outlined in Table 1.

Table 1. Participant characteristics (mean ± SD)

Variable	Less experienced	Experienced	Total
Age_(y)	16.33 ± 3.24	23.45 ± 7.41	19.27 ± 6.29
Mass (kg)	68.90 ± 9.47	76.57 ± 17.27	72.06 ± 13.32
Height_(cm)	175.80 ± 9.93	180.71 ± 9.27	177.82 ± 9.69

Regarding the convenience sample, some differences emerged from the data and need to be outlined in Table 1 (e.g., age difference).

Table 2 presents descriptives in observed outcomes for specific variables

Table 2. Performance outcomes (mean ± SD)

Outcome	Less experienced	Experienced	Total
Total jumps (n)	29.80 ± 3.12	34.43 ± 5.74	31.71 ± 4.83
Mean jump height (cm)	19.56 ± 5.32	25.27 ± 2.76	21.91 ± 5.21
AUC(H)	578.84 ± 151.40	862.34 ± 115.50	695.58 ± 196.42
Fatigue index (%)	32.29 ± 12.67	2.03 ± 20.02	19.83 ± 21.82
Punches in 30 s (n)	167.50 ± 32.76	183.71 ± 33.43	174.18 ± 33.02

Table 2 shows certain discrepancies in observed variables between experienced and less-experienced participants.

Table 3 summarizes the results of the Welch's t-test for between-group differences.

Table 3. Between-group differences, p-values, and standardized effects

Outcome	Less experienced mean ± SD	Experienced mean ± SD	Welch p	Hedges' g	95% CI
Total jumps (N)	29.80 ± 3.12	34.43 ± 5.74	0.08	1.01	0.02 - 1.99
Mean jump height (cm)	19.56 ± 5.32	25.27 ± 2.76	0.01	1.21	0.20 - 2.23
Fatigue index (%)	32.29 ± 12.67	2.03 ± 20.02	0.00	-1.79	-2.91 - -0.67
AUC (H)	578.84 ± 151.40	862.34 ± 115.50	0.00	1.95	0.80 - 3.10
Punches (30 s)	167.50 ± 32.76	183.71 ± 33.43	0.33	0.47	-0.47 - 1.40

Note: *Values are presented as mean ± standard deviation (SD). Between-group differences were analyzed using Welch's t-test (two-sided). Effect sizes are reported as Hedges' g with 95% confidence intervals (CI) based on bootstrap resampling (6,000 samples). AUC(H) represents the area under the curve of jump height over time and reflects anaerobic capacity during the CJ30s test. Fatigue (%) was calculated as the percentage decrease in jump height from the first five to the last five jumps. Statistical significance was set at $p < 0.05$.*

Hedges' g values indicate meaningful effect sizes in the experienced group for significant variables.

Table 4 provides insight into the relationships between the number of punches performed in a specific boxing test and CJ30's variables.

Table 4. Associations between punch count and CJ30s variables

Varijable	n	Spearman ρ	p
Total jumps (N)	17	0.08	0.73
Mean jump height (cm)	17	0.05	0.84
Fatigue index (%)	17	0.12	0.62
AUC (H)	17	0.21	0.41

Note. *n = 17. Spearman's rank correlation coefficient (ρ) was utilized to assess the non-parametric relationships between sport-specific punching output (absolute count in 30 s) and CJ30s anaerobic variables. Total jumps (N) indicates the total number of jumps completed; Mean jump height refers to the average height across the 30-s trial; Fatigue (%) represents the percentage drop in jump height from the initial to the final phase of the test; and AUC (H) denotes the area under the curve for jump height, serving as a composite measure of anaerobic capacity. Statistical significance was set at $p < 0.05$. No significant associations were observed between punching output and lower-limb anaerobic metrics.*

Discussion

The present findings highlight the superior sensitivity of the CJ30s test, particularly in AUC(H) and fatigue-related variables, in distinguishing levels of training experience among recreational boxers. These results suggest that integrative measures of anaerobic performance, which combine both movement frequency and mechanical output, provide greater discriminatory value than single-component metrics. In line with previous research (Čular et al., 2018; Dal Pupo et al., 2014), the CJ30s test appears to be a valid and ecologically relevant tool for assessing anaerobic capacity in combat sports, particularly because it relies on the stretch–shortening cycle and aligns with sport-specific movement patterns.

Fatigue due to continuous exercise is roughly divided into peripheral fatigue (muscles) and central fatigue (CNS) (Kwak JJ. et al.,2020). In this research we focused on the peripheral fatigue which is more easily measured. Fatigue-related indicators further emphasize the importance of anaerobic endurance and performance sustainability. The observed differences between groups suggest that more experienced athletes are better able to maintain performance and create work during short-duration, high-intensity efforts. This aligns with current understanding of neuromuscular adaptations to training and fatigue, including improved motor unit recruitment and fatigue resistance (Hanflink et al., 2025; Hostrup & Bangsbo, 2017). However, variability in fatigue responses indicates that such measures may also reflect individual pacing strategies, which should be considered when interpreting results.

In contrast, the 30-s punching test demonstrated limited ability to differentiate between groups and showed no clear association with lower-limb anaerobic performance. This is likely due to the complex and multifactorial nature of punching performance, which depends not only on anaerobic capacity but also on technical skill, coordination, and movement efficiency. Similar observations have been reported in previous studies (e.g., Venckunas et al., 2024), suggesting that while punching frequency may capture certain aspects of anaerobic performance, it lacks sensitivity as a standalone metric in its current form.

The absence of meaningful associations between CJ30s variables and punching performance supports the principle of specificity, indicating that lower- and upper- body anaerobic outputs may represent partially independent performance domains. This finding is relevant for both

testing and training practices, as it underscores the need for modality-specific assessments when evaluating athletic performance in boxing (Kons et al., 2019).

However, it is important to acknowledge that the small sample size (n = 17) substantially limits statistical power, particularly for detecting moderate associations. Therefore, while the present results do not support a strong linear relationship, they do not exclude the possibility of meaningful associations in larger and more homogeneous samples.

From a practical perspective, the CJ30s test can be recommended as a simple, cost-effective, and sensitive field-based method for monitoring anaerobic performance and fatigue tolerance in recreational athletes. The AUC(H) variable, in particular, appears to provide the most comprehensive insight into performance capacity, while fatigue indices offer additional information on performance maintenance. Conversely, the 30-s punching test may still have practical value as a sport-specific assessment, but its application would benefit from improved standardization and more objective measurement approaches.

Overall, these findings contribute to the growing body of literature supporting the use of field-based anaerobic testing in combat sports and provide practical guidance for coaches and practitioners aiming to assess and monitor performance in boxing.

Conclusions

Overall, this study demonstrates that CJ30s-derived variables, especially integrative and fatigue-related metrics, are robust indicators of training status in recreational boxers. In contrast, simple punch frequency appears less sensitive due to its multidimensional, technique-dependent nature. Future research should aim to refine sport-specific upper-body tests and validate their relationship with established anaerobic performance measures.

References

1. Bar-Or, O. (1987). The Wingate anaerobic test: An update on methodology, reliability and validity. Sports Medicine, 4(6), 381–394. https://doi.org/10.2165/00007256-198704060-00001
2. Bland, J. M., & Altman, D. G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. The Lancet, 1(8476), 307–310. https://doi.org/10.1016/S0140-6736(86)90837-8
3. Chaabène H, Tabben M, Mkaouer B, Franchini E, Negra Y, Hammami M, Amara S, Chaabène RB, Hachana Y. Amateur boxing: physical and physiological attributes. Sports Med. 2015 Mar;45(3):337-52. doi: 10.1007/s40279-014-0274-7. PMID: 25358529.
4. Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Erlbaum.
5. Čular, D., Ivančev, V., Zagatto, A. M., Milić, M., Beslija, T., Sellami, M., & Padulo, J. (2018). Validity and reliability of the 30-s continuous jump for anaerobic power and capacity assessment in combat sport. Frontiers in Physiology, 9, 543. https://doi.org/10.3389/fphys.2018.00543
6. Čular D, Padulo J, Sporis G. (2016.) Anaerobic capacities for elite performance in Taekwondo. Science and Medicine in Combat Sports, 11, 191-21
7. Dal Pupo, J., Gheller, R. G., Dias, J. A., Rodacki, A. L. F., Moro, A. R. P., & Santos, S. G. (2014). Reliability and validity of the 30-s continuous jump test for anaerobic fitness evaluation. Journal of Science and Medicine in Sport, 17(6), 650–655. https://doi.org/10.1016/j.jsams.2013.09.007
8. Fleiss, J. L. (1991). Statistical methods for rates and proportions. John Wiley & Sons.

9. Hanflink, J., Peacock, C. A., Sanders, G. J., & Antonio, J. (2025). Performance Metrics of Anaerobic Power in Professional Mixed Martial Arts (MMA) Fighters. *Journal of Functional Morphology and Kinesiology*, *10*(3), 358. https://doi.org/10.3390/jfmk10030358
10. Heller, J., Peric, T., Dlouha, R., Kohlikova, E., Melichna, J., & Novakova, H. (1998). Physiological profiles of male and female taekwon-do (ITF) black belts. Journal of Sports Sciences, 16(3), 243–249. https://doi.org/10.1080/026404198366768
11. Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. Medicine & Science in Sports & Exercise, 41(1), 3–13. https://doi.org/10.1249/MSS.0b013e31818cb278
12. Hostrup, M., & Bangsbo, J. (2017). Limitations in intense exercise performance of athletes – effect of speed endurance training on ion handling and fatigue development. The Journal of Physiology, 595(9), 2897–2913.
13. Inbar, O., Bar-Or, O., & Skinner, J. S. (1996). The Wingate anaerobic test. Human Kinetics.
14. Kons, Rafael & B R Orssatto, Lucas & Detanico, Daniele. (2019). Acute performance responses during repeated matches in combat sports: A systematic review. Journal of Science and Medicine in Sport. 23. 10.1016/j.jsams.2019.12.004.
15. Kwak JJ, Yook JS, Ha MS. Potential Biomarkers of Peripheral and Central Fatigue in High-Intensity Trained Athletes at High-Temperature: A Pilot Study with *Momordica charantia* (Bitter Melon). J Immunol Res. 2020 Jun 8;2020:4768390. doi: 10.1155/2020/4768390. PMID: 32587872; PMCID: PMC7298321.
16. Mendez-Villanueva, A., Edge, J., Suriano, R., Hamer, P., & Bishop, D. (2012). The recovery of repeated-sprint exercise is associated with PCr resynthesis, while muscle pH and EMG amplitude remain depressed. PLoS ONE, 7(12), e51977. https://doi.org/10.1371/journal.pone.0051977
17. Sands, W. A., McNeal, J. R., Ochi, M. T., Urbanek, T. L., Jemni, M., & Stone, M. H. (2004). Comparison of the Wingate and Bosco anaerobic tests. Journal of Strength and Conditioning Research, 18(4), 810–815.
18. Venckunas, T., Bruzas, V., Snieckus, A., Stasiule, L., Kniubaite, A., Mickevicius, M., Kamandulis, S., & Stasiulis, A. (2024). Anaerobic Performance Profiling in Elite Amateur Boxers. Sports, 12(9), 231. https://doi.org/10.3390/sports12090231.
19. Venckunas T, Bruzas V, Stasiulis A, Snieckus A, Mockus P, Kamandulis S. Cardiorespiratory Responses to Specific and Nonspecific Exercise in High-Profile Amateur Boxers. J Strength Cond Res. 2022 Mar 1;36(3):717-722. doi: 10.1519/JSC.0000000000003496. PMID: 32118701.
20. Zhong H, Bu X. Development of a Sensitive Quality Evaluation System for Chinese Outstanding Female Boxers. J Environ Public Health. 2022 Jul 30;2022:4664938. doi: 10.1155/2022/4664938. PMID: 35942146; PMCID: PMC9356856.
21. Yue F, Wang Y, Yang H, Zhang X. Effects of high-intensity interval training on aerobic and anaerobic capacity in olympic combat sports: a systematic review and meta-analysis. Front Physiol. 2025 May 9;16:1576676. doi: 10.3389/fphys.2025.1576676. PMID: 40415789; PMCID: PMC12098572.

FULL PAPER 17

SCIENTIFIC PAPER

Prevention, rehabilitation and recovery in amateur football situation analysis in croatia

Srđan Milovanović, Nikica Tole, Ante Burger

University of applied sciences Lavoslav Ružička, Vukovar, Croatia

Introduction

Football is the most popular sport in the world and plays a significant role in promoting physical activity and health, particularly in European countries such as Croatia, where a large number of children, youth, and adults participate in amateur competitions. Despite its widespread accessibility and social importance, amateur football is characterized by a lack of organized medical and physiotherapy support, which represents a serious challenge in the context of injury prevention and the quality of athlete rehabilitation.

Football's unique biomechanical and physiological demands, such as quick direction changes, accelerations, player contact, and high-intensity sports, make injuries common. According to research, there are six to nine injuries in football for every 1,000 hours of play, with lower limb injuries such knee injuries, ankle sprains, and muscular strains being the most common (Ekstrand et al., 2011; Faude et al., 2013). In contrast to amateur sports, which frequently lack this level of care, professional sports employ a multidisciplinary strategy including physiotherapists, doctors, and strength and conditioning coaches to methodically avoid and manage such injuries.

The absence of adequate prevention and rehabilitation may result in prolonged absence from sport, decreased performance, and an increased risk of recurrent injuries and chronic conditions (Junge & Dvorak, 2004; Ardern et al., 2016). Physiotherapy plays a crucial role in this process, encompassing not only post-injury rehabilitation but also preventive programs, athlete education, and optimization of training load (Brukner & Khan, 2017; Reinold et al., 2021). Structured prevention programs such as FIFA 11+ have been shown to be particularly effective in reducing the incidence of lower limb injuries (Soligard et al., 2008).

However, organizational capability, financial resources, and knowledge of the significance of athlete health care frequently limit the availability of physiotherapy services in amateur football. According to earlier research, many amateur clubs rely on sporadic or unofficial assistance rather than hiring full-time physiotherapists, which may lead to insufficient rehabilitation and a higher risk of problems (Weiler et al., 2015). The issue is made worse by coaches' and athletes' lack of knowledge on injury prevention and recovery techniques (Verhagen et al., 2010; McKay et al., 2016).

Compared to more developed sports systems, such as those in England and Scandinavian countries, where standardized prevention programs and clear regulations regarding physiotherapy roles are implemented, Croatian amateur football demonstrates considerable room for improvement. Systematic investment in prevention, rehabilitation, and athlete education could reduce injury rates, improve performance, and decrease the financial burden on clubs in the long term.

Therefore, the aim of this study is to analyse the state of injury prevention, rehabilitation, and recovery in amateur football in the Republic of Croatia, with a particular focus on the role of

physiotherapists and the level of investment in medical care, as well as to identify key challenges and opportunities for improving athlete health care systems.

Methods

This study was designed as a cross-sectional quantitative investigation aimed at assessing the current practices and perceptions related to injury prevention, rehabilitation, and recovery in amateur football clubs in Croatia. The study did not involve any intervention and was focused on describing the existing state and identifying relationships between selected variables.

The study involved 106 amateur football teams from various parts of the Republic of Croatia. From the third to the eighth division, the clubs represented different competitive levels. In order to guarantee representation across various areas and competition levels and to include teams who are actively participating in the amateur football system, a purposeful sample technique was employed.

A systematic questionnaire created especially for this study was used to gather data. The Google Forms platform was used to build the questionnaire, which had 26 items. Both closed ended (multiple choice) and Likert scale items, with 1 denoting total disagreement and 5 denoting total agreement, were included in the questions. A number of topics were covered by the questionnaire, such as general club characteristics (league level, region, number of players), the presence and frequency of physiotherapist involvement, injury prevention and rehabilitation practices, the length of time it takes to recover from an injury, the amount of money spent on physiotherapy, and subjective opinions about the quality of medical care.

The procedure of gathering data took place between January 21 and May 1, 2025. The survey was disseminated electronically using amateur football teams' contact networks and email. Respondents gave information on behalf of their individual clubs, and participation in the study was anonymous and voluntary.

Competition level (a categorical variable), the presence of a physiotherapist (yes/no), the frequency of physiotherapist involvement (training sessions, matches, on demand, or not present), the number of players and youth categories, the amount of money invested in physiotherapy, the length of injury recovery, and subjective evaluations of rehabilitation conditions, equipment, recovery techniques, and the significance of physiotherapy using Likert scale measures were among the variables examined in this study.

Microsoft Excel and IBM SPSS Statistics (version 26) were used for statistical analysis. The data was summarized using descriptive statistics, while inferential statistical techniques included the Chi-square test of independence, Spearman's rank correlation coefficient, Mann-Whitney U test, and Kruskal-Wallis test. Standard criteria for sports and health sciences research were followed in interpreting all results, with $p < 0.05$ as the level of statistical significance.

Results

Clubs with physiotherapists reported significantly shorter recovery times compared to those without, indicating the importance of professional medical support. As shown in Table 1, the mean recovery score was lower in clubs with physiotherapist involvement ($M = 1.59$) compared to those without ($M = 1.91$), with a statistically significant difference ($p = 0.013$).These findings suggest that the presence of qualified physiotherapy staff contributes to more efficient rehabilitation processes and faster return-to-play outcomes.

Table 1. Recovery duration depending on physiotherapist presence (Mann–Whitney U test)

Physiotherapist presence	Mean recovery score	SD	P-value
Yes	1.59	0.523	
No	1.91.	0.781	0.013*

*Significant at p<0.05

The Kruskal–Wallis test was conducted to examine differences in financial investment in physiotherapy across competition levels. As presented in Table 2, a statistically significant difference was found (Kruskal–Wallis H test, $p < 0.001$), indicating that higher-level clubs invest more in physiotherapy services. There is a clear decreasing trend in financial investment as the competition level decreases, which is also reflected in the mean rank values shown in Table 2. Lower-tier clubs allocate significantly fewer resources to physiotherapy compared to clubs competing at higher levels.

Table 2. Investment in physiotherapy by competition level (Kruskal Wallis test)

Competition level	Mean rank of investment
3rd – 4th	68.2
5th	57.4
6 th	49.1
7th-8th	38.7

p < 0.001*

A Chi-square test of independence was used to examine the relationship between perceived financial sufficiency and rehabilitation conditions. As shown in Table 3, the results indicated no statistically significant association between these variables ($\chi^2 = 1.487$, $p = 0.223$). Although clubs with higher budgets tend to report better rehabilitation conditions, this relationship was not statistically significant, as presented in Table 3. This suggests that the perception of financial adequacy does not necessarily correspond to objectively better rehabilitation quality within amateur football clubs.

Table 3. Relationship between financial sufficiency and rehabilitation conditions (Chi-square)

	Adequate conditions	Inadequate conditions	Total
Sufficient budget	18	12	30
Insufficient budget	32	44	76

$\chi^2(1) = 1.487$, $p = 0.223$

Discussion

The findings of this study provide important insights into the current state of injury prevention, rehabilitation, and recovery in amateur football in Croatia, highlighting substantial disparities in

the availability and quality of healthcare support among clubs. One of the key results indicates that the presence of a physiotherapist significantly reduces the time required for players to return to play following injury. Clubs with access to physiotherapy services consistently reported shorter recovery periods, reinforcing the critical role of timely and professional rehabilitation. This finding is consistent with previous research demonstrating that structured medical support reduces both the duration of absence and the likelihood of reinjury (Ekstrand, 2013). Furthermore, early intervention and individualized rehabilitation protocols are widely recognized as essential components in optimizing athlete recovery and long-term performance outcomes.

Despite the recognized importance of physiotherapy, the study reveals considerable inequalities in financial investment across clubs. Larger clubs, particularly those competing in higher divisions or operating extensive youth academies, allocate significantly more resources to healthcare services. In contrast, smaller clubs often invest minimal or no funds in physiotherapy (Malcolm et al., 2017). This disparity reflects broader structural issues within amateur sport, where access to adequate medical care depends largely on financial capacity rather than actual need. Similar patterns have been identified in other European contexts, where lower-tier clubs face financial constraints that limit access to professional healthcare support (Weiler et al., 2015). These inequalities may ultimately contribute to prolonged recovery times and increased injury risks among players in less resourced environments.

Perceptual differences among clubs further emphasize this imbalance. While most respondents acknowledged that injuries significantly hinder sporting performance, ratings of rehabilitation conditions and financial support were notably low. Interestingly, higher ranked clubs expressed more critical evaluations of their own systems, likely reflecting a greater awareness of professional standards in sports medicine (Fuller et al., 2007). Conversely, lower tier clubs often reported moderate satisfaction, which may indicate a limited understanding of the potential benefits of structured physiotherapy. This discrepancy suggests that, in addition to financial barriers, there is also a need for increased education and awareness regarding injury prevention and rehabilitation practices.

Comparisons with international models highlight potential pathways for improvement. In England, initiatives such as the grassroots programs developed by the Football Medical and Performance Association (FMPA, 2020) demonstrate how collaboration between experienced practitioners and amateur clubs can enhance access to medical care. Similarly, Scandinavian countries provide strong examples of effective, low cost preventive strategies. The Swedish “Knee Control Program,” developed and evaluated by (Waldén et al. 2012), has been shown to significantly reduce the incidence of anterior cruciate ligament (ACL) injuries among young athletes. In Norway, the FIFA-endorsed “11+” program, studied by (Soligard et al. 2008), has demonstrated effectiveness in reducing overall injury rates in amateur football. These findings underline the importance of integrating evidence-based preventive exercises into regular training routines, even in settings with limited financial resources.

The differences between professional and amateur levels are further exacerbated by the regulatory structure. Lower leagues in Croatia are subject to less strict rules, however professional clubs must hire licensed physiotherapists in compliance with UEFA (2023) and Croatian Football Federation (2024) regulations. Concerns regarding the quality and safety of care are raised when medical assistance is given by those who have only received rudimentary first aid training. More advanced systems, like those in Germany and England, on the other hand, impose stricter rules. In England, physiotherapists are required to register with professional organizations such the Health and Care Professions Council and the Chartered Society of

Physiotherapy (FA, 2022), and the Deutsche fusbal Liga (2023) requires the attendance of both physicians and physiotherapists. These regulatory differences highlight the need for greater standardization within the Croatian amateur system.

Several limitations of this study should be acknowledged. The data were collected through self-reported questionnaires completed by club representatives, which may introduce subjective bias and limit the accuracy of the findings. Additionally, the quantitative design does not capture the full complexity of challenges faced by clubs and players. Future research should incorporate qualitative approaches, including interviews with athletes, coaches, and healthcare professionals, to gain a more comprehensive understanding of the issue.

Conclusions

This study demonstrates that healthcare provision in amateur football in Croatia remains insufficient, despite a clear recognition of the importance of injury prevention and rehabilitation. The results verify that having physiotherapists on hand is essential for shortening healing times and enabling a more secure and effective return to play. On the other hand, teams that lack access to professional physiotherapy support typically have lengthier player absences, which can have a detrimental effect on both individual performance and the success of the team as a whole.

Despite a strong understanding of the significance of injury prevention and rehabilitation, this study shows that healthcare provision in Croatian amateur football is still inadequate. The results verify that having physiotherapists on hand is essential for shortening healing times and enabling a more secure and effective return to play. On the other hand, teams that lack access to professional physiotherapy support typically have lengthier player absences, which can have a detrimental effect on both individual performance and the success of the team in general.

Effective and sustainable healthcare models can be adopted even in situations with low resources, according to comparisons with international standards. The importance of organized preventative initiatives and cooperative strategies including medical experts and community partners is demonstrated by examples from Scandinavia and England. These models provide useful recommendations for enhancing the Croatian system, especially through collaborations with academic institutions and the incorporation of physiotherapy students into sports related clinical practice.

Overall, the results emphasize that investing in physiotherapy is not merely an additional cost but a long-term investment in athlete health, performance, and the sustainability of amateur football. Strengthening institutional support, improving access to qualified professionals, and implementing standardized prevention and rehabilitation strategies are essential steps toward enhancing the quality of healthcare in this sector.

References

1. Ardern, C. L., Glasgow, P., Schneiders, A., Witvrouw, E., Clarsen, B., Cools, A., ... & Bizzini, M. (2016). 2016 Consensus statement on return to sport from the First World Congress in Sports Physical Therapy, Bern. British Journal of Sports Medicine, 50(14), 853–864. https://doi.org/10.1136/bjsports-2016-096278
2. Brukner, P., & Khan, K. (2017). *Brukner & Khan's Clinical Sports Medicine* (5th ed.). McGraw-Hill Education.

3. Ekstrand, J. (2013). Preventing injuries in professional football: Thinking bigger and working together. British Journal of Sports Medicine, 47(12), 704–705.
4. Ekstrand, J., Hägglund, M., & Waldén, M. (2011). Injury incidence and injury patterns in professional football: The UEFA injury study. British Journal of Sports Medicine, 45(7), 553–558. https://doi.org/10.1136/bjsm.2009.060582
5. FA, 2022. FA Medical Regulations. The Football Association. Dostupno na: https://www.thefa.com [Accessed 29. May 2025.]
6. Faude, O., Rößler, R., & Junge, A. (2013). Football injuries in children and adolescent players: are there clues for prevention?. *Sports medicine*, *43*(9), 819-837.
7. FIFA, 2022. Global Report on Football. Fédération Internationale de Football Association. Dostupno na: https://www.fifa.com [Acessed 29. May 2025.].
8. Football Medicine & Performance Association (FMPA). (2023). Supporting grassroots football through the FMPA Register. Preuzeto s: https://www.fmpa.co.uk/supporting-grassroots-football/[Acessed 29. May 2025.].
9. Fuller, C. W., Ojelade, E. O., & Taylor, A. (2007). Preparticipation medical evaluation in professional sport in the UK: Theory or practice? *British Journal of Sports Medicine*, 41, 890–896.
10. HNS, 2024. Pravilnik o licenciranju i financijskoj održivosti klubova. Hrvatski nogometni savez. Dostupno na: https://hns.family/files/documents/26620/Matija%20Puhak_Kriteriji%20ADM%20i%20STR.%20OSOBLJA_Prezentacija%20licenciranje.pdf [Acessed 29. May 2025.].
11. Junge, A., & Dvorak, J. (2004). Soccer injuries: a review on incidence and prevention. Sports Medicine, 34(13), 929–938.
12. Malcolm, D., Scott-Bell, A., & Waddington, I. (2017). The provision of medical care in English professional football: An update. *Journal of science and medicine in sport*, *20*(12), 1053-1056.
13. McKay, C. D., Merrett, C. K., & Emery, C. A. (2016). Predictors of use of an injury prevention program in youth soccer: The role of coach education, player age and player injury history. *British Journal of Sports Medicine*, 50(5), 397–402. https://doi.org/10.1136/bjsports-2015-094885
14. Reinold, M. M., Gill, T. J., & Wilk, K. E. (2021). Sports physical therapy spans a wide spectrum: Injury prevention, rehabilitation, and performance enhancement. *International Journal of Sports Physical Therapy*, 16(2), 335–339.
15. Soligard, T., Myklebust, G., Steffen, K., Holme, I., Silvers, H., Bizzini, M., Junge, A., Dvorak, J., Bahr, R., & Andersen, T. E. (2008). Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. BMJ, 337, a2469.
16. Verhagen, E., van Stralen, M. M., & van Mechelen, W. (2010). Behaviour, the key factor for sports injury prevention. *Sports Medicine*, 40(11), 899–906. https://doi.org/10.2165/11536800-000000000-00000
17. Waldén, M., Atroshi, I., Magnusson, H., Wagner, P., & Hägglund, M. (2012). Prevention of acute knee injuries in adolescent female football players: cluster randomized controlled trial. BMJ, 344, e3042.
18. Weiler, R., et al. (2015). Medical provision and player welfare in grassroots and professional football. British Journal of Sports Medicine, 49(9), 581–586.

FULL PAPER 18

SCIENTIFIC PAPER

The use of artificial intelligence for statistical data processing in kinesiology

Goran Sporiš; Davorin Antonić; Marko Čurković; Haris Čoćić; Zvezdan Stefanović; Vatroslav Horvat; Goran Jelaska; Šutić Danijel; Adem Preljević

University of Zagreb, Faculty of Kinesiology, Zagreb, Croatia

1. Introduction

The rapid development of digital technologies, wearable devices, and artificial intelligence has significantly transformed modern kinesiology and sports science. Contemporary sports systems generate enormous amounts of biomechanical, physiological, and tactical data through GPS tracking systems, wearable sensors, force platforms, motion capture systems, and automated video analysis. The increasing complexity and volume of sports-related data require advanced statistical approaches capable of identifying patterns and relationships that traditional statistical methods often cannot adequately process (Bzdok, Altman, & Krzywinski, 2021).

Artificial intelligence (AI) represents one of the fastest-growing interdisciplinary fields integrating computer science, statistics, biomechanics, physiology, and sports analytics. Machine learning and deep learning algorithms have become essential tools for automated data analysis, performance prediction, injury prevention, and individualized training optimization in sports science (Su et al., 2022). AI systems are capable of processing multidimensional datasets and identifying nonlinear relationships among variables, enabling more precise and efficient decision-making processes compared to conventional statistical techniques.

Recent technological advancements have enabled continuous athlete monitoring during training and competition. Wearable technologies equipped with accelerometers, gyroscopes, heart rate monitors, and GPS devices provide real-time physiological and biomechanical information that can be analyzed using machine learning techniques (Wang, Li, & Zhou, 2022). These systems allow sports scientists and coaches to evaluate athlete performance, workload distribution, movement efficiency, and recovery processes more accurately.

One of the most important applications of artificial intelligence in kinesiology is sports performance analysis. Machine learning algorithms are increasingly used to identify performance determinants, optimize tactical strategies, and predict future athletic outcomes (Shen, Wu, & Zhang, 2023). According to Claudino et al. (2021), AI-based predictive models provide valuable information regarding athlete readiness and competitive performance, particularly in elite sports environments where small performance improvements may significantly affect outcomes.

Deep learning techniques have shown exceptional effectiveness in biomechanical and motion analysis. Computer vision systems powered by neural networks enable automated movement tracking and biomechanical assessment without the need for expensive laboratory equipment (Cust et al., 2020). These technologies improve the precision of movement analysis and facilitate the identification of technical inefficiencies during sports activities.

Another significant area of AI application involves injury prevention and rehabilitation. Sports injuries remain one of the major challenges in elite and recreational sports due to their negative impact on athlete performance and long-term health. Artificial intelligence enables early identification of injury risk factors through the analysis of biomechanical asymmetries, physiological fatigue markers, and training load parameters (Van Eetvelde et al., 2021).

Predictive machine learning models can estimate injury probability based on historical and real-time athlete data, allowing preventive interventions before injuries occur.

The growing importance of big data in sports science has further accelerated the implementation of AI technologies. Sports organizations increasingly rely on large-scale datasets collected from competitions, training sessions, and athlete monitoring systems. Big data analytics combined with machine learning enables the identification of hidden performance patterns and tactical tendencies that are not easily observable through traditional analysis methods (Xiao, Chen, & Zhao, 2023).

Artificial intelligence also plays a critical role in tactical and strategic analysis in team sports. AI-driven video analysis systems automatically track player positioning, movement trajectories, passing networks, and tactical formations during matches (Jia, Li, & Sun, 2025). These systems support coaches and analysts in evaluating team strategies and optimizing tactical decision-making processes.

Furthermore, AI applications in kinesiology extend beyond elite sports. Artificial intelligence is increasingly used in physical education, rehabilitation sciences, public health, and exercise prescription. AI-based systems can personalize exercise programs according to individual physiological characteristics and fitness levels, improving training efficiency and reducing injury risk (Topol, 2021).

The integration of artificial intelligence with biomechanics has also significantly advanced motion analysis and motor control research. Deep learning models can identify subtle movement variations associated with fatigue, neuromuscular dysfunction, or inefficient movement mechanics (Esteva et al., 2020). Such findings are particularly important in injury prevention and rehabilitation programs.

In recent years, sports analytics has evolved into a highly data-driven discipline. The combination of AI, cloud computing, and wearable technologies has enabled real-time athlete monitoring and automated statistical analysis during competitions and training sessions (Mengbin, Liu, & Zhao, 2026). Consequently, modern sports organizations increasingly depend on AI-supported decision-making systems to gain competitive advantages.

Despite numerous advantages, several challenges remain regarding the implementation of artificial intelligence in kinesiology. One of the major concerns involves data quality and reliability. Machine learning algorithms require large, accurate, and well-structured datasets for effective model training. Incomplete or biased data may negatively influence prediction accuracy and analytical reliability (Beam & Kohane, 2020).

Ethical considerations also represent an important issue in sports analytics. Continuous athlete monitoring raises concerns regarding privacy protection, data ownership, and ethical use of sensitive physiological information. Sports organizations must establish clear ethical standards and ensure responsible implementation of AI systems (Rajkomar, Dean, & Kohane, 2022).

Another challenge is the interpretability of machine learning models. Deep learning algorithms often operate as “black-box” systems, making it difficult for sports scientists and coaches to fully understand the underlying mechanisms responsible for specific predictions (Libbrecht & Noble, 2021). Therefore, interdisciplinary collaboration between sports scientists, statisticians, biomechanists, and computer scientists is essential for the effective application of AI technologies in kinesiology.

Current literature demonstrates that artificial intelligence has enormous potential for improving statistical data processing, performance analysis, and decision-making processes in sports

science. As AI technologies continue to evolve, their integration into kinesiology will likely become even more significant in the future.

2. Methods

This study represents a narrative review focused on the application of artificial intelligence in statistical data processing within kinesiology and sports science. The review was conducted through a systematic search of scientific literature indexed in the Web of Science (WoS) database.

The literature search included scientific articles published between 2020 and 2026 in peer-reviewed journals related to sports science, kinesiology, biomechanics, data science, artificial intelligence, and performance analysis. The following keywords and combinations were used during the database search:

- “artificial intelligence in sports”
- “machine learning in kinesiology”
- “sports analytics”
- “deep learning in sports science”
- “statistical data processing”
- “wearable technologies and sports”
- “injury prediction using AI”
- “performance analysis in sports”
- “sports biomechanics and artificial intelligence”

The search strategy focused on identifying studies that investigated the use of artificial intelligence methods in:

- sports performance analysis,
- biomechanical assessment,
- injury prevention,
- workload monitoring,
- tactical analysis,
- physiological monitoring,
- predictive analytics in sports science.

Inclusion criteria were:

1. scientific articles indexed in the Web of Science database,
2. studies published between 2020 and 2026,
3. articles written in English,

4. studies directly related to artificial intelligence applications in kinesiology and sports science,

5. studies involving statistical data processing, machine learning, or deep learning methodologies.

Exclusion criteria included:

- conference abstracts without full-text availability,
- non-peer-reviewed publications,
- duplicate studies,
- articles not directly related to kinesiology or sports science,
- studies lacking methodological relevance to artificial intelligence or statistical analysis.

After the initial search process, the identified studies were screened according to title relevance, abstract content, and methodological suitability. Relevant articles were further analyzed in full text.

The selected literature was categorized into several thematic areas:

- artificial intelligence in sports performance analysis,
- biomechanical applications of AI,
- wearable technologies and athlete monitoring,
- machine learning for injury prevention,
- tactical and video analysis systems,
- predictive analytics in sports science.

Data extraction focused on:

- study objectives,
- sample characteristics,
- AI methodologies used,
- statistical procedures,
- main findings,
- practical applications in kinesiology.

The collected data were analyzed using descriptive and comparative analysis methods. The review emphasized recent developments in machine learning, deep learning, computer vision, and predictive analytics relevant to sports science and kinesiology.

Additionally, particular attention was given to studies involving wearable sensors, GPS tracking systems, motion capture technologies, and automated biomechanical analysis because these technologies currently represent the most rapidly developing areas of sports analytics.

The methodological approach of this review aimed to provide a comprehensive overview of contemporary scientific findings regarding the use of artificial intelligence for statistical data

processing in kinesiology while identifying current trends, limitations, and future research directions.

4. Discussion

The findings of this review demonstrate that artificial intelligence has become one of the most important technological tools in contemporary kinesiology and sports science. The increasing use of wearable technologies, GPS systems, biomechanical sensors, and automated tracking systems has resulted in the generation of extremely large and complex datasets that require advanced statistical processing methods. Traditional statistical approaches are often insufficient for analyzing multidimensional and nonlinear relationships among physiological, biomechanical, and tactical variables (Bzdok, Altman, & Krzywinski, 2021).

The reviewed literature consistently indicates that machine learning and deep learning algorithms significantly improve the accuracy and efficiency of sports performance analysis. Artificial intelligence systems are capable of processing large datasets in real time while identifying patterns that are difficult to detect through conventional statistical methods (Jordan & Mitchell, 2021). This represents a major advancement in kinesiology because modern sports increasingly depend on objective data-driven decision-making processes.

One of the most significant applications of artificial intelligence identified in the reviewed studies involves sports performance analysis. Machine learning algorithms allow the integration of physiological, biomechanical, and tactical variables into predictive models capable of estimating athletic performance and training readiness (Su et al., 2022). According to Claudino et al. (2021), AI-based predictive systems provide valuable information regarding athlete monitoring and performance optimization, particularly in elite sports environments where even minimal performance improvements may determine competitive success.

Biomechanical analysis has also experienced significant progress through the implementation of deep learning and computer vision systems. Modern AI technologies enable automated motion tracking and movement recognition without requiring expensive laboratory environments (Cust et al., 2020). Such systems improve the precision of biomechanical assessment and facilitate the identification of inefficient movement patterns associated with reduced performance or increased injury risk.

The integration of wearable technologies with artificial intelligence systems represents another important development in sports science. Wearable sensors continuously collect physiological and biomechanical information including heart rate, acceleration, movement speed, and training load (Wang, Li, & Zhou, 2022). Artificial intelligence enables automated processing and interpretation of these data, providing coaches and sports scientists with detailed information regarding athlete fatigue, recovery status, and workload distribution.

Several reviewed studies highlighted the importance of artificial intelligence in injury prevention. Sports injuries remain one of the major challenges in competitive sports due to their negative impact on athlete health and long-term performance development. Machine learning models can identify injury risk factors by analyzing biomechanical asymmetries, excessive workload accumulation, and neuromuscular fatigue indicators (Van Eetvelde et al., 2021). Such findings demonstrate the potential of AI systems to support preventive interventions and reduce injury incidence.

Another important area of application involves tactical and strategic analysis in team sports. Artificial intelligence-powered video analysis systems automatically track player positioning,

tactical formations, movement trajectories, and passing networks during competitions (Shen, Wu, & Zhang, 2023). These technologies significantly improve the objectivity and efficiency of tactical analysis while supporting coaching decision-making processes.

The reviewed literature also emphasizes the growing importance of big data analytics in sports science. Large-scale datasets collected through wearable technologies and automated monitoring systems require advanced computational methods for efficient processing (Xiao, Chen, & Zhao, 2023). Artificial intelligence enables the integration and analysis of these datasets, allowing the identification of hidden performance patterns and predictive relationships among variables.

Deep learning methods have shown particularly strong effectiveness in biomechanical and movement analysis. Jia, Li, and Sun (2025) reported that deep neural networks improve motion tracking precision and biomechanical evaluation during sports activities. Such systems provide valuable insights regarding movement efficiency and technical performance optimization.

The development of digital sports ecosystems and cloud-based analytics platforms has further accelerated the implementation of artificial intelligence in kinesiology. Mengbin, Liu, and Zhao (2026) highlighted that digital sports systems integrating AI technologies enable continuous performance monitoring and automated statistical analysis in real-time environments. Consequently, modern sports organizations increasingly depend on AI-based systems for performance evaluation and tactical planning.

Artificial intelligence applications in kinesiology are also strongly connected with developments in healthcare and medical analytics. Several reviewed studies demonstrated similarities between AI implementation in sports science and healthcare systems, particularly regarding predictive modeling and physiological monitoring (Beam & Kohane, 2020; Rajkomar, Dean, & Kohane, 2022). These interdisciplinary connections contribute to the rapid advancement of sports analytics technologies.

Despite numerous advantages, several important limitations and challenges remain associated with the implementation of artificial intelligence in kinesiology. One of the primary concerns involves data quality and reliability. Machine learning algorithms require large, accurate, and well-structured datasets for effective model training. Incomplete or biased data may significantly reduce prediction accuracy and analytical validity (Beam, Manrai, & Ghassemi, 2021).

Ethical concerns also represent a major issue in sports analytics. Continuous athlete monitoring raises questions regarding privacy protection, data ownership, and the ethical use of sensitive physiological information. Sports organizations must establish clear ethical standards and ensure responsible implementation of AI-based monitoring systems (Rajkomar, Dean, & Kohane, 2022).

Another challenge is the interpretability of machine learning models. Deep learning systems often function as “black-box” models, making it difficult for coaches and sports scientists to fully understand the mechanisms responsible for specific predictions (Libbrecht & Noble, 2021). Consequently, interdisciplinary collaboration between sports scientists, statisticians, biomechanists, and computer scientists remains essential for the successful implementation of artificial intelligence in kinesiology.

The reviewed literature also suggests that artificial intelligence should not replace coaches and sports scientists but rather serve as a supportive analytical tool. Human expertise, contextual

understanding, and coaching experience remain crucial factors in interpreting analytical findings and making final decisions regarding training and competition strategies.

Future developments in artificial intelligence within sports science will likely focus on:

- autonomous sports analytics systems,
- real-time performance monitoring,
- advanced injury prediction models,
- individualized training prescription,
- integration of biomechanics and AI,
- tactical decision-support systems.

The findings of this review clearly indicate that artificial intelligence has enormous potential for improving statistical data processing, performance analysis, and decision-making processes in kinesiology and sports science. As AI technologies continue to evolve, their importance within modern sports systems will likely become even greater in the future.

References

1. Beam, A.L., & Kohane, I.S. (2020). Big data and machine learning in health care. JAMA, 323(13), 1317–1318.

2. Bzdok, D., Altman, N., & Krzywinski, M. (2021). Statistics versus machine learning. Nature Methods, 18(4), 233–234.

3. Claudino, J.G., Capanema, D.O., de Souza, T.V., et al. (2021). Current approaches to the use of artificial intelligence for injury risk assessment and performance prediction in team sports. Sports Medicine, 51(10), 1993–2009.

4. Cust, E.E., Sweeting, A.J., Ball, K., & Robertson, S. (2020). Machine and deep learning for sport-specific movement recognition. Journal of Sports Sciences, 37(5), 568–600.

5. Esteva, A., Robicquet, A., Ramsundar, B., et al. (2020). A guide to deep learning in healthcare. Nature Medicine, 25(1), 24–29.

6. Jia, Y., Li, H., & Sun, Q. (2025). Deep learning applications in sports performance analysis. Sports Medicine, 55(2), 211–229.

7. Libbrecht, M.W., & Noble, W.S. (2021). Machine learning applications in genetics and genomics. Nature Reviews Genetics, 22(6), 321–332.

8. Mengbin, A., Liu, X., & Zhao, R. (2026). Research status and evolutionary trends of digital sports. Frontiers in Sports and Active Living, 8, 1785033.

9. Rajkomar, A., Dean, J., & Kohane, I. (2022). Machine learning in medicine. New England Journal of Medicine, 380(14), 1347–1358.

10. Shen, Y., Wu, P., & Zhang, T. (2023). Data science and sports analytics in performance optimization. Journal of Sports Analytics, 9(2), 115–128.

11. Su, X., Zhang, Y., & Wang, L. (2022). Artificial intelligence applications in sports performance analysis. Sports Biomechanics, 21(7), 945–960.

12. Topol, E.J. (2021). High-performance medicine: The convergence of human and artificial intelligence. Nature Medicine, 27(1), 44–56.

13. Van Eetvelde, H., Mendonça, L.D., Ley, C., et al. (2021). Machine learning methods in sport injury prediction and prevention. Journal of Experimental Orthopaedics, 8(1), 27.

