



SPORTSKE NAUKE I ZDRAVLJE

SPORTS SCIENCE AND HEALTH

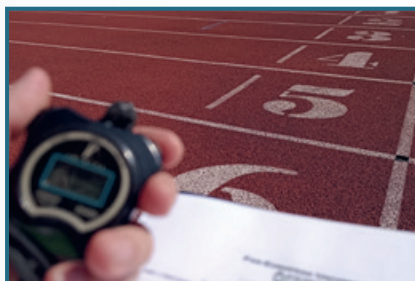
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Dragi čitaoci,

pred vama je novo izdanje časopisa „Sportske nauke i zdravlje”, koje donosi bogat korpus savremenih istraživanja. Ovaj broj okuplja radove eminentnih domaćih i međunarodnih autora koji nude konkretna rešenja i teorijske doprinose kineziološkoj nauci. Uredništvo je u ovaj broj uvrstilo 18 radova autora iz: Bosne i Hercegovine, Srbije, Hrvatske, Turske, Indonezije, Češke i Italije.

U ovom broju, čitaoci i stručna javnost imaju priliku da se upoznaju sa sledećim naučnim i stručnim radovima: ispitivanju uticaja socioekonomskog statusa na učešće mladih u sportu, formulaciji sportskih grickalica sa visokim sadržajem proteina i njihov uticaj na snagu mišića i muskuloskeletno zdravlje: sistematski pregled, značaj biomehanike doskoka u prevenciji povreda u sportskoj gimnastici: sistematski pregled, poređenju efekata šestonedelnog programa FIFA 11+ i Harmoknee na poboljšanje sposobnosti skakanja kod amaterskih fudbalerki, unapređenju izvođenja kratkih pasova i angažovanosti kroz situacione igre 5 na 5 kod mladih fudbalera, razlikama u fleksibilnosti između učenika osnovnih škola iz urbanih i ruralnih sredina: pilot studija, uticaju eksplozivne snage, izokinetičkog potencijala i stabilnosti na uspešnost izvođenja džudo tehnike Uči-mata kod studenata, potencijalnoj primeni hlađenja vrata i glave tokom mečeva kao termoregulatorne strategije za optimizaciju performansi badmintonera, digitalnoj marketing strategiji sportskih organizacija u funkciji povećanja participacije građana u sportu i rekreaciji, efektima različitih grupnih fitnes programa na telesni sastav i funkcionalni kapacitet, poređenju dihotomnih i politomnih instrumenata u proceni tehnike plivanja zasnovanoj na kognitivnim modelima dijagnostike, evaluaciji forhend i bekhend tehnike: eksperimentalna studija efikasnosti treninga u stonom tenisu, evaluaciji uticaja aerobnog vežbanja na telesni sastav kod adolescenata: sistematski pregled, bibliometrijskom mapiranju istraživanja gejmfikacije u obrazovanju: studija zasnovana na Scopus bazi (2016–2025), efektima programa prilagođene fizičke aktivnosti integrisanog sa primenjenom analizom ponašanja kod dece i adolescenata sa poremećajem iz spektra autizma: pilot studija, uticaju košarkaškog programa na transformaciju motoričkih sposobnosti desetogodišnjih osnovaca, uticaju sportskih događaja na turističku ponudu destinacije: studija slučaja Pannonian Challenge i DOBRO World Cup, te primenljivosti motoričkih procena u praćenju ishoda fizičkog vežbanja kod dece sa poremećajem iz spektra autizma.

Uredništvo izražava veliku zahvalnost svim autorima na poverenju i izuzetnom naučnom doprinosu, kao i recenzentima koji su svojim stručnim recenzijama obezbedili visok kvalitet publikovanih radova. Časopis nastavlja da raste i služi kao nezamenjiv izvor znanja za akademsku zajednicu, trenere i zdravstvene radnike.

UREDNIŠTVO ČASOPISA

Dear readers,

In front of you is the new edition of the Journal “Sports Science and Health”, which brings a rich corpus of contemporary research. This issue gathers papers by eminent domestic and international authors who offer concrete solutions and theoretical contributions to kinesiological science. The Editorial Board has included 18 papers in this issue, authored by researchers from Bosnia and Herzegovina, Serbia, Croatia, Turkey, Indonesia, the Czech Republic, and Italy.

In this issue, readers and the professional public will have the opportunity to familiarize themselves with the following scientific and professional papers: an examination of the effect of socioeconomic status on young people's participation in sport, high-protein sports snack formulations and their impact on muscle strength and musculoskeletal health: a systematic review, the importance of landing biomechanics in injury prevention in artistic gymnastics: a systematic review, comparison of the effects of a 6-week FIFA 11+ program and harmoknee on jumping ability improvement in amateur female football players, enhancing short-pass performance and engagement through 5 v 5 small-sided games in young football athletes, differences in flexibility between urban and rural elementary school children: a pilot study, the influence of explosive strength, isokinetic potential, and stability on the performance success of the uchi-mata throw technique in students, the potential application of neck-head cooling during matches as a thermoregulatory strategy to optimize badminton athletes' performance, digital marketing strategies of sports organizations in the function of increasing citizen participation in sports and recreation, effects of different group fitness programs on body composition and functional capacity, comparing dichotomous and polytomous instruments in cdm-based swimming technique assessment, evaluation of forehand and backhand technique: an experimental study of training effectiveness in table tennis, evaluating the influence of aerobic exercise on body composition in adolescents: a systematic review, bibliometric mapping of gamification research in education: a scopus-based study (2016–2025), effects of an adapted physical activity program integrated with applied behavior analysis in children and adolescents with autism spectrum disorder: a pilot study, the effect of the basketball program on the transformation of motor skills of ten-years old school children, impact of sporting events on destination tourism offer: case study of pannonian challenge and dobro world cup, as well as applicability of motor assessments in monitoring physical exercise outcomes in children with autism spectrum disorder.

The Editorial Board expresses its deepest gratitude to all authors for their trust and exceptional scientific contribution, as well as to the reviewers whose professional evaluations ensured the high quality of the published papers. The journal continues to grow and serve as an indispensable source of knowledge for the academic community, coaches, and health-care professionals.

EDITORIAL BOARD OF THE JOURNAL

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DIGITAL MARKETING STRATEGIES OF SPORTS ORGANIZATIONS IN THE FUNCTION OF INCREASING CITIZEN PARTICIPATION IN SPORTS AND RECREATION

DIGITALNE MARKETING STRATEGIJE SPORTSKIH ORGANIZACIJA U FUNKCIJI POVEĆANJA PARTICIPACIJE GRAĐANA U SPORTU I REKREACIJI

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Abstract: This paper analyzes the effect of modern digital marketing strategies of sports organizations on increasing the involvement of citizens in recreational activities. The focus is on multi-channel content distribution models (OTT and FAST), social-first approaches and AI-based personalization. The research is based on secondary data that are standardized and recombined into a simulated dataset of 20 units, which enables the application of basic statistical techniques. Descriptive analysis, Poisson GLM models, and nonparametric tests were applied to assess the impact of digital strategies on digital reach and audience response. The results of the Poisson GLM model show that FAST platforms have the strongest positive effect on the number of views ($\beta = 0.4539$; $p = 0.0661$), while OTT platforms have a moderate, but statistically insignificant contribution ($\beta = 0.337$; $p = 0.1708$). The number of digital channels shows a weak negative effect ($\beta = -0.1123$; $p = 0.2055$). Ttest does not confirm that AI personalization significantly affects the open rate ($p = 0.8582$). The findings indicate the existence of a positive, but limited statistically substantiated trend in favor of multichannel and FAST distribution models. Limitations arise from a small and simulated sample, which reduces the possibility of generalizing the results. However, the paper contributes to the literature by connecting digital platforms with the potential to increase the information and motivation of citizens in the field of recreational sports. In addition, the results of the research indicate that the effects of modern digital marketing strategies depend on the way they are integrated and optimized, and not exclusively on the number of channels used. Of particular importance is the quality of content and the adaptation of communication to specific target groups, which creates the preconditions for a long-term increase in the participation of citizens in sports and recreation.