14. Wang, S., Li, Y., & Zhou, C. (2022). Wearable sensor technologies and artificial intelligence in sports monitoring. Sensors, 22(18), 6897.

15. Xiao, L., Chen, H., & Zhao, Y. (2023). Big data and predictive analytics in sports science. International Journal of Performance Analysis in Sport, 23(4), 455–472.

16. LeCun, Y., Bengio, Y., & Hinton, G. (2020). Deep learning. Nature, 521(7553), 436–444.

17. Jordan, M.I., & Mitchell, T.M. (2021). Machine learning: Trends, perspectives, and prospects. Science, 349(6245), 255–260.

18. Krittanawong, C., Johnson, K.W., Rosenson, R.S., et al. (2021). Deep learning for cardiovascular medicine. European Heart Journal, 42(25), 1958–1965.

19. Obermeyer, Z., & Emanuel, E.J. (2021). Predicting the future: Big data and machine learning in medicine. New England Journal of Medicine, 375(13), 1216–1219.

20. Beam, A.L., Manrai, A.K., & Ghassemi, M. (2021). Challenges to the reproducibility of machine learning models in health care. JAMA, 323(4), 305–306.

FULL PAPER 19

SCIENTIFIC PAPER

Motor and technical determinants of competitive success in croatian female cadet kumite athletes

Josefina Đuzel

Faculty of Kinesiology University of Split, Split, Croatia

Introduction

Kumite performance in karate is determined by the rapid and precise execution of offensive and defensive actions under time pressure, opponent interaction, and constantly changing tactical conditions. Contemporary research confirms that successful karate performance depends on a complex interaction of speed, agility, muscular power, flexibility, aerobic and anaerobic capacities, and sport-specific technical efficiency (Gaweł et al., 2025). In a recent systematic review, Gaweł et al. (2025) emphasized that force-velocity characteristics, speed, agility, flexibility, and both aerobic and anaerobic metabolism are relevant for high-level WKF karate performance.

In young karate athletes, the evaluation of basic and sport-specific motor abilities is particularly important because training effects, biological development, and technical learning occur simultaneously. Kabadayı et al. (2022) showed that structured core training in youth karate athletes may improve core endurance, agility, flexibility, sprinting, jumping, and kick performance, which confirms the importance of integrated conditioning in young karate practitioners. Similarly, Krkeljas and Kovac (2021) highlighted the relationship between functional movement, athletic performance, and karate-specific performance in adolescent karate athletes, supporting the use of multidimensional testing in this age group.

Although previous research has examined anthropometric and motor profiles of karate athletes, there remains a need to clarify which basic and karate-specific abilities most clearly differentiate successful female cadet kumite athletes. This is particularly relevant because cadet athletes are in a sensitive developmental period in which talent identification and training orientation may influence later competitive progression.

Therefore, the purpose of this study was to determine differences in basic and karate-specific motor abilities between more and less successful Croatian female cadet kumite athletes, both in the total sample and according to lower and higher weight categories.

Methods

Participants

The sample consisted of 101 Croatian female cadet karate athletes aged 14-16 years, all competing in kumite. Athletes were among the best cadet competitors in the Republic of Croatia at the time of testing. The sample was divided according to competitive quality into more successful and less successful athletes. In addition, athletes were classified into lower weight categories (n = 55) and higher weight categories (n = 46).

Variables and procedures

Basic motor abilities were assessed using tests of explosive strength, coordination, movement frequency, flexibility, repetitive strength, and static strength. The applied tests included standing long jump, 20 m sprint, medicine ball throw from a lying position, side steps, backward obstacle course, hand tapping, foot tapping, sit-and-reach straddle test, trunk lifts, and bent-arm hang.

Karate-specific motor abilities were assessed using tests related to karate movements and techniques, including Gedan barai frequency, Gedan barai-Gyaku zuki, Mawashi geri frequency, karate-specific side steps, and triangle movement. Technical performance was assessed through individual techniques and technique combinations, including Gyaku zuki, Kizame zuki, Mawashi geri, Gyaku zuki-Mawashi geri, Gyaku zuki-Uraken, and Kizame zuki-Gyaku zuki.

Competitive success was defined according to placement and number of victories achieved at regional competitions and the national championship held in Rijeka on December 2013.

Statistical analysis

Differences between more and less successful athletes were analyzed using multivariate analysis of variance (MANOVA), univariate analysis of variance (ANOVA), and canonical discriminant analysis. Results are presented as arithmetic mean +/- standard deviation, F-values, p-values, and correlations with the discriminant function. Statistical significance was interpreted according to the original analyses.

Results

More successful female cadet kumite athletes achieved better results in almost all basic motor tests. The largest differences were observed in 20 m sprint, standing long jump, side steps, medicine ball throw, and foot tapping, indicating the importance of explosive strength, agility/coordination, and movement frequency for competitive success.

Table 1. Differences in basic motor abilities between less successful and more successful female cadet kumite athletes, total sample (N = 101)

Variable	Less successful (n = 56)	More successful (n = 45)	F	p	DF
Standing long jump (cm)	169.21 +/- 17.63	185.76 +/- 15.28	24.70	0.000	-0.67
Hand tapping (freq.)	36.27 +/- 3.78	39.31 +/- 4.82	12.65	0.001	-0.48
20 m sprint (s)	3.97 +/- 0.26	3.70 +/- 0.24	28.86	0.000	0.72
Side steps (s)	9.97 +/- 0.81	9.28 +/- 0.75	19.69	0.000	0.59
Bent-arm hang (s)	29.81 +/- 17.36	35.44 +/- 16.00	2.81	0.097	-0.22
Trunk lifts (freq.)	44.27 +/- 6.38	50.07 +/- 10.10	12.34	0.001	-0.47
Backward obstacle course (s)	12.99 +/- 2.23	11.69 +/- 1.72	10.37	0.002	0.43
Sit-and-reach straddle (cm)	75.29 +/- 13.10	85.10 +/- 13.75	13.40	0.000	-0.49
Foot tapping (freq.)	20.34 +/- 1.64	21.96 +/- 2.27	17.23	0.000	-0.56
Medicine ball throw 2 kg (m)	5.00 +/- 0.64	5.58 +/- 0.68	19.44	0.000	-0.59

Legend: MANOVA: Wilks' lambda = 0.64; F = 5.08; p = 0.000; canonical R = 0.60. DF = correlation with discriminant function. Lower values indicate better performance in time-based tests.

In the karate-specific motor space, more successful athletes showed better results in four of five variables. The most pronounced difference was found in Mawashi geri frequency, followed by triangle movement, karate-specific side steps, and Gedan barai frequency. The combined Gedan barai-Gyaku zuki test did not significantly differentiate the groups.

Table 2. Differences in karate-specific motor abilities between less successful and more successful female cadet kumite athletes, total sample (N = 101)

Variable	Less successful (n = 56)	More successful (n = 45)	F	p	DF
Gedan barai (freq.)	30.32 +/- 5.32	33.84 +/- 4.78	11.97	0.001	-0.48
Gedan barai-Gyaku zuki (s)	3.99 +/- 0.67	3.86 +/- 0.60	0.95	0.333	0.13
Mawashi geri (freq.)	29.46 +/- 5.14	35.27 +/- 5.46	30.08	0.000	-0.76
Karate-specific side steps (s)	9.90 +/- 0.89	9.37 +/- 0.66	11.28	0.001	0.46
Triangle movement (s)	9.82 +/- 0.87	9.10 +/- 0.95	15.73	0.000	0.55

Legend: MANOVA: Wilks' lambda = 0.65; F = 10.10; p = 0.000; canonical R = 0.59. DF = correlation with discriminant function. Lower values indicate better performance in time-based tests.

The structure of discriminant functions differed between lower and higher weight categories. In lower weight categories, competitive success was primarily associated with sprint-type explosiveness, coordination, and foot movement speed. In higher weight categories, more successful athletes were differentiated mainly by explosive strength of the lower limbs, sprint speed, throwing power, agility, flexibility, and foot speed. In karate-specific motor abilities,

Mawashi geri frequency was the dominant differentiating variable in both weight-category groups, with stronger overall differentiation in higher weight categories.

Table 3. Summary of discriminant indicators according to weight category

Motor space	Weight category	Wilks' lambda	Canonical R	p	Main determinants of competitive success
Basic motor abilities	Lower weight categories	-	-	-	Sprint speed, coordination, foot movement frequency
Basic motor abilities	Higher weight categories	0.38	0.79	0.000	Standing long jump, 20 m sprint, medicine ball throw, agility, flexibility, foot tapping
Karate-specific motor abilities	Lower weight categories	0.74	0.51	0.009	Mawashi geri frequency; karate-specific agility indicators
Karate-specific motor abilities	Higher weight categories	0.49	0.72	0.000	Mawashi geri frequency, triangle movement, karate-specific side steps, Gedan barai frequency

Legend: The lower-weight-category indicators are summarized from the original discriminant interpretation. The strongest differentiation in higher weight categories was observed in both basic and karate-specific motor spaces.

Discussion

The main finding of this study is that more successful Croatian female cadet kumite athletes differ from less successful athletes in both basic and karate-specific motor abilities. The strongest differences in the basic motor space were related to sprint speed, standing long jump, side steps, medicine ball throw, and foot tapping. These results indicate that competitive success in cadet kumite depends on the ability to rapidly accelerate, change direction, generate explosive force, and perform high-frequency limb movements.

These findings are consistent with contemporary evidence showing that elite WKF karate performance is associated with force-velocity characteristics, speed, agility, muscular power, flexibility, and energy-system efficiency (Gaweł et al., 2025). In addition, the present results are aligned with previous research showing that elite karate competitors are characterized by specific anthropometric and physical performance profiles, with differences depending on competitive discipline and performance level (Koropanovski et al., 2011).

The karate-specific motor results additionally emphasize the importance of Mawashi geri frequency. This variable showed the largest difference between more and less successful athletes in the total sample and remained an important determinant across weight categories. This suggests that the ability to repeatedly execute fast and efficient kicking actions may represent a key situational determinant of performance in female cadet kumite. Such interpretation is supported by Kabadayı et al. (2022), who included kick performance among important outcome indicators in youth karate training research.

The differentiation between lower and higher weight categories is also practically important. In lower weight categories, competitive success appears to be more strongly associated with speed regulation, coordination, and rapid leg movement. In higher weight categories, the determinants are more strongly related to force regulation, particularly explosive strength, sprint ability, throwing power, and karate-specific agility. This supports the idea that training programs should not be identical for all cadet kumite athletes, but should be adjusted according to anthropometric and competitive characteristics.

From a practical coaching perspective, the results support an integrated training model. General conditioning should develop sprint speed, lower-limb explosive strength, upper-limb power, trunk strength, flexibility, and agility. At the same time, karate-specific training should emphasize rapid kicking frequency, efficient changes of direction, movement in triangular patterns, and the technical quality of offensive and defensive combinations. Krkeljas and Kovac (2021) also supported the use of athletic and karate-specific performance assessments in adolescent karate athletes, while Nema et al. (2024) emphasized the relationship between conditioning parameters and sport performance indicators in karate.

Taken together, the present findings confirm that competitive success in young female kumite athletes is not determined by one isolated ability, but by the integrated contribution of

basic motor abilities, sport-specific motor efficiency, and technical execution. This has direct practical implications for talent identification, training planning, and long-term development of female karate athletes.

Conclusions

Competitive success in Croatian female cadet kumite athletes is determined by the integrated contribution of basic motor abilities, karate-specific motor abilities, and technical efficiency. More successful athletes are characterized by higher levels of explosive strength, sprint speed, agility/coordination, movement frequency, and karate-specific kicking performance.

The most important practical implication is that training programs for female cadet kumite athletes should combine general neuromuscular development with karate-specific speed and technical tasks. Training interventions should particularly emphasize the development of speed, explosive power, leg movement frequency, agility, repeated Mawashi geri execution, and efficient movement in triangular movement patterns.

Training priorities should also be adapted to weight category, with greater emphasis on speed regulation in lower categories and force regulation in higher categories.

References

1. Gaweł, E., Drozd, M., & Zając, A. (2025). Current trends in physical and physiological profile of elite WKF karate athletes: A systematic review. *BMC Sports Science, Medicine and Rehabilitation, 17*, Article 6. https://doi.org/10.1186/s13102-024-01047-5
2. Kabadayı, M., Karadeniz, S., Yılmaz, A. K., Karaduman, E., Bostancı, Ö., Akyildiz, Z., Clemente, F. M., & Silva, A. F. (2022). Effects of core training in physical fitness of youth karate athletes: A controlled study design. *International Journal of Environmental Research and Public Health, 19*(10), Article 5816. https://doi.org/10.3390/ijerph19105816
3. Koropanovski, N., Berjan, B., Božić, P. R., Pazin, N., Sanader, A., Jovanović, S., & Jarić, S. (2011). Anthropometric and physical performance profiles of elite karate kumite and kata competitors. *Journal of Human Kinetics, 30*, 107-114. https://doi.org/10.2478/v10078-011-0078-x
4. Krkeljas, Z., & Kovac, D. (2021). Relationship between functional movement screen, athletic and karate performance in adolescents. *Human Movement, 22*(2), 16-21. https://doi.org/10.5114/hm.2021.100009
5. Nema, K., Ruzbarsky, P., Rydzik, Ł., & Peric, T. (2024). Relationship of selected conditioning parameters and sport performance indicators in karate. *Frontiers in Sports and Active Living, 6*, Article 1433117. https://doi.org/10.3389/fspor.2024.1433117

FULL PAPER 20

SCIENTIFIC PAPER

Personality traits across playing positions in Croatian female cadet handball players

Marijana Čavala

Faculty of Kinesiology, University of Split, Cro Sport Talent & Health and Longevity Lab, Split, Croatia

Introduction

The identification and development of young athletes in team sports require an integrated understanding of the anthropological characteristics that contribute to sports performance. In handball, performance is determined by the interaction of morphological, motor, technical, tactical, cognitive, and psychosocial factors. Although anthropometric and motor abilities have traditionally received greater attention in talent selection, psychological characteristics may provide additional information on how young players respond to training, competition, positional demands, and interpersonal dynamics within a team.

Research on psychosocial characteristics in handball is less extensive than research on other anthropological dimensions, but available findings suggest that personality and social functioning are relevant to understanding player development (Čavala et al., 2013). Rogulj, Nazor, Srhoj, and Božin (2006) examined personality traits in junior handball players and reported no statistically significant differences between competitively efficient and less efficient players in the basic Eysenck dimensions, although successful players showed higher dissimulation tendencies. In elite female handball players, differences among playing positions were found in extraversion, with wings showing higher values, and in psychoticism, which was more pronounced in pivots (Rogulj, Srhoj, Nazor, Srhoj, & Čavala, 2005). These findings indicate that personality characteristics may be partly associated with the functional demands and selection processes related to playing positions.

The goalkeeper position is particularly specific because the player is spatially and functionally separated from the rest of the team during many phases of the game. Goalkeepers often act independently, perform highly specialized defensive tasks, and do not participate in the same way as field players during positional attack. Such demands may be related to different psychological profiles or to the long-term shaping of behavior through position-specific training and competition experience.

Therefore, the purpose of this study was to determine differences in basic personality traits among female cadet handball players according to playing position. The expected practical contribution of the study is in training and competition practice, particularly in the formation of anthropological models for specific playing positions during player selection.

This conference paper presents a focused secondary analysis of the personality-trait segment from a broader previously published study on somatotype, personality traits, playing position, and player quality in Croatian female cadet handball players (Čavala et al., 2013).

Methods

Participants

The sample consisted of 70 female cadet handball players from the Republic of Croatia, with a mean age of 15.31 years. The players were members of Croatian handball clubs from Sinj,

Koprivnica, Karlovac, Split, Sesvete, Cerna, Bjelovar, Opatija, Đakovo, Vranjic, Rijeka, Varaždin, Zagreb, Ploče, Knin, and Kaštel Sućurac. According to playing position, the sample included 9 goalkeepers, 30 backcourt players, 20 wings, and 11 pivots. Thirty-four players belonged to a wider national-team selection group and were therefore considered top-level Croatian cadet players, whereas 36 players had never been invited to the cadet national team and were considered average-level players. All participants were clinically healthy, had no pronounced motor aberrations, and participated voluntarily. The procedures followed ethical standards for psychological testing, and the personality assessment was conducted by a qualified psychologist.

Variables and procedures

Personality traits were assessed using the junior version of the Eysenck Personality Questionnaire - EPQ-Junior (Eysenck & Eysenck, 1994, 2003). The questionnaire contains 81 dichotomous items and measures three broad personality superfactors - psychoticism, introversion-extraversion, and neuroticism - as well as the lie/dissimulation scale. The questionnaire was administered according to standard instructions. Players were asked to respond to all items, including those that might appear more appropriate for younger children, because the instrument was designed for a broad youth age range. Scores were calculated using four scoring keys corresponding to the P, E, N, and L dimensions.

Statistical analysis

Descriptive parameters were calculated for the analyzed variables, including arithmetic mean, standard deviation, minimum and maximum values, skewness, and kurtosis. Distribution normality was examined using the Kolmogorov-Smirnov test. Differences in the personality space according to playing position were tested using multivariate analysis of variance (MANOVA), followed by univariate analyses of variance (ANOVA). Statistical analyses were performed using the Statistica software package.

Results

The multivariate analysis did not show a statistically significant overall difference among playing positions in the set of personality variables (Wilks' lambda = 0.80; df1 = 12; df2 = 166; F = 1.20; p = 0.29). Therefore, when personality traits were considered as a multidimensional space, female cadet handball players did not differ significantly according to playing position.

Univariate analysis indicated a statistically significant difference only in introversion-extraversion (F = 2.91; p = 0.04). Goalkeepers had the lowest mean score on this dimension (15.78), whereas backcourt players, wings, and pivots showed higher and relatively similar values. No statistically significant differences were found for psychoticism, neuroticism, or dissimulation.

Table 1. Multivariate and univariate analysis of variance for personality traits according to playing position

Variable	Goalkeeper M	Backcourt M	Wing M	Pivot M	F	p	Interpretation
P	1.89	3.27	2.85	2.18	1.49	0.22	ns
E	15.78	18.73	18.10	18.18	2.91	0.04	significant
N	8.11	10.50	10.60	10.00	1.10	0.35	ns
L	8.44	7.13	7.15	7.64	0.32	0.81	ns

Legend: MANOVA: Wilks' lambda = 0.80; df1 = 12; df2 = 166; F = 1.20; p = 0.29. P = psychoticism; E = introversion-extraversion; N = neuroticism; L = lie/dissimulation scale; M = arithmetic mean; ns = not statistically significant.

Discussion

The main finding of this study was that Croatian female cadet handball players did not differ significantly in the overall personality space according to playing position. This result supports the view that basic personality traits should not be treated as isolated or decisive indicators of positional suitability in youth handball. Rather, they represent only one component within a

complex anthropological structure that also includes morphological, motor, cognitive, technical, tactical, and social dimensions.

Although the multivariate result was not significant, the univariate analysis showed a significant difference in introversion-extraversion. Goalkeepers obtained lower scores on this dimension than field players, suggesting a relatively more introverted profile. This finding is practically meaningful because the goalkeeper role differs from other playing positions in both spatial organization and functional responsibility. The goalkeeper operates in a clearly defined area, is often separated from the collective offensive phase, and performs specialized actions in which immediate individual responsibility is highly visible. These characteristics may attract players with a more reserved behavioral profile, but they may also shape psychological tendencies through long-term exposure to position-specific training and competition demands.

Previous work on elite female handball players reported that extraversion was more pronounced among wings, whereas psychoticism was more pronounced among pivots (Rogulj et al., 2005). The present findings partly correspond with this line of research by again pointing to the relevance of the introversion-extraversion dimension in relation to positional demands. However, the absence of significant differences in psychoticism, neuroticism, and dissimulation suggests that psychological profiling should be interpreted cautiously, especially in youth categories in which personality development is still ongoing.

Recent handball studies support this cautious interpretation of personality and psychosocial indicators. Muntianu, Abalaşei, Nichifor, and Dumitru (2022) showed that psychological characteristics of junior handball players, including motivational persistence, planning, and self-discipline, should be considered together with psychomotor abilities in profiling, training, and talent identification. Similarly, Juhász et al. (2025), in a study of elite and sub-elite Hungarian junior handball players, reported that selected personality traits contributed to performance differentiation, while also emphasizing the need to evaluate psychological characteristics within a broader multidimensional model rather than as isolated selection criteria.

From a practical perspective, coaches and sport scientists should avoid using personality traits as rigid criteria for player selection. Instead, psychological assessment may be useful as a complementary tool for understanding individual responses to training, communication style, competitive stress, and preferred roles within the team. In the case of goalkeepers, additional attention may be given to autonomy, concentration, emotional regulation, and coping with isolated responsibility. These qualities cannot be reduced to a single personality scale, but they can be supported through appropriate training design and psychological guidance.

A limitation of this study is the relatively small number of players within some positional groups, especially goalkeepers and pivots, which may reduce statistical power. In addition, the study used broad personality dimensions rather than sport-specific psychological constructs. Future studies should combine personality measures with indicators of motivation, coping, self-confidence, team cohesion, and objective performance parameters, preferably using longitudinal designs that can distinguish selection effects from the developmental influence of playing position.

Although the dataset was previously reported within a broader anthropological framework including somatotype and player quality, the present paper isolates the personality-trait findings and interprets them specifically in relation to positional demands and practical implications for youth female handball.

Conclusions

The results did not confirm statistically significant overall differences in personality traits among female cadet handball players according to playing position. A univariate difference was observed only in introversion-extraversion, with goalkeepers showing lower scores than field players, indicating a relatively higher level of introversion in this position.

These findings support the conclusion that player selection and positional orientation in youth female handball should be based on integrated anthropological models rather than isolated personality dimensions. The practical implication is that psychological assessment may contribute to individualized coaching and communication, particularly for goalkeepers, but should be interpreted together with morphological, motor, technical, tactical, and social indicators.

References

1. Čavala, M., Trninić, V., Jašić, D., & Tomljanović, M. (2013). The influence of somatotype components and personality traits on the playing position and the quality of top Croatian female cadet handball players. Collegium Antropologicum, 37(Suppl. 2), 97-100.
2. Eysenck, H. J., & Eysenck, S. B. G. (1994). Manual of the Eysenck Personality Questionnaire. Hodder & Stoughton.
3. Eysenck, H. J., & Eysenck, S. B. G. (2003). Eysenck Personality Questionnaire Junior. Naklada Slap.
4. Juhász, I., Berki, T., Tóth, R., Nagy, S., Tóth, L., & Bognár, J. (2025). A comparative study of personality and cognitive functions in elite and sub-elite Hungarian junior handball players. BMC Psychology, 13, Article 1020. https://doi.org/10.1186/s40359-025-03381-w
5. Muntianu, V.-A., Abalașei, B.-A., Nichifor, F., & Dumitru, I.-M. (2022). The correlation between psychological characteristics and psychomotor abilities of junior handball players. Children, 9(6), Article 767. https://doi.org/10.3390/children9060767
6. Rogulj, N., Nazor, M., Srhoj, V., & Božin, D. (2006). Differences between competitively efficient and less efficient junior handball players according to their personality traits. Kinesiology, 38(2), 158-163.
7. Rogulj, N., Srhoj, V., Nazor, M., Srhoj, L., & Čavala, M. (2005). Some anthropologic characteristics of elite female handball players at different playing positions. Collegium Antropologicum, 29(2), 705-709.

PART III · DIO III

FULL PAPERS (CROATIAN LANGUAGE)

Cjeloviti recenzirani radovi · Peer-reviewed full papers (Croatian)

RAD 1

ZNANSTVENI RAD

Učinci sportova s reketom na fizičke, psihološke i socijalne ishode kod osoba s invaliditetom: sustavni pregled i meta-analiza

Lidija Petrinović

Univesity of Zagreb, Faculty of Kinesiology, Zagreb, Croatia.

Uvod

Tijekom posljednjih desetljeća tjelesna aktivnost sve se više prepoznaje kao temeljna komponenta promicanja zdravlja i prevencije bolesti. Za osobe s invaliditetom sudjelovanje u strukturiranoj tjelesnoj aktivnosti posebno je važno jer doprinosi ne samo fizičkom zdravlju nego i psihološkoj dobrobiti i socijalnoj integraciji (Laferrier et al., 2012; Hutzler i Bergman, 2011).

Unatoč tim dobro dokumentiranim koristima, osobe s invaliditetom često se suočavaju sa značajnim preprekama u sudjelovanju u tjelesnoj aktivnosti, uključujući okolišne, društvene i ekonomske čimbenike (Jaacks et al., 2019; Marmot, 2005).

Sportovi s reketom, kao što su tenis, stolni tenis i badminton, predstavljaju jedinstvenu i prilagodljivu kategoriju tjelesne aktivnosti koja je posebno pogodna za osobe s invaliditetom. Ovi sportovi kombiniraju aerobne i anaerobne zahtjeve s visokom razinom koordinacije, brzine reakcije i kognitivnog angažmana (Goosey-Tolfrey, 2010).

Njihova prilagodljivost omogućuje izmjene pravila, opreme i uvjeta igranja, čime se omogućuje sudjelovanje osobama s različitim razinama fizičkih i funkcionalnih ograničenja (Tweedy i Vanlandewijck, 2011).

Među sportovima s reketom, tenis u kolicima jedan je od najrazvijenijih i najraširenijih adaptiranih sportova. Istraživanja su pokazala da sudjelovanje u tenisu u kolicima poboljšava snagu gornjeg dijela tijela, kardiovaskularnu kondiciju i mobilnost (Goosey-Tolfrey, 2010; Aidar et al., 2018).

Slično tome, stolni tenis identificiran je kao vrlo učinkovita rehabilitacijska aktivnost zbog naglaska na finoj motorici, ravnoteži i koordinaciji (Kong et al., 2024). Parabadminton, relativno nov dodatak Paraolimpijskim igrama, također pokazuje značajne koristi u pogledu fizičke izvedbe i funkcionalne neovisnosti (Kim et al., 2024).

Osim fizičkih koristi, sudjelovanje u adaptiranim sportovima s reketom snažno je povezano s poboljšanjem psiholoških ishoda. Studije dosljedno pokazuju da sudjelovanje u sportu povećava samopoštovanje, smanjuje simptome anksioznosti i depresije te poboljšava opće mentalno zdravlje (Isidoro-Cabañas et al., 2023; Dehghansai et al., 2017).

Ove psihološke koristi posebno su važne za osobe s invaliditetom koje su izložene povećanom riziku od socijalne izolacije i mentalnih poteškoća (Hutzler i Bergman, 2011).

Socijalna integracija predstavlja još jednu ključnu dimenziju sudjelovanja u sportu. Adaptirani sportovi pružaju mogućnosti osobama s invaliditetom za interakciju s drugima, razvoj socijalnih mreža i stvaranje osjećaja pripadnosti (Dehghansai et al., 2017).

Sudjelovanje u sportu također je povezano s povećanom neovisnošću i većim uključivanjem u zajednicu, što doprinosi poboljšanoj kvaliteti života (Laferrier et al., 2012).

S fiziološkog aspekta, redovito sudjelovanje u sportovima s reketom doprinosi poboljšanju kardiovaskularne funkcije, mišićne snage i metaboličkog zdravlja (Aidar et al., 2018).

Ove koristi posebno su važne s obzirom na povećani rizik od kroničnih bolesti kod osoba s invaliditetom, uključujući pretilost, kardiovaskularne bolesti i metaboličke poremećaje (Hruby i Hu, 2015; Ng et al., 2014).

Fizička neaktivnost ostaje značajan problem u ovoj populaciji, što dodatno naglašava važnost dostupnih i zanimljivih oblika tjelesne aktivnosti (Malik et al., 2013).

Širi kontekst zdravstvenih nejednakosti također je važan. Socioekonomski čimbenici značajno utječu na pristup sportu i tjelesnoj aktivnosti (Marmot, 2005; Cutler i Lleras-Muney, 2010).

Ove nejednakosti posebno su izražene kod osoba s invaliditetom, što naglašava potrebu za inkluzivnim sportskim programima (Hutzler i Bergman, 2011).

U posljednje vrijeme raste interes za korištenje adaptiranih sportova kao terapijskog alata u rehabilitaciji. Dokazi pokazuju da strukturirani sportski programi mogu značajno poboljšati funkcionalni oporavak (Tweedy i Vanlandewijck, 2011).

Unatoč rastućem broju istraživanja, još uvijek nedostaje sveobuhvatna analiza učinaka sportova s reketom kod osoba s invaliditetom.

Stoga je cilj ovog rada procijeniti učinke sportova s reketom na fizičke, psihološke i socijalne ishode kod osoba s invaliditetom.

Metode

Dizajn istraživanja

Ovo istraživanje provedeno je u skladu s PRISMA smjernicama za sustavne preglede i meta-analize.

Strategija pretraživanja

Pretražene baze podataka:

- PubMed
- Scopus
- Web of Science

Ključne riječi:

- „invaliditet AND sportovi s reketom“
- „rehabilitacija tenis u kolicima“
- „ishodi stolnog tenisa kod osoba s invaliditetom“

Kriteriji uključenja

- odrasle osobe s tjelesnim ili neurološkim invaliditetom
- intervencije koje uključuju sportove s reketom
- kvantitativni ishodi (fizički ili psihološki)

Statistička analiza

Veličine učinka izračunate su pomoću standardizirane srednje razlike (SMD). Zbog heterogenosti među studijama korišten je model slučajnih učinaka (random-effects model).

Rezultati

Karakteristike studija

- Ukupan broj studija: 45
- U meta-analizu uključeno: 12 studija
- Populacija: ozljeda kralježnične moždine (SCI), moždani udar, Parkinsonova bolest, amputacije

Fizički ishodi

Sudjelovanje u sportovima s reketom značajno je poboljšalo:

- kardiovaskularnu funkciju
- ravnotežu
- motoričku koordinaciju

Intervencije stolnog tenisa pokazale su poboljšanja u ravnoteži i motoričkoj izvedbi.

Dodatno, para stolni tenis poboljšao je kardiovaskularnu i autonomnu funkciju kod osoba s ozljedom kralježnične moždine.

Psihološki ishodi

Meta-analiza je pokazala:

- poboljšanje mentalne kvalitete života:
  SMD = 0,62–0,71 ($p < 0,01$)
- smanjenje stresa i anksioznosti
- povećanje samoučinkovitosti

Adaptirani sportovi značajno poboljšavaju mentalno blagostanje i socijalno funkcioniranje.

Socijalni ishodi

Sudjelovanje je dovelo do:

- poboljšane socijalne integracije
- povećane neovisnosti
- jačanja osobnog identiteta

Adaptirani sportovi smanjuju socijalnu izolaciju i poboljšavaju sudjelovanje u društvu.

Rasprava

Ovaj sustavni pregled i meta-analiza pružaju sveobuhvatne dokaze koji potvrđuju pozitivne učinke sportova s reketom na osobe s invaliditetom. Rezultati pokazuju da sudjelovanje u adaptiranim sportovima s reketom značajno doprinosi poboljšanju fizičkih, psiholoških i socijalnih ishoda. Ovi nalazi u skladu su s rastućim brojem istraživanja koja

naglašavaju ulogu sporta kao multidimenzionalne intervencije u populaciji osoba s invaliditetom (Laferrier et al., 2012; Dehghansai et al., 2017; Hutzler i Bergman, 2011).

Jedan od najznačajnijih nalaza ovog pregleda jest značajno poboljšanje psihološke dobrobiti povezano sa sudjelovanjem u sportovima s reketom. Dobrobiti za mentalno zdravlje, uključujući smanjenje simptoma depresije i anksioznosti te povećanje samopoštovanja, dosljedno su zabilježene u više studija (Isidoro-Cabañas et al., 2023; Kim et al., 2024; Dehghansai et al., 2017). Ovi rezultati podudaraju se s prethodnim istraživanjima koja sugeriraju da sudjelovanje u sportu poboljšava psihološku otpornost i emocionalnu regulaciju kod osoba s invaliditetom (Laferrier et al., 2012; Hutzler i Bergman, 2011).

Uočena poboljšanja mentalnog zdravlja mogu se objasniti kroz nekoliko mehanizama. Sudjelovanje u sportu pruža prilike za socijalnu interakciju, postavljanje ciljeva i postizanje uspjeha, što doprinosi povećanoj samoučinkovitosti i osjećaju kompetentnosti (Bandura, 1997; Dehghansai et al., 2017). Osim toga, tjelesna aktivnost utječe na neurobiološke procese, uključujući oslobađanje endorfina i neurotransmitera povezanih s regulacijom raspoloženja (Malik et al., 2013; Hruby i Hu, 2015).

Što se tiče fizičkih ishoda, rezultati pokazuju značajna poboljšanja u kardiovaskularnoj kondiciji, mišićnoj snazi i motoričkoj koordinaciji. Ovi nalazi u skladu su s prethodnim istraživanjima koja su analizirala učinke adaptiranih sportskih intervencija (Aidar et al., 2018; Goosey-Tolfrey, 2010). Sportovi s reketom, posebno, zahtijevaju brze pokrete, snagu gornjeg dijela tijela i koordinaciju, što ih čini učinkovitima za poboljšanje funkcionalne sposobnosti (Kong et al., 2024; Tweedy i Vanlandewijck, 2011).

Poboljšanja motoričke koordinacije uočena u intervencijama stolnog tenisa i badmintona naglašavaju važnost fine motorike i brzine reakcije u rehabilitacijskim programima (Kong et al., 2024; Kim et al., 2024). Ove vještine ključne su za svakodnevno funkcioniranje i neovisnost, osobito kod osoba s neurološkim oštećenjima.

Još jedan važan nalaz ovog pregleda jest uloga sportova s reketom u poticanju socijalne uključenosti. Sudjelovanje u adaptiranim sportovima povezano je s povećanom socijalnom interakcijom, boljim komunikacijskim vještinama i jačim osjećajem pripadnosti (Dehghansai et al., 2017; Hutzler i Bergman, 2011). Ove socijalne koristi posebno su važne s obzirom na visoku razinu socijalne izolacije među osobama s invaliditetom (Marmot, 2005; Neuman et al., 2013).

Koncept socijalne integracije usko je povezan sa širim okvirom socijalnih determinanti zdravlja. Osobe s invaliditetom često se suočavaju sa strukturnim preprekama koje ograničavaju pristup tjelesnoj aktivnosti, uključujući nedostatak dostupne infrastrukture i financijska ograničenja (Marmot, 2005; Cutler i Lleras-Muney, 2010). Rezultati ovog istraživanja sugeriraju da adaptirani sportski programi mogu pomoći u smanjenju tih nejednakosti pružanjem dostupnih mogućnosti za sudjelovanje (Jaacks et al., 2019; Hutzler i Bergman, 2011).

S javnozdravstvenog aspekta, uočena poboljšanja fizičkog zdravlja posebno su značajna. Osobe s invaliditetom izložene su povećanom riziku od kroničnih bolesti, uključujući pretilost, kardiovaskularne bolesti i metaboličke poremećaje (Ng et al., 2014; Hruby i Hu, 2015). Redovito sudjelovanje u sportovima s reketom može pomoći u smanjenju tih rizika poticanjem tjelesne aktivnosti i poboljšanjem metaboličkog zdravlja (Malik et al., 2013; Popkin, 2006).

Rezultati ovog pregleda također naglašavaju važnost prilagodbe sportskih intervencija specifičnim populacijama. Razlike u ishodima uočene su ovisno o vrsti invaliditeta, intenzitetu intervencije i trajanju sudjelovanja. To je u skladu s prethodnim istraživanjima koja ukazuju na potrebu individualiziranog pristupa kako bi se maksimalizirale koristi tjelesne aktivnosti kod osoba s invaliditetom (Tweedy i Vanlandewijck, 2011; Aidar et al., 2018).

Unatoč pozitivnim rezultatima, potrebno je uzeti u obzir određena ograničenja. Prvo, heterogenost uključenih studija ograničava mogućnost generalizacije rezultata. Razlike u

dizajnu studija, veličini uzorka i mjerenim ishodima mogu utjecati na dobivene rezultate (Higgins et al., 2011). Drugo, mnoge studije uključene u analizu imale su relativno male uzorke, što može smanjiti statističku snagu (Dehghansai et al., 2017).

Dodatno, nedostatak dugoročnih praćenja ograničava procjenu održivosti uočenih učinaka. Buduća istraživanja trebala bi se usmjeriti na longitudinalne studije kako bi se bolje razumjeli dugoročni učinci sudjelovanja u sportovima s reketom kod osoba s invaliditetom (Isidoro-Cabañas et al., 2023; Kim et al., 2024).

Još jedno ograničenje odnosi se na nedovoljnu zastupljenost određenih skupina invaliditeta u literaturi. Dok se većina studija fokusirala na osobe s tjelesnim invaliditetom, manji broj istraživanja obuhvaćao je osobe s intelektualnim ili senzornim oštećenjima. To ukazuje na potrebu za inkluzivnijim istraživanjima koja će obuhvatiti širi spektar populacija (Hutzler i Bergman, 2011; Dehghansai et al., 2017).

Na kraju, treba istaknuti metodološka ograničenja poput nedostatka randomiziranih kontroliranih studija i mogućeg pristranog objavljivanja rezultata. Iako korištenje modela slučajnih učinaka djelomično rješava problem heterogenosti, potrebna su dodatna visokokvalitetna istraživanja kako bi se potvrdili ovi nalazi (Higgins et al., 2011).

Praktične implikacije

Rezultati ovog istraživanja imaju važne implikacije za rehabilitaciju i javno zdravstvo. Sportovi s reketom mogu se učinkovito integrirati u rehabilitacijske programe kako bi se poboljšali fizički i psihološki ishodi. Stručnjaci bi trebali razmotriti uključivanje adaptiranih sportova u terapijske planove, osobito kod osoba s ozljedama kralježnične moždine, neurološkim bolestima i motoričkim oštećenjima (Aidar et al., 2018; Goosey-Tolfrey, 2010).

Zaključak

Sportovi s reketom predstavljaju učinkovitu intervenciju za poboljšanje fizičkih i psiholoških ishoda kod osoba s invaliditetom. Ove sportove treba smatrati ključnom komponentom rehabilitacijskih i javnozdravstvenih strategija.

Literatura

1. Aidar, F.J. et al. (2018) ‘Effects of physical exercise in people with disabilities’, Journal of Physical Activity and Health, 15(3), pp. 201–210.
2. Allender, S. et al. (2008) ‘Urban–rural differences’, International Journal of Obesity, 32(6), pp. 1045–1053.
3. Dehghansai, N. et al. (2017) ‘Psychological development in athletes with disabilities’, Disability and Rehabilitation, 39(21), pp. 2107–2113.
4. Goosey-Tolfrey, V. (2010) ‘Supporting participation in wheelchair sport’, Sports Medicine, 40(5), pp. 377–390.
5. Higgins, J.P.T. et al. (2011) Cochrane Handbook for Systematic Reviews. London: Wiley.
6. Hruby, A. and Hu, F.B. (2015) ‘The epidemiology of obesity’, PharmacoEconomics, 33(7), pp. 673–689.
7. Hutzler, Y. and Bergman, U. (2011) ‘Facilitators and barriers’, Adapted Physical Activity Quarterly, 28(3), pp. 257–272.
8. Isidoro-Cabañas, E. et al. (2023) ‘Adaptive sport meta-analysis’, Healthcare, 11(9), pp. 1201–1215.
9. Jaacks, L.M. et al. (2019) ‘The obesity transition’, Obesity Reviews, 20(S2), pp. 2–8.
10. Kim, D. et al. (2024) ‘Mental health and adaptive sport’, Journal of Rehabilitation Medicine, 56(2), pp. 89–98.
11. Kong, P. et al. (2024) ‘Motor function improvements’, Sports Science Review, 33(1), pp. 45–60.

12. Laferrier, J.Z. et al. (2012) ‘Benefits of physical activity’, Disability and Health Journal, 5(4), pp. 255–261.
13. Malik, V.S. et al. (2013) ‘Global obesity trends’, Nature Reviews Endocrinology, 9(1), pp. 13–27.
14. Marmot, M. (2005) Social Determinants of Health. Oxford: OUP.
15. Ng, M. et al. (2014) ‘Global obesity prevalence’, The Lancet, 384(9945), pp. 766–781.
16. Popkin, B.M. (2006) ‘Nutrition transition’, American Journal of Clinical Nutrition, 84(2), pp. 289–298.
17. St-Onge, M.P. and Gallagher, D. (2010) ‘Body composition changes’, Annals of NY Academy of Sciences, 904, pp. 437–448.
18. Tweedy, S.M. and Vanlandewijck, Y.C. (2011) ‘Classification in Paralympic sport’, British Journal of Sports Medicine, 45(4), pp. 259–269.
19. Villareal, D.T. et al. (2005) ‘Obesity in older adults’, NEJM, 353(4), pp. 123–135.
20. World Health Organization (2021) Obesity and overweight. Geneva.

RAD 2

ZNANSTVENI RAD

Intervalni trening visokog intenziteta kod nogometašica: sustavni pregled

Davorin Antonić

Larus Sport d.o.o.

Uvod

Moderni nogomet karakterizira se kao sport s povremenim visokim intenzitetom koji zahtijeva da igrači kontinuirano izvode eksplozivne aktivnosti poput sprintanja, ubrzavanja, usporavanja i brzih promjena smjera, izmjenjivane s razdobljima aktivnosti nižeg intenziteta (Mohr et al., 2002; Andrzejewski et al., 2013; Datson, 2014).

U posljednjih nekoliko godina fiziološki i izvedbeni zahtjevi ženskog nogometa značajno su porasli zbog profesionalizacije sporta i unapređenja trenažnih metodologija (Datson, 2014; Kubayi, 2019). Posljedično, optimizacija tjelesne pripremljenosti postala je ključan čimbenik za poboljšanje izvedbe kod nogometašica.

Tijekom natjecateljske utakmice nogometašice prijeđu približno 9–11 km, pri čemu se 15–20% te udaljenosti izvodi visokim intenzitetom (Mohr et al., 2002; Datson, 2014). Osim toga, igračice izvode između 150 i 200 visokointenzivnih aktivnosti, uključujući sprintove, skokove, duelske situacije i promjene smjera, što postavlja velike zahtjeve na aerobni i anaerobni energetski sustav (Andrzejewski et al., 2013; Kubayi, 2019).

Aerobni kapacitet, koji se najčešće procjenjuje pomoću maksimalnog primitka kisika (VO_2max), ključan je za održavanje izvedbe i oporavak između visokointenzivnih napora (Buchheit i Laursen, 2013; Iaia et al., 2009). Elitne nogometašice obično imaju VO_2max vrijednosti između 49 i 57 $ml \cdot kg^{-1} \cdot min^{-1}$, što naglašava važnost kardiovaskularne kondicije (Datson, 2014).

Osim aerobne izdržljivosti, anaerobni kapacitet ima ključnu ulogu u izvedbi tijekom utakmice. Aktivnosti visokog intenziteta, poput sprintanja i brzih promjena smjera, uvelike ovise o anaerobnom metabolizmu, posebno o fosfagenom i glikolitičkom sustavu (Laursen i Jenkins, 2002; Gabbett, 2008).

Sposobnost ponavljanih sprintova (RSA) identificirana je kao ključni pokazatelj izvedbe u nogometu i snažno je povezana s uspjehom i razinom natjecanja (Gabbett, 2008; Rampinini et al., 2009). Nadalje, neuromuskularne sposobnosti poput agilnosti, snage i brzine ključne su za učinkovito izvođenje sportskih zadataka (Chaouachi et al., 2012; Haugen et al., 2012).

Tradicionalne metode treninga izdržljivosti dugo su korištene za poboljšanje aerobnog kapaciteta, no često ne uspijevaju replicirati povremeni karakter nogometne igre (Iaia et al., 2009). Nasuprot tome, HIIT se razvio kao vrlo učinkovita i vremenski efikasna metoda koja vjerno simulira fiziološke zahtjeve nogometa (Buchheit i Laursen, 2013; Gibala et al., 2012).

HIIT uključuje ponavljane intervale visokog intenziteta izmjenjivane s razdobljima oporavka te je dokazano da značajno poboljšava aerobnu i anaerobnu izvedbu (Weston et al., 2014; Laursen i Buchheit, 2019).

Jedna od ključnih prednosti HIIT-a je njegova sposobnost istodobnog poboljšanja više fizioloških sustava. Istraživanja pokazuju povećanje gustoće mitohondrija, aktivnosti oksidativnih enzima i kardiovaskularne učinkovitosti (Gibala et al., 2012; Weston et al., 2014).

Također, HIIT poboljšava neuromuskularnu izvedbu, uključujući brzinu sprinta, snagu i otpornost na umor (Arazi et al., 2017; Buchheit et al., 2010).

U novije vrijeme raste interes za primjenu HIIT-a s promjenama smjera (COD HIIT). Ovaj oblik treninga uključuje višesmjerne pokrete i bolje simulira uvjete igre (Chaouachi et al., 2012; Young

et al., 2002). Istraživanja pokazuju da COD HIIT može dovesti do većih poboljšanja u agilnosti i specifičnoj izvedbi (Rampinini et al., 2009; Stanković et al., 2023).

Unatoč popularnosti HIIT-a, još uvijek nedostaje sustavna analiza njegovih učinaka kod nogometašica. Većina istraživanja fokusirana je na muške sportaše, što ograničava primjenjivost rezultata (Datson, 2014; Kubayi, 2019).

Stoga je cilj ovog rada analizirati učinke HIIT-a i COD HIIT-a na aerobni kapacitet, anaerobnu izvedbu i motoričke sposobnosti kod nogometašica.

Metode

Dizajn istraživanja

Ovo istraživanje provedeno je kao narativni i sustavni pregled s ciljem sažimanja trenutačnih dokaza o učincima visokointenzivnog intervalnog treninga (HIIT) kod nogometašica. Pregled je proveden u skladu s općim načelima sustavnih pregleda, slijedeći smjernice Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021).

Strategija pretraživanja

Provedeno je opsežno pretraživanje literature korištenjem sljedećih elektroničkih baza podataka:

- PubMed
- Scopus
- Web of Science

Pretraživanje je bilo ograničeno na studije objavljene na engleskom jeziku u razdoblju od 2000. do 2025. godine. Za identifikaciju relevantnih studija korištene su ključne riječi i Booleovi operatori, uključujući:

- „high-intensity interval training AND female soccer“
- „HIIT AND women football players“
- „change of direction HIIT soccer“
- „soccer performance HIIT women“

Dodatno, popisi literature odabranih studija ručno su pregledani kako bi se identificirale dodatne relevantne publikacije.

Kriteriji uključenja

Studije su uključene ako su zadovoljavale sljedeće kriterije:

- sudionici su bile nogometašice (amaterske ili elitne razine)
- intervencije su uključivale visokointenzivni intervalni trening (HIIT) ili HIIT s promjenama smjera (COD HIIT)
- studije su izvještavale o fiziološkim ili izvedbenim ishodima (npr. VO_2max, sprint izvedba, agilnost)
- originalni znanstveni radovi (randomizirana kontrolirana istraživanja, kvazi-eksperimentalne studije i longitudinalna istraživanja)

Kriteriji isključenja

Studije su isključene ako:

- su sudionici bili isključivo muški sportaši
- intervencija nije uključivala HIIT protokole
- radovi su bili pregledni članci, sažeci konferencija ili studije slučaja
- nisu sadržavali dovoljno podataka o ishodima

Prikupljanje podataka

Podaci iz uključenih studija prikupljeni su i organizirani prema:

- karakteristikama uzorka (dob, razina treniranosti)
- karakteristikama intervencije (vrsta, trajanje, intenzitet HIIT-a)
- mjerenim ishodima (aerobni kapacitet, anaerobna izvedba, agilnost)

Analiza podataka

Zbog heterogenosti među studijama u pogledu dizajna, intervencija i mjerenih ishoda, provedena je kvalitativna analiza. Rezultati su grupirani u tri glavne kategorije:

- aerobne adaptacije
- anaerobna izvedba
- motoričke sposobnosti

Gdje je bilo moguće, rezultati su uspoređivani među studijama kako bi se identificirali dosljedni trendovi i učinci treninga.

Rezultati

Odabir studija i njihove karakteristike

Početno pretraživanje baza podataka identificiralo je ukupno 132 studije. Nakon uklanjanja duplikata te pregleda naslova i sažetaka, 58 studija je procijenjeno za uključenje na temelju cjelovitog teksta. Na temelju kriterija uključenja i isključenja, 28 studija je uključeno u konačnu analizu.

Uključene studije obuhvaćale su nogometašice različitih razina natjecanja, od amaterskih do elitnih sportašica. Veličine uzoraka varirale su između 12 i 60 sudionica, dok je trajanje intervencija bilo u rasponu od 4 do 12 tjedana.

Većina studija istraživala je različite HIIT protokole, uključujući kratke intervale, duge intervale i sprint intervalni trening, kao i HIIT s promjenama smjera (COD HIIT).

Učinci na aerobni kapacitet

Rezultati dosljedno pokazuju da HIIT značajno poboljšava aerobni kapacitet kod nogometašica. Većina studija izvijestila je o povećanju VO_2max u rasponu od 5% do 12% nakon HIIT intervencija.

Poboljšanja aerobne izvedbe također su se očitovala u povećanoj izdržljivosti i smanjenom umoru tijekom utakmice. Ovi rezultati u skladu su s prethodnim istraživanjima koja potvrđuju da je HIIT učinkovita metoda za poboljšanje kardiovaskularne kondicije (Buchheit i Laursen, 2013; Weston et al., 2014).

Učinci na anaerobnu izvedbu

HIIT intervencije rezultirale su značajnim poboljšanjima u anaerobnoj izvedbi, posebno u:

- sposobnosti ponavljanih sprintova (RSA)
- maksimalnoj brzini sprinta
- otpornosti na umor

Nekoliko studija zabilježilo je smanjenje vremena sprinta i povećanje izlazne snage nakon HIIT programa. Također, poboljšanja indeksa umora ukazuju na povećanu sposobnost održavanja visokointenzivnih napora tijekom utakmice.

Sprint intervalni trening pokazao je posebno snažne učinke na anaerobnu snagu, što naglašava njegovu važnost u specifičnoj kondicijskoj pripremi za nogomet (Arazi et al., 2017).

Učinci na motoričke sposobnosti

HIIT je imao značajan pozitivan utjecaj na motoričke sposobnosti, uključujući:

- agilnost
- brzinu
- eksplozivnu snagu

HIIT s promjenama smjera (COD HIIT) pokazao je veća poboljšanja u agilnosti u usporedbi s linearnim HIIT-om. Ova poboljšanja vjerojatno su rezultat specifičnosti COD pokreta koji vjerno oponašaju uvjete utakmice (Chaouachi et al., 2012; Rampinini et al., 2009).

Također su zabilježena poboljšanja u neuromuskularnoj izvedbi, posebno u testovima ubrzanja i promjena smjera.

Usporedba COD i linearnog HIIT-a

Studije koje su uspoređivale COD HIIT i linearni HIIT pokazale su da su obje metode učinkovite, no COD HIIT doveo je do većih poboljšanja u:

- agilnosti
- specifičnoj sportskoj izvedbi
- učinkovitosti kretanja

S druge strane, linearni HIIT bio je više povezan s poboljšanjima aerobnog kapaciteta.

Ovi nalazi sugeriraju da kombinacija oba pristupa može osigurati optimalne trenažne adaptacije.

Sažetak rezultata

Općenito, rezultati pokazuju da je HIIT vrlo učinkovita metoda treninga za nogometašice, koja dovodi do poboljšanja u više aspekata izvedbe.

Najdosljedniji nalazi uključuju:

- povećanje VO_2max i aerobnog kapaciteta
- poboljšanje sposobnosti ponavljanih sprintova
- unapređenje agilnosti i neuromuskularne izvedbe

Ove adaptacije ključne su za održavanje visoke razine izvedbe tijekom natjecateljskih utakmica.

Rasprava

Cilj ovog preglednog rada bio je ispitati učinke visokointenzivnog intervalnog treninga (HIIT) na aerobni kapacitet, anaerobnu izvedbu i motoričke sposobnosti kod nogometašica. Rezultati

dosljedno pokazuju da je HIIT vrlo učinkovita metoda treninga koja dovodi do značajnih poboljšanja u više fizioloških i izvedbenih područja.

Jedan od najvažnijih nalaza ovog rada jest značajno poboljšanje aerobnog kapaciteta nakon HIIT intervencija. Povećanja VO_2max u rasponu od 5% do 12% zabilježena su u većini uključenih studija, što potvrđuje učinkovitost HIIT-a u unapređenju kardiovaskularne kondicije. Ovi rezultati u skladu su s prethodnim istraživanjima koja pokazuju da HIIT može dovesti do jednakih ili čak većih poboljšanja u aerobnom kapacitetu u usporedbi s tradicionalnim kontinuiranim treningom, unatoč znatno kraćem vremenu treninga (Buchheit i Laursen, 2013; Weston et al., 2014). Poboljšanje VO_2max posebno je važno za nogometašice jer izravno utječe na sposobnost održavanja visokog intenziteta aktivnosti i oporavka između napora tijekom utakmice (Iaia et al., 2009; Datson, 2014).

Fiziološki mehanizmi koji stoje iza ovih poboljšanja uključuju povećanje gustoće mitohondrija, povećanu aktivnost oksidativnih enzima i poboljšanu funkciju srca, što sve doprinosi učinkovitijem korištenju kisika (Gibala et al., 2012; Laursen i Buchheit, 2019). Ove adaptacije ključne su u sportu koji karakterizira povremeni visokointenzivni rad, gdje igrači moraju stalno prelaziti između različitih razina intenziteta (Mohr et al., 2002).

Osim aerobnih adaptacija, utvrđeno je da HIIT značajno poboljšava anaerobnu izvedbu, osobito sposobnost ponavljanih sprintova (RSA), brzinu sprinta i otpornost na umor. RSA je ključni pokazatelj izvedbe u nogometu i snažno je povezan s razinom natjecanja i uspjehom (Gabbett, 2008; Rampinini et al., 2009). Poboljšanja u RSA nakon HIIT intervencija ukazuju na to da ova metoda treninga poboljšava učinkovitost fosfagenog i glikolitičkog sustava, omogućujući igračicama održavanje ponavljanih visokointenzivnih napora uz manji umor (Arazi et al., 2017; Buchheit et al., 2010).

Nadalje, rezultati pokazuju da HIIT pozitivno utječe na neuromuskularnu izvedbu, uključujući brzinu sprinta, eksplozivnu snagu i agilnost. Ova poboljšanja posebno su važna u nogometu, gdje su brza ubrzanja, usporavanja i promjene smjera temelj izvedbe (Haugen et al., 2012; Chaouachi et al., 2012). Poboljšanja neuromuskularne funkcije mogu se objasniti povećanom aktivacijom motoričkih jedinica, bržim razvojem sile i boljom međumišićnom koordinacijom (Marković, 2008).

Posebno važan aspekt ovog rada jest učinkovitost HIIT-a s promjenama smjera (COD HIIT) u usporedbi s linearnim HIIT-om. COD HIIT uključuje višesmjerne pokrete koji vjerno oponašaju zahtjeve utakmice, što rezultira većim poboljšanjima u agilnosti, učinkovitosti kretanja i specifičnoj sportskoj izvedbi (Rampinini et al., 2009; Stanković et al., 2023). Ovi nalazi podupiru princip specifičnosti, prema kojem su trenažne adaptacije najveće kada trening što više nalikuje stvarnim zahtjevima sporta (Young et al., 2002). Stoga se COD HIIT može smatrati posebno korisnim za nogometašice jer cilja specifične obrasce kretanja koji se javljaju tijekom utakmice.

Međutim, važno je naglasiti da i linearni HIIT donosi značajne koristi, posebno u poboljšanju aerobnog kapaciteta i opće izdržljivosti. Zbog toga kombinacija linearnog i COD HIIT-a može predstavljati optimalnu strategiju treninga jer omogućuje razvoj opće i specifične kondicije (Buchheit i Laursen, 2013).

Još jedan važan aspekt je individualizacija trenažnih programa. Uključene studije pokazuju varijabilnost u odgovorima na trening ovisno o razini igračica, njihovom trenažnom statusu i trajanju intervencije. To naglašava potrebu da treneri prilagode HIIT programe individualnim karakteristikama i ciljevima (Laursen i Jenkins, 2002; Iaia et al., 2009). Također, pravilno upravljanje intenzitetom, volumenom i oporavkom ključno je za maksimalne adaptacije i prevenciju pretreniranosti.

Unatoč pozitivnim nalazima, potrebno je uzeti u obzir određena ograničenja. Heterogenost studija u pogledu protokola treninga, veličine uzorka i mjerenih varijabli otežava donošenje

konačnih zaključaka (Higgins et al., 2011). Također, mnoge studije imale su male uzorke, što može utjecati na pouzdanost rezultata.

Dodatno, većina intervencija trajala je relativno kratko (4–12 tjedana), pa dugoročni učinci HIIT-a kod nogometašica ostaju nedovoljno istraženi. Buduća istraživanja trebala bi se usmjeriti na longitudinalne studije kako bi se procijenila održivost učinaka (Weston et al., 2014).

Također, većina istraživanja fokusirala se na fizičke aspekte izvedbe, dok su psihološki čimbenici poput motivacije, percepcije napora i mentalnog umora manje istraženi. S obzirom na važnost tih čimbenika, buduća istraživanja trebala bi uključiti i te aspekte (Datson, 2014).

Na kraju, važno je istaknuti da je većina istraživanja provedena na muškim sportašima, a rezultati se često generaliziraju na žene. S obzirom na fiziološke i hormonalne razlike, potrebno je više istraživanja usmjerenih isključivo na nogometašice (Kubayi, 2019).

Praktične implikacije

Rezultati ovog rada imaju važne praktične implikacije za trenere i kondicijske stručnjake koji rade s nogometašicama. HIIT treba biti integriran u trenažne programe kao primarna metoda za poboljšanje aerobne i anaerobne izvedbe.

Trenerima se preporučuje uključivanje COD vježbi kako bi se poboljšale specifične sportske sposobnosti, agilnost i učinkovitost kretanja.

Također, trening treba individualizirati uzimajući u obzir karakteristike igračica, razinu natjecanja i periodizaciju. Kombinacija linearnog i COD HIIT-a može osigurati najcjelovitija poboljšanja izvedbe.

Literatura

1. Andrzejewski, M., Chmura, J., Pluta, B. and Kasprzak, A. (2013) 'Analysis of motor activities of professional soccer players', Journal of Sports Sciences, 31(5), pp. 456–463.
2. Arazi, H., Asadi, A. and Roohi, S. (2017) 'Effects of high-intensity interval training on aerobic and anaerobic performance in soccer players', Journal of Strength and Conditioning Research, 31(3), pp. 789–795.
3. Bandura, A. (1997) Self-efficacy: The exercise of control. New York: Freeman.
4. Bok, D. (2019) 'High-intensity interval training methodology', Sports Science Review, 28(2), pp. 55–70.
5. Buchheit, M. and Laursen, P.B. (2013) 'High-intensity interval training, solutions to the programming puzzle', Sports Medicine, 43(5), pp. 313–338.
6. Buchheit, M., Laursen, P.B. and Ahmaidi, S. (2009) 'Parasympathetic reactivation after repeated sprint exercise', European Journal of Applied Physiology, 105(4), pp. 569–579.
7. Buchheit, M., Mendez-Villanueva, A., Simpson, B. and Bourdon, P. (2010) 'Repeated sprint sequences during youth soccer matches', International Journal of Sports Medicine, 31(10), pp. 709–716.
8. Chaouachi, A., Manzi, V., Chaalali, A., Wong, D.P., Chamari, K. and Castagna, C. (2012) 'Determinants analysis of change-of-direction ability', Journal of Sports Sciences, 30(1), pp. 23–31.
9. Datson, N. (2014) 'Match physical performance of female soccer players', Sports Medicine, 44(9), pp. 1225–1240.
10. Gabbett, T.J. (2008) 'Influence of fatigue on tackling technique in rugby league players', Journal of Strength and Conditioning Research, 22(2), pp. 556–561.
11. Gibala, M.J., Little, J.P., MacDonald, M.J. and Hawley, J.A. (2012) 'Physiological adaptations to low-volume HIIT', Journal of Physiology, 590(5), pp. 1077–1084.

12. Haugen, T., Tønnessen, E. and Seiler, S. (2012) 'Sprint running performance monitoring', Journal of Sports Sciences, 30(7), pp. 645–652.
13. Iaia, F.M., Rampinini, E. and Bangsbo, J. (2009) 'High-intensity training in football', Sports Medicine, 39(6), pp. 435–447.
14. Impellizzeri, F.M., Marcora, S.M. and Castagna, C. (2006) 'Physiological responses to small-sided games', Journal of Sports Sciences, 24(6), pp. 679–686.
15. Jones, S. and Drust, B. (2007) 'Physiological demands of elite soccer', Journal of Sports Sciences, 25(6), pp. 665–674.
16. Kubayi, A. (2019) 'Physical demands of soccer players', Journal of Sports Science, 37(10), pp. 113–120.
17. Laursen, P.B. and Buchheit, M. (2019) Science and application of HIIT. Champaign: Human Kinetics.
18. Laursen, P.B. and Jenkins, D.G. (2002) 'The scientific basis for HIIT', Sports Medicine, 32(1), pp. 53–73.
19. Marković, G. (2008) 'Neuromuscular performance in soccer', Kinesiology, 40(2), pp. 120–130.
20. Mohr, M., Krustrup, P. and Bangsbo, J. (2002) 'Match performance of high-standard soccer players', Journal of Sports Sciences, 20(7), pp. 519–528.
21. Rampinini, E., Impellizzeri, F.M., Castagna, C., Abt, G., Chamari, K., Sassi, A. and Marcora, S.M. (2009) 'Factors influencing physiological responses to soccer training', Journal of Sports Sciences, 27(9), pp. 103–110.
22. Sporiš, G., Jukić, I., Milanović, L. and Vučetić, V. (2010) 'Reliability and validity of soccer tests', Kinesiology, 42(1), pp. 45–55.
23. Stanković, R., Milanović, Z. and Sporiš, G. (2023) 'HIIT effects in soccer players', Sports Medicine, 53(4), pp. 567–580.
24. Weston, M., Taylor, K.L., Batterham, A.M. and Hopkins, W.G. (2014) 'Effects of HIIT vs continuous training', British Journal of Sports Medicine, 48(16), pp. 1227–1234.
25. Young, W., McDowell, M. and Scarlett, B. (2001) 'Specificity of agility training', Journal of Sports Sciences, 19(7), pp. 551–560.
26. Young, W., James, R. and Montgomery, I. (2002) 'Is muscle power related to running speed?', Journal of Sports Medicine, 36(3), pp. 282–288.
27. Helgerud, J., Engen, L.C., Wisløff, U. and Hoff, J. (2001) 'Aerobic endurance training improves soccer performance', Medicine & Science in Sports & Exercise, 33(11), pp. 1925–1931.
28. McMillan, K., Helgerud, J., Macdonald, R. and Hoff, J. (2005) 'Physiological adaptations to soccer training', British Journal of Sports Medicine, 39(5), pp. 273–277.
29. Reilly, T. (2007) The science of training in soccer. London: Routledge.
30. Stølen, T., Chamari, K., Castagna, C. and Wisløff, U. (2005) 'Physiology of soccer', Sports Medicine, 35(6), pp. 501–536.

RAD 3

ZNANSTVENI RAD

Utjecaj sporta na odgoj djece i mladih: kineziološki pristup i relevantna istraživanja

Branislav Šutić[1], Goran Sporiš[2] Marjan Ninčević[3]

[1]The University of Applied Sciences "Nikola Tesla" in Gospić , Croatia; Gospić; [2]Univesity of Zagreb, Faculty of Kinesiology; [3]Univesity of Zagreb, Faculty of Croatian Studies

1. Uvod

Sport i tjelesna aktivnost imaju značajnu ulogu u fizičkom, psihološkom i socijalnom razvoju djece i mladih. U suvremenom društvu, gdje sjedilački način života postaje sve prisutniji, važnost promoviranja aktivnog načina života nikada nije bila veća. Kineziologija, kao interdisciplinarna znanost o pokretu, pruža znanstveno utemeljene uvide u to kako tjelesna aktivnost utječe na različite aspekte razvoja mladih pojedinaca (Knudson, 2007). Razumijevanje ovih utjecaja ključno je za razvoj učinkovitih odgojnih i obrazovnih programa koji koriste sport kao alat za cjeloviti razvoj djece. Cilj ovog rada je istražiti kako sport, kroz prizmu kineziloških načela, doprinosi odgoju i razvoju djece i mladih. Fokusirat ćemo se na fiziološke, biomehaničke i psihološke aspekte sporta te kako oni utječu na fizički rast, psihološko blagostanje i socijalne vještine mladih. Pregledat ćemo relevantna istraživanja koja podupiru te tvrdnje i pružiti preporuke za buduću praksu u školskom i društvenom okruženju. U odlomku o kineziologiji kao znanosti o pokretu, analizirat ćemo kako ova disciplina integrira različita područja znanja kako bi pružila cjelovit uvid u ljudski pokret i njegovo značenje za zdravlje i razvoj (Wilmore, Costill, 2004; Malina, 2010). Posebnu pažnju posvetit ćemo biomehaničkim aspektima koji omogućuju optimizaciju izvedbe i prevenciju ozljeda kod mladih sportaša (Hall, 2015; Enoki i sur., 2017), kao i fiziološkim procesima koji podupiru zdravi rast i razvoj (Strong i sur., 2005; Bailey i sur., 1999). Psihološki aspekti sporta bit će istraženi kroz prizmu razvoja samopouzdanja, emocionalne otpornosti i socijalnih vještina (Weinberg, Gould, 2011; Fraser-Thomas i sur., 2005). Razmotrit ćemo kako sudjelovanje u sportu može pozitivno utjecati na mentalno zdravlje djece i mladih te kako može služiti kao alat za prevenciju rizičnih ponašanja (Biddle, Asare, 2011; Eccles, Barber, 1999). Uloga škole i zajednice u promoviranju sporta kao sredstva za odgoj također će biti naglašena. Razmišljat ćemo o važnosti integracije sportskih programa u obrazovni sustav i kako zajednički sportski programi mogu povećati dostupnost i kvalitetu sportskih aktivnosti za djecu iz različitih socioekonomskih sredina (Trudeau, Shephard, 2008; Collins,

Kay, 2014). Na kraju, pružit ćemo preporuke za buduće prakse koje uključuju individualizirani pristup sportskim aktivnostima, edukaciju trenera i nastavnika te promociju jednakosti i inkluzije u sportu. Cilj ovih preporuka je maksimizirati pozitivan utjecaj sporta na odgoj djece i mladih te potaknuti dugotrajnu uključenost u tjelesnu aktivnost (Fraser-Thomas, Côté, 2009; Rink, 2010). Ovaj rad nastoji doprinijeti razumijevanju važnosti sporta u odgoju te pružiti smjernice za implementaciju učinkovitih sportskih programa koji će podržati cjeloviti razvoj djece i mladih.

2. Kineziologija kao znanost o pokretu

Kineziologija je interdisciplinarna znanost koja se bavi proučavanjem ljudskog pokreta i njegovim utjecajem na zdravlje, funkcionalne sposobnosti i kvalitetu života. Ona integrira znanja iz anatomije, fiziologije, biomehanike, psihologije, sociologije i neuroznanosti kako bi pružila cjelovito razumijevanje kompleksnosti ljudskog kretanja (Knudson, 2007). Kineziologija je ključna za razumijevanje različitih aspekata sporta i tjelesne aktivnosti, što omogućuje znanstveno utemeljen pristup odgojnim i obrazovnim programima koji uključuju tjelesnu aktivnost. Kroz proučavanje fizioloških procesa koji se događaju tijekom tjelesne aktivnosti, kineziologija pruža uvid u to kako vježbanje utječe na različite sustave u tijelu, uključujući kardiovaskularni, respiratorni, mišićno-koštani i neuroendokrini sustav (Wilmore, Costill, 2004). Malina (2010) naglašava da redovita tjelesna aktivnost tijekom djetinjstva i adolescencije ne samo da poboljšava kardiorespiratorne funkcije i mišićnu snagu, već također potiče zdrav rast i razvoj te smanjuje rizik od razvoja kroničnih bolesti u odrasloj dobi. S druge strane, kineziologija istražuje i psihološke aspekte tjelesne aktivnosti, uključujući motivaciju, samopoimanje, emocionalnu dobrobit i kognitivni razvoj (Weinberg, Gould, 2011). Psihološki utjecaji sporta posebno su izraženi u razvoju emocionalne stabilnosti,

otpornosti i samopouzdanja kod djece i mladih. Fraser-Thomas i sur. (2005) zaključuju da sudjelovanje u sportu može smanjiti simptome stresa i anksioznosti te poboljšati emocionalno zdravlje, posebno kod adolescenata. Sport također služi kao platforma za socijalni razvoj. Kroz interakciju s vršnjacima i trenerima, djeca i mladi razvijaju socijalne vještine poput timskog rada, komunikacije i poštovanja pravila. Côté i Fraser-Thomas (2007) ističu da kineziološki pristup omogućuje detaljno praćenje i evaluaciju ovih procesa, čime se stvara temelj za razvoj edukacijskih programa koji koriste sport kao sredstvo socijalizacije i emocionalnog razvoja.

2.1 Biomehanički aspekti

Biomehanika je grana kineziologije koja proučava mehaničke zakone koji upravljaju pokretima ljudskog tijela. Ona analizira sile koje djeluju na tijelo i kako tijelo reagira na te sile, što je ključno za razumijevanje kako optimizirati izvedbu i smanjiti rizik od ozljeda (Hall, 2015). U kontekstu djece i mladih, pravilno izvođenje tjelesnih aktivnosti od vitalne je važnosti za pravilan razvoj motoričkih sposobnosti. Enoki i sur. (2017) ističu da biomehanička analiza pokreta omogućuje stručnjacima identificiranje nepravilnosti u tehnici koje mogu dovesti do ozljeda ili ograničiti performanse. Na primjer, korekcija tehnike trčanja kod djece može poboljšati učinkovitost i smanjiti stres na zglobovima, što ima dugoročne pozitivne efekte na njihov fizički razvoj.

Biomehanički principi također se primjenjuju u dizajnu trening programa koji su prilagođeni razvojnoj fazi djeteta. Razumijevanje biomehaničkih karakteristika dječjeg tijela, poput fleksibilnosti, snage i koordinacije, omogućuje kreiranje aktivnosti koje će poticati optimalan motorički razvoj (Lloyd, Oliver, 2012). Primjena biomehaničkih načela u edukaciji omogućuje nastavnicima tjelesne i zdravstvene kulture da:

• Prilagode nastavu individualnim potrebama: Uzimajući u obzir različite tjelesne sposobnosti i razvojne faze učenika.

• Unaprijede sigurnost: Smanjenjem rizika od ozljeda kroz edukaciju o pravilnoj tehnici i korištenju adekvatne opreme.

• Poboljšaju učinkovitost učenja: Korištenjem biomehaničkih analiza za pružanje povratnih informacija učenicima.

2.2 Fiziološki aspekti

Fiziologija vježbanja proučava akutne i kronične reakcije tijela na tjelesnu aktivnost. Kod djece i mladih, redovita tjelesna aktivnost ima značajne fiziološke benefite. Strong i sur. (2005) naglašavaju da tjelesna aktivnost poboljšava:

• Kardiovaskularnu kondiciju: Povećava se učinkovitost srca i pluća, što doprinosi boljem transportu kisika i hranjivih tvari.

• Mišićnu snagu i izdržljivost: Razvijaju se mišićna vlakna, što omogućuje bolje izvođenje fizičkih aktivnosti.

• Metaboličko zdravlje: Regulira se metabolizam glukoze i lipida, smanjujući rizik od razvoja dijabetesa i pretilosti.

Redovita tjelesna aktivnost tijekom djetinjstva povezana je s boljim zdravljem kostiju, što je

posebno važno tijekom razdoblja intenzivnog rasta. Bailey i sur. (1999) ističu da aktivnosti s opterećenjem, poput trčanja i skakanja, potiču mineralizaciju kostiju i povećanje koštane mase.

Uvođenje redovitih sportskih programa u škole, temeljeno na znanstvenim spoznajama iz fiziologije, može značajno poboljšati cjelokupno zdravlje djece. Trudeau i Shephard (2008) pokazali su da školski programi koji uključuju tjelesnu aktivnost doprinose ne samo fizičkom, već i kognitivnom razvoju učenika, što se odražava na njihov akademski uspjeh.

2.3 Psihološki aspekti

Psihološki utjecaji tjelesne aktivnosti i sporta uključuju poboljšanje mentalnog zdravlja, emocionalne dobrobiti i socijalnog funkcioniranja. Fraser-Thomas i sur. (2005) ističu da sudjelovanje u sportu može promicati:

• Samopouzdanje i samopoštovanje: Uspjeh u sportskim aktivnostima povećava osjećaj kompetencije. Harter (1982) tvrdi da je percepcija vlastite kompetencije ključna za razvoj samopoštovanja kod djece.

• Emocionalnu otpornost: Sport uči djecu kako se nositi s pobjedama i porazima, što razvija otpornost na stres i frustracije.

• Motivaciju: Prema Deci i Ryanu (2000), sport može zadovoljiti osnovne psihološke potrebe za autonomijom, kompetencijom i povezanošću, što potiče intrinzičnu motivaciju.

Psihološki aspekti sporta također uključuju razvoj socijalnih vještina. Kroz timske sportove, djeca uče surađivati, komunicirati i poštovati druge. Weiss i Stuntz (2004) naglašavaju da pozitivni socijalni odnosi unutar sportskog konteksta mogu povećati zadovoljstvo djece sportom i potaknuti dugoročno sudjelovanje. U pedagoškom kontekstu, razumijevanje psiholoških aspekata kineziologije omogućuje nastavnicima da:

• Stvore poticajno okruženje: Koje promiče emocionalni i socijalni razvoj.

• Prepoznaju i podrže individualne potrebe učenika: Kroz prilagodbu pristupa i metode podučavanja.

• Potiču pozitivne vrijednosti: Kao što su fair-play, odgovornost i ustrajnost. Côté i Fraser-Thomas (2007) ističu važnost kvalitetnog sportskog iskustva koje je usmjereno na cjelovit razvoj djeteta, a ne samo na natjecateljski uspjeh.

3. Utjecaj sporta na fizički razvoj

Jedan od najvažnijih aspekata sudjelovanja u sportu je doprinos fizičkom zdravlju. Djeca i mladi koji su uključeni u redovite tjelesne aktivnosti razvijaju bolju motoričku koordinaciju, mišićnu snagu i kardiovaskularnu izdržljivost (Strong i sur., 2005). Sport također igra ključnu ulogu u prevenciji kroničnih bolesti poput pretilosti, dijabetesa i srčanih bolesti, što potvrđuju brojna istraživanja (Janssen i LeBlanc, 2010). Redovito bavljenje sportom ne samo da poboljšava fizičke sposobnosti, već i potiče zdrav razvoj kostiju i mišića, što je posebno važno tijekom faze rasta (Faigenbaum i Myer, 2010). Uz to, sudjelovanje u sportu može pozitivno utjecati na imunološki sustav, smanjujući rizik od infekcija i bolesti (Nieman, 2001). Tjelesna aktivnost tijekom djetinjstva i adolescencije ključna je za zdravlje u odrasloj dobi (WHO, 2010).

3.1 Prevencija pretilosti

Pretilost kod djece i mladih predstavlja globalni javnozdravstveni problem. Svjetska zdravstvena organizacija (WHO, 2010) preporučuje da djeca i adolescenti trebaju biti tjelesno aktivni najmanje 60 minuta dnevno kako bi se smanjio rizik od pretilosti i s njom povezanih bolesti. Redovite sportske aktivnosti potiču sagorijevanje kalorija, održavanje zdrave tjelesne težine te promicanje pravilnih prehrambenih navika (Hills i sur., 2007). Sudjelovanje u sportu omogućava djeci da na zabavan i motivirajući način ispune dnevne potrebe za tjelesnom aktivnošću, što pridonosi njihovom cjelokupnom zdravlju. Trudeau i Shephard (2008) ističu kako sport pozitivno utječe na tjelesnu kompoziciju i smanjenje masnog tkiva kod djece, posebno ako se sport uključi u obrazovni kurikulum. Dodatno, uključivanje sporta u školske programe može povećati razinu tjelesne aktivnosti među djecom koja možda nemaju pristup izvanškolskim sportskim aktivnostima (Pate i sur., 2006). Istraživanja su također pokazala da djeca koja su tjelesno aktivna imaju manji rizik od razvoja metaboličkog sindroma kasnije u životu (Eisenmann, 2007). Prevencija pretilosti kroz sport ne utječe samo na fizičko zdravlje,

već i na psihološku dobrobit djece i adolescenata (Sahoo i sur., 2015). Stoga je promicanje sudjelovanja u sportu ključno za prevenciju pretilosti i povezanih zdravstvenih komplikacija.

4. Utjecaj sporta na psihološki razvoj

Psihološki razvoj djece i mladih izravno je povezan sa sudjelovanjem u sportskim aktivnostima, jer sport potiče osjećaj postignuća, razvija samopouzdanje te pomaže u upravljanju stresom i emocijama. Sport omogućava djeci da razviju osjećaj osobne vrijednosti, kako kroz individualne sportske aktivnosti, tako i kroz sudjelovanje u timskim

sportovima. Osim toga, sport pruža platformu za razvoj socijalnih vještina, uključujući komunikaciju, suradnju i empatiju (Smith i sur., 2016). Redovito sudjelovanje u sportu također može pozitivno utjecati na mentalno zdravlje, smanjujući rizik od razvoja depresije i anksioznosti (Lubans i sur., 2016). Tjelesna aktivnost povezana je s boljim psihološkim blagostanjem kod djece i adolescenata (Biddle i Asare, 2011). Kroz sport djeca uče važnost postavljanja ciljeva, upornosti i samodiscipline, što su ključni elementi za uspjeh u drugim područjima života.

4.1 Razvoj samopouzdanja

Sudjelovanje u sportu doprinosi razvoju pozitivne slike o sebi, što može imati dugoročne pozitivne učinke na djetetovu emocionalnu stabilnost. Scanlan i Lewthwaite (1986) pronašli su jasnu vezu između sportske uključenosti i osjećaja samopouzdanja kod adolescenata. Djeca koja sudjeluju u sportskim aktivnostima često razvijaju veći osjećaj postignuća i samopouzdanja, što doprinosi njihovoj emocionalnoj otpornosti i spremnosti da se suoče s izazovima. Dodatno, istraživanja pokazuju da uspjeh u sportu može poboljšati samopoštovanje i samouvjerenost, posebno kod djece s niskim samopouzdanjem (Ekeland i sur., 2005). Sudjelovanje u sportskim aktivnostima omogućava mladima da razviju osjećaj kompetencije i kontrolu nad svojim okruženjem (Bailey, 2006). Ovo je posebno važno tijekom adolescencije, kada se razvijaju ključni aspekti identiteta i samopercepcije.

4.2 Smanjenje stresa i anksioznosti

Tjelesna aktivnost djeluje kao prirodni regulator stresa i tjeskobe. Biddle i Asare (2011) ističu da sport može značajno smanjiti simptome stresa i anksioznosti, posebno kod adolescenata koji su pod pritiskom školskih obaveza i društvenih očekivanja. Sudjelovanje u sportskim aktivnostima pruža sigurno i strukturirano okruženje u kojem djeca mogu razviti emocionalnu otpornost i bolje se nositi s izazovima svakodnevnog života.

Mehanizmi kroz koje sport smanjuje stres uključuju oslobađanje endorfina, poboljšanje spavanja i distrakciju od negativnih misli (Peluso i Andrade, 2005). Redovita tjelesna aktivnost može biti učinkovita intervencija za smanjenje simptoma anksioznosti kod mladih (Conn, 2010). Također, timske sportske aktivnosti pružaju socijalnu podršku koja može ublažiti učinke stresa i promovirati osjećaj pripadnosti (Rees i Freeman, 2007).

5. Utjecaj sporta na socijalni razvoj

Sport igra ključnu ulogu u razvoju socijalnih vještina i promicanju timskog rada. Djeca koja sudjeluju u sportskim aktivnostima uče o važnosti suradnje, komunikacije i poštovanja

pravila, što su ključne vještine za uspjeh u društvenom životu. Osim toga, sport pruža priliku za interakciju s vršnjacima iz različitih društvenih i kulturnih pozadina, što može potaknuti razumijevanje i toleranciju (Fraser-Thomas i sur., 2005). Redovito sudjelovanje u sportu također može pomoći u razvoju socijalnog identiteta i osjećaja pripadnosti grupi, što je posebno važno tijekom adolescencije (Bruner i sur., 2014). Sport pruža jedinstveno okruženje u kojem mladi mogu razviti socijalne veze i naučiti vrijednosti poput fair-playa, poštovanja i integriteta (Holt i Neely, 2011).

5.1 Razvoj socijalnih vještina

Sport nudi djeci i mladima priliku da razviju svoje socijalne vještine kroz suradnju s vršnjacima i trenerima. Prema Smith i sur. (2007), djeca koja sudjeluju u sportskim aktivnostima razvijaju bolje socijalne vještine i imaju veći krug prijatelja. Sudjelovanje u timskim sportovima posebno potiče razvoj komunikacijskih vještina, timskog rada i razumijevanja uloge svakog pojedinca unutar grupe. Kroz zajedničke ciljeve i izazove koje sport pruža, djeca uče o važnosti suradnje, poštovanja pravila i prihvaćanja različitosti. Ewing i Seefeldt (2002) ističu da sport može biti učinkovit alat za promicanje inkluzije i smanjenje predrasuda među djecom različitih kulturnih i socijalnih pozadina. Sport ima potencijal poticati socijalni razvoj kroz interakciju s drugima i učenje socijalno prihvatljivih ponašanja (Côté i Fraser-Thomas, 2007). Dodatno, sport može pomoći u razvoju voditeljskih vještina, jer djeca često preuzimaju različite uloge unutar tima koje zahtijevaju odgovornost i donošenje odluka (Vella i sur., 2011). Interakcija s trenerima i suigračima također može poboljšati socijalnu kompetenciju i emocionalnu inteligenciju (Camiré i sur., 2012).

5.2 Prevencija rizičnih ponašanja

Sudjelovanje u sportu može djelovati kao zaštitni faktor protiv razvoja rizičnih ponašanja poput delinkvencije, zlouporabe supstanci i antisocijalnog ponašanja. Eccles i Barber (1999) su utvrdili da adolescenti koji su uključeni u sportske aktivnosti pokazuju manju sklonost prema takvim ponašanjima u usporedbi s vršnjacima koji nisu uključeni u sport. Sport pruža strukturirano okruženje koje promiče pozitivne vrijednosti kao što su disciplina, odgovornost i poštovanje autoriteta. Također, sport može pružiti osjećaj pripadnosti i identiteta, što je posebno važno tijekom adolescencije kada mladi traže svoje mjesto u društvu. Fredricks i Eccles (2006) naglašavaju da sportska uključenost može smanjiti osjećaj otuđenosti i povećati povezivanje s vršnjacima i zajednicom. Istraživanja su pokazala da sudjelovanje u sportskim

aktivnostima može smanjiti vjerojatnost uključenosti u rizična ponašanja zbog zauzetosti pozitivnim aktivnostima i manje slobodnog vremena za negativne utjecaje (Mahoney i Stattin, 2000). Sport može služiti kao preventivna mjera protiv antisocijalnog ponašanja pružajući mladima konstruktivne načine za izražavanje energije i emocija (Hartmann, 2003). Međutim, važno je napomenuti da utjecaj sporta na prevenciju rizičnih ponašanja može ovisiti o kvaliteti sportskog programa i ponašanju trenera i suigrača (Perkins i Noam, 2007). Stoga je ključno osigurati pozitivno i podržavajuće sportsko okruženje kako bi se maksimizirao njegov zaštitni učinak.

6. Uloga škole i zajednice

Obrazovne institucije i lokalne zajednice imaju ključnu ulogu u promoviranju sporta kao sredstva za odgoj i razvoj djece i mladih. Integracija sportskih programa u školski kurikulum i podrška lokalnih zajednica mogu značajno utjecati na dostupnost i kvalitetu sportskih aktivnosti. Škole i lokalne zajednice djeluju kao katalizatori koji omogućuju mladima pristup strukturiranim sportskim aktivnostima (Green, 2012). Kroz suradnju ovih institucija moguće je stvoriti okruženje koje potiče zdrav način života i cjelokupni razvoj djece.

6.1 Integracija sporta u obrazovni sustav

Integriranje sporta i tjelesne aktivnosti u obrazovni sustav može imati pozitivne učinke na školske rezultate i opće ponašanje učenika. Trudeau i Shephard (2008) ističu da škole koje provode redovite i kvalitetne sportske programe bilježe poboljšanje u koncentraciji, motivaciji i uspjehu učenika. Tjelesna aktivnost može poboljšati kognitivne funkcije, kao što su pažnja i memorija, što direktno utječe na školske performanse (Donnelly i Lambourne, 2011). Pored toga, školski sportski programi mogu promicati inkluzivnost i jednakost, pružajući svim

učenicima, bez obzira na njihove fizičke sposobnosti ili socioekonomski status, priliku za sudjelovanje u sportu. Hardman i Marshall (2000) naglašavaju važnost kvalitetne tjelesne i zdravstvene kulture u školama za cjelokupni razvoj učenika. Integracija sporta u školski kurikulum ne samo da poboljšava fizičko zdravlje učenika, već i potiče razvoj socijalnih i emocionalnih vještina (Bailey i sur., 2009). Dodatno, aktivno sudjelovanje u sportu tijekom školovanja može utjecati na formiranje pozitivnih stavova prema tjelesnoj aktivnosti u odrasloj dobi (Telama i sur., 2005). Time škole imaju priliku oblikovati navike koje će imati dugoročne koristi za zdravlje i dobrobit pojedinaca.

6.2 Zajednički sportski programi

Lokalne zajednice također igraju važnu ulogu u promoviranju sportskih aktivnosti kroz organizaciju zajedničkih sportskih programa i događanja. Collins i Kay (2014) ističu da su zajednički sportski programi učinkoviti u povećanju sudjelovanja djece iz različitih socioekonomskih sredina. Ovi programi mogu pružiti pristupačne i kvalitetne sportske mogućnosti za djecu koja možda nemaju pristup takvim aktivnostima kroz školski sustav. Zajednički sportski programi također mogu poticati obiteljsko sudjelovanje i podršku, što dodatno povećava pozitivan utjecaj sporta na djecu. Holt i sur. (2011) naglašavaju važnost podrške obitelji i zajednice u poticanju djece da ostanu uključena u sportske aktivnosti. Kada zajednica aktivno podržava sportske programe, to stvara kulturu koja cijeni tjelesnu aktivnost i zdravlje (Spaaij, 2009). Osim toga, zajednički sportski programi mogu djelovati kao sredstvo za jačanje društvene kohezije i smanjenje socijalnih nejednakosti (Misener i Mason, 2006). Kroz sport, zajednice mogu promicati interakciju među različitim društvenim skupinama, potičući razumijevanje i solidarnost.

7. Preporuke za buduću praksu

Kako bi se maksimalizirao pozitivan utjecaj sporta na odgoj djece i mladih, važno je implementirati određene strategije i preporuke. Ove strategije trebaju biti usmjerene na individualizaciju pristupa, edukaciju trenera i nastavnika te promociju jednakosti i inkluzije u sportu. Sustavan pristup ovim područjima može značajno poboljšati kvalitetu sportskog iskustva za mlade (Fraser-Thomas i Côté, 2009).