Keywords: Digital marketing, sports management, AI in marketing, digital content management

Sažetak: Ovaj rad analizira efekat savremenih digitalnih marketinških strategija sportskih organizacija na povećanje uključenosti građana u rekreativne aktivnosti. Fokus je na multikanalnim modelima distribucije sadržaja (OTT i FAST), social-first pristupima i AI-zasnovanoj personalizaciji. Istraživanje se zasniva na sekundarnim podacima koji su standardizovani i rekombinovani u simulirani dataset od 20 jedinica, čime je omogućena primjena osnovnih statističkih tehnika. Primijenjeni su deskriptivna analiza, Poisson GLM modeli i neparametrijski testovi radi procjene uticaja digitalnih strategija na digitalni domet i reakcije publike. Rezultati Poisson GLM modela pokazuju da FAST platforme ostvaruju naj-snažniji pozitivan efekat na broj pregleda ($\beta = 0.4539$; $p = 0.0661$), dok OTT platforme imaju umjeren, ali statistički neznatčan doprinos ($\beta = 0.337$; $p = 0.1708$). Broj digitalnih kanala pokazuje slab negativan efekat ($\beta = -0.1123$; $p = 0.2055$). T-test ne potvrđuje da AI-personalizacija značajno utiče na open rate ($p = 0.8582$). Nalazi ukazuju na postojanje pozitivnog, ali ograničeno statistički potkrijepljenog trenda u korist multikanalnih i FAST modela distribucije. Ograničenja proističu iz malog i simuliranog uzorka, što smanjuje mogućnost generalizacije rezultata. Ipak, rad doprinosi literaturi time što povezuje digitalne platforme sa potencijalom za povećanje informisanosti i motivacije građana u oblasti rekreativnog sporta. Dodatno, rezultati istraživanja ukazuju da efekti savremenih digitalnih marketing strategija zavise od načina njihove integracije i optimizacije, a ne isključivo od broja korišćenih kanala. Poseban značaj ima kvalitet sadržaja i prilagođavanje komunikacije specifičnim ciljnim grupama, čime se stvaraju preduslovi za dugoročno povećanje participacije građana u sportu i rekreaciji.

Ključne riječi: Digitalni marketing, sportski menadžment, AI u marketingu, upravljanje digitalnim sadržajem

INTRODUCTION

The digital transformation of sport has significantly changed the way sports organizations interact with audiences. The upward trend in the use of social networks, dedicated applications, streaming services and data-driven technologies has led to digital engagement becoming a key indicator of the success of sports organizations. In this context, an important role is played by all interest groups with which clubs can communicate through various digital channels.

The subject of this scientific paper is the application of modern digital marketing strategies in the function of increasing the participation of citizens in sports and recreation. The purpose of the research is to analytically examine the way in which sports organizations use digital marketing, and in particular advanced digital strategies that contribute to increasing citizen participation in sport.

The research aims to offer a systematic overview of secondary data, identify key trends in digital sports marketing and point out how digital technologies affect citizens' behaviour when it comes to sport and recreation. The aim is also to use statistical tests to verify the credibility and accuracy of the hypotheses and to theoretically explain the impact of digital tactics and strategies on the behavior of citizens. The research problem of this paper stems from the fact that, despite the growth in the use of digital strategies in sports marketing, there is still not enough empirical evidence on which digital tactics actually increase citizen participation in sports and recreation.

The contemporary context of sport and recreation is increasingly marked by social challenges such as a decrease in physical activity, an increase in sedentary lifestyle and inadequate motivation of citizens to engage in organized or independent recreational activities. In this sense, digital marketing of sports organizations does not have an exclusively promotional function, but also a broader social role in informing, educating and motivating citizens to healthier lifestyle habits. The effective use of digital channels enables sports organizations to tailor messages to different target groups, connect with the local community and encourage long-term citizen participation in sports and recreation.

The paper presents one main and two auxiliary hypotheses. The empirical part of the paper is based on the analysis of secondary data sources and the application of statistical methods, including descriptive analysis, correlation tests and regression models. Microsoft Excel was used to process the data and perform statistical calculations.

Uvod

Digitalna transformacija sporta značajno je izmijenila način na koji sportske organizacije komuniciraju sa publikom. Trend rasta korišćenja društvenih mreža, namjenskih aplikacija, streaming servisa i data-driven tehnologija doveo je do toga da digitalni angažman postane ključni indikator uspješnosti sportskih organizacija. U tom kontekstu, važnu ulogu imaju sve interesne grupe sa kojima klubovi mogu da komuniciraju kroz različite digitalne kanale.

Predmet istraživanja ovog naučnog rada je primjena savremenih digitalnih marketing strategija u funkciji povećanja učešća građana u sportu i rekreaciji. Svrha istraživanja jeste da se analitički ispita način na koji sportske organizacije koriste digitalni marketing, a posebno napredne digitalne strategije koje doprinose povećanju participacije građana u sportu.

Istraživanje ima za cilj da ponudi sistemski pregled sekundarnih podataka, identifikuje ključne trendove u digitalnom sportskom marketingu i ukaže na to kako digitalne tehnologije utiču na ponašanje građana kada je u pitanju sport i rekreacija. Cilj je i da se statističkim testovima provjeri vjerodostojnost i tačnost postavljenih hipoteza te da se teoretski objasni uticaj digitalnih taktika i strategija na ponašanje građana. Istraživački problem ovog rada proizilazi iz činjenice da, uprkos rastu korišćenja digitalnih strategija u sportskom marketingu, još uvijek ne postoji dovoljno empirijskih dokaza o tome koje digitalne taktike zaista povećavaju participaciju građana u sportu i rekreaciji.

Savremeni kontekst sporta i rekreacije sve više je obilježen društvenim izazovima poput smanjenja fizičke aktivnosti, porasta sedentiranog načina života i neodgovarajuće motivacije građana za uključivanje u organizovane ili samostalne rekreativne aktivnosti. U tom smislu, digitalni marketing sportskih organizacija nema isključivo promotivnu funkciju, već i širu društvenu ulogu u informisanju edukaciji i motivisanju građana ka zdravijim životnim navikama. Efikasno korišćenje digitalnih kanala omogućava sportskim organizacijama da prilagode poruke različitim ciljnim grupama, povežu se sa lokalnom zajednicom i podstaknu dugoročnu participaciju građana u sportu i rekreaciji.

Rad predstavlja jednu glavnu i dvije pomoćne hipoteze. Empiriski dio rada zasnovan je na analizi sekundarnih izvora podataka i primjeni statističkih metoda, uključujući deskriptivnu analizu, korelacione testove i regresione modele. Za obradu podataka i izvođenje statističkih izračuna korišten je Microsoft Excel.

LITERATURE REVIEW

The literature review includes key academic and industry sources that analyze contemporary digital strategies in sports marketing, with a particular focus on omnichannel models, socialfirst approaches, and AI personalization.

Digital marketing in the modern sports environment has become one of the key mechanisms for increasing citizen participation in recreation. Multi-channel distribution platforms such as OTT and FAST models significantly expand the availability of sports content to a wider population and stimulate interest in recreational activities (Markets, 2025). According to Deloitte Digital (2025), sports organizations that implement socialfirst strategies record a higher growth in overall digital reach, which affects citizens' awareness of sports programs and motivates them to engage in activities that contribute to health (Digital., 2025). Deloitte Digital's results are in line with industry trends that indicate that organizations with a pronounced social-first approach achieve more stable growth in digital reach compared to traditional promotional models.

Leite (2024) emphasizes that AI-based personalization strategies have significant potential in bringing sports content closer to different age groups of citizens, as they enable the creation of recommendations according to individual needs and interests. (Leite, 2024). However, most of the available work focuses on the potential of AIpersonalization, while empirical studies on its real impact on citizens' behavior are still lacking. SportsPro (2025) points out that promotional campaigns with video formats and real-time posts increase audience engagement and facilitate access to information about available recreational programs. (SportsPro, 2025) These results complement previous sources and indicate that different digital formats play a different role in increasing audience engagement.