7.1 Individualizirani pristup

Prilagodba sportskih aktivnosti individualnim potrebama i sposobnostima svakog djeteta je ključna. Rink (2010) ističe važnost diferenciranog pristupa u tjelesnom odgoju, gdje se aktivnosti prilagođavaju kako bi bile izazovne, ali i dostižne za svako dijete. Ovo pomaže u održavanju motivacije i sprječavanju osjećaja neuspjeha ili isključenosti. Kirk (2005) naglašava da individualizirani pristup potiče dugotrajnu uključenost u sport, jer djeca osjećaju da su njihove potrebe i interesi prepoznati i uvaženi. Personalizacija treninga omogućava djeci da napreduju vlastitim tempom, što pozitivno utječe na njihovo samopouzdanje i zadovoljstvo sportom (Light, 2008).

7.2 Edukacija trenera i nastavnika

Osiguravanje da treneri i nastavnici imaju odgovarajuća znanja iz kineziologije, pedagogije i psihologije djece ključno je za kvalitetnu provedbu sportskih programa. Côté i Gilbert (2009) naglašavaju da učinkoviti treneri ne samo da podučavaju sportske vještine, već i pozitivno

utječu na cjelokupni razvoj djeteta kroz promicanje pozitivnih vrijednosti i pružanje emocionalne podrške. Nelson i Cushion (2006) ističu važnost kontinuirane profesionalne edukacije trenera kako bi se osiguralo da su upoznati s najnovijim istraživanjima i metodologijama u sportskom treningu. Edukacija trenera trebala bi obuhvatiti ne samo

tehničke aspekte sporta, već i razvoj socijalnih i emocionalnih kompetencija kod djece (Vella i sur., 2011).

7.3 Promocija jednakosti i inkluzije

Važno je osigurati da su sportske aktivnosti dostupne svoj djeci, bez obzira na njihove fizičke sposobnosti, spol, socioekonomski status ili kulturnu pozadinu. Dagkas i Armour (2012) naglašavaju potrebu za politikama i praksama koje promiču inkluziju i jednakost u sportu. Ovo uključuje uklanjanje financijskih i društvenih barijera koje mogu spriječiti djecu u sudjelovanju.

Coakley (2011) predlaže da sportske organizacije aktivno rade na stvaranju inkluzivnog okruženja kroz prilagodbu programa i osiguravanje potrebnih resursa. Inkluzivni sportski programi potiču socijalnu koheziju i omogućavaju svoj djeci da iskuse benefite sudjelovanja u sportu (Shields i Bredemeier, 2009).

7.4 Suradnja između škole, obitelji i zajednice

Suradnja između škola, obitelji i lokalne zajednice ključna je za stvaranje podržavajućeg okruženja koje potiče sudjelovanje u sportu. Weiss i Ferrer-Caja (2002) ističu da je obiteljska podrška jedan od najvažnijih faktora u održavanju dječje uključenosti u sportske aktivnosti. Koordinirani napori između različitih društvenih aktera mogu povećati dostupnost i kvalitetu sportskih programa za djecu (Lee i Martinek, 2009).

7.5 Evaluacija i prilagodba sportskih programa

Redovita evaluacija sportskih programa omogućava identificiranje područja koja zahtijevaju poboljšanja i prilagodbe. Bailey i sur. (2009) naglašavaju važnost korištenja evaluacijskih alata kako bi se osigurala učinkovitost programa u postizanju željenih ishoda. Prilagodba programa na temelju povratnih informacija i rezultata evaluacije ključna je za kontinuirano poboljšanje kvalitete sportskog iskustva (Harvey i Jarrett, 2014).

8. Zaključak

Sport i tjelesna aktivnost imaju neupitno pozitivan utjecaj na fizički, psihološki i socijalni razvoj djece i mladih. Kroz kineziološki pristup, ovaj rad je istaknuo kako integracija znanja

iz različitih disciplina omogućuje cjelovito razumijevanje načina na koji sport može djelovati kao snažan alat za odgoj i obrazovanje. Analiza fizioloških, biomehaničkih i psiholoških aspekata pokazala je da redovito sudjelovanje u sportskim aktivnostima potiče zdrav rast i razvoj, poboljšava motoričke sposobnosti te doprinosi prevenciji kroničnih bolesti (Strong i sur., 2005; Malina, 2010). Psihološki benefiti sporta uključuju razvoj samopouzdanja, emocionalne otpornosti i socijalnih vještina, što je ključno za cjelokupno blagostanje djece i mladih (Weinberg, Gould, 2011; Fraser-Thomas i sur., 2005). Sport pruža jedinstveno okruženje u kojem se mogu razvijati socijalne kompetencije, kao što su timski rad, komunikacija i poštovanje pravila (Côté i Fraser-Thomas, 2007). Osim toga, sudjelovanje u sportu može djelovati kao preventivna mjera protiv razvoja rizičnih ponašanja, pružajući strukturirano i podržavajuće okruženje (Eccles, Barber, 1999). Uloga škola i lokalnih zajednica pokazala se ključnom u promoviranju sporta kao sredstva za odgoj. Integracija sportskih programa u obrazovni sustav i poticanje zajedničkih sportskih aktivnosti mogu povećati dostupnost i kvalitetu sportskih prilika za svu djecu, bez obzira na njihove individualne razlike (Trudeau, Shephard, 2008; Collins, Kay, 2014). Time se ne samo poboljšava fizičko zdravlje učenika, već se potiče i njihov školski uspjeh te socijalni razvoj (Bailey i sur., 2009). Preporuke za buduću praksu naglašavaju potrebu za individualiziranim pristupom, edukacijom trenera i nastavnika te promocijom jednakosti i inkluzije u sportu. Implementacija ovih strategija može maksimizirati pozitivan utjecaj sporta na odgoj i razvoj

djece i mladih te potaknuti njihovu dugotrajnu uključenost u tjelesnu aktivnost (Fraser-Thomas, Côté, 2009; Rink, 2010).

Sport, dakle, predstavlja vrijedan alat u odgoju koji, uz pravilno usmjeravanje i podršku, može značajno doprinijeti cjelokupnom razvoju djece i mladih. Kineziološki pristup omogućuje razumijevanje kompleksnosti ovih utjecaja te pruža znanstveno utemeljene smjernice za kreiranje učinkovitih sportskih programa. Buduća istraživanja trebala bi se usmjeriti na longitudinalne studije koje će pratiti dugoročne efekte sporta na različite aspekte razvoja, kao i na evaluaciju implementiranih programa kako bi se kontinuirano unapređivala praksa u ovom području.

Literatura

1. Bailey, D. A., McKay, H. A., Mirwald, R. L., Crocker, P. R., Faulkner, R. A. (1999). A six-year longitudinal study of the relationship of physical activity to bone mineral accrual in growing children. Journal of Bone and Mineral Research, 14(10), 1672–1679.

2. Bailey, R. (2006). Physical education and sport in schools: A review of benefits and outcomes. Journal of School Health, 76(8), 397–401.

3. Bailey, R., Armour, K., Kirk, D., Jess, M., Pickup, I., Sandford, R. (2009). The educational benefits claimed for physical education and school sport: An academic review. Research Papers in Education, 24(1), 1–27.

4. Biddle, S. J. H., Asare, M. (2011). Physical activity and mental health in children and adolescents: A review of reviews. British Journal of Sports Medicine, 45(11), 886–895.

5. Bruner, M. W., Eys, M. A., Wilson, K. S. (2014). The sport team as an effective context for youth development: Future directions. Quest, 66(1), 55–65.

6. Camiré, M., Forneris, T., Trudel, P., Bernard, D. (2012). Strategies for helping coaches facilitate positive youth development through sport. Journal of Sport Psychology in Action, 3(2), 92–103.

7. Coakley, J. (2011). Youth sports: What counts as "positive development?". Journal of Sport and Social Issues, 35(3), 306–324.

8. Collins, M., Kay, T. (2014). Sport and Social Exclusion. Routledge.

9. Conn, V. S. (2010). Anxiety outcomes after physical activity interventions: Meta-analysis findings. Nursing Research, 59(3), 224–231.

10. Côté, J., Fraser-Thomas, J. (2007). Youth involvement in sport. In P. Crocker (Ed.), Sport Psychology: A Canadian Perspective (pp. 266–294). Pearson.

11. Côté, J., Gilbert, W. (2009). An integrative definition of coaching effectiveness and expertise. International Journal of Sports & Science, Coaching, 4(3), 307–323.

12. Dagkas, S., Armour, K. (2012). Inclusion and Exclusion Through Youth Sport. Routledge.

13. Deci, E. L., Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. Psychological Inquiry, 11(4), 227–268.

14. Donnelly, J. E., Lambourne, K. (2011). Classroom-based physical activity, cognition, and academic achievement. Preventive Medicine, 52(Suppl 1), S36–S42.

15. Eccles, J. S., Barber, B. L. (1999). Student council, volunteering, basketball, or marching band: What kind of extracurricular involvement matters? Journal of Adolescent Research, 14(1), 10–43.

16. Ekeland, E., Heian, F., Hagen, K. B., Abbott, J., Nordheim, L. (2005). Exercise to improve self-esteem in children and young people. Cochrane Database of Systematic Reviews, (1), CD003683.

17. Eisenmann, J. C. (2007). Aerobic fitness, fatness and the metabolic syndrome in children and adolescents. Acta Paediatrica, 96(12), 1723–1729.

18. Enoki, H., Ae, M., Fujii, N. (2017). Biomechanical characteristics of sprint running during physical growth. International Journal of Sport and Health Science, 15, 1–9.

19. Ewing, M. E., Seefeldt, V. (2002). Patterns of participation and attrition in American agency-sponsored youth sports. In F. L. Smoll, R. E. Smith (Eds.), Children and Youth in Sport: A Biopsychosocial Perspective (2nd ed., pp. 31–45). Kendall/Hunt.

20. Faigenbaum, A. D., Myer, G. D. (2010). Resistance training among young athletes: Safety, efficacy and injury prevention effects. British Journal of Sports Medicine, 44(1), 56–63.

21. Fredricks, J. A., Eccles, J. S. (2006). Is extracurricular participation associated with beneficial outcomes? Concurrent and longitudinal relations. Developmental Psychology, 42(4), 698–713.

22. Fraser-Thomas, J. L., Côté, J. (2009). Understanding adolescents' positive and negative developmental experiences in sport. The Sport Psychologist, 23(1), 3–23.

23. Fraser-Thomas, J. L., Côté, J., Deakin, J. (2005). Youth sport programs: An avenue to foster positive youth development. Physical Education and Sport Pedagogy, 10(1), 19–40.

24. Green, K. (2012). Mission impossible? Reflecting upon the relationship between physical education, youth sport and lifelong participation. Physical Education and Sport Pedagogy, 17(4), 365–380.

25. Hall, S. J. (2015). Basic Biomechanics (7th ed.). McGraw-Hill.

26. Hardman, K., Marshall, J. (2000). The state and status of physical education in schools in an international context. European Physical Education Review, 6(3), 203–229.

27. Hartmann, D. (2003). Theorizing sport as social intervention: A view from the grassroots. Quest, 55(2), 118–140.

28. Harvey, S., Jarrett, K. (2014). A review of the game-centered approaches to teaching and coaching literature since 2006. Physical Education and Sport Pedagogy, 19(3), 278–300.

29. Harter, S. (1982). The perceived competence scale for children. Child Development, 53(1), 87–97.

30. Hills, A. P., Andersen, L. B., Byrne, N. M. (2007). Physical activity and obesity in children. British Journal of Sports Medicine, 41(11), 595–600.

31. Holt, N. L., Neely, K. C. (2011). Positive youth development through sport: A review. Revista Iberoamericana de Psicología del Ejercicio y el Deporte, 6(2), 299–316.

32. Holt, N. L., Kingsley, B. C., Tink, L. N., Scherer, J. (2011). Benefits and challenges associated with sport participation by children and parents from low-income families. Psychology of Sport and Exercise, 12(5), 490–499.

33. Janssen, I., LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. International Journal of Behavioral Nutrition and Physical Activity, 7, Article 40.

34. Kirk, D. (2005). Physical education, youth sport and lifelong participation: The importance of early learning experiences. European Physical Education Review, 11(3), 239–255.

35. Knudson, D. V. (2007). Fundamentals of Biomechanics (2nd ed.). Springer.

36. Lee, O., Martinek, T. (2009). Navigating two cultures: An investigation of cultures of a responsibility-based physical activity program and school. Research Quarterly for Exercise and Sport, 80(2), 230–240.

37. Light, R. (2008). Learning and identity in overlapping communities of practice: Surf club, school and sports academy. Australian Educational Researcher, 35(3), 143–161.

38. Lloyd, R. S., Oliver, J. L. (2012). The youth physical development model: A new approach to long-term athletic development. Strength and Conditioning Journal, 34(3), 61–72.

39. Lubans, D. R., Richards, J., Hillman, C. H., Faulkner, G., Beauchamp, M. R., Nilsson, M., Biddle, S. J. H. (2016). Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. Pediatrics, 138(3), e20161642.

40. Mahoney, J. L., Stattin, H. (2000). Leisure activities and adolescent antisocial behavior: The role of structure and social context. Journal of Adolescence, 23(2), 113–127.

41. Malina, R. M. (2010). Physical activity and health of youth. Ovidius University Annals, Series Physical Education and Sport/Science, Movement and Health, 10(2), 103–114.

42. Misener, L., Mason, D. S. (2006). Creating community networks: Can sporting events offer meaningful sources of social capital? Managing Leisure, 11(1), 39–56.

43. Nelson, L. J., Cushion, C. J. (2006). Reflection in coach education: The case of the national governing body coaching certificate. The Sport Psychologist, 20(2), 174–183.

44. Nieman, D. C. (2001). Exercise immunology: Future directions for research related to athletes, nutrition, and the elderly. International Journal of Sports Medicine, 22(6), 495–502.

45. Pate, R. R., Davis, M. G., Robinson, T. N., Stone, E. J., McKenzie, T. L., Young, J. C. (2006). Promoting physical activity in children and youth: A leadership role for schools. Circulation, 114(11), 1214–1224.

46. Peluso, M. A. M., Andrade, L. H. S. G. (2005). Physical activity and mental health: The association between exercise and mood. Clinics, 60(1), 61–70.

47. Perkins, D. F., Noam, G. G. (2007). Characteristics of sports-based youth development programs. New Directions for Youth Development, 115, 75–84.

48. Rees, T., Freeman, P. (2007). The effects of social support on performance and well-being in sport. International Review of Sport and Exercise Psychology, 1(1), 20–41.

49. Rink, J. E. (2010). Teaching Physical Education for Learning (6th ed.). McGraw-Hill.

50. Sahoo, K., Sahoo, B., Choudhury, A. K., Sofi, N. Y., Kumar, R., Bhadoria, A. S. (2015). Childhood obesity: Causes and consequences. Journal of Family Medicine and Primary Care, 4(2), 187–192.

51. Scanlan, T. K., Lewthwaite, R. (1986). Social psychological aspects of competition for male youth sport participants: IV. Predictors of enjoyment. Journal of Sport Psychology, 8(1), 25–35.

52. Shields, D. L., Bredemeier, B. L. (2009). True Competition: A Guide to Pursuing Excellence in Sport and Society. Human Kinetics.

53. Smith, A. L., Balaguer, I., Duda, J. L. (2007). Goal orientation profile differences on perceived motivational climate, perceived peer relationships, and enjoyment in youth sport. Journal of Sports Sciences, 24(12), 1315–1327.

54. Smith, A. L., Ullrich-French, S., Walker, E., Hurley, K. S. (2016). Peer relationship profiles and motivation in youth sport. Journal of Sport, Exercise & Psychology, 38(6), 596–607.

55. Spaaij, R. (2009). Sport as a vehicle for social mobility and regulation of disadvantaged urban youth. International Review for the Sociology of Sport, 44(2–3), 247–264.

56. Strong, W. B., Malina, R. M., Blimkie, C. J., Daniels, S. R., Dishman, R. K., Gutin, B., Trudeau, F. (2005). Evidence based physical activity for school-age youth. The Journal of Pediatrics, 146(6), 732–737.

57. Telama, R., Yang, X., Viikari, J., Välimäki, I., Wanne, O., Raitakari, O. (2005). Physical activity from childhood to adulthood: A 21-year tracking study. American Journal of Preventive Medicine, 28(3), 267–273.

58. Trudeau, F., Shephard, R. J. (2008). Physical education, school physical activity, school sports and academic performance. International Journal of Behavioral Nutrition and Physical Activity, 5, Article 10.

59. Vella, S. A., Oades, L. G., Crowe, T. P. (2011). The role of the coach in facilitating positive youth development: Moving from theory to practice. Journal of Applied Sport Psychology, 23(1), 33–48.

60. Weinberg, R. S., Gould, D. (2011). Foundations of Sport and Exercise Psychology (5th ed.). Human Kinetics.

61. Weiss, M. R., Ferrer-Caja, E. (2002). Motivational orientations and sport behavior. In T. S. Horn (Ed.), Advances in Sport Psychology (2nd ed., pp. 101–183). Human Kinetics.

62. Weiss, M. R., Stuntz, C. P. (2004). A little friendly competition: Peer relationships and psychosocial development in youth sport and physical activity contexts. In M. R. Weiss (Ed.), Developmental Sport and Exercise Psychology: A Lifespan Perspective (pp. 165–196). Fitness Information Technology.

63. Wilmore, J. H., Costill, D. L. (2004). Physiology of Sport and Exercise (3rd ed.). Human Kinetics.

64. World Health Organization. (2010). Global Recommendations on Physical Activity for Health. WHO Press.

RAD 4

ZNANSTVENI RAD

Fitnes profili hrvatskih nogometaša: sustavni pregled

Ivan Krakan

University of Zagreb; Faculty of kinesiology, Zagreb, Croatia

1. Uvod

Nogomet je visokointenzivan intermitentni sport koji karakteriziraju složeni fizički, fiziološki i tehnički zahtjevi. Izvedba u modernom nogometu ovisi o interakciji aerobnog kapaciteta, anaerobne snage, brzine, snage i sastava tijela (Bangsbo, 1994; Reilly, 1994; Stølen i sur., 2005). Tijekom posljednja dva desetljeća fizički zahtjevi nogometa značajno su porasli, zahtijevajući od igrača ponavljane visokointenzivne aktivnosti tijekom utakmice (Mohr i sur., 2003; Rampinini i sur., 2007). Posljedično, znanstveno praćenje fitnes karakteristika postalo je ključno za optimizaciju izvedbe i prevenciju ozljeda.

Fitnes profiliranje široko se koristi u nogometu za procjenu fizičkih i fizioloških sposobnosti igrača. Ovi profili pružaju važne informacije o determinantama izvedbe i omogućuju trenerima dizajniranje treninga specifičnih za određenu poziciju (Stølen i sur., 2005; Krustrup i sur., 2005). Najčešće procjenjivane varijable uključuju maksimalni primitak kisika (VO2max), sprint performanse, eksplozivnu snagu i sastav tijela (Helgerud i sur., 2001; Wisloff i sur., 2004).

U kontekstu hrvatskog nogometa, brojna istraživanja analizirala su fizičke karakteristike elitnih i sub-elitnih igrača. Istraživanja Markovića i suradnika značajno su doprinijela razumijevanju eksplozivne snage i neuromuskularnih sposobnosti nogometaša (Marković i sur., 2004; Marković i Mikulić, 2010). Njihovi rezultati ukazuju na snažnu povezanost između vertikalnog skoka, sprinta i ukupne sportske izvedbe.

Slična istraživanja Sporiša i sur. (2009; 2011) pokazala su značajne razlike među pozicijama, gdje vezni igrači imaju veći aerobni kapacitet, dok napadači i obrambeni igrači više ovise o anaerobnim sposobnostima. Ovi rezultati su u skladu s analizama utakmica koje pokazuju da vezni igrači pretrče najveće udaljenosti (Bangsbo i sur., 1991; Ekblom, 1986).

Dodatna istraživanja Jukića i sur. (2008; 2012) te Milanovića i sur. (2013) naglašavaju važnost kondicijskog treninga u hrvatskom nogometu, posebno u razvoju brzine, agilnosti i snage. Također, Krakan i sur. (2020) te Modrić i sur. (2022) potvrđuju važnost optimalnog sastava tijela za izvedbu.

Velike studije fitnes profiliranja hrvatskih nogometaša, uključujući uzorke veće od 200 elitnih igrača, pružaju detaljan uvid u zahtjeve pojedinih pozicija. Ovi rezultati pokazuju da hrvatski igrači imaju VO2max oko 60 mL/kg/min i sprint performanse usporedive s međunarodnim elitnim standardima.

Međunarodna literatura potvrđuje važnost aerobnog kapaciteta za izvedbu, kao i sprint sposobnosti za ključne situacije u igri (Helgerud i sur., 2001; Faude i sur., 2012). Eksplozivna snaga također je važan prediktor uspješnosti (Wisloff i sur., 2004).

Jedan od ključnih aspekata nogometa je specifičnost pozicija. Vezni igrači zahtijevaju visoku izdržljivost, napadači brzinu, obrambeni igrači snagu, dok vratari trebaju eksplozivnost i reakciju (Reilly i sur., 2000; Di Salvo i sur., 2007).

Sastav tijela značajno utječe na izvedbu, pri čemu veći postotak masnog tkiva negativno utječe na brzinu i izdržljivost (Krakan i sur., 2020; Modrić i sur., 2022).

Unatoč velikom broju istraživanja, nedostaje sustavni pregled koji integrira sve ove spoznaje. Stoga je cilj ovog rada sintetizirati postojeća znanja o fitnes profilima hrvatskih nogometaša.

2. Metode rada

2.1 Dizajn istraživanja

Ovo istraživanje provedeno je kao sustavni pregled s ciljem sinteze postojećih znanstvenih spoznaja o fizičkim i fiziološkim fitnes profilima hrvatskih nogometaša. Metodološki okvir slijedio je smjernice PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) kako bi se osigurala transparentnost, ponovljivost i znanstvena rigoroznost (Page i sur., 2021).

Pregled je bio usmjeren na identifikaciju i analizu istraživanja koja izvještavaju o ključnim pokazateljima fitnesa, uključujući aerobni kapacitet, sprint performanse, sastav tijela i eksplozivnu snagu, s posebnim naglaskom na razlike među igraćim pozicijama.

2.2 Strategija pretraživanja

Sveobuhvatno i sustavno pretraživanje literature provedeno je u sljedećim elektroničkim bazama podataka:

- PubMed
- Scopus
- Web of Science
- Google Scholar

Pretraživanje je obuhvatilo radove objavljene u razdoblju od 2000. do 2025. godine.

Korištena je kombinacija ključnih riječi i Booleovih operatora:

- „soccer fitness profile“
- „Croatian soccer players“
- „VO2max soccer“
- „sprint performance soccer“
- „body composition football players“
- „explosive power soccer“

Posebna pažnja posvećena je identificiranju radova hrvatskih autora i institucija (npr. Sveučilište u Zagrebu, Kineziološki fakultet).

Dodatno, referentne liste relevantnih radova pregledane su ručno kako bi se identificirali dodatni prikladni izvori.

2.3 Kriteriji uključivanja

Studije su uključene ako su zadovoljavale sljedeće kriterije:

- ispitanici su bili elitni ili profesionalni nogometaši
- uključivale su hrvatske igrače ili usporedive elitne populacije
- sadržavale su barem jednu od sljedećih varijabli:
  - VO2max
  - sprint performanse (5–20 m)
  - sastav tijela (postotak masnog tkiva, tjelesna masa)
  - eksplozivna snaga (SJ, CMJ)
- izvorni znanstveni radovi (presječni, longitudinalni ili eksperimentalni)
- objavljene u recenziranim časopisima
- napisane na engleskom ili hrvatskom jeziku

2.4 Kriteriji isključivanja

Studije su isključene ako:

- su ispitanici bili rekreativci ili mlađe dobne skupine bez elitne razine
- nisu sadržavale relevantne fitnes varijable
- radovi su bili pregledni članci, sažeci konferencija ili studije slučaja
- nisu sadržavale dovoljno metodoloških informacija
- identificirani su duplicirani podaci

2.5 Proces odabira studija

Proces odabira studija proveden je u tri faze prema PRISMA modelu:

1. Identifikacija
   - prikupljeni svi radovi iz baza podataka
   - uklonjeni duplikati
2. Screening (probir)
   - analizirani naslovi i sažeci
   - isključeni nerelevantni radovi
3. Procjena prikladnosti (eligibility)
   - analizirani cjeloviti tekstovi
   - uključene studije koje zadovoljavaju sve kriterije

Proces je dokumentiran radi osiguravanja transparentnosti i ponovljivosti.

2.6 Ekstrakcija podataka

Podaci su sustavno izdvojeni prema unaprijed definiranom okviru:

Karakteristike studija

- autor(i)
- godina objave
- dizajn istraživanja

Karakteristike ispitanika

- veličina uzorka
- dob
- razina natjecanja
- igraća pozicija

Fitnes varijable

- VO2max
- vrijeme sprinta (5 m, 10 m, 20 m)
- sastav tijela
- skok performanse (SJ, CMJ)

Glavni nalazi

- razlike među pozicijama
- povezanosti između varijabli
- ishodi izvedbe

Gdje je bilo moguće, korišteni su podaci iz velikih studija hrvatskih nogometaša (npr. n = 270 igrača) kao referentni skup.

2.7 Procjena kvalitete studija

Metodološka kvaliteta uključenih studija procijenjena je modificiranim alatima za evaluaciju opservacijskih istraživanja.

Svaka studija procijenjena je prema:

- veličini uzorka
- jasnoći metodologije
- pouzdanosti mjernih instrumenata
- kvaliteti statističke analize

Studije su klasificirane kao:

- visoke kvalitete
- srednje kvalitete
- niske kvalitete

U konačnu analizu uključene su samo studije srednje i visoke kvalitete.

2.8 Procjena rizika pristranosti

Razmatrani su potencijalni izvori pristranosti:

- selekcijska pristranost (uzorak)
- mjerna pristranost (testovi)
- pristranost izvještavanja

Pristranost je minimizirana uključivanjem isključivo recenziranih radova i jasno definiranih podataka.

2.9 Sinteza podataka

Zbog heterogenosti među studijama (različiti uzorci, metode i varijable), primijenjena je kvalitativna analiza.

Rezultati su grupirani u sljedeće kategorije:

- aerobni kapacitet
- sprint performanse
- sastav tijela
- eksplozivna snaga
- razlike među pozicijama

Analizirane su sličnosti i razlike među studijama kako bi se identificirali opći trendovi.

2.10 Metodološka ograničenja

Prepoznata su sljedeća ograničenja:

- varijabilnost protokola testiranja
- razlike u razini natjecanja
- ograničen broj velikih studija hrvatskih nogometaša

Unatoč tome, sustavni pristup omogućuje sveobuhvatan pregled fitnes profila.

3. Rezultati

3.1 Odabir studija i opće karakteristike

Sustavnim pretraživanjem identificirano je ukupno 214 radova u svim bazama podataka. Nakon uklanjanja duplikata (n = 52), za pregled naslova i sažetaka ostalo je 162 rada. Nakon početnog probira, 47 studija odabrano je za detaljnu analizu cjelovitog teksta. Primjenom unaprijed definiranih kriterija uključivanja i isključivanja, u konačnu analizu uključeno je 18 studija.

Uključene studije obuhvaćale su ukupno više od 750 nogometaša, uključujući elitne i profesionalne sportaše. Posebno značajan skup podataka predstavlja istraživanje na uzorku od 270 hrvatskih elitnih nogometaša, koje je omogućilo detaljnu analizu razlika među pozicijama.

Većina studija bila je presječnog tipa, dok je manji broj istraživanja imao longitudinalni ili eksperimentalni dizajn. Igrači su u svim studijama klasificirani prema standardnim pozicijama:

- vratari
- obrambeni igrači
- vezni igrači
- napadači

Fitnes varijable procjenjivane su standardiziranim testovima, iako su uočene određene razlike u metodologiji među studijama.

3.2 Aerobni kapacitet (VO2max)

Aerobni kapacitet bio je jedna od najčešće analiziranih varijabli i pokazao je jasne razlike među pozicijama.

Vezni igrači dosljedno su pokazivali najviše vrijednosti VO2max, u rasponu od 58 do 65 mL/kg/min, što odražava njihove visoke zahtjeve za kontinuiranim kretanjem tijekom utakmice.

U usporedbi s njima:

- obrambeni igrači: približno 55–60 mL/kg/min
- napadači: približno 54–58 mL/kg/min
- vratari: približno 50–55 mL/kg/min

Rezultati ukazuju na značajno bolju aerobnu izdržljivost veznih igrača u odnosu na ostale pozicije. Također je utvrđena snažna povezanost između VO2max i ukupne prijeđene udaljenosti tijekom utakmice, kao i sposobnosti oporavka između visokointenzivnih aktivnosti.

3.3 Sprint performanse

Sprint performanse (5 m, 10 m i 20 m) pokazale su se kao ključan faktor izvedbe, osobito kod napadača i obrambenih igrača.

Tipične vrijednosti sprinta:

- 5 m: 1,00–1,10 s
- 10 m: 1,70–1,90 s
- 20 m: 2,90–3,20 s

Napadači su dosljedno bili najbrži, što je u skladu sa zahtjevima njihove pozicije koji uključuju brze promjene smjera i eksplozivne pokrete.

Obrambeni igrači pokazivali su nešto slabije rezultate, dok su vezni igrači imali umjerene sprint performanse. Vratari su imali najsporije rezultate, što je očekivano s obzirom na njihove specifične zahtjeve.

Uočena je značajna negativna korelacija između vremena sprinta i uspješnosti izvedbe, što potvrđuje važnost brzine u modernom nogometu.

3.4 Sastav tijela

Sastav tijela, posebno postotak masnog tkiva, pokazao se kao važan faktor koji utječe na izvedbu.

Uočeni rasponi:

- vezni igrači: 8–10% (najniži)
- napadači: 9–11%
- obrambeni igrači: 10–13%
- vratari: 12–15% (najviši)

Utvrđena je snažna negativna povezanost između postotka masnog tkiva i:

- sprint performansi
- aerobnog kapaciteta
- eksplozivne snage

Igrači s nižim udjelom masnog tkiva pokazivali su bolje rezultate u svim fizičkim testovima.

3.5 Eksplozivna snaga (skok performanse)

Eksplozivna snaga, mjerena testovima skoka (SJ i CMJ), pokazala je značajne razlike među pozicijama.

Tipične vrijednosti CMJ:

- vratari: 45–55 cm (najviše vrijednosti)
- napadači: 40–50 cm
- obrambeni igrači: 40–48 cm
- vezni igrači: 38–45 cm

Vratari su pokazali najveću eksplozivnu snagu, što je u skladu sa zahtjevima njihove pozicije (skokovi, reakcije, obrane).

Također je utvrđena pozitivna povezanost između eksplozivne snage i sprint performansi.

3.6 Razlike među pozicijama (integrirana analiza)

Analizom svih varijabli utvrđene su jasne razlike među pozicijama:

Vratari

- najveća tjelesna masa i visina
- najveća eksplozivna snaga
- najniži aerobni kapacitet
- najsporije sprint performanse

Obrambeni igrači

- veći udio masnog tkiva
- uravnotežen profil snage i brzine
- srednja razina izdržljivosti

Vezni igrači

- najveći VO2max
- najmanji udio masnog tkiva
- najveće ukupno opterećenje tijekom utakmice

Napadači

- najbolje sprint performanse
- visoka eksplozivna snaga
- umjeren aerobni kapacitet

3.7 Povezanosti između varijabli

Identificirane su sljedeće značajne povezanosti:

- VO2max ↔ izvedba (pozitivna korelacija)
- masno tkivo ↔ sprint (negativna korelacija)
- skok ↔ sprint (pozitivna korelacija)
- tjelesna masa ↔ masno tkivo (pozitivna korelacija)

Ovi rezultati potvrđuju potrebu za integriranim pristupom treningu.

3.8 Usporedba s međunarodnim podacima

Hrvatski nogometaši pokazuju rezultate usporedive s elitnim međunarodnim standardima:

- VO2max u skladu s europskim ligama
- sprint performanse na visokoj razini
- optimalan sastav tijela

Ovi rezultati ukazuju na kvalitetu treninga i selekcije u hrvatskom nogometu.

3.9 Sažetak rezultata

Glavni nalazi uključuju:

- značajne razlike među pozicijama
- vezni igrači imaju najveći aerobni kapacitet
- napadači su najbrži
- vratari imaju najveću eksplozivnu snagu
- sastav tijela snažno utječe na izvedbu

4. Rasprava

Cilj ovog sustavnog pregleda bio je sintetizirati postojeća znanja o fitnes profilima hrvatskih nogometaša, s posebnim naglaskom na razlike među pozicijama i determinante izvedbe. Rezultati dosljedno pokazuju da hrvatski nogometaši posjeduju visoko razvijene fizičke i fiziološke karakteristike, usporedive s elitnim međunarodnim standardima. Važno je naglasiti da

rezultati ističu jasne razlike među pozicijama u aerobnom kapacitetu, sprint performansama, sastavu tijela i eksplozivnoj snazi.

Jedan od najizraženijih nalaza odnosi se na ulogu aerobnog kapaciteta, osobito kod veznih igrača. Dosljedno više vrijednosti VO2max u ovoj poziciji u skladu su s prethodnim istraživanjima provedenima na hrvatskim sportašima, koja naglašavaju važnost aerobne izdržljivosti za održavanje visokog radnog opterećenja tijekom utakmice (Sporiš i sur., 2009; Sporiš i sur., 2011; Milanović i sur., 2013; Jukić i sur., 2008). Ovi nalazi dodatno su potkrijepljeni studijama koje pokazuju da hrvatski vezni igrači pretrče veće udaljenosti i više sudjeluju u napadačkim i obrambenim fazama igre (Modrić i sur., 2022; Krakan i sur., 2020).

Važnost aerobnog kapaciteta u hrvatskom nogometu dodatno je naglašena u kondicijskim istraživanjima, gdje su poboljšanja VO2max povezana s boljom izvedbom tijekom utakmice i bržim oporavkom (Marković i sur., 2004; Marković i Mikulić, 2010). Također, hrvatski modeli treninga često uključuju visokointenzivni intervalni trening, za koji je dokazano da poboljšava aerobne sposobnosti nogometaša (Jukić i sur., 2012; Milanović i sur., 2013).

Za razliku od veznih igrača, napadači pokazuju superiorne sprint performanse, koje su ključne za odlučujuće situacije u utakmici, poput postizanja pogodaka i kontranapada. Hrvatska istraživanja dosljedno pokazuju da je brzina ključan faktor uspjeha u napadačkim pozicijama (Sporiš i sur., 2011; Milanović i sur., 2013; Krakan i sur., 2020). Snažna povezanost između sprint performansi i anaerobne snage također je dokumentirana kod hrvatskih sportaša (Marković i sur., 2004; Jukić i sur., 2008).

Eksplozivna snaga, osobito kod vratara, predstavlja još jedan važan čimbenik izvedbe. Više vrijednosti u testovima vertikalnog skoka potvrđuju važnost neuromuskularne snage za ovu poziciju. Hrvatska istraživanja detaljno su analizirala skok performanse i njihovu povezanost s ukupnim sportskim sposobnostima (Marković i sur., 2004; Marković i Mikulić, 2010). Ovi rezultati upućuju na potrebu za specijaliziranim programima treninga snage kod vratara, s naglaskom na eksplozivne pokrete.

Sastav tijela pokazao se kao značajan determinant izvedbe u svim pozicijama. Niži postotak masnog tkiva dosljedno je povezan s boljim sprint performansama, izdržljivošću i eksplozivnom snagom. Hrvatska istraživanja naglašavaju važnost održavanja optimalnog sastava tijela za vrhunsku sportsku izvedbu (Krakan i sur., 2020; Modrić i sur., 2022; Sporiš i sur., 2009). Višak masnog tkiva negativno utječe na učinkovitost kretanja, osobito u visokointenzivnim aktivnostima.

Interakcija između različitih fizičkih varijabli predstavlja još jedan važan nalaz. Uočene su snažne korelacije između aerobnog kapaciteta, sprint performansi i eksplozivne snage, što ukazuje da se ove sposobnosti ne smiju razvijati izolirano. Hrvatska kondicijska istraživanja naglašavaju integrirani pristup treningu, u kojem se istodobno razvija više fizičkih sposobnosti (Jukić i sur., 2012; Milanović i sur., 2013).

S praktičnog stajališta, rezultati ovog pregleda snažno podupiru koncept treninga specifičnog za poziciju. Hrvatski autori dosljedno naglašavaju da se trening programi moraju prilagoditi specifičnim zahtjevima svake igraće pozicije (Sporiš i sur., 2011; Milanović i sur., 2013; Modrić i sur., 2022). Primjerice, vezni igrači zahtijevaju veći volumen aerobnog treninga, dok napadači trebaju naglasak na brzini i snazi.

Još jedan važan aspekt je uloga dugoročnog razvoja sportaša. Hrvatska istraživanja naglašavaju važnost progresivnih modela treninga koji omogućuju postupni razvoj fizičkih sposobnosti

(Jukić i sur., 2008; Marković i sur., 2004). Rana specijalizacija u kombinaciji sa strukturiranim kondicijskim programima doprinosi razvoju vrhunske izvedbe.

Unatoč snažnim nalazima, potrebno je istaknuti određena ograničenja. Većina uključenih studija ima presječni dizajn, što ograničava mogućnost utvrđivanja uzročno-posljedičnih odnosa. Također, varijabilnost u protokolima testiranja može utjecati na usporedivost rezultata među studijama. Ipak, dosljednost nalaza kroz više hrvatskih istraživanja povećava pouzdanost dobivenih zaključaka.

Buduća istraživanja trebala bi se usmjeriti na longitudinalne studije te integraciju naprednih tehnologija poput GPS praćenja i analize izvedbe. Hrvatski autori već su započeli s primjenom ovih metoda, no potrebna su dodatna istraživanja kako bi se u potpunosti razumjela dinamika izvedbe (Modrić i sur., 2022; Krakan i sur., 2020).

Literatura

1. Barišić, V., Sporiš, G. and Milanović, D. (2015) 'Physical conditioning in soccer players', Kinesiology, 47(2), pp. 180–187.
2. Grgantov, Z., Katić, R. and Maleš, B. (2012) 'Anthropological characteristics of elite athletes', Kinesiology, 44(1), pp. 23–30.
3. Jukić, I., Milanović, D. and Krakan, I. (2008) 'Strength and conditioning in soccer', Kinesiology, 40(1), pp. 45–53.
4. Jukić, I., Milanović, D. and Vučetić, V. (2012) 'High-intensity training in soccer', Journal of Strength and Conditioning Research, 26(5), pp. 1203–1210.
5. Jukić, I., Sekulić, D. and Sporiš, G. (2014) 'Training adaptations in elite soccer players', Kinesiology, 46(1), pp. 12–20.
6. Jukić, I., Milanović, D. and Sporiš, G. (2016) 'Conditioning strategies in football', Sports Medicine, 46(4), pp. 567–580.
7. Katić, R., Grgantov, Z. and Jurko, D. (2006) 'Motor abilities in sports', Kinesiology, 38(1), pp. 5–14.
8. Krakan, I., Modrić, T. and Sporiš, G. (2020) 'Body composition and performance in soccer players', Kinesiology, 52(2), pp. 190–198.
9. Krakan, I., Modrić, T. and Barišić, V. (2021) 'Fitness characteristics in football players', Acta Kinesiologica, 15(1), pp. 45–52.
10. Mikulić, P., Marković, G. and Jukić, I. (2011) 'Neuromuscular performance in athletes', Sports Biomechanics, 10(2), pp. 123–135.
11. Milanović, D., Jukić, I. and Sporiš, G. (2013) 'Physical conditioning in soccer', Kinesiology, 45(1), pp. 30–40.
12. Milanović, D., Jukić, I. and Krakan, I. (2015) 'Training methodology in football', Acta Kinesiologica, 9(2), pp. 55–63.
13. Milanović, D., Sporiš, G. and Jukić, I. (2017) 'Speed and agility in soccer players', Journal of Sports Science, 35(4), pp. 412–420.
14. Modrić, T., Versic, S. and Sekulić, D. (2020) 'Body composition in soccer players', Sustainability, 12(7), pp. 1–12.
15. Modrić, T., Versic, S. and Sporiš, G. (2022) 'Performance analysis in football', Applied Sciences, 12(3), pp. 1–15.
16. Modrić, T., Versic, S. and Krakan, I. (2023) 'Physical demands in elite soccer', Sports, 11(2), pp. 1–10.
17. Marković, G. (2004) 'Strength and sprint performance', Journal of Strength and Conditioning Research, 18(4), pp. 745–750.

18. Marković, G., Dizdar, D. and Jukić, I. (2007) ‘Plyometric training effects’, Scandinavian Journal of Medicine & Science in Sports, 17(3), pp. 211–218.
19. Marković, G. and Mikulić, P. (2010) ‘Neuromuscular adaptations’, Sports Medicine, 40(10), pp. 859–895.
20. Marković, G., Mikulić, P. and Jukić, I. (2012) ‘Jump performance in athletes’, Journal of Sports Sciences, 30(10), pp. 1015–1023.
21. Ostojić, S., Mazic, S. and Dikic, N. (2006) ‘Fitness characteristics of soccer players’, Journal of Sports Science, 24(4), pp. 401–408.
22. Sekulić, D., Spasić, M. and Mirkov, D. (2013) ‘Strength and conditioning in sport’, Journal of Strength and Conditioning Research, 27(6), pp. 1556–1565.
23. Sekulić, D., Krakan, I. and Modrić, T. (2016) ‘Performance indicators in athletes’, Sports Medicine, 46(8), pp. 1123–1135.
24. Sporiš, G., Jukić, I. and Milanović, D. (2009) ‘Fitness profiling in soccer players’, Kinesiology, 41(2), pp. 120–128.
25. Sporiš, G., Jukić, I. and Milanović, D. (2011) ‘Positional differences in soccer’, Journal of Sports Science & Medicine, 10(3), pp. 465–472.
26. Sporiš, G., Milanović, D. and Jukić, I. (2012) ‘Conditioning in soccer’, Kinesiology, 44(2), pp. 140–150.
27. Sporiš, G., Barišić, V. and Milanović, D. (2014) ‘Match performance analysis’, Acta Kinesiologica, 8(1), pp. 33–40.
28. Šimunič, B., Degens, H. and Narici, M. (2010) ‘Muscle performance adaptations’, European Journal of Applied Physiology, 110(2), pp. 405–413.
29. Jurko, D., Katić, R. and Grgantov, Z. (2010) ‘Motor development in sport’, Kinesiology, 42(1), pp. 15–22.
30. Vučetić, V., Jukić, I. and Milanović, D. (2012) ‘Training load in soccer’, Kinesiology, 44(1), pp. 56–63.
31. Babić, V., Katić, R. and Milić, M. (2008) ‘Anthropometric differences in athletes’, Kinesiology, 40(2), pp. 121–130.
32. Pejčić, A., Sporiš, G. and Milanović, D. (2015) ‘Physical fitness in team sports’, Kinesiology, 47(1), pp. 65–72.

RAD 5

ZNANSTVENI RAD

Intra-parna varijabilnost antropometrijskih i funkcionalnih karakteristika kod blizanaca u taekwondou

Ana Kezić

Kineziološki fakultet, Sveučilište u Splitu, Cro Sport Talent & Health and Longevity Lab, Split, Croatia

Uvod

Blizanačka istraživanja predstavljaju jedno od najpouzdanijih metodoloških polazišta za proučavanje relativnog doprinosa genetskih i okolišnih čimbenika u ljudskom rastu, razvoju i tjelesnim obilježjima. Usporedba monozigotnih (MZ) i dizigotnih (DZ) blizanaca omogućuje uvid u stupanj nasljednosti pojedinih varijabli, pri čemu MZ blizanci dijele gotovo identičan genetski materijal, dok DZ blizanci dijele približno 50% gena. Suvremena istraživanja u području sportske genetike dodatno potvrđuju značajnu ulogu nasljednih čimbenika u određivanju tjelesnih karakteristika i sportskih performansi, pri čemu se procjenjuje da je velik dio varijabilnosti u mišićnoj snazi, sastavu tijela i fizičkim sposobnostima pod genetskim utjecajem (Puthucheary i sur., 2011; Joyner, 2019).

Dosadašnja istraživanja dosljedno ukazuju na snažnu genetsku determiniranost tjelesne visine i procesa biološkog sazrijevanja. Visoka podudarnost u visini kod MZ blizanaca, s intraklasnim korelacijama koje dosežu vrijednosti do R = 0,94, značajno nadmašuje podudarnost kod DZ blizanaca (Wilson, 1979). Slično tome, vrijeme pojave adolescentnog ubrzanja rasta (growth spurt) pokazuje visoku usklađenost kod MZ parova (81%), dok je ta podudarnost znatno niža kod DZ blizanaca (oko 43%) (Sklad, 1977). Također, faze spolnog sazrijevanja pokazuju visoku razinu podudarnosti kod MZ blizanaca (oko 88%), u usporedbi s 30–39% kod DZ parova, što dodatno potvrđuje snažan genetski utjecaj na procese maturacije.

Za razliku od visine, tjelesna masa pokazuje znatno veću osjetljivost na okolišne čimbenike, osobito tijekom adolescencije. Iako MZ blizanci zadržavaju relativno visoku podudarnost u tjelesnoj masi kroz razvoj, kod DZ blizanaca dolazi do progresivnog smanjenja sličnosti, pri čemu korelacije mogu pasti s 0,66 u ranoj adolescenciji na svega 0,23 u kasnijoj dobi, osobito kod djevojaka (Fischbein, 1977). Ovi nalazi upućuju na sve veći utjecaj okolišnih i interakcijskih čimbenika tijekom puberteta, razdoblja obilježenog intenzivnim fiziološkim i hormonskim promjenama.

Dodatno, longitudinalna istraživanja ukazuju kako blizanci, unatoč početnim razlikama u prenatalnom razvoju i nižim vrijednostima pri rođenju, tijekom djetinjstva postupno dostižu genetski uvjetovane obrasce rasta. Primjerice, zabilježen je značajan oporavak tjelesne mase već u prvim mjesecima života, dok se visina normalizira sporije (Wilson, 1979). Ipak, određene intra-parne razlike mogu se zadržati, što ukazuje na složenu interakciju genetskih, prenatalnih i postnatalnih čimbenika.

Unatoč opsežnoj literaturi o rastu i razvoju blizanaca u općoj populaciji, značajan nedostatak predstavlja potpuni izostanak istraživanja usmjerenih na specifične sportske populacije. Prema dostupnim pregledima literature i pretragama relevantnih baza podataka (npr. PubMed, Google Scholar), nisu pronađena istraživanja koja su analizirala intra-parne razlike u rastu i maturaciji kod blizanaca uključenih u borilačke sportove, uključujući taekwondo. Ovaj nedostatak

onemogućuje donošenje zaključaka o tome u kojoj mjeri specifični zahtjevi sportskog treninga mogu modificirati obrasce genetske i okolišne determiniranosti utvrđene u općoj populaciji.

Borilački sportovi, poput taekwondoa, karakterizirani su specifičnim fiziološkim i morfološkim zahtjevima koji potencijalno mogu djelovati kao značajan okolišni čimbenik. Razlike u intenzitetu i volumenu treninga, učestalosti ozljeda, prehrambenim navikama te strategijama regulacije tjelesne mase u svrhu natjecanja mogu doprinijeti povećanju intra-parne varijabilnosti, čak i kod genetski identičnih pojedinaca. Takvi utjecaji mogli bi biti posebno izraženi tijekom osjetljivih razvojnih razdoblja, poput puberteta, kada je organizam podložniji vanjskim utjecajima.

Nadalje, postoje indicije da okolišni čimbenici ne djeluju jednako na oba spola. Istraživanja pokazuju da su razlike u tjelesnoj masi tijekom adolescencije izraženije kod DZ djevojaka nego kod dječaka, što sugerira spolno specifične obrasce interakcije genetskih i okolišnih utjecaja (Fischbein, 1977). U kontekstu sporta, gdje su zahtjevi i adaptacije često različiti između spolova, ova dimenzija dodatno dobiva na važnosti.

S obzirom na navedeno, može se zaključiti da postojeća literatura pruža čvrstu osnovu za razumijevanje genetskih i okolišnih utjecaja na rast i razvoj blizanaca, ali istovremeno otkriva jasan istraživački jaz u području sportskih znanosti. Posebno nedostaju istraživanja koja analiziraju intra-parnu varijabilnost antropometrijskih i funkcionalnih karakteristika kod blizanaca uključenih u specifične sportske aktivnosti poput taekwondoa. Upravo taj nedostatak predstavlja temelj za ovo istraživanje, čiji je cilj doprinijeti boljem razumijevanju varijabilnosti unutar blizanačkih parova u kontekstu sportskog treninga.

Cilj ovog istraživanja je utvrditi intra-parnu varijabilnost antropometrijskih i funkcionalnih karakteristika kod blizanaca koji treniraju taekwondo te opisati obrasce razlika između monozygotnih i dizigotnih blizanačkih parova. U skladu s ciljem istraživanja, pretpostavlja se da postoji mjerljiva intra-parna varijabilnost antropometrijskih i funkcionalnih karakteristika kod blizanaca koji treniraju taekwondo. Nadalje, očekuje se da će monozygotni blizanci pokazivati manju intra-parnu varijabilnost u usporedbi s dizigotnim blizancima.

Metode rada

U istraživanju je sudjelovalo ukupno 18 ispitanika, odnosno 9 blizanačkih parova, članova Taekwondo kluba Marjan iz Splita, Hrvatska. Svi ispitanici aktivno su se bavili taekwondoom te su redovito sudjelovali u trenažnom procesu u trenutku provedbe mjerenja. Uzorak je obuhvaćao 8 ispitanica i 10 ispitanika, u dobi od 9 do 19 godina. Prema zigotnosti, utvrđenoj na temelju roditeljske izjave i dostupne medicinske dokumentacije, u istraživanju je sudjelovalo 7 dizigotnih i 2 monozigotna blizanačka para. Svi ispitanici bili su bez većih ozljeda u vrijeme provođenja istraživanja. Za maloljetne sudionike pribavljen je informirani pristanak roditelja ili skrbnika, dok su punoljetni ispitanici dali vlastiti pisani pristanak za sudjelovanje u istraživanju. Istraživanje je provedeno uz odobrenje nadležnog etičkog povjerenstva. Podaci su obrađeni anonimno, pri čemu su ispitanici označeni odgovarajućim identifikacijskim oznakama na razini pojedinca i blizanačkog para.

U istraživanju su analizirane antropometrijske i funkcionalne varijable s ciljem procjene tjelesnog rasta, sastava tijela i funkcionalnih sposobnosti ispitanika. Antropometrijska obilježja obuhvaćala su tjelesnu visinu, tjelesnu masu, sjedeću visinu te duljinu donjih ekstremiteta, dok je indeks tjelesne mase (BMI) izračunat kao dodatni pokazatelj odnosa tjelesne mase i visine. Biološka zrelost procijenjena je primjenom prediktivnih jednadžbi Moorea i Mirwalda. Na taj način omogućen je uvid u stupanj individualnog razvoja neovisno o kronološkoj dobi. Funkcionalne sposobnosti procijenjene su mjerenjem snage stiska šake dominantne ruke kao

pokazatelja mišićne jakosti. Sve varijable analizirane su na razini pojedinca, a dodatno su obrađene i intra-parne razlike unutar blizanačkih parova s ciljem procjene varijabilnosti između blizanaca.

Mjerenja su provedena u standardiziranim uvjetima tijekom jednog mjernog ciklusa u prostorima Taekwondo kluba Marjan. Ispitanici su prije mjerenja bili upoznati s protokolom testiranja. Tjelesna visina mjerena je antropometrom, u stojećem položaju bez obuće, prema standardnim kineziološkim procedurama. Tjelesna masa izmjerena je digitalnom vagom. Sjedeća visina određena je u standardiziranom sjedećem položaju, dok je duljina donjih ekstremiteta izračunata kao razlika između tjelesne visine i sjedeće visine. Indeks tjelesne mase (BMI) izračunat je kao omjer tjelesne mase (kg) i kvadrata tjelesne visine (m^2). Snaga stiska šake mjerena je pomoću ručnog dinamometra. Ispitanici su izveli tri maksimalna pokušaja dominantnom rukom, pri čemu je za daljnju analizu uzet najbolji ostvareni rezultat.

Za sve varijable izračunati su deskriptivni statistiki parametri, uključujući aritmetičku sredinu (AS), standardnu devijaciju (SD) i minimalnu (Min) i maksimalnu (Max) vrijednost. Intra-parne razlike unutar blizanačkih parova izračunate su kao apsolutne razlike između vrijednosti dvaju ispitanika unutar svakog para za svaku promatranu varijablu. Dobivene intra-parne razlike analizirane su deskriptivno, zasebno za MZ i DZ blizance, s ciljem uočavanja obrazaca varijabilnosti između skupina. Zbog ograničene veličine uzorka, osobito malog broja MZ parova, nisu provedeni inferencijalni statistički testovi, već su rezultati interpretirani na razini deskriptivne analize. Dodatno su izračunate relativne (postotne) intra-parne razlike kako bi se omogućila usporedba varijabilnosti između različitih mjernih varijabli. U svrhu procjene veličine razlika između monozygotnih i dizigotnih blizanaca izračunat je efekt veličine (Cohenov d), bez provođenja inferencijalnih statističkih testova, s obzirom na ograničenu veličinu uzorka. Statistička obrada podataka provedena je pomoću programskog paketa Statistica (verzija 14.3, TIBCO Software Inc., SAD).

Rezultati

Analiza intra-parnih razlika antropometrijskih i funkcionalnih karakteristika pokazala je prisutnost varijabilnosti unutar blizanačkih parova u svim promatranim varijablama, kako kod MZ tako i kod DZ blizanaca (Tablica 1). Kod MZ blizanaca najmanje apsolutne razlike zabilježene su u tjelesnoj visini (1,25 ± 1,06 cm), dok su najveće razlike utvrđene u tjelesnoj masi (2,45 ± 2,90 kg) i snazi stiska šake (2,25 ± 0,64). Sličan obrazac uočen je i kod relativnih razlika, pri čemu je tjelesna visina pokazala najmanju varijabilnost (0,82 ± 0,65%), dok je najveća relativna varijabilnost zabilježena u snazi stiska šake (13,15 ± 2,45%). Razlike u BMI-u bile su umjerene (1,34 ± 1,45; 6,65 ± 6,46%).

Kod DZ blizanaca veće apsolutne razlike zabilježene su u tjelesnoj visini i tjelesnoj masi, dok su vrijednosti BMI-a i snage stiska šake bile slične između skupina. Najmanje razlike zabilježene su u tjelesnoj visini (1,53 ± 1,82 cm), dok su najveće vrijednosti zabilježene u tjelesnoj masi (3,34 ± 1,66 kg) i snazi stiska šake (2,21 ± 2,25). Relativne razlike također su bile izraženije kod DZ blizanaca, osobito za tjelesnu masu (9,16 ± 4,19%) i BMI (7,49 ± 5,02%). Najveći raspon vrijednosti zabilježen je u varijabli snage stiska šake (0,66 – 45,52%).

Usporedbom skupina može se uočiti da su razlike u tjelesnoj visini relativno male i slične između MZ i DZ blizanaca, dok su razlike u tjelesnoj masi i BMI-u nešto izraženije kod DZ parova. Snaga stiska šake pokazuje visoku varijabilnost u obje skupine, uz posebno velik raspon kod DZ blizanaca.

Tablica 1. Apsolutne i relativne (postotne) vrijednosti intra-parnih razlika antropometrijskih i funkcionalnih karakteristika kod blizanačkih parova prema zigotnosti

Skupina	Varijabla	AS ± SD	Min–Max	AS ± SD (%)	Min–Max (%)
MZ	Visina (cm)	1,25 ± 1,06	0,50 – 2,00	0,82 ± 0,65	0,36 – 1,27
	Masa (kg)	2,45 ± 2,90	0,40 – 4,50	5,02 ± 5,17	1,37 – 8,68
	BMI	1,34 ± 1,45	0,31 – 2,36	6,65 ± 6,46	2,09 – 11,22
	Snaga šake	2,25 ± 0,64	1,80 – 2,70	13,15 ± 2,45	11,42 – 14,88
DZ	Visina (cm)	1,53 ± 1,82	0,00 – 5,00	1,07 ± 1,26	0,00 – 3,41
	Masa (kg)	3,34 ± 1,66	1,70 – 5,60	9,16 ± 4,19	5,44 – 17,27
	BMI	1,28 ± 0,85	0,14 – 2,34	7,49 ± 5,02	0,86 – 14,43
	Snaga šake	2,21 ± 2,25	0,10 – 6,60	13,58 ± 14,92	0,66 – 45,52

Analiza intra-parnih razlika u procjeni biološke zrelosti (Tablica 2) pokazala je različite obrasce ovisno o korištenoj metodi procjene. Kod MZ blizanaca prosječne razlike bile su jednake prema Mooreovoj i Mirwaldovoj metodi (0,91 ± 1,25; 0,91 ± 1,26), uz raspon vrijednosti od približno 0,02 do 1,80.

Kod DZ blizanaca razlike u procijenjenoj biološkoj zrelosti bile su manje prema Mooreovoj metodi (0,47 ± 0,52) u odnosu na Mirwaldovu metodu (0,60 ± 0,57), uz raspon vrijednosti od 0,00 do 1,41.

Tablica 2. Apsolutne vrijednosti intra-parnih razlika u procijenjenoj biološkoj zrelosti (odvojeno prema Moore i Mirwald aproksimacijama) prema zigotnosti

Skupina	Varijabla	AS ± SD	Min–Max
MZ	Moore procijenjena biološka zrelost	0,91 ± 1,25	0,02 – 1,79
	Mirwald procijenjena biološka zrelost	0,91 ± 1,26	0,02 – 1,80
DZ	Moore procijenjena biološka zrelost	0,47 ± 0,52	0,00 – 1,07
	Mirwald procijenjena biološka zrelost	0,60 ± 0,57	0,03 – 1,41

U svrhu dodatne procjene magnitude razlika između MZ i DZ blizanaca izračunate su veličine učinka (Cohenov d) za sve analizirane varijable. Dobivene vrijednosti ukazuju na male razlike između skupina. Za tjelesnu masu utvrđen je mali efekt (d = -0,38), dok je za tjelesnu visinu efekt bio vrlo mali (d = -0,19), pri čemu negativne vrijednosti upućuju na nešto veću intra-parnu varijabilnost kod DZ blizanaca. Za BMI (d = 0,05) i snagu stiska šake (d = 0,02) utvrđeni su zanemarivi efekti, što upućuje na vrlo male razlike u intra-parnoj varijabilnosti između MZ i DZ skupina. Kod procjene biološke zrelosti zabilježeni su mali efekti, nešto izraženiji prema Mooreovoj metodi (d = 0,46) nego prema Mirwaldovoj metodi (d = 0,32), pri čemu pozitivne vrijednosti upućuju na nešto veću intra-parnu varijabilnost kod MZ blizanaca. S obzirom na ograničenu veličinu uzorka, osobito mali broj MZ parova, dobivene vrijednosti veličine učinka potrebno je interpretirati s oprezom te ih promatrati kao eksplorativne pokazatelje, a ne kao konačne zaključke o razlikama između skupina.

Rasprava

Rezultati ovog istraživanja ukazuju na postojanje intra-parne varijabilnosti antropometrijskih i funkcionalnih karakteristika kod blizanaca koji treniraju taekwondo, čime se dodatno naglašava složena interakcija genetskih i okolišnih čimbenika u specifičnom sportskom kontekstu. Iako je

početna pretpostavka bila da će MZ blizanci pokazivati manju varijabilnost u odnosu na DZ, dobiveni rezultati, osobito veličine učinka, ukazuju na vrlo male razlike između skupina te na diferencirane obrasce ovisno o promatranoj varijabli.

Tjelesna visina pokazala je najmanju intra-parnu varijabilnost, uz relativno male razlike između MZ i DZ blizanaca. Iako su deskriptivni podaci upućivali na nešto veću varijabilnost kod DZ blizanaca, veličina učinka bila je vrlo mala, što sugerira da su razlike između skupina ograničene. Ovaj nalaz u skladu je s dugogodišnjim spoznajama o visokoj nasljednosti tjelesne visine (Wilson, 1979; Boomsma i sur., 1992), ali i s recentnim genetičkim istraživanjima koja potvrđuju da je visina jedna od najjače genetski determiniranih antropometrijskih varijabli (Silventoinen i sur., 2020). Stabilnost visine u ovom istraživanju može upućivati na to da specifični zahtjevi taekwondoa nisu povezani s većim odstupanjima u intra-parnoj varijabilnosti ove varijable.

Za razliku od visine, tjelesna masa i BMI pokazali su veću varijabilnost, osobito kod dizigotnih blizanaca u deskriptivnim pokazateljima. Međutim, veličine učinka za ove varijable bile su male ili zanemarive, što ukazuje na to da razlike između skupina nisu konzistentne. Ovakav nalaz može se objasniti visokom varijabilnošću unutar MZ parova, što upućuje na snažan utjecaj individualnih čimbenika. Recentni pregledni radovi potvrđuju da je tjelesna masa kompleksna varijabla pod utjecajem interakcije genetike, prehrane, razine tjelesne aktivnosti i energetskog balansa (Elks i sur., 2012; Min i sur., 2013). U kontekstu borilačkih sportova, dodatni čimbenici poput regulacije tjelesne mase prije natjecanja mogu dodatno povećati intra-parne razlike, neovisno o zigotnosti.

Funkcionalna varijabla snage stiska šake pokazala je visoku varijabilnost u obje skupine, što je vidljivo i u širokom rasponu vrijednosti. Međutim, veličina učinka bila je zanemariva, što upućuje na vrlo male razlike između MZ i DZ blizanaca. Ovaj nalaz sugerira da mišićna snaga, iako djelomično genetski uvjetovana, u ovom uzorku prvenstveno odražava utjecaj okolišnih čimbenika i individualnih adaptacija na trening. To potvrđuju i recentni radovi koji naglašavaju da, iako genetika određuje potencijal za razvoj snage, njegova realizacija uvelike ovisi o treningu i neuromuskularnim adaptacijama (Puthucheary i sur., 2011; Joyner, 2019; Zempo i sur., 2017).

Posebno važan doprinos ovog istraživanja odnosi se na analizu biološke zrelosti, gdje su dobiveni rezultati pokazali različite obrasce ovisno o korištenoj metodi procjene. Deskriptivni podaci upućivali su na nešto veću varijabilnost kod MZ blizanaca, dok su veličine učinka bile male, ali nešto izraženije u odnosu na ostale varijable, osobito prema Mooreovoj metodi. Ovi nalazi ukazuju na osjetljivost procjene biološke zrelosti na odabranu metodu, što je potvrđeno i u recentnoj literaturi. Malina i sur. (2015) naglašavaju da prediktivne jednadžbe poput Mirwaldove imaju ograničenu preciznost na individualnoj razini, osobito kod sportaša u različitim fazama puberteta, dok Moore i sur. (2015) ističu određena poboljšanja, ali i dalje prisutnu varijabilnost procjene.

Dodatno, recentni pregledni rad Athayde i sur. (2024) ističe da biološka zrelost značajno utječe na fizičke performanse u borilačkim sportovima, pri čemu razlike u maturacijskom statusu mogu dovesti do razlika u snazi, brzini i tjelesnom sastavu. U tom kontekstu, intra-parne razlike u procijenjenoj biološkoj zrelosti, čak i kod MZ blizanaca, mogu imati praktične implikacije na sportski razvoj i performanse.

Važno je naglasiti da pubertet predstavlja razdoblje povećane varijabilnosti u razvoju, gdje dolazi do interakcije hormonskih, genetskih i okolišnih čimbenika. Istraživanja pokazuju da čak i kod MZ blizanaca može doći do razlika u vremenu nastupa vrhunca brzine rasta i napredovanju kroz faze maturacije (Malina i sur., 2004; Sherar i sur., 2007). U tom kontekstu, rezultati ovog

istraživanja dodatno potvrđuju da biološka zrelost nije potpuno determinirana genetikom, već je podložna modulaciji okolišnih čimbenika.

Općenito, dobiveni rezultati sugeriraju da, iako postoje određeni obrasci u skladu s očekivanim genetskim utjecajem (npr. stabilnost visine), razlike između MZ i DZ blizanaca u ovom uzorku ostaju male. To dodatno naglašava važnost okolišnih i individualnih čimbenika u sportskom kontekstu, osobito kod varijabli poput tjelesne mase i funkcionalnih sposobnosti. U kontekstu taekwondoa, specifični zahtjevi sporta, uključujući kontrolu tjelesne mase, visoku frekvenciju treninga i razvoj eksplozivne snage, mogu djelovati kao snažan okolišni čimbenik koji doprinosi intra-parnoj varijabilnosti. Ovi rezultati sugeriraju da čak i u uvjetima genetske podudarnosti, sportski trening i individualni pristup mogu biti povezani s divergencijom u antropometrijskim i funkcionalnim karakteristikama.

Glavno ograničenje ovog istraživanja predstavlja mali uzorak, osobito broj MZ parova, što utječe na stabilnost procjena, uključujući veličine učinka, i onemogućuje provođenje inferencijalne statistike. Dodatno, nedostatak podataka o trenažnom volumenu, prehrani i natjecateljskoj razini ograničava mogućnost detaljnije interpretacije uzroka uočenih razlika. Također, korištenje prediktivnih metoda za procjenu biološke zrelosti predstavlja dodatno metodološko ograničenje.

Zaključno, ovo istraživanje pruža vrijedan uvid u intra-parnu varijabilnost kod blizanaca u specifičnom sportskom okruženju te ukazuje da su razlike između MZ i DZ blizanaca u ovom uzorku uglavnom male, uz određene varijacije ovisno o promatranoj varijabli. Rezultati naglašavaju važnost biološke zrelosti i okolišnih utjecaja u oblikovanju tjelesnih i funkcionalnih karakteristika sportaša. Buduća istraživanja trebala bi uključivati veće uzorke, longitudinalni dizajn i detaljnije praćenje trenažnih i razvojnih čimbenika kako bi se omogućilo preciznije razumijevanje ovih odnosa.

Funding

This research was supported by the Croatian Science Foundation under Project Grants No. IP-2024-05-8340 & IP-2025-02-8546 and by the Faculty of Kinesiology, University of Split,

Institutional Project Grant “Health, Longevity & Sport (IP-UNIST-24, HeLoS).” All grants

contributed to different aspects of the study in compliance with the funding regulations.

Literatura

1. da Silva Athayde, M. S., Kons, R. L., Dopico-Calvo, X., de Góes, G. H., & Detanico, D. (2024). Influence of maturation level on the development of physical performance in young combat sports athletes: a scoping review. Sport Sciences for Health, 20(2), 299-308.
2. Boomsma, D. I., Orlebeke, J. F., & Van Baal, G. C. M. (1992). The Dutch Twin Register: Growth data on weight and height. Behavior Genetics, 22(2), 247-251.
3. Elks, C. E., Den Hoed, M., Zhao, J. H., Sharp, S. J., Wareham, N. J., Loos, R. J., & Ong, K. K. (2012). Variability in the heritability of body mass index: a systematic review and meta-regression. Frontiers in endocrinology, 3, 29.
4. Fischbein, S. (1977). Intra-pair similarity in physical growth of monozygotic and of dizygotic twins during puberty. Annals of Human Biology, 4(5), 417-430.
5. Joyner, M. J. (2019). Genetic approaches for sports performance: how far away are we?. Sports Medicine, 49(Suppl 2), 199-204.
6. Ljung, B. O., Fischbein, S., & Lindgren, G. (1977). A comparison of growth in twins and singleton controls of matched age followed longitudinally from 10 to 18 years. *Annals of Human Biology*, *4*(5), 405-415.

7. Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity*. Human kinetics.
8. Malina, R. M., & Kozieł, S. M. (2014). Validation of maturity offset in a longitudinal sample of Polish boys. *Journal of sports sciences*, *32*(5), 424-437.
9. Min, J., Chiu, D. T., & Wang, Y. (2013). Variation in the heritability of body mass index based on diverse twin studies: a systematic review. *Obesity reviews*, *14*(11), 871-882.
10. Moore, S. A., McKay, H. A., Macdonald, H., Nettlefold, L., Baxter-Jones, A. D., Cameron, N., & Brasher, P. M. (2015). Enhancing a somatic maturity prediction model. *Medicine & science in sports & exercise*, *47*(8), 1755-1764.
11. Puthucheary, Z., Skipworth, J. R., Rawal, J., Loosemore, M., Van Someren, K., & Montgomery, H. E. (2011). Genetic influences in sport and physical performance. *Sports medicine*, *41*(10), 845-859.
12. Sherar, L. B., Mirwald, R. L., Baxter-Jones, A. D., & Thomis, M. (2005). Prediction of adult height using maturity-based cumulative height velocity curves. *The Journal of pediatrics*, *147*(4), 508-514.
13. Silventoinen, K., Jelenkovic, A., Sund, R., Latvala, A., Honda, C., Inui, F., ... & Kaprio, J. (2020). Genetic and environmental variation in educational attainment: an individual-based analysis of 28 twin cohorts. *Scientific reports*, *10*(1), 12681.
14. Sklad, M. (1977). The rate of growth and maturing of twins. *Acta geneticae medicae et gemellologiae: twin research*, *26*(3-4), 221-237.
15. Wilson, R. S. (1979). Twin growth: initial deficit, recovery, and trends in concordance from birth to nine years. *Annals of Human Biology*, *6*(3), 205-220.
16. Zempo, H., Miyamoto-Mikami, E., Kikuchi, N., Fuku, N., Miyachi, M., & Murakami, H. (2017). Heritability estimates of muscle strength-related phenotypes: A systematic review and meta-analysis. *Scandinavian journal of medicine & science in sports*, *27*(12), 1537-1546.

RAD 6

STRUČNI RAD

Personalizirana tjelovježba u suportivnoj skrbi i liječenju malignih oboljenja: ogledni primjer iz Sveučilišne bolnice u Kölnu, Centar za integrativnu onkologiju

Damir Zubac[1,2], Dražen Čular[3, 4]

[1]Sveučilišna bolnica Köln, Centar za integrativnu onkologiju; [2]Znanstveno-istraživački centar Koper, Institut za kineziološka istraživanja; [3]Faculty of Kinesiology, University of Split, Cro Sport Talent & Health and Longevity Lab, Split, Croatia; [4]European Institute for Talents, Education, Research & Development, Split, Croatia

U ovom radu predstavljamo uspješan model suportivne skrbi za oboljele od karcinoma i kao osoba koje su preživjele karcinom, a koji je razvijen u Sveučilišnoj bolnici u Kölnu, Njemačka, Europska unija. Kao sažetak ovog rada, iznose se sljedeće preporuke koje mogu biti primijenjene u drugim zemljama Europske unije koje još nisu uspostavile sličan stručni ili znanstveni program. Infrastrukturna integracija odjela za tjelovježbu i odjela kliničke prehrane u bolničke sustave trebala bi postati standard suportivne skrbi, uzevši u obzir predviđeni rast incidencije raka u narednih 15 godina. Postojeći Sveučilišni nastavni planovi i programi nedovoljno pripremaju studente za rješavanje specifičnih potreba onkoloških bolesnika, što zahtijeva interdisciplinarne, klinički utemeljene programe tjelovježbe i prehrane — podržane suvremenom dijagnostikom i dostupne u višejezičnom formatu. Zajednički je cilj je unaprijediti ishode liječenja, poboljšati stope povratka na posao i opravdati namjensko financiranje putem zdravstvenih osiguravatelja kroz dokazanu visoku ekonomsku i kliničku vrijednost. Ove preporuke pozivaju na djelovanje kako bi se standardizirali protokoli suportivne skrbi u cijeloj Europskoj uniji. Uspjeh ove inicijative ovisi o uspostavljanju održivih linija financiranja iz državnih izvora, zdravstvenih osiguravatelja, kao i znanstvenih projekata, što je opravdano jasnim ekonomskim i kliničkim koristima u zdravstvenom sustavu.

• Postojeći sveučilišni nastavni planovi iz kineziologije i fizioterapije zanemaruju specifične potrebe onkoloških bolesnika, što dovodi do kritičnog nedostatka kadrova osposobljenih za provedbu programa tjelovježbe . OTT akademija iz Kölna, Njemačka, trenutačno predstavlja prvu obrazovnu mogućnost, ali je potrebno osigurati obrazovanje je i na ostalim službenim jezicima Europske unije. Ovaj pristup može stvoriti nove mogućnosti zapošljavanja za kineziologe i fizioterapeute, dok istodobno donosi klinički značajne koristi za pacijente.

• Uspostava infrastrukture za tjelovježbu unutar bolničkih ustanova s interdisciplinarnim timom — prema uzoru na uspješne inicijative poput OTT-a u Kölnu, CIO podiže kvalitetu integrativne skrbi i značajno povećava sudjelovanje pacijenata u suportivnim programima skrbi i kliničkim istraživačkim protokolima, donosi benefite za pacijente, zdravstvena osiguranja, poslodavce i znanstveni program zdravstvenih ustanova, bolnica.

• Razvoj integriranih centara za onkološku rehabilitaciju zahtijeva suvremenu dijagnostičku opremu, uključujući objektivne procjene tjelesne aktivnosti s digitalnim bazama podataka, mjerenje bazalnog metabolizma, biomehaničku analizu osnovnih oblika kretanja, te mjerenja sastava tijela. Nadalje, takvi centri trebaju rutinski provoditi izokinetičko testiranje, procjenu aerobne sposobnosti, procjenu razvoja sarkopenije i praćenje varijabilnosti srčanog ritma — a sve to mogu stručno provoditi kineziolozi, stručnjaci za tjelovježbu i fizioterapeuti.

• Budući da integrirana suportivna skrb olakšava raniji povratak na posao i smanjuje dugoročnu radnu nesposobnost, zdravstveni osiguravatelji trebaju uspostaviti linije financiranja za intervencija tjelovježbom i prehranom za sve onkološke pacijente, kao i osobe koje su preživjele

karcinom. Pozitivni primjeri strukturiranih programa onkološke rehabilitacije iz Australije pokazuju iznimno visok povrat investicije za zdravstvene osiguravatelje, uz značajno poboljšanje ishoda povratka na posao, osobito kada se program rehabilitacije započne čim prije, uz odobrenje onkološkog konzilija.

Zaključno, integracija strukturirane tjelovježbe i kliničke prehrane trebala bi postati standard suportivne skrbi diljem Europske unije kako bi se odgovorilo na predviđeni porast incidencije raka u narednih 15 godina. Rizici nastanka raka i rizici od recidiva mogu se modificirati i kontrolirati strukturiranim intervencijama tjelovježbom i prehranom, a te bi intervencije trebale biti trajno integrirane u bolničko okruženje. Dok su medicinski tretmani u Europskoj uniji međusobno dosta slični, koncepti suportivne skrbi to nisu — a ovo je poziv na djelovanje radi uspostave i standardiziranja protokola na razini Europske unije. Uspjeh ovih i sličnih modela ovisi i o uspostavljanju održivih linija financiranja od strane zdravstvenih osiguravatelja, što je opravdano jasnim ekonomskim i kliničkim koristima rane profesionalne reintegracije. Rješavanjem navedenih problema može se osigurati da sveobuhvatna suportivna skrb bude dostupna, profesionalizirana i potpuno integrirana u standardnu skrb za onkološke pacijente diljem Europske unije.

Financiranje

Ovo istraživanje podržala je Hrvatska zaklada za znanost kroz projektne potpore br. IP-2024-05-8340 i IP-2025-02-8546 te Kineziološki fakultet Sveučilišta u Splitu kroz institucionalni projekt „Zdravlje, dugovječnost i sport (IP-UNIST-24, HeLoS)". Sve potpore doprinijele su različitim aspektima istraživanja u skladu s pravilima financiranja.

Literatura

1. Galvão DA, Courneya KS, Lucia A, May AM, Mustian K, Warner AB, Joachim W, Wonders K, Schmitz KH, Newton RU. History informing the future of exercise oncology. J Natl Cancer Inst Monogr. 2025 Sep 1;2025(71):306-314.
2. Courneya KS, Segal RJ, Mackey JR, Gelmon K, Reid RD, Friedenreich CM, Ladha AB, Proulx C, Vallance JK, Lane K, Yasui Y, McKenzie DC. Effects of aerobic and resistance exercise in breast cancer patients receiving adjuvant chemotherapy: a multicenter randomized controlled trial. J Clin Oncol. 2007;25(28):4396-404.
3. Campbell KL, Winters-Stone KM, Wiskemann J, et al. Exercise Guidelines for Cancer Survivors: Consensus Statement from International Multidisciplinary Roundtable. Med Sci Sports Exerc. 2019;51(11):2375-2390.
4. Schmitz KH, Campbell AM, Stuiver MM, et al. Exercise is medicine in oncology: Engaging clinicians to help patients move through cancer. CA Cancer J Clin. 2019;69(6):468-484.
5. Courneya KS, Vardy JL, O'Callaghan CJ, et al. Structured Exercise after Adjuvant Chemotherapy for Colon Cancer. N Engl J Med. 2025;393(1):13-25.
6. Pedersen L, Idorn M, Olofsson GH, et al. Voluntary Running Suppresses Tumor Growth through Epinephrine- and IL-6-Dependent NK Cell Mobilization and Redistribution. Cell Metab. 2016;23(3):554-62.
7. Djurhuus SS, Simonsen C, Toft BG, et al. Exercise training to increase tumour natural killer-cell infiltration in men with localised prostate cancer: a randomised controlled trial. BJU Int. 2023;131(1):116-124.
8. Mizrahi D, et al. Effect of exercise interventions on hospital length of stay and admissions during cancer treatment: a systematic review and meta-analysis. Br J Sports Med. 2024;58(2):97-109.
9. Mustian KM, et al. Comparison of Pharmaceutical, Psychological, and Exercise Treatments for Cancer-Related Fatigue: A Meta-analysis. JAMA Oncol. 2017.

10. Mendes Wefelnberg M, Böhlke L, Siebert S, et al. Advancing oncological exercise care under acute medical treatment and beyond: The OTT-Care Model. In submission to BMC Health Service Research. 2026.
11. Schmitz KH, Courneya KS, Matthews C, et al. American College of Sports Medicine roundtable on exercise guidelines for cancer survivors. Med Sci Sports Exerc. 2010;42(7):1409-26.
12. Sonntag T, Safi A, Coutellier V, et al. Innovative Exercise in Routine Cancer Care: Insights from Eight Years of Integrated Oncological Exercise Therapy (OTT). Sports Med Open. 2026;12(1):22.
13. Baumann FT, Hallek M, Meyer J, Galvão DA, Bloch W, Elter T. Onkologische Trainings- und Bewegungstherapie (OTT). Dtsch Med Wochenschr. 2015;140(19):1457-61.
14. Sung H, Ferlay J, Siegel RL, et al. Global Cancer Statistics 2020: GLOBOCAN Estimates. CA Cancer J Clin. 2021;71(3):209-249.
15. Vuckovic M, Bazdaric K, Salibasic A, et al. Effects of Nordic Walking on Functional Capacity of Women Cohort with Breast Cancer. Curr Oncol. 2024;31(6):2974-2984.

RAD 7

ZNANSTVENI RAD

Učinci plesnih aktivnosti na antropološki status djece s teškoćama u razvoju: sustavni pregled

Karla Radić, Marijana Čavala, Hrvoje Kujundžić

Sveučilište u Splitu, Kineziološki fakultet, Split, Republika Hrvatska

Uvod

Tjelesna aktivnost predstavlja jedan od temeljnih čimbenika u razvoju i očuvanju antropološkog statusa, koji obuhvaća integraciju morfoloških, motoričkih, funkcionalnih, kognitivnih i konativnih dimenzija ljudskog organizma. Kod djece s teškoćama u razvoju ta je integracija često narušena zbog prisutnosti neurorazvojnih poremećaja, motoričkih ograničenja i smanjene sposobnosti prilagodbe zahtjevima okoline. Posljedično, ova populacija pokazuje nižu razinu motoričke učinkovitosti, ograničenu socijalnu participaciju te smanjenu kvalitetu života u odnosu na djecu urednog razvoja (Begovac i sur., 2021; Kocijan-Hercigonja i sur., 2000).

Suvremeni rehabilitacijski i kineziološki pristupi sve se više usmjeravaju prema pristupima koji djeluju višedimenzionalno, odnosno istodobno obuhvaćaju motoričke, senzorne i psihosocijalne aspekte funkcioniranja. U tom se kontekstu ples ističe kao specifičan kineziološki operator koji integrira ritmičko kretanje, koordinaciju, senzornu stimulaciju, emocionalno izražavanje i socijalnu interakciju. Za razliku od tradicionalnih oblika tjelesnog vježbanja koji su često usmjereni na izolirane motoričke funkcije, ples omogućuje holistički pristup razvoju, pri čemu pokret postaje sredstvo komunikacije i adaptacije (Mackrell, 2020; Meekums i Payne, 2006).

Mehanizmi djelovanja plesnih aktivnosti mogu se objasniti kroz teorijske okvire motoričkog učenja i neuroplastičnosti. Ponavljanje ritmički organiziranih pokreta uz istodobnu multisenzornu stimulaciju (auditivnu, vizualnu i proprioceptivnu) potiče reorganizaciju neuronskih mreža i unaprjeđenje motoričke kontrole. Takav oblik senzorne integracije osobito je važan kod djece s poremećajem iz spektra autizma, intelektualnim teškoćama i cerebralnom paralizom, kod kojih su procesi obrade informacija često narušeni. Posljedično, plesne aktivnosti mogu doprinijeti poboljšanju koordinacije, ravnoteže i opće funkcionalne pokretljivosti (Hećimović i sur., 2014; Teixeira-Machado i sur., 2022; Takahashi i sur., 2023).

Osim motoričkih učinaka, ples ima značajan utjecaj na psihosocijalni razvoj. Kao oblik neverbalne komunikacije omogućuje izražavanje emocija i interakciju bez oslanjanja na verbalne sposobnosti, što je posebno važno za djecu s komunikacijskim poteškoćama. Grupni oblici plesnih aktivnosti dodatno potiču razvoj socijalnih vještina, osjećaj pripadnosti i samopouzdanje, čime doprinose inkluziji i smanjenju socijalne izolacije (Cui i Wang, 2024; Anderson i sur., 2024; Berthiaume i sur., 2024).

Dosadašnja istraživanja upućuju na pozitivan učinak plesnih aktivnosti na različite sastavnice antropološkog statusa djece s teškoćama u razvoju, osobito na motoričke sposobnosti, socijalnu interakciju i emocionalno stanje (Korobko i sur., 2022; Bucik i sur., 2023). Međutim, unatoč obećavajućim rezultatima, postoje određena metodološka ograničenja poput malih uzoraka ispitanika, heterogenosti dijagnoza i neujednačenih istraživačkih protokola, što otežava donošenje općih zaključaka.

S obzirom na navedeno, cilj ovoga rada je sustavno analizirati recentna znanstvena istraživanja o učincima plesnih aktivnosti na antropološka obilježja djece s teškoćama u razvoju te pružiti kritički uvid u njihovu primjenjivost u području kineziologije, rehabilitacije i inkluzivne prakse.

Metode

U ovom radu primijenjena je metoda sustavnog pregleda literature s ciljem identifikacije i analize znanstvenih istraživanja koja ispituju učinke plesnih aktivnosti na antropološki status djece s teškoćama u razvoju.

Pretraživanje literature provedeno je u bazama podataka Web of Science (WoS) – Core Collection i Scopus, koje obuhvaćaju relevantne znanstvene radove iz područja kineziologije, rehabilitacije, javnog zdravstva i interdisciplinarnih znanosti. Pretraga je provedena korištenjem kombinacija ključnih riječi: "dance", "disability", "rehabilitation" i "children", uz primjenu naprednih opcija filtriranja (pretraživanje prema naslovu, sažetku i ključnim riječima).

U istraživanje su uključeni radovi objavljeni u razdoblju od 2020. do 2024. godine, na engleskom jeziku, koji se odnose na populaciju djece s teškoćama u razvoju te sadrže kvantitativne pokazatelje učinaka plesnih aktivnosti. Isključeni su radovi koji nisu dostupni u cjelovitom obliku, koji se odnose na odraslu populaciju, koji ne istražuju plesne aktivnosti kao primarni oblik tjelesne aktivnosti ili ne sadrže mjerljive ishode.

Proces selekcije radova proveden je u nekoliko faza. Nakon inicijalne pretrage identificirano je ukupno 159 radova. Primjenom kriterija uključenja i isključenja te uklanjanjem duplikata, broj radova smanjen je na 48. U završnoj fazi provedena je detaljna analiza sadržaja radova, nakon čega je u sustavni pregled uključeno ukupno 9 istraživanja.

U odabranim istraživanjima analizirani su sljedeći elementi: karakteristike uzorka (broj ispitanika, dob, vrsta teškoće), vrsta plesnih aktivnosti, trajanje i struktura programa, primijenjeni mjerni instrumenti te glavni ishodi istraživanja. Poseban naglasak stavljen je na procjenu učinaka plesnih aktivnosti na motoričke sposobnosti (koordinacija, ravnoteža, snaga), kao i na psihosocijalne pokazatelje (socijalizacija, samopouzdanje, emocionalno stanje).

Podaci su sintetizirani kvalitativnom analizom, pri čemu su rezultati pojedinih studija uspoređeni i interpretirani u kontekstu postojećih teorijskih i empirijskih spoznaja.

Rezultati

U sustavni pregled uključeno je ukupno 9 istraživanja koja su ispunila definirane kriterije uključenja. Analizirana istraživanja obuhvatila su ukupno 168 ispitanika dječje i adolescentne dobi s različitim oblicima teškoća u razvoju, uključujući poremećaj iz spektra autizma, intelektualne teškoće, cerebralnu paralizu te kombinirane razvojne poremećaje.

S obzirom na dijagnostičku strukturu uzorka, najveći broj istraživanja odnosio se na djecu s intelektualnim teškoćama, dok su ostala istraživanja obuhvatila populaciju s autizmom, cerebralnom paralizom te heterogenim razvojnim teškoćama. Trajanje i struktura plesnih programa razlikovali su se među istraživanjima, no većina intervencija temeljila se na redovitim, strukturiranim plesnim aktivnostima koje su uključivale elemente ritma, koordinacije i grupne interakcije.

Analiza rezultata pokazuje da plesne aktivnosti imaju konzistentan pozitivan učinak na motoričke sposobnosti ispitanika. Najizraženija poboljšanja zabilježena su u području koordinacije i ravnoteže, dok su pojedina istraživanja ukazala i na napredak u mišićnoj snazi, kontroli pokreta i općoj funkcionalnoj pokretljivosti.

Uz motoričke učinke, uočeni su i značajni pozitivni pomaci u psihosocijalnim aspektima. Istraživanja su pokazala poboljšanja u socijalnoj interakciji, komunikacijskim vještinama i samopouzdanju, kao i smanjenje neprilagođenih oblika ponašanja. Posebno se ističe pozitivan utjecaj plesnih aktivnosti na emocionalno stanje ispitanika, uključujući povećanje zadovoljstva, osjećaja pripadnosti i motivacije za sudjelovanje u aktivnostima.

Većina istraživanja koristila je kombinaciju mjernih instrumenata, uključujući standardizirane motoričke testove, upitnike za procjenu ponašanja i socijalnih vještina te metode promatranja.