The digitalization of the sports sector, as stated by Matić and Maksimović (2023), affects the transformation of the way recreational activities are planned and promoted, especially in the context of increasing awareness of the health benefits of physical activity. (Matić & Maksimović, 2023) Uremović, Landika and Sredojević (2025) add that the specifics of the promotional mix in sports have a strong impact on the perception of recreation in the population, because the emotional connection and experiential elements of the content affect citizens' decisions about participation in sports. (Uremović, Landika, & Sredojević, 2025)

Although the available literature points to the growth of the use of digital technologies in sports marketing, most papers primarily describe trends, while em-

PREGLED LITERATURE

Pregled literature obuhvata ključne akademske i industrijske izvore koji analiziraju savremene digitalne strategije u sportskom marketingu, sa posebnim fokusom na multikanalne modele, social-first pristupe i AI-personalizaciju.

Digitalni marketing u savremenom sportskom okruženju postao je jedan od ključnih mehanizama za povećanje participacije građana u rekreaciji. Multikanalne distribucione platforme poput OTT i FAST modela značajno proširuju dostupnost sportskog sadržaja široj populaciji i podstiču interesovanje za rekreativne aktivnosti (Markets, 2025). Prema Deloitte Digital (2025), sportske organizacije koje primjenjuju social-first strategije bilježe veći rast ukupnog digitalnog dometa, što utiče na informisanost građana o sportskim programima i motiviše ih da se uključe u aktivnosti koje doprinose zdravlju (Digital., 2025). Rezultati Deloitte Digital u skladu su sa industrijskim trendovima koji ukazuju da organizacije s izraženim social-first pristupima ostvaruju stabilniji rast digitalnog dometa u odnosu na klasične promotivne modele.

Leite (2024) naglašava da AI-zasnovane personalizacije strategije imaju značajan potencijal u približavanju sportskih sadržaja različitim starosnim grupama građana, jer omogućavaju kreiranje preporuka prema individualnim potrebama i interesima. (Leite, 2024). Ipak, većina dostupnih radova fokusira se na potencijal AI-personalizacije, dok empirijskih studija o njenom stvarnom uticaju na ponašanje građana još uvijek nema dovoljno. SportsPro (2025) ističe da promotivne kampanje sa video formatima i real-time objavama povećavaju angažman publike i olakšavaju pristup informacijama o dostupnim rekreativnim programima. (SportsPro, 2025) Ovi rezultati dopunjuju prethodne izvore i ukazuju da različiti digitalni formati imaju različitu ulogu u povećanju angažmana publike.

Digitalizacija sportskog sektora, kako navode Matić i Maksimović (2023), utiče na transformaciju načina planiranja i promocije rekreativnih aktivnosti, posebno u kontekstu povećanja svijesti o zdravstvenim benefitima fizičke aktivnosti. (Matić & Maksimović, 2023) Uremović, Landika i Sredojević (2025) dodaju da specifičnosti promotivnog miksa u sportu imaju snažan uticaj na percepciju rekreacije u populaciji, jer emocionalna povezanost i iskustveni elementi sadržaja utiču na odluke građana o učešću u sportu. (Uremović, Landika, & Sredojević, 2025)

Iako dostupna literatura ukazuje na rast primjene digitalnih tehnologija u sportskom marketingu, većina ra-

pirical evidence on the direct impact of digital strategies on citizen engagement in sport remains limited. It is particularly noticeable that industry reports offer rich practical insights and examples of the application of digital tools, while academic papers rarely provide quantitative research on the effects of digital approaches on the recreational habits of the population. Therefore, it is necessary to systematically link industry and academic knowledge in order to better understand the extent to which data-driven approaches, AI personalization and multi-channel digital strategies contribute to citizens' participation in sport and the development of healthy habits.

METHODOLOGICAL FRAMEWORK OF THE RESEARCH

The research combined exploratory and quantitative approaches, using secondary data as the primary source of information. This approach allows for a clear definition of the research design and a transparent presentation of the methods used. The sample of 20 units was formed by deliberately selecting the most relevant secondary sources available, including scientific papers, industry analyses, and market reports. The secondary data were partially standardized and recombined into a simulated dataset to allow the application of statistical tests and models, while maintaining values and relationships consistent with the findings in the literature.

Key variables (ER, reach, views, social-first share, number of channels, AI/personalization) are operationalized according to definitions commonly used in digital marketing and analytics of sports organizations.

In the course of writing this paper, the following methods were used:

- A method of content analysis, used to systematically review and interpret secondary data sources, including scientific papers, industry reports, and market analyses.
- A comparative method, used to compare the findings of different types of sources.
- A synthesis method for integrating various secondary data sources into a single theoretical and empirical framework.
- A method of descriptive analysis, used to describe and systematize key trends in digital marketing of sports organizations.
- Descriptive statistics, used to view the basic characteristics of a data set.
- Correlation analysis, although secondary in this paper, was used to preliminarily examine the relationships between variables.
- Multiple regression and Poisson GLM models were used to assess the impact of digital strategies on engagement rate and number of views.

dova prvenstveno opisuje trendove, dok empirijski dokazi o direktnom uticaju digitalnih strategija na uključivanje građana u sport ostaju ograničeni. Posebno je uočljivo da industrijski izvještaji nude bogate praktične uvide i primjere primjene digitalnih alata, dok akademski radovi rijetko pružaju kvantitativna istraživanja o efektima digitalnih pristupa na rekreativne navike stanovništva. Zbog toga je neophodno sistematsko povezivanje industrijskih i akademskih saznanja kako bi se preciznije razumjelo u kojoj mjeri data-driven pristupi, AI personalizacija i multikanalne digitalne strategije doprinose participaciji građana u sportu i razvoju zdravih navika.

METODOLOŠKI OKVIR ISTRAŽIVANJA

Istraživanje je kombinovalo eksplorativni i kvantitativni pristup, uz primjenu sekundarnih podataka kao osnovnog izvora informacija. Ovakav pristup omogućava jasno definisanje dizajna istraživanja i transparentnu prezentaciju korištenih metoda. Uzorak od 20 jedinica formiran je namjernim odabirom najrelevantnijih dostupnih sekundarnih izvora uključujući naučne radove, industrijske analize i tržišne izvještaje. Sekundarni podaci su djelimično standardizovani i rekombinovani u simulirani dataset kako bi se omogućila primjena statističkih testova i modela, uz zadržavanje vrijednosti i odnosa koji su dosljedni nalazima iz literature.

Ključne varijable (ER, reach, views, social-first udio, broj kanala, AI/personalizacija) operacionalizovane su prema definicijama koje se uobičajeno primjenjuju u digitalnom marketingu i analitici sportskih organizacija.

U toku pisanja ovog rada koristile su se sljedeće metode:

- Metoda analize sadržaja, korištena za sistemsko pregledavanje i interpretaciju sekundarnih izvora podataka, uključujući naučne radove, industrijske izvještaje i tržišne analize.
- Komparativna metoda, korištena za poređenje nalaza različitih tipova izvora.
- Metoda sinteze, za integrisanje različitih sekundarnih izvora podataka u jedinstveni teorijski i empirijski okvir.
- Metoda deskriptivne analize, korištena za opisanje i sistematizaciju ključnih trendova u digitalnom marketingu sportskih organizacija.
- Deskriptivna statistika, korištena za pregled osnovnih karakteristika skupa podataka.
- Korelaciona analiza, iako sekundarna u ovom radu, korištena je za preliminarno ispitivanje odnosa među varijablama.
- Višestruka regresija i Poisson GLM modeli korišteni su za procjenu uticaja digitalnih strategija na engagement rate i broj pregleda. Poisson

The Poisson GLM model was chosen because the dependent variable (number of views) is a numerical figure that is naturally modeled by the distribution of events.

- The T-test was used to assess the differences between groups that use and do not use AI/personalization, in accordance with standard digital marketing methods.
- The Kruskal-Wallis test was used due to deviations from normality in certain data groups and a small sample, which makes it a methodologically justified choice.