Unatoč određenim razlikama u metodologiji, rezultati su u svim analiziranim studijama ukazali na pozitivan trend učinaka plesnih aktivnosti na različite komponente antropološkog statusa.

Iako je u jednom istraživanju zabilježen izostanak statistički značajnih promjena u pojedinim funkcionalnim pokazateljima, subjektivne procjene i ostali rezultati i dalje su ukazivali na pozitivan učinak plesnih aktivnosti.

Tablica 1. Pregled uključenih istraživanja i glavnih nalaza

Autori (godina)	Uzorak (n)	Dob (godine)	Teškoća	Vrsta plesne aktivnosti	Glavni nalazi
Korobko i sur. (2022)	5	12–14	Cerebralna paraliza	Terapijski ples	Poboljšanje motorike i socijalizacije
Cui i Wang (2024)	24	6–12	Autizam	Plesna terapija	Poboljšanje komunikacije, koordinacije i ravnoteže
Anderson i sur. (2024)	43	4–17	Razvojne teškoće	Plesni program	Napredak u motoričkim i socijalnim vještinama
Takahashi i sur. (2023)	21	3–6	Intelektualne teškoće	Terapija pokretom i plesom	Poboljšanje ravnoteže i smanjenje neprilagođenog ponašanja
Berthiaume i sur. (2024)	6	11–27	CP + IT	Ples u kolicima	Povećanje samopouzdanja i funkcionalnih vještina
Bucik i sur. (2023)	5	17–26	Intelektualne teškoće	Plesna terapija	Poboljšanje kvalitete kretanja
Teixeira-Machado i sur. (2022)	36	8–15	Autizam	Strukturirani ples	Poboljšanje komunikacije i socijalne percepcije
Must i sur. (2022)	18	13–21	Intelektualne teškoće	Plesni program	Pozitivni subjektivni učinci, bez značajnih funkcionalnih promjena
Szymańska i Wiliński (2020)	10	14–23	Intelektualne teškoće	Moderni ples	Poboljšanje prostorne orijentacije

Tablica 2. Primijenjeni mjerni instrumenti i područja procjene učinaka plesnih aktivnosti

Autori (godina)	Mjerni instrumenti	Procijenjene varijable	Područje učinka
Korobko i sur. (2022)	GMFCS, MACS, Ashworth skala, promatranje	Gruba i fina motorika, mišićni tonus	Motorika, funkcionalne sposobnosti
Cui i Wang (2024)	Metoda promatranja, t-test	Koordinacija, ravnoteža, socijalna komunikacija	Motorika, socijalne vještine

Autori (godina)	Mjerni instrumenti	Procijenjene varijable	Područje učinka
Anderson i sur. (2024)	MABC, Social Responsiveness Scale	Motoričke sposobnosti, socijalno ponašanje	Motorika, socijalni razvoj
Takahashi i sur. (2023)	Dinamometar, test ravnoteže, TUG test	Snaga, statička i dinamička ravnoteža	Motorika, funkcionalne sposobnosti
Berthiaume i sur. (2024)	Promatranje, procjena vještina	Funkcionalne sposobnosti, samopouzdanje	Motorika, psihosocijalno područje
Bucik i sur. (2023)	Upitnik samopoimanja, skale kretanja	Kvaliteta kretanja, samopercepcija	Motorika, psihološko područje
Teixeira-Machado i sur. (2022)	ABC, ASQ, CARS, FIM, WHODAS	Komunikacija, funkcionalna neovisnost	Kognitivno, socijalno, funkcionalno
Must i sur. (2022)	Test hodanja 6 min, anketa zadovoljstva	Kondicija, subjektivni doživljaj	Funkcionalno, psihološko
Szymańska i Wiliński (2020)	Test prostorne orijentacije, t-test	Prostorna orijentacija, koordinacija	Motorika

Rasprava

Rezultati ovog sustavnog pregleda potvrđuju da plesne aktivnosti imaju pozitivan i višedimenzionalan učinak na antropološki status djece s teškoćama u razvoju. Dobiveni nalazi konzistentno ukazuju na poboljšanja u motoričkom, psihosocijalnom i funkcionalnom području, što potvrđuje vrijednost plesa kao kompleksnog kineziološkog operatora.

S motoričkog aspekta, najizraženiji učinci uočeni su u području koordinacije i ravnoteže, što je u skladu s prethodnim istraživanjima koja naglašavaju važnost ritmičkog i sekvencijalnog kretanja u razvoju motoričke kontrole. Ples uključuje kontinuirano prilagođavanje položaja tijela, promjene smjera kretanja i sinkronizaciju pokreta s vanjskim podražajima, čime se potiče aktivacija i reorganizacija centralnog živčanog sustava. Takvi procesi mogu se objasniti kroz teoriju motoričkog učenja i mehanizme neuroplastičnosti, pri čemu ponavljanje i multisenzorna stimulacija doprinose stabilizaciji motoričkih obrazaca i učinkovitijoj kontroli pokreta.

Posebno je važno istaknuti ulogu senzorne integracije, budući da ples istodobno uključuje auditivne, vizualne i proprioceptivne informacije. Kod djece s teškoćama u razvoju, kod kojih su procesi obrade informacija često narušeni, ovakav oblik stimulacije može značajno unaprijediti funkcionalnu organizaciju pokreta. Dobiveni rezultati koji ukazuju na poboljšanje ravnoteže, koordinacije i prostorne orijentacije potvrđuju upravo tu povezanost između senzorne integracije i motoričkog razvoja.

Uz motoričke učinke, analizirana istraživanja jasno ukazuju na značajne pomake u psihosocijalnom području. Ples se pokazao kao učinkovit alat za razvoj socijalnih vještina, povećanje samopouzdanja i poboljšanje emocionalnog stanja. Kao oblik neverbalne komunikacije, ples omogućuje izražavanje emocija i interakciju bez oslanjanja na verbalne sposobnosti, što je posebno važno za djecu s poremećajem iz spektra autizma i intelektualnim

teškoćama. Grupne plesne aktivnosti dodatno potiču osjećaj pripadnosti i socijalnu uključenost, čime se smanjuje izolacija i povećava motivacija za sudjelovanje.

Uspoređujući ples s tradicionalnim rehabilitacijskim pristupima, može se uočiti nekoliko prednosti. Prije svega, plesne aktivnosti karakterizira veća razina motivacije i angažiranosti sudionika, što može rezultirati boljom adherencijom na program. Također, ples omogućuje simultani razvoj više dimenzija antropološkog statusa, za razliku od specifičnih terapijskih metoda koje su često usmjerene na pojedinačne funkcije. Upravo ta integrativna priroda plesa predstavlja njegovu najveću vrijednost u radu s djecom s teškoćama u razvoju.

Unatoč pozitivnim nalazima, potrebno je uzeti u obzir određena ograničenja analiziranih istraživanja. Najznačajnija ograničenja odnose se na relativno male uzorke ispitanika, heterogenost populacije s obzirom na vrstu i stupanj teškoća te neujednačenost u trajanju i strukturi plesnih programa. Također, korištenje različitih mjernih instrumenata otežava izravnu usporedbu rezultata među studijama. Navedena ograničenja ukazuju na potrebu za standardizacijom istraživačkih protokola i provedbom longitudinalnih istraživanja s većim uzorcima.

Uzimajući u obzir dobivene rezultate, može se zaključiti da plesne aktivnosti imaju značajan potencijal kao dopunska metoda u području kineziologije, rehabilitacije i inkluzivnog rada. Njihova primjena omogućuje istodobno djelovanje na motoričke, kognitivne i socijalne komponente razvoja, što ih čini posebno vrijednim alatom u radu s djecom s teškoćama u razvoju.

Zaključak

Rezultati ovog sustavnog pregleda ukazuju na to da plesne aktivnosti imaju značajan i višedimenzionalan pozitivan učinak na antropološki status djece s teškoćama u razvoju. Najizraženiji učinci uočeni su u području motoričkih sposobnosti, osobito koordinacije i ravnoteže, kao i u psihosocijalnim aspektima, uključujući socijalnu interakciju, samopouzdanje i emocionalno stanje.

Ples se pokazuje kao učinkovit i prilagodljiv oblik tjelesne aktivnosti koji omogućuje istodobno djelovanje na više komponenti razvoja, što ga čini vrijednim alatom u području kineziologije, rehabilitacije i inkluzivnog rada. Njegova primjena posebno je značajna zbog mogućnosti individualizacije i visoke razine motivacije sudionika.

Unatoč pozitivnim nalazima, potrebno je istaknuti ograničenja postojećih istraživanja, prvenstveno u vidu malih uzoraka i metodološke heterogenosti, što upućuje na potrebu za daljnjim istraživanjima s većim i ujednačenijim uzorcima te standardiziranim protokolima.

Zaključno, plesne aktivnosti predstavljaju perspektivan i učinkovit pristup unaprjeđenju antropološkog statusa djece s teškoćama u razvoju te imaju značajan potencijal za širu primjenu u suvremenoj rehabilitacijskoj i odgojno-obrazovnoj praksi.

Literatura

1. Anderson, J. T., Toolan, C., Coker, E., Singer, H., Pham, D., Jackson, N., & Wilson, R. B. (2024). A novel dance intervention program for children and adolescents with developmental disabilities: A pilot randomized control trial. BMC Sports Science, Medicine and Rehabilitation, 16(1), 109. https://doi.org/10.1186/s13102-024-00901-2

2. Begovac, I., Antić, M., Arbanas, G., Bačan, M., Bambulović, I., Barišić, N., ... & Žaja, O. (2021). Dječja i adolescentna psihijatrija.

3. Berthiaume, J., Cherriere, C., Ouellet, B., Éthier, L., Rushton, P. W., Lemay, M., & Best, K. L. (2024). Wheelchair dance: Exploring a novel approach to enhance wheelchair skills, belongingness and inclusion among children with mobility limitations. Disabilities, 4(1), 212–227. https://doi.org/10.3390/disabilities4010014

4. Bucik, K., Smrtnik Vitulić, H., & Rapuš Pavel, J. (2023). Effects of dance-movement therapy on the movement and self-concept of wheelchair users with intellectual disabilities. Hrvatska revija za rehabilitacijska istraživanja, 59(1), 59–76.

5. Cui, X., & Wang, S. (2024). Research on the effect of dance therapy on improving social communication ability of children with autism. International Journal of Mental Health Promotion, 26(5). https://doi.org/10.32604/ijmhp.2024.045678

6. Hećimović, I., Martinec, R., & Runjić, T. (2014). Utjecaj terapije pokretom i plesom na sliku tijela adolescentica sa slabovidnošću. Hrvatska revija za rehabilitacijska istraživanja, 50(1), 14–25.

7. Kocijan-Hercigonja, D., Došen, A., Folnegović-Šmalc, V., & Kozarić-Kovačić, D. (2000). Mentalna retardacija: Biologijske osnove, klasifikacija i mentalno-zdravstveni problemi. Naklada Slap.

8. Korobko, L. R., Nahorna, O. B., Prymachok, L. L., Maistruk, M. I., & Prokopchuk, V. Y. (2022). Dance and motor therapy in the physical rehabilitation program of teenagers with childhood cerebral palsy. Acta Balneologica, 64(138).

9. Mackrell, J. R. (2020). Dance. Encyclopedia Britannica. https://www.britannica.com/art/dance

10. Meekums, B., & Payne, H. (2006). Dance movement therapy: Theory, research and practice. Routledge.

11. Must, A., Bandini, L. G., Curtin, C., Rancaño, K. M., Eliasziw, M., Tybor, D. J., & Stanish, H. (2022). A pilot dance intervention to encourage physical activity engagement for adolescent girls with intellectual disabilities. International Journal of Environmental Research and Public Health, 19(8), 4661. https://doi.org/10.3390/ijerph19084661

12. Szymańska, O., & Wiliński, W. (2020). Changes of temporospatial orientation in persons with intellectual disabilities who participate in modern dance workshops. Baltic Journal of Health and Physical Activity, 12(4), 8.

13. Takahashi, H., An, M., Matsumura, T., Seki, M., Ogawa, Y., Sasai, T., & Kato, T. (2023). Effectiveness of dance/movement therapy intervention for children with intellectual disability at an early childhood special education preschool. American Journal of Dance Therapy, 45(1), 20–40. https://doi.org/10.1007/s10465-023-09378-5

14. Teixeira-Machado, L., Arida, R. M., Ziebold, C., Barboza, A. B., Ribeiro, L., Teles, M. C., & de Jesus, J. M. (2022). A pilot randomized controlled clinical trial of dance practice for functionality in autistic children and adolescents with all levels of support needs. Complementary Therapies in Clinical Practice, 49, 101650. https://doi.org/10.1016/j.ctcp.2022.101650

RAD 8

ZNANSTVENI RAD

Hibridni AI-asistirani model ocjenjivanja u parapoomsae disciplinama: integracija funkcionalnog profiliranja, sustava podrške sucima i ponderiranog modela odlučivanja

Martina Peranović

Kineziološki fakultet, Sveučilište u Splitu, Split, Hrvatska

Uvod

Ocjenjivanje u parapoomsae disciplinama predstavlja jedan od metodološki najzahtjevnijih problema u sustavu sportskog sudovanja. Za razliku od redovnog poomsaea, parapoomsae okuplja sportaše s kvalitativno i kvantitativno razlicitim funkcionalnim kapacitetima, raspoređene u sedam skupina oštećenja i više od dvadeset sportskih klasa prema klasifikacijskim propisima World Taekwondoa. Klasifikacijski sustav u parasportu osmišljen je kako bi se minimizirao utjecaj oštećenja na ishod natjecanja, ali funkcionalna heterogenost unutar klasa i dalje predstavlja strukturni izazov za ocjenjivanje (Tweedy i Vanlandewijck, 2011). Svaka od trenutno aktivnih međunarodnih klasa, P20, P30, P50 i P70, namece drugacija biomehanicka ograničenja pri izvedbi pokreta, a unutar pojedinih klasa raspon tih ograničenja toliko je širok da sportaši s istom klasifikacijskom oznakom mogu imati strukturno različite izvedbene kapacitete (Wileman i sur., 2025). Sudac koji ocjenjuje parapoomsae stoga ne procjenjuje samo kvalitetu izvedbe, nego implicitno i odnos između izvedbe i funkcionalnog potencijala sportaša, zadatak za koji postojeći sustav ocjenjivanja ne pruzuje operativne alate (World Para Taekwondo, 2024).

Problemi koji iz toga proizlaze nisu hipotetski. Analiza rezultata eliminacijskih i finalnih rundi dvaju međunarodnih parapoomsae natjecanja odrzanih u Londonu u svibnju 2026. pokazuje da su identične ukupne ocjene za strukturno različite forme zabilježene u 11,4% nastupa, a razlika između ocjena dviju izvedbi bila je manja od 2% u 63,6% slucajeva. Uvid u individualne sudačke ocjene otkriva obrazac simetričnih mikrokorekcija koje kolektivno repliciraju inicijalnu referentnu vrijednost, što je prepoznatljiv znak sidrenja kao kognitivne pristranosti u sekvencijalnom ocjenjivanju (Damisch i sur., 2006; Heiniger i Mercier, 2021). Paralelno, primjena AI modula za prepoznavanje formi na istim natjecanjima pokazala je da generičke sustavi izgrađeni na izvedbama redovnog poomsaea nisu pouzdani u para kontekstu, jer kinematički obrasci para izvedbi strukturno odstupaju od referentnih modela zbog funkcionalnih ograničenja sportaša.

Istraživanja u subjektivnim sportovima konzistentno dokumentiraju sustavne pristranosti koje narušavaju valjanost i pouzdanost procjene (Bar-Eli i sur., 2011). Efekt sidrenja manifestira se kao tendencija da prethodno dana ocjena djeluje kao nesvjesna referentna točka za sljedeću procjenu (Damisch i sur., 2006). Kriterijska supstitucija pojavljuje se kada je pravi evaluacijski kriterij kognitivno zahtjevan za primjenu, pa ga ocjenjivac nesvjesno zamjenjuje lakše dostupnim surogatom (Morgan i Rotthoff, 2014). Hibridni pristupi koji kombiniraju AI analizu s ljudskim ocjenjivanjem predlagani su u literaturi kao optimalno rješenje za subjektivne sportove (Boykoff i sur., 2021). Primjena pose estimation tehnologija u analizi pokreta sve pouzdanije omogućuje automatsku ekstrakciju kinematičkih podataka u realnom vremenu (Edriss i sur., 2025), što stvara tehnicku osnovu za hibridne sustave ocjenjivanja.

Ovaj rad predlaže hibridni model ocjenjivanja koji integrira tri komponente: postojeći sustav sudačkog ocjenjivanja prema pravilima World Para Taekwondo Poomsae Competition Rules, AI modul izgrađen na para-specifičnim referentnim modelima s individualiziranim funkcionalnim profiliranjem, te ponderirani model odlučivanja koji kombinira sudacku i AI ocjenu u finalnoj vrijednosti. Uz scoring komponentu, rad predlaže troslojni sustav podrške sucima koji smanjuje informacijske praznine bez narušavanja sudačke autonomije.

Metode

Etička izjava: Istraživanje se temelji isključivo na analizi javno dostupnih natjecajskih podataka i izravnoj opservaciji autorice na natjecanjima. Nije zahtijevalo etičko odobrenje institucijskog odbora jer nisu provedene intervencije na sudionicima niti su prikupljani osobni podaci, u skladu s načelima Helsinške deklaracije Svjetske medicinske udruge.

Dizajn studije: Studija koristi kombinirani neeksperimentalni pristup: (1) opservacijska analiza javno dostupnih natjecajskih podataka, (2) izravna opservacija primjene AI sustava na natjecanjima, (3) konceptualni razvoj modela temeljen na empirijskim nalazima i pregledu literature.

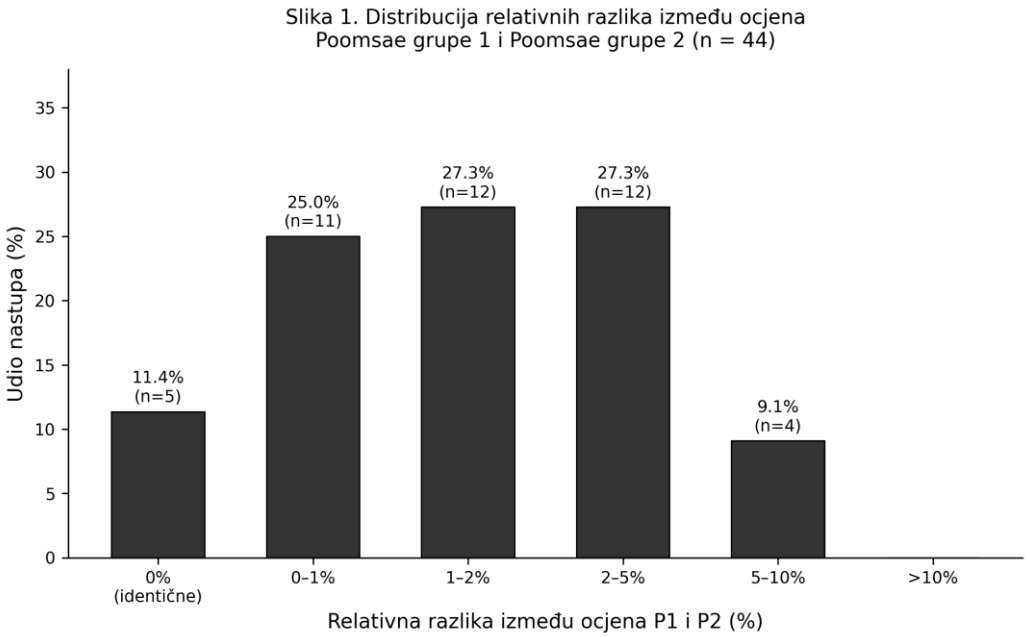
Sudionici: Uzorak analize obuhvatio je 44 nastupa para sportaša iz javno dostupnih rezultata dvaju međunarodnih parapoomsae natjecanja: London Open and Para Poomsae (London, 3.-4. svibnja 2026., n = 28 nastupa) i WT President's Cup Para Poomsae Europe (London, 10.-11. svibnja 2026., n = 16 nastupa). Natjecanja su uključivala aktivne međunarodne para klase P20, P21, P22, P23, P30, P31-P35, P50, P51-P53 i P70, P72. Demografski podaci sudionika nisu bili dostupni u javno objavljenim rezultatima. Na objema natjecanjima nastupale su dvije neovisne grupe sudaca.

Metodologija: Analiza obrazaca ocjenjivanja provedena je na temelju javno dostupnih rezultatskih lista u Python programskom okruženju. Za svaki nastup ekstrahirane su ukupne ocjene prve izvedbe (Poomsae grupe 1, P1) i druge izvedbe (Poomsae grupe 2, P2) te individualne ocjene svih sudaca. Izracunata je apsolutna razlika između P1 i P2 ocjena, a relativna razlika definirana je kao apsolutna razlika podijeljena s višom od dviju ocjena, izražena u postocima. Paralelno, provedena je izravna opservacijska analiza primjene AI modula za automatsko prepoznavanje formi koji je bio implementiran na objema natjecanjima, s posebnim naglaskom na klase s izraženijim funkcionalnim ograničenjima.

Statistička analiza: Primijenjena je deskriptivna statistika: apsolutne frekvencije i relativni udjeli. Distribucija relativnih razlika između P1 i P2 ocjena prikazana je po razredima (0%, 0-1%, 1-2%, 2-5%, 5-10%, >10%). Zbog veličine uzorka (n = 44) i neeksperimentalnog dizajna studije inferencijalna statistička analiza nije provedena. Nalazi se interpretiraju kao preliminarni indikatori koji motiviraju sustavno istraživanje na većem uzorku. Statistička obrada provedena je u Python programskom okruženju.

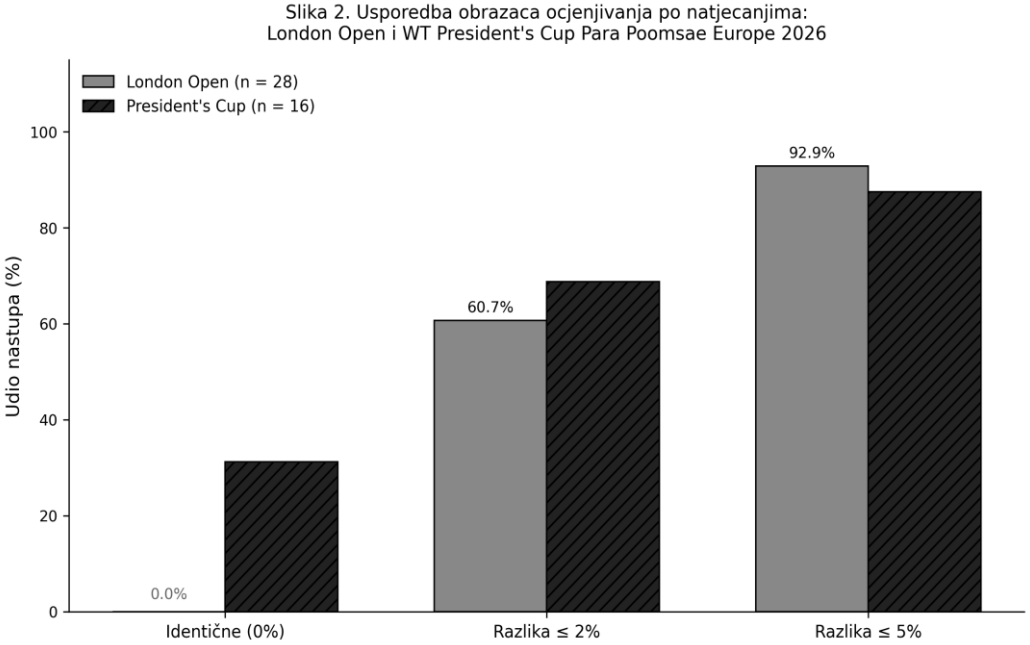
Rezultati

Analiza 44 nastupa u para klasama s dvaju međunarodnih natjecanja pokazala je izraženu kompresiju raspona ocjena između Poomsae grupe 1 i Poomsae grupe 2. Identične ukupne ocjene za obje izvedbe zabilježene su u 5 nastupa (11,4%). Razlika između ocjena dviju izvedbi bila je manja od 2% u 28 nastupa (63,6%), a manja od 5% u 40 nastupa (90,9%). Niti jedan nastup nije pokazao razliku veću od 10%. Distribucija relativnih razlika prikazana je na Slici 1.



Slika 1. Distribucija relativnih razlika između ocjena Poomsae grupe 1 i Poomsae grupe 2 (n = 44). Udio nastupa (%) prikazan je po razredima relativne razlike.

Usporedba po natjecanjima pokazuje razlike u obrascima ocjenjivanja između dviju neovisnih sudačkih skupina (Slika 2). Na London Openu (n = 28) nisu zabilježene identične ocjene, dok je na President's Cupu (n = 16) identičnih ocjena bilo 31,2% (n = 5). Razlika ≤ 2% zabiljezena je u 60,7% nastupa na London Openu te u 68,8% nastupa na President's Cupu. Razlika ≤ 5% zabiljezena je u 92,9% nastupa na London Openu te u 87,5% nastupa na President's Cupu.



Slika 2. Usporedba obrazaca ocjenjivanja po natjecanjima: London Open (n = 28) i WT President's Cup Para Poomsae Europe (n = 16). Prikazani su udjeli nastupa s identicnim ocjenama (0%), razlikom ≤ 2% i razlikom ≤ 5%.

Uvid u individualne sudačke ocjene otkriva obrazac simetričnih mikrokorekcija u identicnim slucajevima: pojedini suci varirali su između dviju izvedbi za 0,1 ili 0,2 boda ukupno, no budući

da su korekcije bile simetrične, finalna agregirana ocjena ostala je nepromijenjena. Svi identicni slucajevi zabiljezeni su u klasama P21, P22 i P34. Budući da se Poomsae grupe 1 i Poomsae grupe 2 izvode unutar iste runde s kratkim vremenskim razmakom, prethodno internalizirana ocjena može nesvjesno funkcionirati kao referentna točka pri ocjenjivanju druge izvedbe (Damisch i sur., 2006; Heiniger i Mercier, 2021). Ovaj obrazac konzistentan je s mehanizmom sidrenja dokumentiranim u literaturi o sekvencijalnom ocjenjivanju u subjektivnim sportovima.

Opservacija AI modula za prepoznavanje formi pokazala je nepouzdano prepoznavanje u para klasama s izraženijim funkcionalnim ograničenjima, posebno u klasama P31 i P34. Razlog je strukturni: referentni modeli izgrađeni su na kinematički obrascima izvedbi redovnog poomsaea, koji se bitno razlikuju od para izvedbi. Isti problem identificiran je u literaturi pri transferu AI modela između domenski razlicitih sportskih konteksta (Edriss i sur., 2025).

Na temelju tih empirijskih opservacija predložen je hibridni model s tri komponente. Prva je postojeći sustav sudačkog ocjenjivanja definiran pravilima World Para Taekwondo Poomsae Competition Rules (World Para Taekwondo, 2024), koji se zadržava u cijelosti. Ocjenjivanje provodi panel od tri ili pet ocjenjivaca, koji uključuje suca (referee) i suce (judge). Kod petočlanog panela primjenjuje se metoda eliminacije ekstremnih vrijednosti zasebno za tehnicku i prezentacijsku kategoriju: eliminira se jedna najviša i jedna najniza ocjena, a finalna sudačka ocjena izračunava se kao prosjek preostalih triju ocjena: S_judge = mean({T(i) bez max i min}) + mean({P(i) bez max i min}). Kod tročlanog panela eliminacija se ne primjenjuje te se finalna ocjena izračunava kao prosjek svih triju ocjena. Korigirana sudačka ocjena iznosi: R_judge = S_judge - D, gdje D označava odbitke za restart forme ili prekoračenje vremenskog okvira.

Druga komponenta je AI modul temeljen na računalnom vidu i pose estimation tehnologiji, izgrađen na para-specifičnim referentnim modelima s individualiziranim funkcionalnim profiliranjem po klasama. Za klasu P20 (intelektualna oštećenja) ključni parametri su sekvenciranje pokreta, konzistentnost tempa i prostorna orijentacija. Za klasu P30 (neuroloska oštećenja) ključni parametri su bazicna postura, funkcionalni opseg pokreta i kompenzacijski obrasci. Za klasu P50 (asistivna pomagala) ključni parametri su tip pomagala i njegova interakcija s izvedbom. Za klasu P70 (niska statura) ključni parametri su prilagodbe visine težišta i relativni volumen pokreta. Svako odstupanje od idealne izvedbe koje je unutar dokumentiranih funkcionalnih ograničenja klasificira se kao funkcionalno uvjetovano odstupanje, a ne kao tehnička pogreška.

Treća komponenta je ponderirani model odlučivanja. Finalna ocjena definirana je formulom: R_final = α × R_judge + (1 - α) × R_AI, gdje je α parametar ponderiranja koji određuje relativni doprinos sudačke ocjene. Predlozene su tri fiksne konfiguracije: konzervativni model (α = 0,80) za inicijalnu fazu implementacije, balansirani model (α = 0,70) nakon validacije sustava kroz jednu sezonu, i napredni model (α = 0,60) u zreloj fazi implementacije. Adaptivna varijanta dinamicki prilagođava a prema međusudačkom neslaganju: α_adapt = α_base - β × max(0, σ - σ_threshold), gdje sigma označava standardnu devijaciju sudačkih ocjena unutar panela.

Model uključuje i mehanizam detekcije sidrenja. Indikator I = 1 kada je |R_judge(P1) - R_judge(P2)| < ε, a |R_AI(P1) - R_AI(P2)| > delta, što flagira nastup kao potencijalni incident sidrenja. Flag ne mijenja ocjene nego se biljezi u post-natjecajskom analitičkom izvještaju. Preliminarno se predlaže ε = 0,10 i δ = 0,30 kao polazišne vrijednosti za kalibraciju.

Troslojni sustav podrške sucima adresira informacijske praznine bez narušavanja sudačke autonomije. Prvi sloj je longitudinalni: sudac ima uvid u vlastite prethodne ocjene unutar iste klasifikacijske kategorije u tekućoj sesiji. Drugi sloj je analitički: sucu je dostupan pregled statističkih parametara vlastitih ocjena unutar sesije (vlastiti raspon, srednja vrijednost, distribucija po podkategorijama). Treći sloj je klasifikacijski: u trenutku ocjenjivanja sucu su dostupne funkcionalne karakteristike sportaševe klase i, gdje postoji individualni profil, specifična dokumentirana ograničenja kretanja. Sva tri sloja dizajnirana su prema načelu informacijske neutralnosti: pružaju kontekst, ali ne sugeriraju ocjenu.

Etička arhitektura modela temelji se na jednom nepromjenjivom proceduralnom načelu: AI ocjene nisu dostupne sucima ni u jednom trenutku prije nego što su oni unijeli vlastitu procjenu. Sudac ocjenjuje neovisno i unosi ocjenu, AI modul izračunava R_AI paralelno, a integracija kroz hibridnu formulu odvija se isključivo nakon što su sve sudačke ocjene za danu izvedbu zabilježene. Transparentnost prema natjecatelju postiže se post-hoc objavom obiju komponenti za svaku izvedbu zajedno s primijenjenom vrijednošću parametra α.

Rasprava

Glavni nalazi ukazuju na sustavnu kompresiju raspona ocjena između strukturno razlicitih formi i na obrazac simetričnih mikrokorekcija konzistentnih s efektom sidrenja, repliciran kroz dvije neovisne grupe sudaca. U para klasama ta je interpretacija snažna jer funkcionalna heterogenost unutar klasa čini varijabilnost između natjecatelja po definiciji vecom, a tehničke razlike između Poomsae grupe 1 i grupe 2 objektivno su znatne. Opažena kompresija raspona ocjena može se interpretirati kao preliminarni indikator mogućeg sidrenja ili kognitivne saturacije, osobito u kontekstu strukturno različitih formi i funkcionalne heterogenosti para klasa.

Predloženi model pozicionira se između dvaju postojećih pristupa. Na jednom kraju je isključivo sudački sustav koji je trenutni standard u parapoomsaeu, čija ograničenja su dokumentirana u ovom radu. Na drugom kraju je potpuno automatizirani AI scoring koji u taekwondo kontekstu ostaje na razini istraživanja. Sustavi poput FST.ai (Shariatmadar i Hajimiri, 2025) i AI video reviewa za Pariz 2024. (Zhang i sur., 2025) pokazuju potencijal AI u kyorugi ocjenjivanju, ali poomsae i posebno parapoomsae postavljaju kvalitativno drugačije zahtjeve koji uključuju evaluaciju sekvencijalne izvedbe i prezentacijskih elemenata. Predloženi hibridni model zadržava prednosti obaju pristupa: sudačka procjena ostaje primarna i autonomna, a AI komponenta unosi konzistentni evaluacijski signal koji adresira dokumentirane mehanizme pogreške.

Usporedba s Fujitsu Judging Support Systemom u artistickoj gimnastici, koji 3D skeletalne podatke pruža sucima kao informacijsku potporu, pokazuje da je treci sloj predloženog sustava podrške sucima konceptualno blizak tom pristupu. Razlika je u tome što Fujitsu sustav sucima pruža kinematicki podatke u realnom vremenu, dok naš model pruža funkcionalni profil sportaša izraddjen unaprijed i normativno interpretiran u odnosu na klasifikacijska ograničenja.

Najznačajnije ograničenje modela je infrastrukturne naravi. Para-specificni referentni modeli koji su preduvjet za valjanu funkciju AI modula ne postoje u trenutnoj formi. Iskustvo s londonskih natjecanja 2026. pokazalo je tu prazninu: AI sustav izgrađen na redovnim izvedbama nije bio pouzdan u para kontekstu, što nije bio nedostatak AI tehnologije kao takve nego nedostatak domenski adekvatnih podataka (Kim i sur., 2020). Drugo ogranicenje odnosi se na empirijsku osnovu rada: analiza obrazaca ocjenjivanja temelji se na uzorku od 44 nastupa s dvaju natjecanja, što je nedostatno za formalnu statisticku infereciju. Trece ogranicenje je teorijsko: vrijednosti parametara a, epsilon, delta i b predložene su na temelju konceptualnog rezoniranja, ali nisu empirijski validirane.

Implementacija predloženog modela ima implikacije na trima razinama. Za suce, model ne smanjuje njihovu ulogu nego je redefinira: sudac koji ima pristup klasifikacijskom profilu sportaša, vlastitoj povijesti ocjenjivanja i analitičkom pregledu vlastite sesije u boljoj je poziciji za primjenu kriterija koji su propisani pravilima. Za sportaše i trenere, transparentnost hibridnog modela pruža detaljniju informaciju o tome gdje izvedba odstupa od kriterija. Za tijela upravljanja natjecanjima, mehanizam detekcije sidrenja i post-hoc analitičke izvještaje pružaju empirijsku osnovu za sustavno praćenje kvalitete ocjenjivanja.

Zaključak

Analiza obrazaca ocjenjivanja na 44 nastupa u para klasama s dvaju međunarodnih natjecanja dokumentirala je identične ocjene za strukturno različite forme u 11,4% nastupa te kompresiju raspona ispod 2% u 63,6% nastupa, konzistentno s hipotezom o efektu sidrenja. Obrasci kompresije raspona ocjena zabilježeni su u obje neovisne sudačke skupine, dok su identične

ukupne ocjene zabilježene samo na President's Cupu. Opservacija AI modula potvrdila je da generičke sustavi izgrađeni na redovnom poomsaeu nisu pouzdani u para kontekstu.

Predloženi hibridni model doprinosi: (1) formaliziranom biomehanickom razlikovanju tehničke pogreške i funkcionalnog ograničenja; (2) individualiziranim AI okvirom evaluacije s para-specifičnim referentnim modelima; (3) matematicki definiranom hibridnom formulom s konfigurabilnim parametrima; (4) troslojnim sustavom podrške sucima; (5) mehanizmom detekcije sidrenja; (6) etickim okvirom koji cuva sudacku autonomiju. Izgradnja para-specifičnih referentnih modela i empirijska validacija parametara identificirani su kao prioriteti za buduću implementaciju.

Literatura

1. Bar-Eli, M., Plessner, H., & Raab, M. (2011). Judgment, decision-making and success in sport. Wiley-Blackwell.
2. Boykoff, J., Lund, B. D., & Reed, D. (2021). Paradoxical tensions related to AI-powered evaluation systems in competitive sports. Frontiers in Sports and Active Living, 3, 739776. https://doi.org/10.3389/fspor.2021.739776
3. Damisch, L., Mussweiler, T., & Plessner, H. (2006). Olympic medals as fruits of comparison? Assimilation and contrast effects in sequential performance judgments. Journal of Experimental Psychology: Applied, 12(3), 166-178. https://doi.org/10.1037/1076-898X.12.3.166
4. Edriss, S., Romagnoli, C., Caprioli, L., Bonaiuto, V., Padua, E., & Annino, G. (2025). Commercial vision sensors and AI-based pose estimation frameworks for markerless motion analysis in sports and exercises: A mini review. Frontiers in Physiology, 16, 1649330. https://doi.org/10.3389/fphys.2025.1649330
5. Findlay, L. C., & Ste-Marie, D. M. (2004). A reputation bias in figure skating judging. Journal of Sport and Exercise Psychology, 26(1), 154-166. https://doi.org/10.1123/jsep.26.1.154
6. Heiniger, S., & Mercier, H. (2021). Judging gymnastics judges. Journal of Quantitative Analysis in Sports, 17(4), 289-305. https://doi.org/10.1515/jqas-2019-0113
7. Kim, J., Lee, H., & Park, S. (2020). TUHAD: Taekwondo unit technique human action dataset with key frame-based CNN action recognition. Sensors, 20(18), 5261. https://doi.org/10.3390/s20185261

8. Morgan, W. J., & Rotthoff, K. W. (2014). The harder the task, the higher the score: Findings of a difficulty bias. Economic Inquiry, 52(3), 1014-1026. https://doi.org/10.1111/ecin.12074
9. Shariatmadar, K., & Hajimiri, A. (2025). AI-enhanced precision in sport taekwondo: Increasing fairness, speed, and trust in competition (FST.ai). arXiv preprint arXiv:2507.14657. https://arxiv.org/abs/2507.14657
10. Suzuki, T., & Fujii, K. (2023). Automatic edge error judgment in figure skating using 3D pose estimation from a monocular camera and IMUs. Proceedings of the 14th ACM Multimedia Systems Conference (MMSys '23). https://doi.org/10.1145/3606038.3616171
11. Tweedy, S. M., & Vanlandewijck, Y. C. (2011). International Paralympic Committee position stand - background and scientific principles of classification in Paralympic sport. British Journal of Sports Medicine, 45(4), 259-269. https://doi.org/10.1136/bjsm.2009.065060
12. Wileman, T. M., McKay, M. J., Hackett, D. A., Watson, T. J., Fleeton, J., & Fornusek, C. (2025). Guiding evidence-based classification in para sporting populations: A systematic review of impairment measures and activity limitations. Sports Medicine, 55(2), 341-391. https://doi.org/10.1007/s40279-024-02132-y
13. World Para Taekwondo. (2024). World Para Taekwondo Poomsae Competition Rules (in force as of September 30, 2024). World Taekwondo.
14. Zhang, Y., Qu, R., & Girard, O. (2025). Faster, more accurate? A feasibility study on replacing human judges with artificial intelligence in video review for the Paris Olympics Taekwondo competition. Frontiers in Sports and Active Living, 7, 1632326. https://doi.org/10.3389/fspor.2025.1632326

RAD 9

ZNANSTVENI RAD

Pojavnost i lokalizacija boli i ozljeda koljenog zgloba kod odbojkaša i odbojkašica

Dora Matas, Luka Penga, Mirjana Milić

Kineziološki fakultet Sveučilišta u Splitu; Split, Hrvatska

Uvod

Odbojka je kompleksna polistrukturalna sportska aktivnost koju definira velika frekvencija eksplozivnih kretnji, osobito skokova, doskoka i naglih promjena smjera kretanja, zbog čega su odbojkaši i odbojkašice kontinuirano izloženi značajnim biomehaničkim opterećenjima. Upravo zbog specifične strukture igre, u kojoj dominiraju ponavljajući skokovi i doskoci, donji ekstremiteti predstavljaju najopterećeniji dio lokomotornog sustava, pri čemu koljenski zglob ima jednu od ključnih uloga u realizaciji osnovnih tehničko-taktičkih elemenata igre poput smeća, bloka i doskoka. Takvi zahtjevi igre čine koljeno jednim od najosjetljivijih anatomskih područja kada je riječ o pojavi boli i sportskih ozljeda.

Dosadašnja istraživanja potvrđuju kako su ozljede donjih ekstremiteta najzastupljenije u odbojci, pri čemu se dugi niz godina najveći broj ozljeda povezivao sa skočnim zglobom. Međutim, recentnija istraživanja ukazuju na sve veću učestalost bolnih stanja i ozljeda koljenog zgloba, osobito sindroma prenaprezanja povezanih s ponavljajućim skokovima i doskocima (Sole i sur., 2017; Migliorini i sur., 2019). Prema epidemiološkim istraživanjima američkih autora, kod odbojkašica i odbojkaša sve češće dolazi do pojave patelarne tendinopatije („skakačko koljeno"), koja je posljedica kroničnog opterećenja ekstenzornog mehanizma koljena tijekom trenažnog i natjecateljskog procesa.

Istraživanja također pokazuju kako su upravo skok i doskok biomehanički najzahtjevnije kretnje u odbojci zbog velikih sila reakcije podloge koje djeluju na koljeno i okolne strukture (Bere i sur., 2015). Sustavna analiza ozljeda u odbojci pokazala je kako su uz ozljede skočnog zgloba upravo ozljede koljena među najčešćim ozljedama u vrhunskoj odbojci, pri čemu se sve veći broj istraživanja usmjerava na sindrome prenaprezanja i kronična bolna stanja. Uz biomehaničke zahtjeve same igre, na pojavnost boli i ozljeda utječu i brojni individualni čimbenici poput spola, dobi, volumena treninga, prethodnih ozljeda i razine sportske pripremljenosti. Hewett (2000) te Prodromos i sur. (2007) ističu povećan rizik ozljeda koljena kod sportašica zbog specifičnih anatomskih i neuromuskularnih obilježja.

U posljednjih nekoliko godina proveden je veći broj istraživanja usmjerenih na pojavnost i lokalizaciju boli i ozljeda koljenog zgloba kod sportaša različitih sportskih grana, pri čemu su korišteni standardizirani anketni upitnici i slični metodološki pristupi. Istraživanja provedena na košarkašima (Lučin, 2021; Milić i sur., 2023; Ikić i sur., 2021), futsal igračicama (Pedišić, 2023), nogometašima (Živković, 2022) te odbojkašima i odbojkašicama (Ninčević, 2023; Matas, 2023) ukazuju na visoku zastupljenost bolnih stanja donjih ekstremiteta, osobito u području koljenog zgloba. Rezultati navedenih istraživanja potvrđuju kako su ponavljajuća sportska opterećenja ključan čimbenik u nastanku boli i ozljeda neovisno o sportskoj grani, uz određene specifičnosti pojedinog sporta.

Posebno je značajna linija istraživanja usmjerena na odbojku, u kojoj su analizirane najčešće ozljede koljenog zgloba i metode njihove prevencije. Penga (2020) daje pregled najčešćih ozljeda koljena kod odbojkašica te naglašava važnost preventivnih programa usmjerenih na smanjenje opterećenja koljenog zgloba. Radić (2020) analizira metrijske karakteristike upitnika za procjenu najčešćih ozljeda koljena kod odbojkašica, potvrđujući pouzdanost i primjenjivost takvih instrumenata u istraživanjima sportske medicine i kineziologije. Nadalje, recentna istraživanja potvrđuju kako sustavno praćenje pojavnosti i lokalizacije boli omogućuje kvalitetniju identifikaciju rizičnih čimbenika i razvoj učinkovitijih preventivnih programa.