Statistical data processing was performed in Microsoft Excel, which was used to calculate descriptive indicators, regression models, and differences tests.

The methods used allow for a reliable and consistent assessment of the effects of digital strategies within the available sample, while respecting the limitations arising from the nature of secondary data.

The data used in the research was taken from industry reports such as Deloitte Digital (Digital., 2025) and market analysis by Research and Markets/Parks Associates on sports streaming. (Markets, 2025) These reports provide an overview of the performance of digital campaigns, OTT/FAST models, and audience behavior. The values were standardized and recombined into a simulated dataset to test the relationship between digital strategies and audience reactions. OR and CTR, as standard digital marketing metrics, are methodologically justified for use within secondary data.

The following table provides an overview of the dependent and independent variables and their role in the analysis.

Table 1. Dependent and Independent Variables

Variable type / Tip varijable	Variable name / Naziv varijable	Opis / operationalization Opis / operacionalizacija	Role in the analysis / Uloga u analizi
Dependent / Zavisna	Reach	Total digital reach of sports content; An indicator of citizens' awareness / Ukupan digitalni domet sportskih sadržaja; indikator informisanosti građana	Outcome Measurement Variable / Mjerna varijabla ishoda
Dependent / Zavisna	Views	Total number of views of sports and recreational digital content / Ukupan broj pregleda sportskih i rekreativnih digitalnih sadržaja	Dependent variable in the Poisson GLM model / Zavisna varijabla u Poisson GLM modelu
Dependent / Zavisna	Open Rate (OR)	Percentage of open digital campaigns / Procenat otvorenih digitalnih kampanja	A measurement variable of audience reaction / Mjerna varijabla reakcije publike
Dependent / Zavisna	Click-Through Rate (CTR)	Percentage of clicks on digital content / Procenat klikova na digitalni sadržaj	Active Engagement Indicator / Indikator aktivnog angažmana
Independent / Nezavisna	OTT presence / OTT prisustvo	Presence of sports content on OTT platforms (0=no, 1=yes) / Prisustvo sportskih sadržaja na OTT platformama (0=ne, 1=da)	Predictor variable / Prediktorska varijabla
Independent / Nezavisna	FAST presence / FAST prisustvo	Presence of sports content on FAST platforms (0=no, 1=yes) / Prisustvo sportskih sadržaja na FAST platformama (0=ne, 1=da)	Predictor variable / Prediktorska varijabla
Independent / Nezavisna	Number of digital channels / Broj digitalnih kanala	Total number of active digital channels / Ukupan broj aktivnih digitalnih kanala	Predictor variable / Prediktorska varijabla

GLM model je izabran zato što zavisna varijabla (broj pregleda) predstavlja brojčani podatak koji se prirodno modeluje distribucijom događaja.

- T-test je korišten za procjenu razlika između grupa koje koriste i ne koriste AI/personalizaciju, u skladu sa standardnim metodama digitalnog marketinga.
- Kruskal-Wallis test primijenjen je zbog odstupanja od normalnosti u pojedinim grupama podataka i malog uzorka, što ga čini metodološki opravdanim izborom.

Statistička obrada podataka izvršena je u programu Microsoft Excel, koji je korišten za izračunavanje deskriptivnih pokazatelja, regresionih modela i testova razlika.

Korištene metode omogućavaju pouzdanu i konzistentnu procjenu efekata digitalnih strategija u okviru dostupnog uzorka, uz uvažavanje ograničenja koja proizlaze iz prirode sekundarnih podataka.

Podaci korišteni u istraživanju preuzeti su iz industrijskih izvještaja kao što su Deloitte Digital (Digital., 2025) i tržišnih analiza Research and Markets / Parks Associates o sportskom streamingu. (Markets, 2025) Ovi izvještaji daju pregled performansi digitalnih kampanja, OTT/FAST modela i ponašanja publike. Vrijednosti su standardizovane i rekombinovane u simulirani dataset radi testiranja odnosa između digitalnih strategija i reakcija publike. OR i CTR, kao standardne metrike digitalnog marketinga, metodološki su opravdane za korištenje u okviru sekundarnih podataka.

U narednoj tabeli dat je prikaz zavisnih i nezavisnih varijabli i njihova uloga u analizi.

Tabela 1. Zavisne i nezavisne varijable

Independent / Nezavisna	Social-first pristup / Social-first pristup	A strong focus on social media and real-time content / Dominantna orijentacija ka društvenim mrežama i real-time sadržaju	A component of the digital strategy / Komponenta digitalne strategije
Independent / Nezavisna	AI/Personalization / AI / personalizacija	Apply AI and personalized recommendations (0=no, 1=yes) / Primjena AI i personalizovanih preporuka (0=ne, 1=da)	Group variable in t-test / Grupna varijabla u t-testu

Source: Authors

Izvor: Autori

Correlation with hypotheses: The variables examine the impact of multi-channel models, AI personalization, and the number of channels on the reach and reactions of citizens.

In accordance with the defined subject and goal of the research, the following hypotheses are set in the paper:

H1: Multi-channel digital strategies increase the digital reach and interest of citizens in sports and recreational content.

H1a: AI/personalized digital approaches affect a higher level of citizen response (open rate, click-through rate).

The empirical research base for this paper relies on secondary data sources, including academic papers, industry reports, and market analyses in the field of digital marketing of sports and recreation. A simulated dataset of 20 observed units was created, which is based on the values of digital reach, number of views, presence of OTT/FAST platforms and AIpersonalization. This dataset retains the proportions from the literature and enables the application of statistical methods (descriptive statistics, correlations, regression, Poisson GLM) to assess the effects of multichannel digital strategies on citizen participation and their reaction to sports and creative content.

THEORETICAL FRAMEWORK OF THE TOPIC

The success of a sporting event is a consequence of a systemic approach through the phases of planning, coordination and control and defines the basis for an effective promotional campaign and the realization of the event. In other words, the basic prerequisites for the successful organization and promotion of sports events are internal factors - two-way communication, efficient financial management, personnel and technical-technological support. Critical success factors for sporting events include communication, financial resources, technical and technological capabilities, community support, and effective involvement of key stakeholders. (Kokolakis, 2018)

We are witnessing that the attractiveness of sports and sports events is significantly influenced by the applied marketing strategies, i.e. the adequate selection of its elements - price, location promotion, communication, segmentation. Uremović and the authors especially emphasize the importance of the promotional factor within the defined marketing mix, and state that “the promotional mix in the sports industry differs from promotion in other sectors due to the

Povezanost sa hipotezama: Varijable ispituju uticaj multikanalnih modela, AI personalizacije i broja kanala na domet i reakcije građana.

U skladu sa definisanim predmetom i ciljem istraživanja, u radu su postavljene sljedeće **hipoteze**:

H1: Multikanalne digitalne strategije povećavaju digitalni domet i interesovanje građana za sportsko-rekreativne sadržaje.

H1a: AI/personalizovani digitalni pristupi utiču na viši nivo reakcija građana (open rate, click-through rate).

Empirijska baza istraživanja za ovaj rad se oslanja na sekundarne izvore podataka, uključujući akademske radove, industrijske izvještaje i tržišne analize u oblasti digitalnog marketinga sporta i rekreacije. Kreiran je simulirani dataset od 20 posmatranih jedinica koji se zasniva na vrijednostima digitalnog dometa (reach), broja pregleda (views), prisustva OTT/FAST platformi i AI-personalizacije. Ovaj dataset zadržava proporcije iz literature i omogućava primjenu statističkih metoda (deskriptivna statistika, korelacije, regresija, Poisson GLM) radi procjene efekata multikanalnih digitalnih strategija na participaciju građana i njihovu reakciju na sportsko-rekreativne sadržaje.

TEORETSKI OKVIR TEME

Uspješnost sportskog događaja predstavlja posljedicu sistemskog pristupa kroz faze planiranja, koordinacije i kontrole i definišu osnovu za efikasnu promotivnu kampanju i realizaciju događaja. Drugim riječima, osnovni preduslovi za uspješnu organizaciju i promociju sportskih događaja su interni faktori- dvosmjerna komunikacija, efikasno finansijsko upravljanje, kadrovska i tehničko-tehnološka podrška. Kritični faktori uspjeha sportskih događaja uključuju komunikaciju, finansijske resurse, tehničke i tehnološke kapacitete, podršku zajednice i efikasno uključivanje ključnih stejkholdera. (Kokolakis, 2018)

Svjedočimo da na atraktivnost sporta i sportskih događaja značajan uticaj imaju primjenjene marketinške strategije, odnosno adekvatan odabir njenih elemenata-cijene, promocije lokacije, komunikacije, segmentacije. Uremović i autori posebno naglašavaju značaj promotivnog faktora unutar definisanog marketing miksa, te navode da „promotivni miks u sportskoj industriji razlikuje se od promocije u drugim sektorima zbog specifičnog

specific character of the sports market, the way sports content is consumed and the strong emotional connection of the audience with sports organizations.” (Uremović, Landika, & Sredojević, 2025). A wide range of tools dedicated to promotion give the possibility of combining and adapting to market preferences and differentiating the offer in relation to the competition. (Uremović, Landika, & Sredojević, 2025). Unifying different promotion tools – advertising, digital platforms, public relations, sponsorships, branding, etc. into one integrated promotional model is a “ticket” for the valorization of a sporting event.

Modern approaches to sports marketing increasingly emphasize the integration of traditional and digital promotional activities in order to create sustainable value for the sports organization and the wider community. In this context, digital platforms and interactive communication channels allow for a two-way exchange of information between sport organisations and the audience, thereby strengthening trust, loyalty and long-term involvement of citizens. The theory of integrated marketing communications is based on the assumption that the coordinated use of different promotional tools contributes to a higher degree of recognition of a sporting event and a more positive public perception of sport. Of particular importance is the adaptation of communication messages to different segments of the audience, taking into account their interests, motivation and level of digital literacy. In this way, sports organizations not only improve the effectiveness of promotion, but also contribute to the development of socially responsible practices that encourage physical activity, a healthy lifestyle and the active participation of citizens in sports and recreational activities.

RESEARCH RESULTS

The results of the survey are based on a standardized dataset of 20 units, which includes key digital metrics of sports organizations, including reach, views, OTT/FAST attendance, number of digital channels, and AI personalization.

Table 2 shows the basic descriptive indicators for key variables. The average values of the reach and views indicators indicate a wide digital reach and high visibility of content among citizens. Large standard deviations confirm that sports organizations have different levels of digital presence and performance.

Table 2. Basic descriptive indicators for key variables

Variable / Varijabla	Mean value / Srednja vrijednost	Standard deviation / Standardna devijacija
Reach	711906.85	433682.31
Views	1000187.45	544064.37

Source: Authors

karaktera sportskog tržišta, načina konzumiranja sportskih sadržaja i jake emocionalne povezanosti publike sa sportskim organizacijama.“ (Uremović, Landika, & Sredojević, 2025). Široka lepeza alata namjenjenih promociji daju mogućnost kombinovanja i prilagođivanja tržišnim preferencijama i diferencijacije ponude u odnosu na konkurenciju. (Uremović, Landika, & Sredojević, 2025). Objedinjavanje različitih alata promocije – oglašavanja, digitalnih platformi, odnosa s javnošću, sponzorstava, brendiranja i dr. u jedan integrisani promotivni model je „ulaznica“ za valorizaciju sportskog događaja.

Savremeni pristupi sportskom marketingu sve više naglašavaju integraciju tradicionalnih i digitalnih promotivnih aktivnosti u cilju stvaranja održive vrijednosti za sportsku organizaciju i širu zajednicu. U tom kontekstu, digitalne platforme i interaktivni kanali komunikacije omogućavaju dvosmjernu razmjenu informacija između sportskih organizacija i publike, čime se jača povjerenje, lojalnost i dugoročna uključenost građana. Teorija integrisanih marketinških komunikacija polazi od pretpostavke da usklađeno korišćenje različitih promotivnih alata doprinosi većem stepenu prepoznatljivosti sportskog događaja i pozitivnijoj percepciji sporta u javnosti. Poseban značaj ima prilagođavanje komunikacionih poruka različitim segmentima publike, uz uvažavanje njihovih interesovanja, motivacije i nivoa digitalne pismenosti. Na taj način sportske organizacije ne samo da unapređuju efikasnost promocije, već i doprinose razvoju društveno odgovornih praksi koje podstiču fizičku aktivnost, zdrav način života i aktivno učešće građana u sportskim i rekreativnim aktivnostima.

REZULTATI ISTRAŽIVANJA

Rezultati istraživanja zasnivaju se na standardizovanom dataset-u od 20 jedinica, koji obuhvata ključne digitalne metrike sportskih organizacija, uključujući reach, views, OTT/FAST prisustvo, broj digitalnih kanala i AI-personalizaciju.

Tabela 2. pokazuje osnovne deskriptivne pokazatelje za ključne varijable. Prosječne vrijednosti pokazatelja reach i views ukazuju na širok digitalni domet i visoku vidljivost sadržaja među građanima. Velike standardne devijacije potvrđuju da sportske organizacije imaju različite nivoe digitalne prisutnosti i performansi.

Tabela 2. Osnovni deskriptivni pokazatelji za ključne varijable

Variable / Varijabla	Mean value / Srednja vrijednost	Standard deviation / Standardna devijacija
Reach	711906.85	433682.31
Views	1000187.45	544064.37

Izvor: Autori

High values of standard deviations indicate marked differences between sports organizations in the level of digital reach and the number of views, which is consistent with the heterogeneity of their digital strategies.

Table 3. I show the minimum representation of the Poisson coefficient of the GLM model. The results of the Poisson model show that FAST platforms have the strongest positive effect on the number of views, while OTT shows a moderate but insignificant effect. The number of channels has a weak negative impact. These findings indicate that types of distribution platforms have different contributions to digital visibility.

Table 3. Minimum representation of the Poisson coefficients GLM model

Variable / Varijabla	Koef. (log)	p-value / p-vrijednost
OTT	0.337	0.1708
FAST	0.4539	0.0661
Channels	-0.1123	0.2055

Source: Authors

A negative channel number coefficient may indicate audience fragmentation or insufficiently optimized multi-channel communication, which is also cited in the literature as a common challenge of digital marketing.

HYPOTHESIS TESTING

Testing hypothesis H1: Multi-channel digital strategies (OTT, FAST and social networks) increase the digital reach and interest of citizens in sports and recreational content.

To test the main hypothesis, the Poisson GLM model was used with the number of views as the dependent variable and OTT presence, FAST platforms and the number of digital channels as predictors. The results show that FAST platforms have the strongest positive effect on the number of views ($p = 0.0661$), while OTT has a positive, but statistically insignificant effect ($p = 0.1708$). The number of channels has a weak negative effect ($p = 0.2055$). These findings partially confirm the H1 hypothesis, as they indicate a trend of increasing reach in organizations using modern digital distribution models.

Table 4. Poisson GLM Model Results (Views ~ OTT + FAST + Channels)

Variable / Varijabla	Koef. (log)	p-value / p-vrijednost
OTT	0.337	0.1708
FAST	0.4539	0.0661
Channels	-0.1123	0.2055

Source: Authors

Visoke vrijednosti standardnih devijacija ukazuju na izražene razlike među sportskim organizacijama u nivou digitalnog dometa i broju pregleda, što je u skladu sa heterogenošću njihovih digitalnih strategija.

Tabela 3. pokazujem minimalni prikaz koeficijenta Poisson GLM modela. Rezultati Poisson modela pokazuju da FAST platforme imaju najsnažniji pozitivan efekat na broj pregleda, dok OTT pokazuje umjeren, ali neznatčan efekat. Broj kanala ima slab negativan uticaj. Ovi nalazi ukazuju da vrste distribucijskih platformi imaju različit doprinos digitalnoj vidljivosti.