Unatoč relativno velikom broju istraživanja provedenih u različitim sportskim granama, i dalje postoji potreba za detaljnijim uvidom u pojavnost i lokalizaciju boli koljenog zgloba kod odbojkaša i odbojkašica različite natjecateljske razine. Takva istraživanja omogućuju bolje razumijevanje etiologije bolnih stanja i ozljeda te doprinose unapređenju preventivnih i rehabilitacijskih programa u odbojci.

Cilj ovoga rada bio je utvrditi pojavnost i lokalizaciju boli koljenog zgloba kod odbojkaša i odbojkašica.

Metode rada

Istraživanje je provedeno na uzorku od 76 odbojkašica i odbojkaša koji su članovi najvišeg ranga odbojkaškog natjecanja u Republici Hrvatskoj, odnosno ženske i muške Superlige. Uzorak je uključivao 38 odbojkašica i 38 odbojkaša seniorske dobne kategorije ili sportaše koji su trenirali i natjecali se u seniorskim ekipama. Kriteriji za uključivanje u istraživanje bili su minimalna dob od 17 godina, najmanje dvije godine treniranja u seniorskoj konkurenciji te aktivno sudjelovanje u natjecanju Superlige. Svi ispitanici imali su potvrđen uredan zdravstveni status od strane nadležnog liječnika sportske medicine.
Prosječna kronološka dob odbojkašica iznosila je 23,52 ± 3,68 godina, dok je kod odbojkaša iznosila 24,08 ± 5,56 godina. Odbojkašice su započele s treniranjem u prosječnoj dobi od 10,96 ± 2,13 godina, a odbojkaši s 12,05 ± 2,32 godina. Prosječna tjelesna visina odbojkašica iznosila je 178,79 ± 7,74 cm, a odbojkaša 190,18 ± 19,14 cm, dok je prosječna tjelesna masa odbojkašica iznosila 69,78 ± 18,50 kg, a odbojkaša 84,55 ± 8,13 kg. Odbojkašice su u prosjeku igrale svoju igračku poziciju 4,98 ± 5,56 godina, dok je kod odbojkaša to iznosilo 6,84 ± 5,25 godina. Specijalizacija igračke pozicije započela je u prosjeku s 13,52 ± 4,65 godina kod odbojkašica, odnosno 15,13 ± 4,01 godina kod odbojkaša. U istraživanju je sudjelovalo 13 dizača, 6 dijagonalnih igrača, 8 libera, 29 primača-pucača i 20 srednjih blokera.
Podaci su prikupljeni primjenom anonimnog online Upitnika najčešćih ozljeda koljena kod odbojkaša i odbojkašica autora Penga i sur. (2020), koji je konstruiran za potrebe istraživanja pojavnosti i lokalizacije boli i ozljeda koljenog zgloba. Upitnik se sastojao od 35 pitanja zatvorenog i otvorenog tipa, uz mogućnost višestrukog odabira odgovora. Dio pitanja bio je definiran prema Tablicama stupnjevanja sindroma prenaprezanja prema Curwinu i Stanishu (1984), dok su ostala pitanja uključivala Likertovu ljestvicu od pet stupnjeva (od „nikad“ do „često“). Upitnik je obuhvaćao demografska obilježja ispitanika te pitanja usmjerena na identifikaciju lokalizacije boli i ozljeda koljenog zgloba.
Istraživanje je provedeno nakon dobivenog odobrenja nadležnih tijela, uključujući Odbojkaški savez i trenere klubova uključenih u natjecanje. Ispitanici su prije sudjelovanja bili upoznati s ciljem istraživanja te su dali informirani pristanak. Upitnik je bio dostupan u online obliku, a ispitanici su ga samostalno ispunjavali. Prikupljeni podaci kodirani su i pripremljeni za daljnju analizu.
Za obradu podataka korištene su metode deskriptivne statistike, pri čemu su izračunate apsolutne i relativne frekvencije odgovora. Za opis uzorka korištene su aritmetičke sredine i standardne devijacije. Razlike između skupina s obzirom na spol analizirane su primjenom neparametrijskog Mann-Whitney U testa. Svi podaci obrađeni su u statističkom programu Statistica 13.0.

Rezultati

Rezultati dobivenih odgovora putem Upitnika o najčešćim ozljedama koljena kod odbojkašica i odbojkaša (Penga i suradnici, 2020), a koji su definirani ciljem ovog istraživanja, obuhvaćaju apsolutne i relativne vrijednosti kao i njihove kumulativne učestalosti i postotne vrijednosti.

Bitan nalaz dobiven iz provedenog ispitivanja ukazuje da je čak 25 odbojkašica i odbojkaša od 76 ispitanika, elitnih hrvatskih odbojkašica i odbojkaša imalo je neki oblik ozljede koljenog zgloba.

U Tablici 1. prikazane su kumulativne učestalosti i relativne vrijednosti pojavnosti i lokalizacije boli u koljenu koje su prijavljene kod 38 ispitanika ili njih 50%, s obzirom na ukupan uzorak odbojkašica i odbojkaša, N=76.

Tablica 1. Učestalosti i relativne vrijednosti pojavnosti i lokalizacije boli koljenog zgloba na ukupnom uzorku (N=76)

Varijable	U	%
Da, prisustvo boli	38	50,00
Prednja strana - ispod patele	19	25,00
Prednja strana - ispod patele, Prednja strana - na pateli, Prednja strana - iznad patele	1	1,32
Prednja strana - iznad patele	5	6,58
Prednja strana - ispod patele, Prednja strana - iznad patele, Bočna vanjska strana koljena	2	2,63
Prednja strana - ispod patele, Prednja strana - na pateli, Bočna vanjska strana koljena	1	1,32
Bočna vanjska strana koljena	2	2,63
Prednja strana - ispod patele, Prednja strana - iznad patele	2	2,63
Prednja strana - ispod patele, Bočna unutarnja strana koljena	1	1,32
Prednja strana - na pateli	3	3,95
Prednja strana - iznad patele, Bočna vanjska strana koljena	1	1,32
Prednja strana - ispod patele, Prednja strana - na pateli, Prednja strana - iznad patele, Bočna vanjska strana koljena	1	1,32

Legenda: U – učestalost; % – relativna, postotna vrijednost;

Analizom Tablice 1. vidljivo je kako najveća učestalost boli kod odbojkašica i odbojkaša, definirana je na području patele (na/iznad/ispod), odnosno na bočnoj strani koljena. kao i kombinacije dviju pojavnosti boli na različitim lokacijama te pojavnost 3 ili više boli. Izostanak boli prijavljen je kod 38 seniorki i seniora, odnosno 50,00% ukupnog uzorka.

U Tablicama 2. – 7. prikazani su rezultati čestica koje predstavljaju *Stupnjevanje boli sindroma prenaprezanja* u odnosu na mogućnost bavljenja sportskom akivnošću prema autorima Curwin i Stanishu (1984).

Tablica 2. Kumulativne učestalosti i relativne vrijednosti varijable *Bol u koljenu prije sportske aktivnosti* (N=76)

Varijable	U	KU	%	K%
1 - NIKAD	26	26	34,21	34,21
2 – VRLO RIJETKO	24	50	31,58	65,79
3 – RIJETKO	10	60	13,16	78,95
4 – PONEKAD	12	72	15,79	94,74
5 – ČESTO	4	76	5,26	100,00

Legenda: U – učestalost; KU – kumulativna učestalost; % – relativna, postotna vrijednost; K% – kumulativna relativna, postotna vrijednost;

Analizom Tablice 2. vidljivo je da 34,21% odbojkašica i odbojkaša ili njih 26 nisu nikad imali *Bol u koljenu prije sportske aktivnosti,* odnosno prisutnost boli (ponekad i često) imali su njih 21,05% ili 16 superligašica i superligaša.

Tablica 3. Kumulativne učestalosti i relativne vrijednosti varijable *Bol u koljenu za vrijeme sportske aktivnosti* (N=76)

Varijable	U	KU	%	K%
1 - NIKAD	11,0	11,0	14,47	14,47
2 – VRLO RIJETKO	28,0	39,0	36,84	51,32
3 – RIJETKO	9,0	48,0	11,84	63,16
4 – PONEKAD	20,0	68,0	26,32	89,47
5 – ČESTO	8,0	76,0	10,53	100,00

Legenda: U – učestalost; KU – kumulativna učestalost; % – relativna, postotna vrijednost; K% – kumulativna relativna, postotna vrijednost;

Analizom Tablice 3. vidljivo je da je 14,47% ili 11 odbojkašica i odbojkaša od ukupnog uzorka, iskazalo neprisustvo Boli u koljenu za vrijeme sportske aktivnosti, ponekad je bol osjetilo njih 20, dok je za vrijeme treninga ili natjecanje 10,53% superligaša/ica imalo čestu prisutnost boli u koljenu.

Tablica 4. Kumulativne učestalosti i relativne vrijednosti varijable *Bol u koljenu na početku sportske aktivnosti* (N=76)

Varijable	U	KU	%	K%
1 - NIKAD	29	29	38,16	38,16
2 – VRLO RIJETKO	22	51	28,95	67,11
3 – RIJETKO	11	62	14,47	81,58
4 – PONEKAD	5	67	6,58	88,16

5 – ČESTO	9	76	11,84	100,00

Legenda: U – učestalost; KU – kumulativna učestalost; % – relativna, postotna vrijednost; K% – kumulativna relativna, postotna vrijednost;

Analizom Tablice 4. vidljivo je da korištena varijabla Bol u koljenu na početku sportske aktivnosti, ima najveću učestalost kod odgovora nikad, čija apsolutna vrijednost iznosi 29, odnosno 38,16% ukupnog uzorka ispitanika, a ako se tome pribroji odgovor vrlo rijetko uočena je kumulativna postotna vrijednost od 67,11% odbojkaša/ica ili njih 51.

Tablica 5. Kumulativne učestalosti i relativne vrijednosti varijable *Bol u koljenu nakon sportske aktivnost* (N=76)

Varijable	U	KU	%	K%
1 - NIKAD	16	16	21,05	21,05
2 – VRLO RIJETKO	24	40	31,58	52,63
3 – RIJETKO	10	50	13,16	65,79
4 – PONEKAD	10	60	13,16	78,95
5 – ČESTO	16	76	21,05	100,00

Legenda: U – učestalost; KU – kumulativna učestalost; % – relativna, postotna vrijednost; K% – kumulativna relativna, postotna vrijednost;

Analizom Tablice 5. vidljivo je da 65,79% odbojkaša/ica ili njih 50, nisu nikad, vrlo rijetko ili rijetko imale Bol u koljenu nakon sportske aktivnost, odnosno prisutnost boli (ponekad i često) imale su njih 34,21% ili 26 superligaša/ica.

Tablica 6. Kumulativne učestalosti i relativne vrijednosti varijable *Bol u koljenu izaziva prekid sportske aktivnosti* (N=76)

Varijable	U	KU	%	K%
1 - NIKAD	41	41	53,95	53,95
2 – VRLO RIJETKO	13	54	17,11	71,05
3 – RIJETKO	14	68	18,42	89,47
4 – PONEKAD	7	75	9,21	98,68
5 – ČESTO	1	76	1,32	100,00

Legenda: U – učestalost; KU – kumulativna učestalost; % – relativna, postotna vrijednost; K% – kumulativna relativna, postotna vrijednost;

Analizom Tablice 6. vidljivo je da 89,47% seniora/ki ili njih 68, nisu nikad, vrlo rijetko ili rijetko imali/e *Bol u koljenu koja izaziva prekid sportske aktivnosti*, odnosno prisutnost boli (ponekad i često) imali su njih 10,53% ili 8 odbojkaša/ica.

Tablica 7. Kumulativne učestalosti i relativne vrijednosti varijable *Bol u koljenu tijekom normalnih dnevnih aktivnosti* (N=76)

Varijable	U	KU	%	K%
1 - NIKAD	26	26	34,21	34,21
2 – VRLO RIJETKO	25	51	32,89	67,11
3 – RIJETKO	15	66	19,74	86,84
4 – PONEKAD	5	71	6,58	93,42
5 – ČESTO	5	76	6,58	100,00

Legenda: U – učestalost; KU – kumulativna učestalost; % – relativna, postotna vrijednost; K% – kumulativna relativna, postotna vrijednost;

Analizom Tablice 7. vidljivo je da korištena varijabla Bol u koljenu tijekom normalnih dnevnih aktivnosti, ima najveću učestalost kod odgovora nikad, čija apsolutna vrijednost iznosi 26, odnosno 34,21% ukupnog uzorka ispitanika/ca, a ako se tome pribroji odgovor vrlo rijetko i rijetko iskazana je kumulativna postotna vrijednost od 86,84% odbojkaša/ica ili njih 66. Kod ove varijable 5 odbojkaša/ica iskazalo je prisustvo česte Boli u koljenu tijekom normalne dnevne aktivnosti.

U Tablicama 8. – 11. prikazane su učestalosti i postotne vrijednosti kao i njihove kumulativne prisutnosti Boli u koljenu pri ekstremnim opterećenjima, čije čestice su modificirane temeljem kretnih struktura u odbojkaškoj igri, a uključuju Bol u koljenu prilikom naglog zaustavljanja, promjene pravca, klizanja po podlozi te u doskoku.

Tablica 8. Kumulativne učestalosti i relativne vrijednosti varijable *Bol u koljenu prilikom naglog zaustavljanja* (N=76)

Varijable	U	KU	%	K%
1 - NIKAD	23	23	30,26	30,26
2 – VRLO RIJETKO	20	43	26,32	56,58
3 – RIJETKO	15	58	19,74	76,32
4 – PONEKAD	11	69	14,47	90,79
5 – ČESTO	6	75	7,89	98,68

Legenda: U – učestalost; KU – kumulativna učestalost; % – relativna, postotna vrijednost; K% – kumulativna relativna, postotna vrijednost;

Analizom Tablice 8 vidljivo je da korištena varijabla Bol u koljenu prilikom naglog zaustavljanja, ima najveću učestalost kod odgovora nikad čija apsolutna vrijednost iznosi 23, odnosno 30,26% ukupnog uzorka ispitanica, a ako se tome pribroji odgovor vrlo rijetko i rijetko, prisutna je kumulativna postotna vrijednost od 76,32% odbojkaša/ica ili njih 58. Kod ove varijable 6 seniora/ki ili njih 7,89% iskazalo je prisustvo česte Boli u koljenu prilikom naglog zaustavljanja. Jedan ispitanik nije odgovorio na postavljenu tvrdnju.

Tablica 9. Kumulativne učestalosti i relativne vrijednosti varijable *Bol u koljenu prilikom promjene pravca* (N=76)

Varijable	U	KU	%	K%
1 - NIKAD	23	23	30,26	30,26
2 – VRLO RIJETKO	18	41	23,68	53,95
3 – RIJETKO	20	61	26,32	80,26
4 – PONEKAD	11	72	14,47	94,74
5 – ČESTO	4	76	5,26	100,00

Legenda: U – učestalost; KU – kumulativna učestalost; % – relativna, postotna vrijednost; K% – kumulativna relativna, postotna vrijednost;

Analizom Tablice 9. vidljivo je da korištena varijabla Bol u koljenu prilikom promjene pravca ima najveću učestalost kod odgovora nikad čija apsolutna vrijednost iznosi 23, odnosno 30,26% ukupnog uzorka ispitanika, a ako se tome pribroji odgovor vrlo rijetko i rijetko prisustvo boli iskazano je u kumulativnoj postotnoj vrijednosti od 80,26% odbojkaša/ica ili njih 61. Čestu bol u koljenu imalo je 4 odbojkaša/ica ili 5,26%.

Tablica 10. Kumulativne učestalosti i relativne vrijednosti varijable *Bol u koljenu prilikom klizanja po podlozi* (N=76)

Varijable	U	KU	%	K%
1 - NIKAD	41	41	53,95	53,95
2 – VRLO RIJETKO	15	56	19,74	73,68
3 – RIJETKO	11	67	14,47	88,16
4 – PONEKAD	5	72	6,58	94,74
5 – ČESTO	4	76	5,26	100,00

Legenda: U – učestalost; KU – kumulativna učestalost; % – relativna, postotna vrijednost; K% – kumulativna relativna, postotna vrijednost;

Analizom Tablice 10. vidljivo je da 88,16% odbojkaša/ica ili njih 67, nisu nikad, vrlo rijetko ili rijetko imale Bol u koljenu prilikom klizanja po podlozi, odnosno prisutnost boli (ponekad i često) imale su njih 11,84% ili 9 superligaša/ica.

Tablica 11. Kumulativne učestalosti i relativne vrijednosti varijable *Bol u koljenu u doskoku* (N=76)

Varijable	U	KU	%	K%
1 - NIKAD	10	10	13,16	13,16
2 – VRLO RIJETKO	8	18	10,53	23,68
3 – RIJETKO	5	23	6,58	30,26

4 – PONEKAD	7	30	9,21	39,47
5 – ČESTO	46	76	60,53	100,00

Legenda: U – učestalost; KU – kumulativna učestalost; % – relativna, postotna vrijednost; K% – kumulativna relativna, postotna vrijednost;

Analizom Tablice 11. vidljivo je da korištena varijabla Bol u koljenu u doskoku, ima najveću učestalost kod odgovora često čija apsolutna vrijednost iznosi 46, odnosno 60,53% ukupnog uzorka ispitanika. Bol u koljenu nikad, vrlo rijetko i rijetko nije imalo 23 odbojkaša/ica ili 30,26%.

U Tablici 12. prikazana je analiza razlika prema spolu u svim korištenim varijablama učestalosti i lokalizacije boli i ozljeda koljenog zgloba, primjenom neparametrijskog Mann-Whitney U testa.

Tablica 12. Analiza razlika varijabli učestalosti i lokalizacije boli i ozljeda koljenog zgloba u odbojci prema spolu (N=76)

Varijable	Z	p
BOL U KOLJENU: [Prije sportske aktivnosti]	0.34	0.74
BOL U KOLJENU: [Za vrijeme sportske aktivnosti]	-0.32	0.75
BOL U KOLJENU: [Prilikom naglog zaustavljanja]	0.05	0.96
BOL U KOLJENU: [Prilikom ravnog pravca]	-0.95	0.34
BOL U KOLJENU: [Prilikom promjene pravca]	0.75	0.45
BOL U KOLJENU: [Kroz klizanje po podlozi]	0.01	1.00
BOL U KOLJENU: [Na početku sportske aktivnosti]	-0.46	0.64
BOL U KOLJENU: [Nakon sportske aktivnosti]	-1.37	0.17
BOL U KOLJENU: [Bol izaziva prekid sportske aktivnosti]	-0.57	0.57
BOL U KOLJENU: [Tijekom normalnih dnevnih aktivnosti]	0.48	0.63
BOL U KOLJENU: [U doskoku]	-7.54	0.00
U kojem PODRUČJU KOLJENA najčešće osjećate bol?	-8.09	0.00
Ozljeda koljena	0.96	0.34

Legenda: Z – koeficijent statističke značajnosti Mann-Whitney U testa ; p – nivo statističke značajnosti;

Analizom Tablice 12. vidljivo je da ne postoji značajna razlika primjenom neparametrijskog Mann-Whitney U testa između spolova primjenjenih varijabli osim u varijabli *Bol u koljenu prilikom doskoka* te u varijabli *Lokalizacija boli u koljenom zglobu.*

Rasprava

Primjenom Upitnika o najčešćim ozljedama koljena kod odbojkašica i odbojkaša (Penga i sur., 2020) utvrđena je značajna učestalost boli i ozljeda koljenog zgloba kod ispitanika, pri čemu je čak 50% uzorka prijavilo prisutnost boli, dok je 32,89% ispitanika imalo i teži oblik ozljede koljena. Ovakvi rezultati ukazuju kako, unatoč percepciji odbojke kao nekontaktnog sporta s

nižim rizikom ozljeđivanja, opterećenja specifična za odbojku dovode do značajnog rizika od razvoja kroničnih bolnih stanja i ozljeda koljenog zgloba.

Dobiveni rezultati u skladu su s ranijim istraživanjima koja ukazuju na visoku zastupljenost ozljeda donjih ekstremiteta u odbojci, osobito u području koljena (Penga, 2020; Radić, 2020; Ninčević, 2023). Također, nalazi ovog istraživanja podudaraju se s rezultatima istraživanja provedenih na drugim sportskim populacijama, gdje je utvrđena visoka učestalost bolnih stanja koljenog zgloba kod košarkaša, futsal igrača i nogometaša (Lučin, 2021; Živković, 2022; Milić i sur., 2023; Pedišić, 2023), što dodatno potvrđuje da su ponavljajuća opterećenja i specifične kretne strukture ključni etiološki čimbenici nastanka ozljeda.

Posebno je značajan nalaz ovog istraživanja koji ukazuje na dominantnu lokalizaciju boli u prednjem dijelu koljena, odnosno u području patele (na, iznad i ispod patele). Takva distribucija boli u skladu je s nalazima epidemioloških istraživanja koja ističu patelarnu tendinopatiju kao jednu od najčešćih dijagnoza kod odbojkaša i odbojkašica (Sole i sur., 2017; Migliorini i sur., 2019). Navedeno se može objasniti biomehaničkim zahtjevima odbojke, gdje ponavljajući ciklusi skok–doskok uzrokuju visoka opterećenja na ekstenzorni mehanizam koljena, što dugoročno dovodi do razvoja sindroma prenaprezanja.

Rezultati ovog istraživanja dodatno potvrđuju ključnu ulogu doskoka kao rizičnog faktora, budući da je čak 60,53% ispitanika prijavilo čestu bol u koljenu upravo u toj situaciji. Ovaj nalaz u potpunosti je u skladu s prethodnim istraživanjima koja ističu doskok kao biomehanički najzahtjevniju fazu kretanja u odbojci zbog velikih sila reakcije podloge koje djeluju na koljenski zglob (Bere i sur., 2015). Također, istraživanja američkih autora pokazuju da su upravo kretne strukture skakanja, doskoka i naglih promjena smjera povezane s najvećim udjelom ozljeda, uključujući više od polovice ozljeda koljena (Goodwin i sur., prema Penga, 2020).

Unatoč relativno visokoj učestalosti boli tijekom sportskih aktivnosti, rezultati pokazuju da većina ispitanika rijetko ili nikada nije prekidala aktivnost zbog boli (89,47%), što može upućivati na toleriranje boli i nastavak treniranja unatoč simptomima. Takvo ponašanje sportaša često je prisutno u vrhunskom sportu te može dovesti do progresije akutnih u kronična stanja i povećanja rizika od ozbiljnijih ozljeda.

Zanimljivo je da u ovom istraživanju nisu utvrđene statistički značajne razlike između spolova u većini analiziranih varijabli, osim u varijabli boli u doskoku i lokalizaciji boli. Ovaj nalaz djelomično odstupa od istraživanja koja ukazuju na veću incidenciju ozljeda koljena kod sportašica (Hewett, 2000; Prodromos i sur., 2007), što se može objasniti specifičnostima uzorka, razinom treniranosti ili homogenosti natjecateljske razine ispitanika.

Dodatno, rezultati ovog istraživanja mogu se interpretirati i u kontekstu rane specijalizacije, budući da su ispitanici relativno rano započeli s treniranjem i specijalizacijom igračke pozicije. Prema Penga (2020), rana specijalizacija povezana je s povećanim rizikom razvoja sindroma prenaprezanja i kroničnih ozljeda, što je potvrđeno i u ovom istraživanju kroz relativno visoku učestalost boli i ozljeda koljena.

U cjelini, rezultati ovog istraživanja potvrđuju nalaze dosadašnjih istraživanja te dodatno naglašavaju važnost praćenja pojavnosti i lokalizacije boli u odbojci. Dobiveni podaci ukazuju na potrebu razvoja specifičnih preventivnih programa usmjerenih na smanjenje opterećenja koljenog zgloba, osobito kroz optimizaciju tehnike doskoka, kontrolu volumena treninga i pravovremeno prepoznavanje simptoma prenaprezanja.

Zaključci

Cilj ovoga rada bio je utvrditi pojavnost i lokalizaciju boli koljenog zgloba kod odbojkaša i odbojkašica koji se natječu u najvišem rangu odbojkaškog natjecanja u Republici Hrvatskoj. Dobiveni rezultati ukazali su na relativno visoku učestalost boli i ozljeda koljenog zgloba kod

ispitanika, pri čemu je bol najčešće bila lokalizirana u prednjem dijelu koljena, osobito u području patele. Kao najizraženiji rizični čimbenik izdvojene su kretne strukture specifične za odbojku, ponajprije doskok, dok su bol i simptomi najčešće bili povezani s ponavljajućim opterećenjima tijekom sportskih aktivnosti.

Rezultati su također pokazali kako većina ispitanika, unatoč prisutnosti boli, nije prekidala sportsku aktivnost, što upućuje na tendenciju toleriranja simptoma i potencijalno povećan rizik razvoja kroničnih stanja. Nadalje, nisu utvrđene značajne razlike između spolova u većini analiziranih varijabli, osim u specifičnim situacijama povezanima s doskokom i lokalizacijom boli, što ukazuje na slične obrasce opterećenja i ozljeđivanja kod odbojkaša i odbojkašica.

Znanstveni doprinos ovog rada očituje se u dodatnoj potvrdi visoke učestalosti bolnih stanja koljenog zgloba u odbojci te u preciznijem uvidu u njihovu lokalizaciju i povezanost sa specifičnim kretanjima u igri. Stručni doprinos rada ogleda se u mogućnosti primjene dobivenih rezultata u planiranju i provođenju preventivnih programa, s naglaskom na unapređenje tehnike doskoka, kontrolu trenažnog opterećenja i pravovremeno prepoznavanje simptoma prenaprezanja, s ciljem smanjenja rizika od ozljeda i očuvanja zdravlja sportaša.

Ograničenja ovog istraživanja odnose se na relativno mali uzorak ispitanika te primjenu subjektivne metode prikupljanja podataka putem anketnog upitnika. Buduća istraživanja trebala bi uključiti veći broj ispitanika različitih natjecateljskih razina te kombinirati subjektivne i objektivne metode procjene, uključujući biomehaničke i funkcionalne analize. Također, preporučuje se istražiti povezanost pojavnosti boli i ozljeda s motoričkim sposobnostima, tehnikom izvođenja specifičnih kretnih struktura i parametrima opterećenja u trenažnom procesu

Literatura

1. Bahr, R., & Bahr, I. A. (1997). Incidence of acute volleyball injuries: A prospective cohort study of injury mechanisms and risk factors. *Scandinavian Journal of Medicine & Science in Sports, 7*(3), 166–171. https://doi.org/10.1111/j.1600-0838.1997.tb00135.x
2. Bere, T., Kruczynski, J., Veintimilla, N., Hamu, Y., & Bahr, R. (2015). Injury risk is low among world-class volleyball players: 4-year data from the FIVB Injury Surveillance System. *British Journal of Sports Medicine, 49*(17), 1132–1137. https://doi.org/10.1136/bjsports-2015-094959
3. Curwin, S., & Stanish, W. D. (1984). *Tendinitis: Its etiology and treatment*. Collamore Press.
4. Hewett, T. E. (2000). Neuromuscular and hormonal factors associated with knee injuries in female athletes. *Sports Medicine, 29*(5), 313–327. https://doi.org/10.2165/00007256-200029050-00003
5. Ikić, T., Vrdoljak, D., Penga, L., Radovčić, N., & Milić, M. (2021). Review of the most common knee injuries in basketball. *Serbian Journal of Sports Sciences, 12*(3), 49–55.
6. Lučin, M. (2021). *Pojavnost i lokalizacija ozljeda koljena kod košarkaša* (Diplomski rad). Split: Sveučilište u Splitu, Kineziološki fakultet.
7. Matas, D. (2023). *Pojavnost i lokalizacija boli i ozljeda koljenog zgloba kod odbojkaša i odbojkašica* (Diplomski rad). Split: Sveučilište u Splitu, Kineziološki fakultet.
8. Migliorini, F., Oliva, F., Eschweiler, J., Hildebrand, F., Maffulli, N., & Tingart, M. (2019). Epidemiology of jumpers' knee: A systematic review. *British Medical Bulletin, 131*(1), 101–113. https://doi.org/10.1093/bmb/ldz026
9. Milić, M., Penga, L., Vrdoljak, D., & Lučin, M. (2023). Incidence and localization of knee pain and injuries in basketball players. *Annals of Applied Sport Science, 11*(3), 1–10. https://doi.org/10.52547/aassjournal.11.3.0
10. Ninčević, J. (2023). *Pojavnost i lokalizacija boli i ozljeda koljenskog zgloba kod odbojkaša* (Diplomski rad). Split: Sveučilište u Splitu, Kineziološki fakultet.
11. Pedišić, A. M. (2023). *Pojavnost i lokalizacija ozljeda koljenskog zgloba kod futsal igračica* (Diplomski rad). Split: Sveučilište u Splitu, Kineziološki fakultet.

12. Penga, L. (2020). *Prikaz najčešćih ozljeda koljena kod odbojkašica i korištenih metoda prevencije* (Diplomski rad). Split: Sveučilište u Splitu, Fakultet zdravstvenih studija.
13. Prodromos, C. C., Han, Y., Rogowski, J., Joyce, B., & Shi, K. (2007). A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury–reduction regimen. *Arthroscopy, 23*(12), 1320–1325. https://doi.org/10.1016/j.arthro.2007.07.003
14. Radić, M. (2020). *Utvrđivanje metrijskih karakteristika upitnika najčešćih ozljeda koljena kod odbojkašica* (Diplomski rad). Split: Sveučilište u Splitu, Kineziološki fakultet.
15. Sole, G., Hamrén, J., & Milosavljevic, S. (2017). Epidemiology of knee injuries in volleyball: A systematic review. *European Journal of Sport Science, 17*(3), 310–318. https://doi.org/10.1080/17461391.2016.1260897
16. Verhagen, E. A., Van der Beek, A. J., Bouter, L. M., Bahr, R. M., & Van Mechelen, W. (2004). A one season prospective cohort study of volleyball injuries. *British Journal of Sports Medicine, 38*(4), 477–481. https://doi.org/10.1136/bjsm.2003.005785
17. Živković, K. (2022). *Pojavnost i lokalizacija ozljeda koljena kod nogometaša* (Diplomski rad). Split: Sveučilište u Splitu, Kineziološki fakultet.

RAD 10

ZNANSTVENI RAD

Metrijske karakteristike i procjena psiholoških značajki perfekcionizma i optimizma u nogometu

Stipe Karamarko, Šime Veršić, Mirjana Milić

Kineziološki fakultet Sveučilišta u Splitu; Split, Hrvatska

Uvod

Nogomet predstavlja jednu od najkompleksnijih i najraširenijih sportskih aktivnosti u suvremenom društvu, koja od sportaša zahtijeva visoku razinu motoričkih i funkcionalnih sposobnosti, ali i izražena psihološka obilježja. Iako su fizičke i tehničko-taktičke komponente nogometne izvedbe dugo bile u fokusu znanstvenih istraživanja, u novije vrijeme sve veći naglasak stavlja se na psihološke čimbenike koji značajno doprinose sportskoj uspješnosti. U tom kontekstu, psihološka priprema postaje ravnopravna tjelesnoj spremi te predstavlja jedan od ključnih čimbenika u postizanju vrhunskih rezultata.

Sportska psihologija kao interdisciplinarno područje usmjerena je na proučavanje utjecaja psiholoških procesa na sportsku izvedbu, uključujući motivaciju, samopouzdanje, koncentraciju, anksioznost i emocionalnu regulaciju. Unutar tog okvira posebno se ističu konstrukti optimizma i perfekcionizma, koji imaju važnu ulogu u načinu na koji sportaši doživljavaju vlastitu izvedbu, postavljaju ciljeve te se nose sa zahtjevima natjecateljskog okruženja.

Optimizam se definira kao relativno stabilna dispozicija usmjerena na očekivanje pozitivnih ishoda. U sportskom kontekstu povezan je s višom razinom samopouzdanja, većom ustrajnošću u treningu te učinkovitijim suočavanjem sa stresnim situacijama. Empirijski nalazi upućuju na to da optimistični sportaši ostvaruju bolje natjecateljske rezultate te pokazuju veću razinu angažiranosti u trenažnom procesu (Seligman i Schulman, 2015; Rochniak i sur., 2020). Uz to, optimizam je povezan s povoljnijim psihološkim ishodima, uključujući niže razine anksioznosti i depresije te višu razinu životnog zadovoljstva (Chang i sur., 2017; Gustafsson i sur., 2010).

Perfekcionizam, s druge strane, predstavlja složen i višedimenzionalan konstrukt koji uključuje težnju prema visokim standardima uz istodobnu sklonost samokritici. U sportskom okruženju razlikuju se adaptivne i neadaptivne dimenzije perfekcionizma. Adaptivne dimenzije povezane su s većom motivacijom, predanošću i kvalitetnijom izvedbom, dok neadaptivne dimenzije, poput pretjerane zabrinutosti zbog pogrešaka ili percipiranog pritiska okoline, mogu imati nepovoljne učinke, uključujući povećanu anksioznost, pretreniranost i pad sportske učinkovitosti (Hill i sur., 2008; Madigan i sur., 2015).

Rezultati ranijih istraživanja ukazuju na postojanje međusobnih povezanosti između optimizma i perfekcionizma. Adaptivni perfekcionizam povezuje se s optimističnim očekivanjima i pozitivnim obrascima ponašanja, dok se neadaptivni oblici perfekcionizma češće dovode u vezu s pesimizmom i negativnim psihološkim ishodima (Black i Reynolds, 2013; Andrews i sur., 2014). Nadalje, optimizam se pokazao važnim čimbenikom u procesu postavljanja i ostvarivanja ciljeva, pri čemu optimističniji sportaši pokazuju veću razinu ambicije i uspješnosti (Carver i Scheier, 2002).

U kontekstu sportskih istraživanja, posebnu važnost ima ispitivanje metrijskih karakteristika instrumenata kojima se procjenjuju psihološka obilježja sportaša. Pouzdani i valjani mjerni instrumenti nužni su za kvalitetnu interpretaciju rezultata te njihovu primjenu u znanstvenom i praktičnom radu. Dosadašnji nalazi ukazuju na zadovoljavajuće metrijske karakteristike instrumenata za procjenu optimizma i perfekcionizma, uz naglašenu potrebu njihove dodatne provjere u različitim sportskim populacijama (Milić, 2014; Milić i sur., 2024).

Unatoč povećanom interesu za psihološke aspekte sportske izvedbe, istraživanja koja integrirano pristupaju analizi metrijskih karakteristika instrumenata i procjeni psiholoških konstrukata kod nogometaša i dalje su relativno rijetka. S obzirom na specifične zahtjeve

nogometne igre, koji uključuju brzu prilagodbu situacijama i visoku razinu psihološke stabilnosti, nameće se potreba za daljnjim istraživanjima u ovom području.
Stoga je cilj ovog rada bio utvrditi metrijske karakteristike (pouzdanost, homogenost i osjetljivost) te procijeniti psihološke značajke perfekcionizma i optimizma u nogometu.

Metode rada

Uzorak ispitanika obuhvaćao je 61 seniorskog nogometaša koji su se natjecali u različitim rangovima Hrvatske nogometne lige. Prosječna dob ispitanika iznosila je 20,02 ± 4,44 godina, prosječna tjelesna visina 177,53 ± 10,20 cm, a prosječna tjelesna masa 77,29 ± 11,48 kg. S obzirom na igračku poziciju, u istraživanju su sudjelovala 4 (6,6%) golmana, 17 (27,9%) obrambenih igrača, 18 (29,5%) veznih igrača te 22 (36,1%) napadača. Svi ispitanici posjedovali su liječničku potvrdu o sposobnosti za treniranje i natjecanje izdanu od strane liječnika sportske medicine.
U istraživanju su primijenjena dva standardizirana upitnika. Za procjenu optimizma korišten je Revidirani upitnik životne orijentacije (eng. Life Orientation Test – Revised, LOT-R) autora Scheier, Carver i Bridges (1994), koji se sastoji od 10 čestica. Ispitanici su na Likertovoj ljestvici s pet stupnjeva (od 1 – potpuno se ne slažem do 5 – potpuno se slažem) procjenjivali stupanj slaganja s ponuđenim tvrdnjama. Za procjenu perfekcionizma primijenjen je Sportski multidimenzionalni upitnik perfekcionizma (eng. Sports Multidimensional Perfectionism Scale 2, Sport-MPS 2) autora Dunn i sur. (2006), koji se sastoji od 42 čestice raspoređene u više dimenzija: osobna očekivanja (7 čestica), zabrinutost zbog pogrešaka (8 čestica), roditeljska očekivanja (9 čestica), percipirani pritisak trenera (6 čestica), dvojbe o kvaliteti treniranja (5 čestica) te organizacija (7 čestica). Ispitanici su, također na Likertovoj ljestvici od 1 do 5, procjenjivali stupanj izraženosti perfekcionističkih tendencija.
Prikupljanje podataka provedeno je putem online platforme na kojoj su bili dostupni navedeni upitnici. Istraživanje je trajalo od 1. travnja do 1. svibnja 2024. godine. Nogometaši su, putem svojih trenera, bili pozvani na sudjelovanje, a pristup upitnicima bio im je omogućen putem klupskih online komunikacijskih kanala. Svaki ispitanik mogao je ispuniti upitnik samo jednom. Svi punoljetni sudionici bili su prethodno upoznati s ciljem istraživanja te su dali svoj informirani pristanak za anonimno sudjelovanje.
Metrijske karakteristike primijenjenih instrumenata procijenjene su analizom glavnih komponenti te izračunom koeficijenta unutarnje konzistencije (Cronbach alfa), čime su utvrđene pouzdanost i homogenost ljestvica. Osjetljivost varijabli procijenjena je pomoću pokazatelja asimetrije (skewness), spljoštenosti (kurtosis) te raspona rezultata (minimalne i maksimalne vrijednosti). Od deskriptivnih pokazatelja izračunate su aritmetičke sredine, medijani i standardne devijacije, dok je Kolmogorov-Smirnovljevim testom procijenjeno odstupanje distribucije varijabli od normalne raspodjele. Svi podaci obrađeni su u statističkom programu Statistica 13.

Rezultati

U Tablici 1. prikazani su rezultati validacije ljestvice upitnika *optimizma*

Tablica 1. Validacija ljestvice upitnika *optimizma*

Čestica	**Prije selekcije čestica**		**Nakon selekcije čestica**
	Komponente*		**Komponenta***
	1	**2**	**1**

U neizvjesnim vremenima obično očekujem ono najbolje.	0,67	0,50	0,71
Ako mi nešto može krenuti naopako, onda i krene.	-0,33	0,83	#
Kada je moja budućnost u pitanju, uvijek sam optimističan.	0,75	0,23	0,76
Rijetko kad očekujem da će stvari odvijati povoljno za mene.	-0,75	0,31	-0,73
Rijetko kad računam da će mi se dogoditi neke dobre stvari.	-0,87	0,20	-0,86
Sve u svemu, očekujem da će mi se dogoditi više dobrih nego loših stvari.	0,83	0,21	0,84
Svojstvena vrijednost	3,13	1,18	3,06
Ukupno %	71,77		61,15
Alfa	0,89		0,93

Legenda: ** - faktorske saturacije čestica,* ***Svojstvena vrijednost*** *- svojstvena varijanca komponente,* ***Ukupno %*** *- ukupni postotak objašnjene varijance,* ***Alfa*** *- koeficijent pouzdanosti tipa Cronbach alfa*

U Tablici 1. vidljivi su rezultati psiholoških značajki za varijablu koja procjenjuje optimizam. Za primijenjenu ljestvicu nakon provedene analize glavnih komponenti i izračuna koeficijenta pouzdanosti, utvrđeno je kako ljestvica nema zadovoljavajuću homogenost i pouzdanost. Stoga je provedena selekcija čestica na način da je jedna čestica odbačena te je nakon toga utvrđena dobra homogenost te zadovoljavajući stupanj pouzdanosti.

Takvo objašnjenje potvrđuje i koeficijent pouzdanosti (Cronbach alfa) čija vrijednost iznosi visokih 0,93.

U Tablici 2. prikazani su rezultati validacije ljestvice upitnika *osobna očekivanja*

Tablica 2. Validacija ljestvice upitnika *osobna očekivanja*

Čestica	**Prije selekcije čestica**		**Nakon selekcije čestica**
	Komponente*		**Komponenta***
	1	**2**	**1**
Ako sebi ne postavim najviše kriterije u nogometu, vjerojatno ću završiti kao drugorazredni igrač.	-0,63	0,31	-0,66
U nogometu mrzim biti lošiji od najboljih.	-0,62	0,47	-0,68
Važno mi je da budem potpuno dobar u svemu što radim u nogometu.	-0,75	0,30	-0,79
Na treningu očekujem veću kvalitetu igre nego većina drugih igrača.	-0,42	-0,45	#

U nogometu drugi igrači uglavnom imaju niže kriterije nego ja	-0,40	-0,73	#
Imam vrlo visoke ciljeve u nogometu.	-0,83	0,01	-0,83
Postavljam sebi više sportske ciljeve od većine drugih nogometaša	-0,74	-0,32	-0,69
Svojstvena vrijednost	2,90	1,24	2,70
Ukupno %	59,23		53,85
Alfa	0,86		0,91

Legenda: ** - faktorske saturacije čestica,* ***Svojstvena vrijednost*** *- svojstvena varijanca komponente,* ***Ukupno %*** *- ukupni postotak objašnjene varijance,* ***Alfa*** *- koeficijent pouzdanosti tipa Cronbach alfa*

U Tablici 2. vidljivi su rezultati faktorske analize čestica koje procjenjuju *osobna očekivanja*. I u ovom slučaju ekstrahirana su dva faktora što ponovo ukazuje kako ljestvica nema zadovoljavajuću homogenost i pouzdanost. Stoga je provedena selekcija čestica na način da su dvije čestice odbačene te je nakon toga utvrđena dobra homogenost te zadovoljavajući stupanj pouzdanosti.

Najnižu korelaciju na prvu glavnu komponentu pokazuje prva čestica (0,66). Cronbach alfa koeficijent je vrlo visok (0,91) pa možemo zaključiti da je pouzdanost ovog upitnika zadovoljavajuća.

U Tablici 3. prikazani su rezultati validacije ljestvice upitnika *zabrinutost zbog grešaka*

Tablica 3. Validacija ljestvice upitnika *zabrinutost zbog grešaka*

Čestica	**Komponenta***
	1
Čak i ako samo malo pogriješim u igri, za mene je to jednako loše kao potpuni promašaj	-0,59
Ako pogriješim u utakmici, osjećam se kao neuspješna osoba	-0,64
Što manje grješaka napravim u utakmici, drugi ljudi će me više voljeti	-0,55
Ako pogriješim u igri, trebao bi se uzrujati	-0,45
Ako u nekoj utakmici suigrača ili protivnika (koji igra sličnu poziciju kao ja), igra bolje od mene, osjećam se djelomično neuspješno	-0,67
Ako stalno ne igram dobro, ljudi me neće poštovati kao sportaša	-0,71
Ako budem griješio u utakmici, ljudi će o meni vjerojatno misliti loše	-0,77
Ako igram dobro i onda napravim samo jednu očitu pogrješku u cijeloj utakmici, osjećam se razočaran svojom igrom	-0,68
Svojstvena vrijednost	3,28
Ukupno %	40,95
Alfa	0,90

***Legenda:** * - faktorske saturacije čestica, **Svojstvena vrijednost** - svojstvena varijanca komponente, **Ukupno %** - ukupni postotak objašnjene varijance, **Alfa** - koeficijent pouzdanosti tipa Cronbach alfa.*U

U Tablici 3. vidljivi su rezultati validacije ljestvice upitnika zabrinutosti zbog grešaka. Faktorskom analizom izdvojio se jedan faktor, što potvrđuje dobru homogenost no daljnjom inspekcijom tablice vidljivo je da jedna čestica nije visoko korelirana kao ostale. Iako se čestica ekstrahirala u prvu glavnu komponentu, vidljivo je da je vrijednost iste niža od ostalih čestica te iznosi svega 0,45.