Tabela 3. Minimalni prikaz koeficijenta Poisson GLM modela

Izvor: Autori

Negativan koeficijent broja kanala može ukazivati na fragmentaciju publike ili nedovoljno optimizovanu višekanalnu komunikaciju, što se navodi i u literaturi kao čest izazov digitalnog marketinga.

TESTIRANJE HIPOTEZA

Testiranje hipoteze H1: Multikanalne digitalne strategije (OTT, FAST i društvene mreže) povećavaju digitalni domet i interesovanje građana za sportsko-rekreativne sadržaje.

Za testiranje glavne hipoteze korišćen je Poisson GLM model sa brojem pregleda (views) kao zavisnom varijablom, a OTT prisustvom, FAST platformama i brojem digitalnih kanala kao prediktorima. Rezultati pokazuju da FAST platforme imaju najjači pozitivan efekat na broj pregleda ($p = 0.0661$), dok OTT ima pozitivan, ali statistički neznatčan efekat ($p = 0.1708$). Broj kanala ima slab negativan efekat ($p = 0.2055$). Ovi nalazi djelimično potvrđuju hipotezu H1, jer ukazuju na trend povećanja dometa kod organizacija koje koriste savremene digitalne distribucione modele.

Tabela 4. Rezultati Poisson GLM modela (Views ~ OTT + FAST + Channels)

For additional visual interpretation of the results of the Poisson GLM model, Figure 1 shows the average number of views

sports content depending on the presence of OTT and FAST platforms.

Radi dodatne vizuelne interpretacije rezultata Poisson GLM modela, na grafikonu 1. prikazan je prosječan broj pregleda

sportskih sadržaja u zavisnosti od prisustva OTT i FAST platformi.

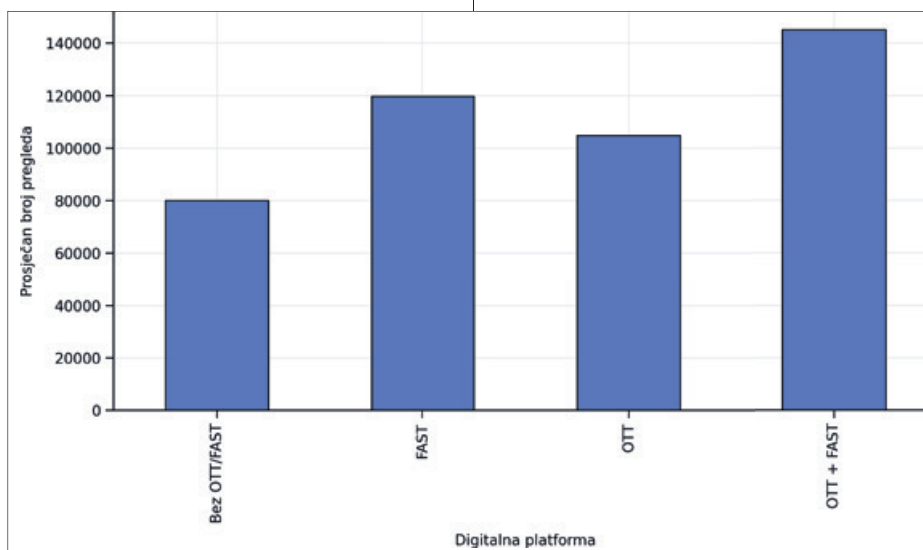


Figure 1. Average number of views of sports content depending on OTT and FAST presence

Source: Authors

Chart 1 shows the average number of views of sports and recreational digital content depending on the presence of OTT and FAST platforms. It is noticeable that organizations that use FAST platforms achieve a higher average number of views compared to organizations without these distribution models, while the presence of OTT platforms shows a moderate but positively directed effect. These findings are in line with the results of the Poisson GLM model, which indicate a more pronounced positive impact of FAST platforms on the number of views compared to OTT presence. The visual representation further confirms that the sheer number of digital channels is not a precedent, but that the type and manner of content distribution play a significant role in increasing the digital visibility of sports content.

In order to verify the adequacy of the received Poisson GLM model, a diagnostic analysis of the residues shown in Graph 2 was performed.

Grafikon 1. Prosječan broj pregleda sportskih sadržaja u zavisnosti od OTT i FAST prisustva

Izvor: Autori

Grafikon 1. prikazuje prosječan broj pregleda sportskih i rekreativnih digitalnih sadržaja u zavisnosti od prisustva OTT i FAST platformi. Uočljivo je da organizacije koje koriste FAST platforme ostvaruju veći prosječan broj pregleda u odnosu na organizacije bez ovih distribucionih modela dok prisustvo OTT platformi pokazuje umjeren, ali pozitivno usmjeren efekat. Ovi nalazi su u skladu sa rezultatima Poisson GLM modela, koji ukazuju na izraženiji pozitivniji uticaj FAST platformi na broj pregleda u poređenju sa OTT prisustvom. Vizuelni prikaz dodatno potvrđuje da sama brojnost digitalnih kanala nije presedan, već da tip i način distribucije sadržaja imaju značajnu ulogu u povećanju digitalne vidljivosti sportskih sadržaja.

Radi provjere adekvatnosti primljenjenog Poisson GLM modela, izvršena je dijagnostička analiza reziduala prikazana na grafikonu 2.

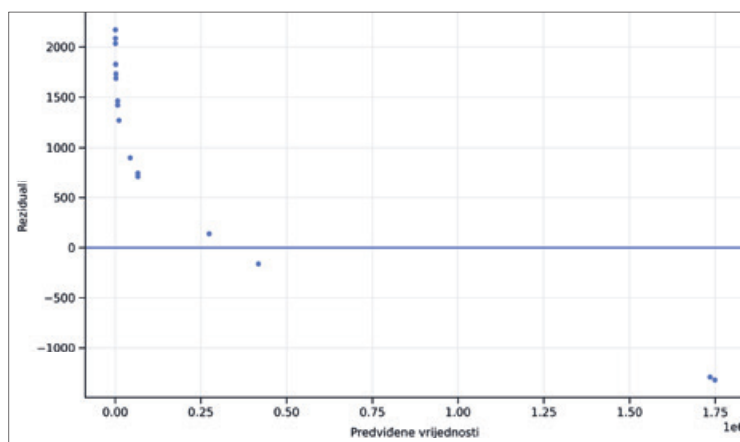


Figure 2. Diagnostic representation of the relationship between residuals and predicted values (Poisson GLM model)

Source: Authors

In order to verify the adequacy and reliability of the received Poisson GLM model, a diagnostic analysis of the residuals was performed. Chart 2 shows the relationship between deviant residues and predicted values, the number of views of sports and recreational digital content. Visual inspection of the graph does not indicate the existence of a pronounced systematic pattern in the arrangement of the residuals, suggesting that the model is adequately specified and that the assumptions of Poisson regression are not significantly distorted within the available sample.

For additional verification of the residue distribution of the Poisson GLM model, Figure 3 shows the QQ plot of the residual diagnostic display.

Grafikon 2. Dijagnostički prikaz odnosa između reziduala i predviđenih vrijednosti (Poisson GLM model)

Izvor: Autori

Radi provjere adekvatnosti i pouzdanosti primljenog Poisson GLM modela, sprovedena je dijagnostička analiza reziduala. Na grafikonu 2. prikazan je odnos između devijans reziduala i predviđenih vrijednosti, broja pregleda sportskih i rekreativnih digitalnih sadržaja. Vizuelni pregled grafikona ne ukazuje na postojanje izraženog sistematskog obrasca u rasporedu reziduala, što sugerše da je model adekvatno specifikovan i da pretpostavke Poisson regresije nisu značajno narušene u okviru dostupnog uzorka.

Radi dodatne provjere distribucije reziduala Poisson GLM modela, na grafikonu 3. prikazan je QQ plot dijagnostičkog prikaza reziduala.

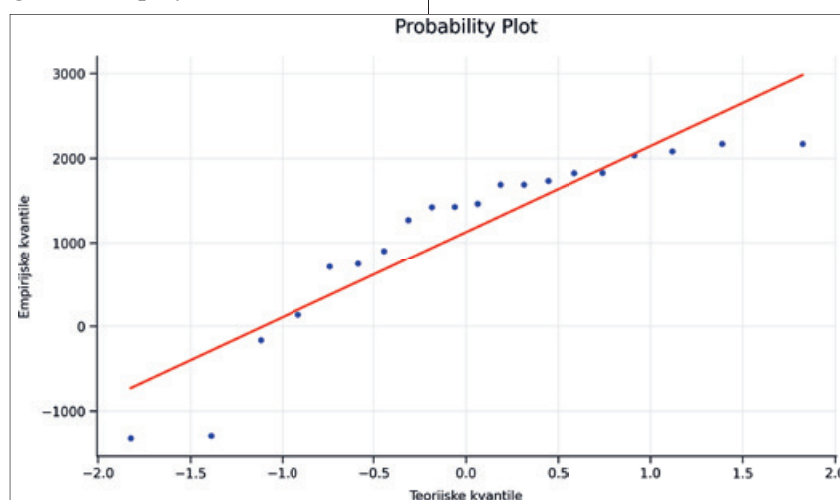


Figure 3. QQ plot diagnostic representation of the residuals of the Poisson GLM model.

Source: Authors

Figure 3 shows the QQ plot of the residuals of the Poisson GLM model, which allows the estimation of their distribution in relation to the theoretical distribu-

Grafikon 3. QQ plot dijagnostičkog prikaza reziduala Poisson GLM modela.

Izvor: Autori

Grafikon 3. pokazuje QQ plot reziduala Poisson GLM modela, koji omogućava procjenu njihove distribucije u odnosu na teorijsku distribuciju. Vizuelni pregled

tion. A visual inspection of the graph shows that most of the points are located near the reference line, with minor deviations at the ends of the distribution. Such discrepancies are expected given the small sample size and do not indicate a serious distortion of the model assumptions. The results obtained confirm the acceptable adaptability of the Poisson GLM model for the analysis of the relationship between digital marketing strategies and the number of views of sports content.

Testing the H1a hypothesis: AI/personalized digital approaches affect a higher level of citizen response (open rate, click-through rate).

The H1a hypothesis was tested by comparing the performance of organizations that use AI/personalized approaches and those that do not. The results of the t-test in Table 5 show that there is no statistically significant difference in open rate between the AI and non-AI groups ($p = 0.8582$), which means that personalized approaches do not contribute to a significant increase in OR scores in the available sample. These findings indicate that **H1a has not been confirmed**.

Table 5. T-test difference in OR between AI and non-AI groups

Statistics / Statistika	Value / Vrijednost
t-value	0.1813
p-value	0.8582

Source: Authors

The results show that the H1a hypothesis is not confirmed, as AI/personalization does not have a statistically significant effect on the open rate within the available sample.

grafikona pokazuje da se većina tačaka nalazi u blizini referentne linije, uz manja odstupanja na krajevima distribucije. Takva odstupanja su očekivana s obzirom na mali uzorak te ne ukazuju na ozbiljno narušavanje pretpostavki modela. Dobijeni rezultati potvrđuju prihvatljivu prilagođenost Poisson GLM modela za analizu odnosa između digitalnih marketing strategija i broja pregleda sportskih sadržaja.

Testiranje hipoteze H1a: AI/personalizovani digitalni pristupi utiču na viši nivo reakcija građana (open rate, click-through rate).

Hipoteza H1a testirana je poređenjem performansi organizacija koje koriste AI/personalizovane pristupe i onih koje ih ne koriste. Rezultati t-testa u tabeli 5. pokazuju da nema statistički značajne razlike u open rate-u između AI i ne-AI grupa ($p = 0.8582$), što znači da personalizovani pristupi ne doprinose značajnom povećanju OR rezultata u dostupnom uzorku. Ovi nalazi ukazuju da **H1a nije potvrđena**.

Tabela 5. T-test razlika u OR između AI i ne-AI grupa

Izvor: Autori

Dobijeni rezultat pokazuje da hipoteza H1a nije potvrđena, jer AI/personalizacija ne ostvaruje statistički značajan uticaj na open rate u okviru dostupnog uzorka.

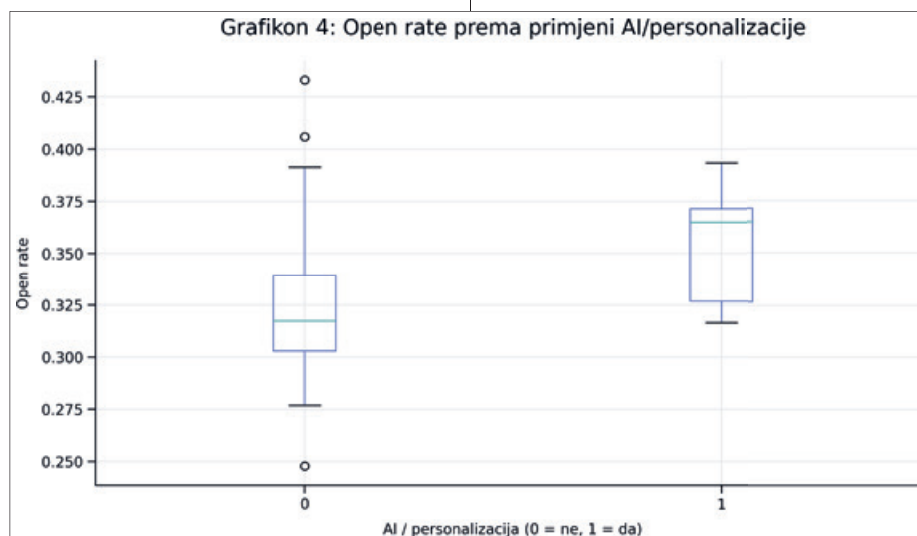


Figure 4. Comparison of open rate values between organizations with and without AI/personalization

Source: Authors

Grafikon 4. Poređenje open rate vrijednosti između organizacija sa i bez AI/personalizacije

Izvor: Autori

These findings form the basis for their interpretation and comparison with previous research, which is presented in more detail in the next chapter of the Discussion.

For additional visual interpretation of the results of the t-test analysis, Figure 5 shows a comparison of open rate values between organizations with and without the use of AI/personalization

Figure 4 shows a comparison of open rate values between organizations that apply AI/personalized digital approaches and those that do not. The visual representation indicates that the differences in the open rate indicator between the observed groups are not pronounced, which is in accordance with the results of the conducted t-test. While slight discrepancies are observed in some cases, there is no clear pattern that would indicate a systematically higher level of audience responsiveness in organizations using AI/personalization. These findings confirm that within the available and simulated sample, the application of AI-personalization does not have a statistically significant impact on the open rate.

DISCUSSION

The results of the research indicate that multi-channel digital strategies of sports organizations have a measurable, but limited effect on the digital reach and interest of citizens in sports and creative content. The results were analyzed in the context of the hypotheses H2 and H2a, in order to look at their empirical consistency and consistency with the existing literature. The Poisson GLM model shows that FAST platforms have the most pronounced positive impact on the number of views, which is in line with contemporary industry trends that highlight FAST/AVOD models as key drivers of digital visibility. Although FAST shows the most pronounced positive effect on the number of views, the value of $p = 0.0661$ indicates a trend, but not formal statistical significance at the conventional level of 5%.

OTT platforms also show a positive, albeit statistically insignificant, effect ($p = 0.1708$). These results are in line with industry reports, in particular Deloitte Digital (2025), which indicates that OTT services contribute to greater availability of sports content, but that their effect varies depending on penetration in the population. In contrast, the number of digital channels has a weak negative impact on the number of views, which may reflect excessive fragmentation of content or insufficient optimization of multi-channel communication. A negative channel number coefficient may indicate audience fragmentation or insufficiently optimized multi-channel communication, which is also cited in the literature as a common challenge of digital marketing.

Ovi nalazi predstavljaju osnovu za njihovu interpretaciju i poređenje sa prethodnim istraživanjima, što je detaljnije prikazano u narednom poglavlju Diskusije.