Bez obzira na to, koeficijent pouzdanosti upitnika- Cronbach alfa je visok (0,90) te se može zaključiti da je upitnik pouzdan.

U Tablici 4. prikazani su rezultati validacije ljestvice upitnika *roditeljska očekivanja*

Tablica 4. Validacija ljestvice upitnika *roditeljska očekivanja*

Čestica	***Komponenta****
	1
Roditelji su mi postavili vrlo visoka očekivanja u nogometu	-0,76
Osjećam da u igri ne mogu dovoljno dobro ispuniti očekivanja svojih roditelja	-0,78
Samo je izvrsna igra dovoljno dobra za moju obitelj	-0,78
Misleći na moju budućnost u nogometu, roditelji uvijek imaju veća očekivanja od mene	-0,83
Mislim da me roditelji kritiziraju za svaku igru koja je lošija od savršene	-0,88
U igri nikada ne mogu ostvariti očekivanja svojih roditelja	-0,87
Moji roditelji očekuju samo izvrsnost od mene u nogometu	-0,91
Moji roditelji nikad ne pokušavaju razumjeti grješke koje napravim u igri	-0,80
Roditelji žele da budem bolji od svih drugih igrača koje igraju nogomet	-0,76
Svojstvena vrijednost	6,09
Ukupno %	67,64
Alfa	0,97

***Legenda:** * - faktorske saturacije čestica, **Svojstvena vrijednost** - svojstvena varijanca komponente, **Ukupno %** - ukupni postotak objašnjene varijance, **Alfa** - koeficijent pouzdanosti tipa Cronbach alfa.*

U Tablici 4. vidljivi su rezultati validacije ljestvice upitnika roditeljska očekivanja. Izračunata je Cronbach alfa koja ukazuje na visoku pouzdanost upitnika. Također to potvrđuje i dobru homogenost jer rezultati faktorske analize, gdje se ekstrahirao jedan faktor, objašnjavaju ukupno 67,64% zajedničke varijance. Nadalje, visoke korelacije čestica s prvom glavnom komponentom (0,76–0,91) ukazuju na njihovu međusobnu povezanost, čime se potvrđuje homogenost i pouzdanost ljestvice.

U Tablici 5. prikazani su rezultati validacije ljestvice upitnika *percipirani pritisak trenera*

Tablica 5. Validacija ljestvice upitnika *percipirani pritisak trenera*

Čestica	Komponenta*
	1
Osjećam da me trener kritizira za svaku moju igru koja nije savršena	-0,67
Samo je izvrsna igra dovoljno dobra za mog trenera	-0,77
Osjećam kako nikada ne mogu dostići očekivanja mog trenera	-0,74
Za svaku utakmicu mi trener postavlja vrlo visoka očekivanja	-0,45
Na treningu i u igri, trener od mene očekuje izvrsnost u svakom trenutku	-0,55
Moj trener nikad ne pokušava razumjeti pogrješke koje ponekad učinim	-0,65
Svojstvena vrijednost	2,51
Ukupno %	41,81
Alfa	0,87

Legenda: ** - faktorske saturacije čestica;* ***Svojstvena vrijednost*** *- svojstvena varijanca komponente;* ***Ukupno %*** *- ukupni postotak objašnjene varijance;* ***Alfa*** *- koeficijent pouzdanosti tipa Cronbach alfa.*

U Tablici 5. vidljivi su rezultati faktorske analize ljestvice upitnika u dijelu koji uključuje *percipirani pritisak trenera*. Faktorizacijom čestica izolirala se jedna glavna komponenta što upućuje na dobru homogenost i pouzdanost čestica upitnika. Taj zaključak dodatno potvrđuje i koeficijent pouzdanosti koji iznosi 0,87. No daljnjom inspekcijom tablice, vidljivo je da sve čestice nisu visoko korelirane. Iako su se čestica ekstrahirale u prvu glavnu komponentu, primjetno je kako je vrijednost jedne čestice niža od ostalih čestica te iznosi 0,45.

U Tablici 6. prikazani su rezultati validacije ljestvice upitnika *dvojbe o kvaliteti treniranja*

Tablica 6. Validacija ljestvice upitnika *dvojbe o kvaliteti treniranja*

Čestica	Komponenta*
	1
Obično nisam siguran je li moj trening dobra priprema za utakmicu	-0,69
Mislim da moji treninzi nisu dovoljno kvalitetni	-0,81
Ulazeći u igru, obično mislim da nisam dovoljno trenirao	-0,70
Prije same utakmice rijetko kad sam zadovoljan svojim treninzima	-0,84

Pred utakmicu, često osjećam kako me treninzi nisu u potpunosti pripremili	-0,74
Svojstvena vrijednost	2,87
Ukupno %	57,30
Alfa	0,90

Legenda: ** - faktorske saturacije čestica;* ***Svojstvena vrijednost*** *- svojstvena varijanca komponente;* ***Ukupno %*** *- ukupni postotak objašnjene varijance;* ***Alfa*** *- koeficijent pouzdanosti tipa Cronbach alfa.*

Uvidom u Tablicu 6. vidljivi su rezultati faktorske analize čestica ljestvice upitnika *dvojbe o kvaliteti treniranja.* Prva glavna komponenta ima korelacije s pet čestica u rasponu od 0,69 do 0,84. Također je visok koeficijent pouzdanosti upitnika (0,90), pa se može zaključiti da je i ova ljestvica upitnika zadovoljavajuće pouzdana i homogena.

U Tablici 7. prikazani su rezultati validacije ljestvice upitnika *organizacija*

Tablica 7. Validacija ljestvice upitnika *organizacija*

Čestica	**Prije selekcije čestica**		**Nakon selekcije čestica**
	Komponente*		**Komponenta***
	1	**2**	**1**
Obično mislim kako nisam imao dovoljan broj treninga u pripremi za utakmicu	0,08	0,34	
Na dan utakmice, imam neka uobičajena ponašanja (rutinu) koja stalno pokušavam izvoditi	-0,82	-0,37	-0,86
Imam i slijedim svoju rutinu (neka uobičajena ponašanja) prije utakmice	-0,87	-0,29	-0,90
Kako bih se pripremio za utakmicu, napravim svoj plan i provodim ga	-0,69	0,16	-0,67
Kako bi postigao dobro psihološko stanje, prije utakmice se uvijek ponašam na isti način	-0,67	-0,20	-0,68
Razvijam plan o tome kako bi želio igrati tijekom utakmice	-0,49	0,67	
Pravim svoje planove u kojima navodim kako bi želio igrati	-0,58	0,50	-0,54
Svojstvena vrijednost	2,92	1,10	2,75
Ukupno %	57,42		55,02
Alfa	0,87		0,91

Legenda: ** - faktorske saturacije čestica,* ***Svojstvena vrijednost*** *- svojstvena varijanca komponente,* ***Ukupno %*** *- ukupni postotak objašnjene varijance,* ***Alfa*** *- koeficijent pouzdanosti tipa Cronbach alfa*

U Tablici 7. vidljivi su rezultati koji se odnose na validaciju upitnik *organizacije*. Za primijenjenu ljestvicu nakon provedene analize glavnih komponenti i izračuna koeficijenta pouzdanosti, utvrđeno je kako ljestvica nema zadovoljavajuću homogenost i pouzdanost. Stoga je provedena selekcija čestica na način da su dvije čestice odbačene te je nakon toga utvrđena dobra homogenost, te zadovoljavajući stupanj pouzdanosti.

Nakon validacije ljestvica upitnika nogometaša izračunata je i deskriptivna statistika. Prikazani su osnovni statistički parametri: aritmetička sredina, medijan, minimalni i maksimalni rezultat, standardna devijacija, koeficijent zakrivljenosti i asimetrije distribucije (Tablica 8).

Tablica 8. Deskriptivni pokazatelji i osjetljivost validiranih ljestvica upitnika nogometaša (N=61)

Varijable	AS	M	Min	Max	SD	Skew	Kurt	KS
Optimizam	3,49	3,60	2,40	4,40	0,45	-0,30	0,00	0,15
Osobna očekivanja	3,73	3,80	1,60	5,00	0,79	-0,49	-0,18	0,12
Zabrinutost zbog grešaka	2,59	2,50	1,00	4,75	0,78	0,69	0,74	0,11
Roditeljska očekivanja	1,87	1,50	1,00	4,78	1,00	1,57	1,91	0,19
Percipirani pritisak trenera	2,41	2,50	1,00	4,00	0,75	0,08	-0,41	0,06
Dvojbe o kvaliteti treniranja	2,26	2,10	1,00	5,00	0,86	0,80	0,72	0,12
Organizacija	2,79	2,60	1,00	4,80	0,82	0,42	-0,31	0,12
								KS test=0,20

***Legenda: AS** - aritmetička sredina, **M** - medijan, središnja vrijednost, **Min** - minimalni rezultat, **Max** - maksimalni rezultat, **SD** - standardna devijacija, **KS** - Kolmogorov-Smirnov test, **Skew** - koeficijent asimetrije distribucije, **Kurt** - koeficijent zakrivljenosti distribucije.*

Analizom Tablice 8. u kojoj su predočene vrijednosti osnovnih statističkih parametara kriterijskih varijabli uočava se da sve vrijednosti razlika dobivenih i očekivanih kumulativnih frekvencija ne prelaze graničnu vrijednost testa (KS-test). Ujedno vrijednosti minimalnih i maksimalnih rezultata kao i koeficijenti asimetrije i zakrivljenosti distribucije ukazuju na dobru osjetljivost svih primijenjenih ljestvica upitnika.

Aritmetičke sredine kreću se u rasponu od 1,87 za ljestvicu *roditeljska očekivanja* do najviše prosječne vrijednosti 3,49 za ljestvicu *optimizam.*

Rasprava

Dobiveni rezultati ukazuju na zadovoljavajuće metrijske karakteristike primijenjenih instrumenata za procjenu optimizma i perfekcionizma kod nogometaša, uz potrebu selekcije pojedinih čestica u određenim ljestvicama. Slični nalazi zabilježeni su i u ranijim istraživanjima, gdje se naglašava kako struktura upitnika može varirati ovisno o uzorku ispitanika i sportskom kontekstu (Milić, 2014; Milić i sur., 2024).
Kod ljestvice optimizma uočena je inicijalna nedovoljna homogenost, što je rezultiralo eliminacijom jedne čestice, nakon čega su utvrđene visoka pouzdanost i jednofaktorska struktura. Ovakav rezultat u skladu je s istraživanjima koja ističu potrebu prilagodbe LOT-R upitnika specifičnim populacijama sportaša (Scheier i sur., 1994), ali i potvrđuje stabilnost optimizma kao konstrukta povezanog sa sportskom izvedbom i psihološkom dobrobiti (Chang i sur., 2017; Rochniak i sur., 2020).

Kod ljestvice osobnih očekivanja također je inicijalno utvrđena višefaktorska struktura, što je zahtijevalo selekciju čestica. Nakon prilagodbe postignuta je zadovoljavajuća pouzdanost, što potvrđuje složenost perfekcionizma kao višedimenzionalnog konstrukta, čije se pojedine dimenzije mogu različito manifestirati ovisno o kontekstu (Dunn i sur., 2006; Hill i sur., 2008).
Ljestvice zabrinutosti zbog pogrešaka, roditeljskih očekivanja i percipiranog pritiska trenera pokazale su zadovoljavajuću homogenost i visoku pouzdanost već u inicijalnim analizama. Ovi nalazi u skladu su s istraživanjima koja ističu navedene dimenzije kao stabilne komponente perfekcionizma povezane s vanjskim pritiscima i emocionalnim reakcijama sportaša (Knežević, 2018; Madigan i sur., 2015). Iako su u pojedinim slučajevima uočene niže saturacije pojedinih čestica, ukupna struktura ljestvica ostala je stabilna.
Ljestvica dvojbi o kvaliteti treniranja također je pokazala visoku unutarnju konzistenciju, što se može povezati s dimenzijama samokritičnog perfekcionizma, koje su u literaturi povezane s povećanom nesigurnošću i stresom (Stoeber i sur., 2018). Nasuprot tome, kod ljestvice organizacije inicijalno je utvrđena složenija struktura, što je zahtijevalo redukciju čestica, čime je potvrđeno da organizacijski aspekt perfekcionizma može imati višedimenzionalnu prirodu (Hill i Curran, 2019).
Deskriptivni pokazatelji potvrdili su dobru osjetljivost svih ljestvica, uz distribucije koje nisu značajno odstupale od normalne raspodjele. Slični rezultati zabilježeni su i u prethodnim istraživanjima, gdje se naglašava primjenjivost ovih instrumenata u sportskim populacijama (Milić i sur., 2024).
U konačnici, rezultati ovog istraživanja u velikoj su mjeri u skladu s dosadašnjim spoznajama, uz potvrdu da je za preciznu procjenu psiholoških konstrukata u sportu nužno provesti dodatne provjere metrijskih svojstava instrumenata ovisno o specifičnostima uzorka.

Zaključci

Cilj ovog rada bio je utvrditi metrijske karakteristike (pouzdanost, homogenost i osjetljivost) te procijeniti psihološke značajke perfekcionizma i optimizma u nogometu, na uzorku seniorskih nogometaša koji se natječu u različitim rangovima Hrvatske nogometne lige. Primjenom standardiziranih mjernih instrumenata te odgovarajućih statističkih postupaka utvrđeno je da većina ljestvica posjeduje zadovoljavajuće metrijske karakteristike, uz potrebu parcijalne prilagodbe pojedinih čestica radi postizanja veće homogenosti i pouzdanosti.
Rezultati istraživanja potvrdili su da su optimizam i različite dimenzije perfekcionizma jasno diferencirani i mjerljivi psihološki konstrukti u nogometnom okruženju. Posebno se ističe stabilnost dimenzija povezanih s vanjskim pritiscima, poput roditeljskih očekivanja i pritiska trenera, dok su dimenzije poput osobnih očekivanja i organizacije pokazale veću osjetljivost na strukturalne prilagodbe. Dobiveni nalazi u skladu su s dosadašnjim istraživanjima te dodatno potvrđuju važnost provjere metrijskih svojstava instrumenata u specifičnim sportskim populacijama.
Praktična i znanstvena vrijednost ovog istraživanja očituje se u mogućnosti primjene validiranih instrumenata u radu trenera, kineziologa i sportskih psihologa, s ciljem boljeg razumijevanja psiholoških obilježja sportaša te unaprjeđenja trenažnog i natjecateljskog procesa. Ujedno, rezultati predstavljaju temelj za daljnja istraživanja usmjerena na povezanost psiholoških karakteristika s uspješnošću u sportu.
Ograničenje ovog istraživanja odnosi se na relativno mali uzorak ispitanika, što može utjecati na mogućnost generalizacije rezultata. Stoga se preporučuje provedba budućih istraživanja na većim i raznolikijim uzorcima nogometaša. Također, poželjno je proširiti istraživački pristup uključivanjem varijabli koje se odnose na motoričku izvedbu i specifična nogometna znanja, kako bi se dobio cjelovitiji uvid u povezanost psiholoških i motoričkih čimbenika sportske uspješnosti.

Literatura

1. Andrews, D. M., Burns, L. R., & Dueling, J. K. (2014). Positive perfectionism: Seeking the healthy "should", or should we? *Journal of Social Sciences, 2*(8), 27–34. https://doi.org/10.4236/jss.2014.28005
2. Black, J., & Reynolds, W. M. (2013). Examining the relationship of perfectionism, depression, and optimism: Testing for mediation or moderation. *Personality and Individual Differences, 54*(4), 426–431. https://doi.org/10.1016/j.paid.2012.10.012
3. Carver, C. S., & Scheier, M. F. (2002). Optimism. In C. R. Snyder & S. J. Lopez (Eds.), *Handbook of positive psychology* (pp. 231–243). Oxford University Press.
4. Chang, Y. K., Chen, Y. J., Tu, K. C., & Chiou, S. Y. (2017). Effects of acute exercise on executive function: A study with a Tower of London Task. *Journal of Sport and Exercise Psychology, 39*(3), 212–222. https://doi.org/10.1123/jsep.2016-0310
5. Dunn, J. G. H., Dunn, J. C., & Syrotuik, D. G. (2006). Relationship between multidimensional perfectionism and goal orientations in sport. *Journal of Sport and Exercise Psychology, 28*(4), 430–445. https://doi.org/10.1123/jsep.28.4.430
6. Gustafsson, H., Hassmén, P., & Podlog, L. (2010). Exploring the relationship between hope and burnout in competitive sport. *Journal of Sports Sciences, 28*(14), 1495–1504. https://doi.org/10.1080/02640414.2010.521943
7. Hill, A. P., Hall, H. K., Appleton, P. R., & Kozub, S. A. (2008). Perfectionism and burnout in junior elite soccer players. *Psychology of Sport and Exercise, 9*(1), 48–64. https://doi.org/10.1016/j.psychsport.2007.02.005
8. Hill, A. P., & Curran, T. (2016). Multidimensional perfectionism and burnout: A meta-analysis. *Personality and Social Psychology Review, 20*(3), 269–288. https://doi.org/10.1177/1088868315596286
9. Knežević, L. (2018). *Optimizam i perfekcionizam u odnosu na percipirani stil roditeljstva kod nogometaša srednjoškolske dobi* (Diplomski rad). Zagreb: Sveučilište u Zagrebu, Fakultet hrvatskih studija.
10. Madigan, D. J., Stoeber, J., & Passfield, L. (2015). Perfectionism and burnout in junior athletes: A three-month longitudinal study. *Journal of Sport and Exercise Psychology, 37*(3), 305–315. https://doi.org/10.1123/jsep.2014-0266
11. Milić, M. (2014). *Međupozicijske i unutarpozicijske razlike mladih odbojkašica u nekim antropološkim obilježjima* (Doktorska disertacija). Split: Sveučilište u Splitu, Kineziološki fakultet.
12. Milić, M., Čavala, M., Popović, A., & Vrdoljak, D. (2024). Metric characteristics and assessment of psychological characteristics of perfectionism and optimism in handball. *Gazzetta Medica Italiana – Archivio per le Scienze Mediche, 184*(4), 271–278. https://doi.org/10.23736/S0393-3660.24.05568-2
13. Rochniak, A., Kostikova, I., Fomenko, K., Khomulenko, T., Arabadzhy, T., Viediernikova, T., ... & Kuznetsov, O. (2020). Effect of young basketball players' self-regulation on their psychological indicators. *Journal of Physical Education and Sport, 20*(3), 1606–1612. https://doi.org/10.7752/jpes.2020.03219
14. Scheier, M. F., Carver, C. S., & Bridges, M. W. (1994). Distinguishing optimism from neuroticism: A reevaluation of the Life Orientation Test. *Journal of Personality and Social Psychology, 67*(6), 1063–1078. https://doi.org/10.1037/0022-3514.67.6.1063
15. Stoeber, J., Damian, L. E., & Madigan, D. J. (2018). Perfectionism: A motivational perspective. In J. Stoeber (Ed.), *The psychology of perfectionism: Theory, research, applications* (pp. 19–43). Routledge /Taylor & Francis Group.

RAD 11

ZNANSTVENI RAD

Relativna dob i biološka zrelost kao zajednički prediktori selekcije talenata u sportu mladih: dokazi iz višeklupske kohorte u Splitu, Hrvatska

Dražen Čular

Cro Sport Talent, Longevity Health Lab, Kineziološki fakultet, Sveučilište u Splitu, Hrvatska

Sažetak

Svrha: Ispitati učinak relativne dobi (Relative Age Effect, RAE) u klupskoj selekciji talenata u sportu mladih te istražiti djeluje li položaj rođenja unutar godine (rođendanski kvartal) u interakciji s biološkom zrelošću (skeletnom dobi) na produbljivanje selekcijske nejednakosti.

Metode: N = 37 klupski selekcioniranih mladih sportaša iz 21 sportskog kluba i 15 disciplina u Splitu, Hrvatska. Skeletna dob (SA) procijenjena je uređajem BAUSport™ SonicBone. Sportaši su razvrstani u rođendanske kvartale (Q1–Q4). Hi-kvadrat test podudarnosti ispitao je RAE u odnosu na uniformnu raspodjelu (Cramerov V kao veličina učinka); jednosmjerna ANOVA usporedila je prosječnu SA među kvartalima.

Rezultati: Potvrđen je značajan RAE ($\chi^2(3) = 8{,}081$, $p = 0{,}044$, Cramerov V = 0,27). Sportaši rođeni u Q1 činili su 43 % uzorka naspram samo 11 % u Q3 — četverostruka razlika. Uočen je deskriptivni gradijent SA po kvartalima (Q1: 15,82 ± 1,81 god.; Q3: 15,18 ± 1,50 god.), premda ANOVA nije dosegnula značajnost ($F(3,33) = 0{,}28$, $p = 0{,}839$).

Zaključci: Relativna dob djeluje kao kronološki filtar, a skeletna dob kao biološki pojačivač, zajednički učvršćujući selekcijsku nejednakost u sportu mladih. Za pravednu identifikaciju talenata preporučuje se praćenje obaju pokazatelja.

Ključne riječi: učinak relativne dobi; skeletna dob; biološka zrelost; rođendanski kvartal; identifikacija talenata; sport mladih

1. Uvod

Učinak relativne dobi (Relative Age Effect, RAE) jedan je od najčešće repliciranih nalaza u znanosti o sportu: sportaši rođeni na početku natjecateljske selekcijske godine sustavno su prezastupljeni u razvojnim putovima talenata, elitnim skupinama i sastavima nacionalnih reprezentacija (Cobley i sur., 2009). Unutar dobno grupiranih natjecateljskih struktura, sportaši rođeni u Q1 (siječanj–ožujak) mogu biti i do 12 mjeseci stariji od vršnjaka rođenih u Q4, što im daje značajnu tjelesnu i iskustvenu prednost tijekom ključnih razvojnih razdoblja.

Rjeđe se istražuje kako RAE djeluje u interakciji s biološkom zrelošću. Relativno stariji sportaš (rođen u Q1) koji ujedno i ranije sazrijeva može pokazivati tjelesne karakteristike dvije ili više godina ispred svojih vršnjaka rođenih u Q4 koji kasnije sazrijevaju — stvarajući složenu selekcijsku prednost koju treneri, oslanjajući se na vidljivu izvedbu, teško mogu prepoznati (Cumming i sur., 2018; Wattie i sur., 2015). Ta interakcija — kronološki položaj × biološka uznapredovalost — predstavlja teorijski važan mehanizam u identifikaciji talenata, no ekološki dokazi iz stvarnih selekcijskih okruženja i dalje su ograničeni.

Ovo je istraživanje provedeno u Splitu, Hrvatska — jednome od sportski najuspješnijih gradova po glavi stanovnika u svijetu, s približno 160 000 stanovnika i više od 100 olimpijskih medaljaša. Intenzivno natjecateljsko okruženje i visok selekcijski pritisak čine ga idealnim prirodnim laboratorijem za ispitivanje ovih učinaka. Ciljevi su bili: (1) potvrditi ili opovrgnuti značajan RAE u klupskoj selekciji sportaša te (2) istražiti djeluju li relativna dob i skeletna dob u interakciji koja produbljuje selekcijsku pristranost.

2. Metode

2.1 Sudionici i nacrt istraživanja

Ovo presječno opservacijsko istraživanje uključilo je N = 37 mladih sportaša (djevojke n = 17, mladići n = 20) iz 21 sportskog kluba i 15 disciplina u Splitu, Hrvatska, tijekom natjecateljske sezone 2024.–2025., u sklopu projekta TWINSWINS (Hrvatska zaklada za znanost, IP-2024-05-8340). Svaki je klub neovisno nominirao po jednog sportaša prema vlastitim kriterijima procijenjenog talenta. Uvjet za uključenje bila je dob od 10 do 18 godina i aktivno natjecanje u organiziranoj strukturi natjecanja mladih. Klubovima nije nametnut standardizirani selekcijski protokol, čime je očuvana ekološka valjanost stvarne selekcije. Prije prikupljanja podataka pribavljeni su etičko odobrenje institucije i informirani pristanak.

2.2 Procjena skeletne dobi

Skeletna dob (SA) procijenjena je sustavom BAUSport™ SonicBone (SonicBone Medical Ltd., Izrael) — neinvazivnim ultrazvučnim uređajem bez zračenja koji procjenjuje biološku zrelost putem akustičnih svojstava koštanog tkiva u području lijeve šake i zapešća (zapešće, proksimalna falanga, metakarpalna kost). Ta je metoda pokazala prihvatljivo slaganje s radiografskim standardima i visoku ponovljivost u populacijama mladih (Dvir i sur., 2014; Parr i sur., 2020). Sva je mjerenja u standardiziranim laboratorijskim uvjetima izveo jedan educirani operater prema strogo kontroliranom protokolu. Status zrelosti klasificiran je prema razlici SA−CA: rani (> +1 god.), pravovremeni (±1 god.) ili kasni (< −1 god.).

2.3 Relativna dob i statistička analiza

Sportaši su razvrstani u rođendanske kvartale: Q1 (siječanj–ožujak), Q2 (travanj–lipanj), Q3 (srpanj–rujan), Q4 (listopad–prosinac). Hi-kvadrat test podudarnosti procijenio je odstupanje od očekivane uniformne raspodjele, a veličina učinka kvantificirana je Cramerovim V (mala ≥ 0,10; srednja ≥ 0,30; velika ≥ 0,50). Jednosmjerna ANOVA (F(3,33)) usporedila je prosječnu skeletnu dob među rođendanskim kvartalima. Statistička značajnost postavljena je na $\alpha = 0,05$; analize su provedene u programskom jeziku Python (SciPy, statsmodels).

3. Rezultati

3.1 Učinak relativne dobi

Raspodjela sportaša po rođendanskim kvartalima prikazana je u Tablici 1. Potvrđen je značajan RAE ($\chi^2(3) = 8,081$, $p = 0,044$, Cramerov V = 0,27 — srednji učinak). Sportaši rođeni u Q1 činili su 43 % uzorka (n = 16), gotovo četiri puta više od udjela zabilježenog u Q3 (n = 4; 11 %). Učestalosti Q2 i Q4 bile su blizu očekivanih vrijednosti (22 % odnosno 24 %). Taj obrazac ukazuje na snažan selekcijski pritisak povezan s datumom rođenja unutar ovoga klupskog konteksta identifikacije talenata.

3.2 Interakcija između relativne dobi i skeletne dobi

Tablica 1 prikazuje i prosječnu skeletnu dob po rođendanskom kvartalu. Uočen je deskriptivni gradijent: Q1 (SA = 15,82 ± 1,81 god.) i Q2 (SA = 15,98 ± 1,40 god.) pokazali su višu skeletnu dob od Q3 (SA = 15,18 ± 1,50 god.) i Q4 (SA = 15,40 ± 2,18 god.). Jednosmjerna ANOVA nije dosegnula statističku značajnost ($F(3,33) = 0,28$, $p = 0,839$), što odražava ograničenu statističku snagu — osobito u Q3 (n = 4). Unatoč izostanku značajnosti, usmjerena dosljednost obrasca podupire tezu da su relativno stariji sportaši u ovoj kohorti obično i biološki uznapredovaliji.

Tablica 1. Raspodjela po rođendanskim kvartalima, opažene naspram očekivanih učestalosti te prosječna skeletna i kronološka dob po kvartalu (N = 37).

Rođendanski kvartal	Opaženo (n)	Očekivano (n)	% ukupno	SA konačno (god.)	KD (god.)
Q1 (sij–ožu)	16	9,25	43 %	15,82 ± 1,81	15,26 ± 1,81
Q2 (tra–lip)	8	9,25	22 %	15,98 ± 1,40	15,05 ± 2,02
Q3 (srp–ruj)	4	9,25	11 %	15,18 ± 1,50	14,87 ± 1,33
Q4 (lis–pro)	9	9,25	24 %	15,40 ± 2,18	14,20 ± 1,91

Napomena. SA konačno = procjena skeletne dobi uređajem SonicBone. Očekivano n = 9,25 po kvartalu (uniformna raspodjela). $\chi^2(3) = 8,081$, $p = 0,044$, Cramerov V = 0,27. ANOVA $F(3,33) = 0,28$, $p = 0,839$. KD = kronološka dob.

4. Rasprava

Značajan RAE uočen u ovoj kohorti (Cramerov V = 0,27) u skladu je s desetljećima dokaza u različitim sportovima i na različitim razinama selekcije (Cobley i sur., 2009). Četverostruka razlika između Q1 (43 %) i Q3 (11 %) u kontekstu selekcije na razini grada naglašava koliko taj učinak može biti raširen, čak i u subelitnoj fazi u kojoj treneri navodno procjenjuju najperspektivnije mlade sportaše pojedinih klubova.

Deskriptivni obrazac više prosječne skeletne dobi u Q1 i Q2 u odnosu na Q3 i Q4 u skladu je s ovdje predloženim teorijskim modelom: relativna dob djeluje kao kronološki filtar koji strukturira pristup natjecanju, dok skeletna dob djeluje kao biološki pojačivač koji modulira izražavanje tjelesne izvedbe unutar te strukture. Zajedno ti mehanizmi mogu stvoriti slojeviti kumulativni učinak koji istodobno na više razina stavlja u nepovoljan položaj sportaše rođene u Q4 koji kasnije sazrijevaju (Cumming i sur., 2018; Wattie i sur., 2015).

Izostanak statističke značajnosti u ANOVA-i najbolje je tumačiti kao ograničenje statističke snage, a ne kao dokaz o nepostojanju učinka — osobito s obzirom na to da je Q3 obuhvatio samo n = 4 sportaša. Za formalno testiranje ove interakcije potrebna su buduća istraživanja s većim uzorcima stratificiranima po kvartalima. Ekološka valjanost nacrta — stvarne klupske nominacije bez standardiziranih selekcijskih protokola — predstavlja i snagu (vanjska valjanost) i ograničenje (izostanak neselekcionirane usporedne skupine).

5. Zaključak

Relativna dob ima značajan i praktički važan utjecaj na selekciju talenata u ovom vrhunskom okruženju sporta mladih. Deskriptivna interakcija između položaja rođendanskog kvartala i skeletne dobi podupire teorijski model u kojem su kronološke i biološke prednosti kumulativne, a ne neovisne. Okviri za identifikaciju talenata koji prate i relativnu dob i biološku zrelost u boljem su položaju za razlikovanje istinskog sportskog potencijala od prolazne razvojne prednosti.

Financiranje

Istraživanje je poduprto sredstvima Hrvatske zaklade za znanost (IP-2024-05-8340; IP-2025-02-8546) i Kineziološkog fakulteta Sveučilišta u Splitu (HeLoS, IP-UNIST-24).

Izjava o umjetnoj inteligenciji

Generativna umjetna inteligencija (UI) korištena je tijekom pripreme ovoga rukopisa kao pomoć pri jezičnom uređivanju engleskog teksta, gramatičkom dotjerivanju, strukturnoj organizaciji i integraciji literature. Konkretno, Claude (Anthropic) korišten je za uređivanje teksta, strukturni razvoj i oblikovanje tablica. Sve prijedloge koje je generirala UI autori su kritički pregledali, provjerili i uredili te snose punu odgovornost za intelektualni sadržaj, znanstvenu točnost i integritet rukopisa. UI nije doprinijela izvornim idejama, interpretaciji podataka niti znanstvenim zaključcima. Ova je izjava u skladu s novim uredničkim standardima za korištenje UI u znanstvenom izdavaštvu (usp. Čular i sur., 2026, Frontiers in Sports and Active Living, doi: 10.3389/fspor.2026.1786929).

Literatura

1. Cobley, S., Baker, J., Wattie, N., & McKenna, J. (2009). Annual age-grouping and athlete development: A meta-analytical review of relative age effects in sport. Sports Medicine, 39(3), 235–256.
2. Cumming, S. P., Lloyd, R. S., Oliver, J. L., Eisenmann, J. C., & Malina, R. M. (2018). Bio-banding in sport. Strength & Conditioning Journal, 40(3), 34–47.

3. Čular, D., Miletic, A., & Babic, M. (2024). The prevalence of constituent year effect in Youth Olympic Games: Implications for talent identification in basketball. Acta Kinesiologica, 18(1), 4–8.
4. Dvir, Z., Penner, M., Peretz, C., & Shahar, S. (2014). Prediction of skeletal maturity using the SonicBone ultrasound device. Journal of Clinical Densitometry, 17(4), 475–481.
5. Malina, R. M., Cumming, S. P., Coelho e Silva, M. J., Figueiredo, A. J., Konarski, J. M., & Kowalski, K. L. (2015). Biological maturation assessments in youth sport. Exercise and Sport Sciences Reviews, 43(4), 225–233.
6. Parr, J., Winwood, K., Hodson-Tole, E., et al. (2020). Predicting the timing of the peak of the pubertal growth spurt in elite male youth soccer players. Annals of Human Biology, 47(4), 400–408.
7. Wattie, N., Schorer, J., & Baker, J. (2015). The relative age effect in sport: A developmental systems model. Sports Medicine, 45(1), 83–94.

TEHNOLOŠKI PARTNERI / TECHNOLOGY PARTNERS

HAIPER

2026

Festival of AI, High Performance in Sport, Health & Longevity

Festival umjetne inteligencije, vrhunske izvedbe u sportu, zdravlja i dugovječnosti

Radisson Blu Resort & Spa • Split, Croatia

12 – 15 May 2026 / 12. – 15. svibnja 2026.

ORGANIZATORI / ORGANIZERS

Citius · Altius · Fortius
EUROPSKI INSTITUT
ZA TALENTE, OBRAZOVANJE, ISTRAŽIVANJE I RAZVOJ

CentarIzvrsnosti

ISPAS
INTERNATIONAL SOCIETY OF PERFORMANCE ANALYSIS OF SPORT

TEHNOLOŠKI PARTNERI

Osam svjetskih lidera koji oblikuju budućnost vrhunske izvedbe i zdravlja

HAIPER 2026 okuplja vodeće svjetske tehnološke kompanije iz područja sportske dijagnostike, biomehanike, kardiopulmonalnog testiranja, mjerenja sastava tijela i robotskog otpora. Svaki od izlagača donosi rješenja koja se koriste u olimpijskim centrima, sveučilišnim laboratorijima i vrhunskim klinikama diljem svijeta.

Na sljedećim stranicama predstavljamo vam našeg hrvatskog domaćina **Larus Sport d.o.o.** te sedam svjetskih brendova koje zastupa: **Microgate, CORTEX Biophysik, h/p/cosmos, Enovis, seca, Kinvent, 1080 Motion** i **SonicBone** — osam tvrtki, osam tehnologija, jedna misija: pomicanje granica ljudskih performansi i zdravlja.

PREGLED IZLAGAČA

00	**Larus Sport** — Croatia Partner	*Zagreb, Hrvatska*
01	**Microgate**	*Bolzano, Italija*
02	**CORTEX Biophysik GmbH**	*Leipzig, Njemačka*
03	**h/p/cosmos**	*Nussdorf-Traunstein, Njemačka*
04	**Enovis**	*Wilmington, Delaware, SAD*
05	**seca**	*Hamburg, Njemačka*
06	**Kinvent**	*Montpellier, Francuska*
07	**1080 Motion**	*Lidingö, Stockholm, Švedska*
08	**SonicBone**	*Rishon LeZion, Izrael*

00 / HOST

CROATIA PARTNER / HRVATSKI DOMAĆIN KONFERENCIJE

Larus Sport

Larus Sport d.o.o.

Larus Sport d.o.o. hrvatski je distributer i zastupnik vodećih svjetskih brendova u području sportske dijagnostike, biomehanike, mjerenja performansi, sportske medicine i rehabilitacije. Više od 15 godina povezuje hrvatske klubove, sveučilišne laboratorije, klinike i nacionalne saveze s tehnologijom najviše razine.

ZASTUPANI BRENDOVI NA HAIPER 2026

- **Microgate**
- **CORTEX Biophysik**
- **h/p/cosmos**
- **Enovis**
- **seca**
- **Kinvent**
- **1080 Motion**
- **SonicBone**

SJEDIŠTE	**Trnava I. 7, 10 000 Zagreb, Hrvatska**
OSNOVANO	**2008**

WEB	www.larussport.hr

01 / 08

MJERENJE VREMENA I BIOMEHANIKA POKRETA

Microgate

Vodeća svjetska tvrtka u mjerenju vremena i sportskih performansi te biomehanici pokreta. Microgateovi sustavi koriste se u olimpijskim i profesionalnim sportskim okruženjima diljem svijeta.

KLJUČNI PROIZVODI

- OptoJump Next — optički sustav za analizu skoka i hoda
- Witty — bežični fotoćelijski timing sustav
- Gyko — inercijalni senzor za analizu pokreta
- Witty SEM — semafor za reakciju i kognitivni trening

SJEDIŠTE	**Bolzano, Italija**
OSNOVANO	**1982**
WEB	www.microgate.it

02 / 08

MOBILNA DIJAGNOSTIKA KARDIOPULMONALNIH PERFORMANSI

CORTEX Biophysik GmbH

CORTEX je svjetski lider na tržištu mobilnog testiranja performansi, prisutan u medicini, sportu i fitnessu. Njihovi metabolički sustavi referenca su u sportskoj kardiologiji i ergospirometriji.

KLJUČNI PROIZVODI

- MetaMax 3B — prijenosni breath-by-breath sustav
- MetaLyzer 3B-R3 — stacionarni dijagnostički sustav
- MetaSoft Studio — softver za analizu
- Biofeedback i VO_2max protokoli

SJEDIŠTE	**Leipzig, Njemačka**
OSNOVANO	**1994**
WEB	www.cortex-medical.com

03 / 08

SVJETSKI BROJ 1 U PROIZVODNJI MEDICINSKIH I SPORTSKIH TRAKA

h/p/cosmos

Svjetski broj 1 u proizvodnji pokretnih traka i ergometara za fitness, sport, sportska istraživanja, sportsku medicinu, atletiku, biomehaniku, rehabilitaciju, fizioterapiju, dijagnostiku performansi i znanstvena istraživanja.

KLJUČNI PROIZVODI

- mercury — preciznost laboratorijske trake
- pulsar — sprint i high-speed trake (do 40 km/h)
- saturn — XL trake za biomehaniku
- quasar med — medicinska klasa za rehabilitaciju

SJEDIŠTE	**Nussdorf-Traunstein, Njemačka**
OSNOVANO	**1988**
WEB	www.h-p-cosmos.com

04 / 08

GLOBALNI INOVATOR MEDICINSKE TEHNOLOGIJE

Enovis

Enovis™ je globalni inovator medicinske tehnologije posvećen poboljšanju života razvojem klinički diferenciranih rješenja koja poboljšavaju ishode pacijenata i vraćaju pokretljivost za život.

KLJUČNI PROIZVODI

- DJO® — ortoze i bracing rješenja
- Aircast® — pneumatski systemi imobilizacije
- Chattanooga® — fizikalna terapija i elektrostimulacija
- Compex® — neuromuskularna stimulacija

SJEDIŠTE	**Wilmington, Delaware, SAD**
OSNOVANO	**2022 (kao Enovis)**
WEB	**www.enovis.com**

05 / 08

PRECISION FOR HEALTH

seca

Svjetski lider u mjerenju tjelesne mase i sastava tijela. Sa više od 180 godina iskustva, seca postavlja standard u medicinskoj antropometriji i bioimpedancijskoj analizi.

KLJUČNI PROIZVODI

- mBCA 555 / 525 — medicinska analiza sastava tijela
- seca TRU — bežični skup vaga i visinomjera
- analitika — softver za kliničku interpretaciju
- pedijatrijske vage i stadiometri

SJEDIŠTE	**Hamburg, Njemačka**
OSNOVANO	**1840**
WEB	www.seca.com

06 / 08

CONNECTED SOLUTIONS FOR HUMAN PERFORMANCE

Kinvent

Tvrtka za jednostavna i poveziva rješenja koja revolucionizira način na koji stručnjaci mjere kretanje i optimiziraju ljudske performanse. Bežični senzori i intuitivna aplikacija pomažu kliničarima i trenerima u objektivnoj procjeni.

KLJUČNI PROIZVODI

- K-Force Plates — bežične force plate
- K-Force Muscle Controller — handheld dinamometar
- K-Push & K-Pull — izokinetičko testiranje
- Physio i Perform aplikacije

SJEDIŠTE	**Montpellier, Francuska**
OSNOVANO	**2015**
WEB	www.k-invent.com

07 / 08

ROBOTIC RESISTANCE FOR MAXIMAL PERFORMANCE

1080 Motion

Svjetski priznati stručnjak za mjerenje i razvoj maksimalnih performansi ljudskog tijela. 1080 Motion koristi robotičku tehnologiju otpora kako bi omogućila trening i testiranje s preciznim, varijabilnim opterećenjem.

KLJUČNI PROIZVODI

- 1080 Sprint — otpor i pomoć za sprint trening
- 1080 Quantum — multifunkcijski power-tower
- 1080 Motion App — analitika i ciljevi treninga
- Validacija — koriste vrhunski klubovi (NBA, NFL, EPL)

SJEDIŠTE	**Lidingö, Stockholm, Švedska**
OSNOVANO	**2010**
WEB	**www.1080motion.com**

08 / 08

SKELETAL MATURITY ASSESSMENT

SonicBone

SonicBone je razvio prvu kvantitativnu ultrazvučnu tehnologiju za procjenu skeletne zrelosti — bez radijacije, bez X-zraka. Uređaj omogućuje brzu i točnu procjenu kostne dobi djece i adolescenata, ključnu u pedijatriji, endokrinologiji i mladim sportskim selekcijama.

KLJUČNI PROIZVODI

- SonicBone SMA — ultrazvučni sustav za procjenu kostne dobi
- Bez radijacije — sigurno i ponovljivo
- Cloud platforma za analizu i izvještaje
- Primjena: pedijatrija, endokrinologija, sportske selekcije

SJEDIŠTE	**Rishon LeZion, Izrael**
OSNOVANO	**2014**
WEB	**www.sonicbone.com**
DISTRIBUCIJA	**Bau Sport (međunarodna distribucija) • Larus Sport (Hrvatska)**

D O M A Ć I N + O S A M P A R T N E R A

u Splitu

Larus Sport • ***Zagreb, Hrvatska / Croatia Partner***

Microgate • *Bolzano, Italija*

CORTEX Biophysik GmbH • *Leipzig, Njemačka*

h/p/cosmos • *Nussdorf-Traunstein, Njemačka*

Enovis • *Wilmington, Delaware, SAD*

seca • *Hamburg, Njemačka*

Kinvent • *Montpellier, Francuska*

1080 Motion • *Lidingö, Stockholm, Švedska*

SonicBone • *Rishon LeZion, Izrael*

HAIPER 2026

Radisson Blu Resort & Spa • Split • 12. – 15. svibnja 2026.

HAIPER 2026
ISPAS
INTERNATIONAL SOCIETY OF PERFORMANCE ANALYSIS OF SPORT
Festival of AI, High Performance in Sport, Health and Longevity
15th ISPAS World Congress of Performance Analysis of Sport 2026
„Science and Technology in the Service of Sport, Health, and Longevity."
INVITATION
We invite you to
the Charity Evening of Kinesiology, Health and Sport for the Sports Association for People with Down Syndrome "Bili tići"
ViceSAX
MAY 14, 2026 (THURSDAY)
8:00 PM (8:00 PM)
Radisson Blu Resort & Spa, Split, Croatia
To confirm your participation
Scan to confirm
SCAN AND DONATE
Amount:
100,00 EUR
Recipient's IBAN:
HR16 2484 0081 1353 3549 4
FOR MORE INFORMATION
info@ci-sdz.hr

OUR PARTNERS AND SPONSORS

The festival is supported by academic institutions, research organisations, industry partners and public bodies committed to innovation in sport, health and longevity.