Radi dodatne vizuelne interpretacije rezultata t-testa analize, na grafikonu 5 prikazano je poređenje open rate vrijednosti između organizacije sa i bez primjene AI/personalizacije

Grafikon 4. prikazuje poređenje open rate vrijednosti između organizacija koje primjenjuju AI/personalizovane digitalne pristupe i onih koje je ne koriste. Vizuelni prikaz ukazuje da razlike u open rate pokazatelju između posmatranih grupa nisu izražene, što je u skladu sa rezultatima sprovedenog t-testa. Iako se u pojedinim slučajevima uočavaju blaga odstupanja, ne postoji jasan obrazac koji bi ukazao na sistematski viši nivo reakcije publike kod organizacija koje koriste AI/personalizaciju. Ovi nalazi potvrđuju da u okviru dostupnog i simuliranog uzorka primjena AI-personalizacije ne ostvaruje statistički značajan uticaj na open rate.

DISKUSIJA REZULTATA

Rezultati istraživanja ukazuju da multikanalne digitalne strategije sportskih organizacija imaju mjerljiv, ali ograničen efekat na digitalni domet i interesovanje građana za sportsko-rekreativne sadržaje. Rezultati su analizirani u kontekstu postavljenih hipoteza H2 i H2a, kako bi se sagledala njihova empirijska dosljednost i usklađenost sa dosadašnjom literaturom. Poisson GLM model pokazuje da FAST platforme imaju najizraženiji pozitivan uticaj na broj pregleda, što je u skladu sa savremenim industrijskim trendovima koji ističu FAST/AVOD modele kao ključne pokretače digitalne vidljivosti. Iako FAST pokazuje najizraženiji pozitivan efekat na broj pregleda, vrijednost $p = 0.0661$ ukazuje na trend, ali ne i na formalnu statističku značajnost na konvencionalnom nivou od 5%.

OTT platforme takođe pokazuju pozitivan, iako statistički neznačajan efekat ($p = 0.1708$). Ovi rezultati su u skladu sa industrijskim izvještajima, posebno Deloitte Digital (2025), koji ukazuje da OTT servisi doprinose većoj dostupnosti sportskih sadržaja, ali da njihov efekat varira u zavisnosti od penetracije u populaciji. Suprotno tome, broj digitalnih kanala bilježi slab negativan uticaj na broj pregleda, što može odražavati prekomjernu fragmentaciju sadržaja ili nedovoljnu optimizaciju višekanalne komunikacije. Negativan koeficijent broja kanala može ukazivati na fragmentaciju publike ili nedovoljno optimizovanu višekanalnu komunikaciju, što se navodi i u literaturi kao čest izazov digitalnog marketinga.

U okviru hipoteze H2a, t-test pokazuje da organi-

Within the H2a hypothesis, ttest shows that organizations that use AIpersonalized approaches do not achieve statistically significantly higher open rate values than those that do not use them ($p = 0.8582$). The absence of a statistically significant effect of AI personalization may be due to the heterogeneity of the population, as personalized digital approaches according to earlier studies (Leite, 2024) work better in more technologically active user segments. The results indicate that the H2a hypothesis has not been confirmed.

An additional aspect that is important to consider in the discussion relates to the institutional and organizational context of the implementation of digital strategies in sports organizations. The effectiveness of modern digital tools does not depend solely on their technical availability, but also on the level of digital literacy of management, clearly defined campaign goals, and the organization's capacity to analyze and interpret data. Sports organizations that apply digital strategies fragmented or without clear integration into the overall marketing plan often fail to realize the full potential of these tools. It is especially important to emphasize that digital marketing in sports also has a social dimension, as it can act as a mechanism to spread awareness of the importance of physical activity and healthy lifestyle habits. In this context, digital strategies should be seen not only as an instrument to increase visibility, but also as a means of long-term shaping of citizens' attitudes and behaviour towards sport and recreation.

Overall, the results show that omnichannel digital strategies have the potential to increase the visibility of recreational content and reach a wider audience, but that the effects are not yet strong enough to be statistically confirmed in small samples. The trends are consistent with industry reports, but indicate that larger samples and primary data are needed to measure citizens' reactions more accurately. The results should be viewed in the context of a limited and simulated sample of 20 units, which affects the statistical power of the model and probably contributes to the lack of significance of certain parameters.

Overall, the results suggest the existence of positive trends in favor of modern digital strategies in sports marketing, but at the same time confirm the need for empirical research on larger, primary samples, which is discussed in more detail in the concluding part of the paper.

CONCLUSION

The results of the research show that multi-channel digital strategies of sports organizations – including OTT, FAST and other digital communication channels – have the potential to increase the visibility and acces-

zacije koje koriste AI-personalizovane pristupe ne ostvaruju statistički značajno veće open rate vrijednosti od onih koje ih ne koriste ($p = 0.8582$). Izostanak statistički značajnog efekta AI-personalizacije može biti posljedica heterogenosti populacije, budući da personalizovani digitalni pristupi prema ranijim studijama (Leite, 2024) bolje funkcionišu u tehnološki aktivnijim segmentima korisnika. Dobijeni rezultat ukazuje da hipoteza H2a nije potvrđena.

Dodatni aspekt koji je važno razmotriti u diskusiji odnosi se na institucionalni i organizacioni kontekst primjene digitalnih strategija u sportskim organizacijama. Efikasnost savremenih digitalnih alata ne zavisi isključivo od njihove tehničke dostupnosti, već i od nivoa digitalne pismenosti menadžmenta, jasno definisanih ciljeva kampanja i kapaciteta organizacije za analizu i interpretaciju podataka. Sportske organizacije koje digitalne strategije primjenjuju fragmentarno ili bez jasne integracije u ukupni marketinški plan često ne uspijevaju da ostvare puni potencijal ovih alata. Posebno je važno naglasiti da digitalni marketing u sportu ima i društvenu dimenziju, jer može djelovati kao mehanizam širenja svijesti o značaju fizičke aktivnosti i zdravih životnih navika. U tom kontekstu, digitalne strategije treba posmatrati ne samo kao instrument povećanja vidljivosti, već i kao sredstvo dugoročnog oblikovanja stavova i ponašanja građana prema sportu i rekreaciji.

Generalno, rezultati pokazuju da multikanalne digitalne strategije imaju potencijal da povećaju vidljivost rekreativnih sadržaja i dopru do šire publike, ali da efekti još nisu dovoljno snažni da bi bili statistički potvrđeni u malim uzorcima. Trendovi su konzistentni sa industrijskim izvještajima, ali ukazuju da su za preciznije mjerenje reakcija građana potrebni veći uzorci i primarni podaci. Rezultate je potrebno posmatrati u kontekstu ograničenog i simuliranog uzorka od 20 jedinica, što utiče na statističku snagu modela i vjerovatno doprinosi nedostatku značajnosti pojedinih parametara.

Ukupno posmatrano, rezultati sugerišu postojanje pozitivnih trendova u korist savremenih digitalnih strategija u sportskom marketingu, ali istovremeno potvrđuju potrebu za empirijskim istraživanjima na većim, primarnim uzorcima, što je detaljnije razmotreno u zaključnom dijelu rada.

ZAKLJUČAK

Rezultati istraživanja pokazuju da multikanalne digitalne strategije sportskih organizacija – uključujući OTT, FAST i druge digitalne kanale komunikacije – imaju potencijal da povećaju vidljivost i dostupnost sport-

sibility of sports and recreational content to citizens. The Poisson GLM analysis indicates that FAST platforms have the most pronounced positive effect on the number of views, which is in line with industry trends that confirm the growing impact of free streaming services on the behavior of the wider population. Although this effect is positive, the parametric values indicate that this is a trend that is not statistically significant at the conventional level, which is expected given the small sample.

OTT platforms show a moderate but insignificant effect, while the number of digital channels records a weak and negative relationship, which may indicate audience fragmentation or the need for better optimization of the digital presence. These results partially confirmed the H2 hypothesis, since a positive direction of multichannel effects was identified, but without statistical confirmation.

The H2a hypothesis, which referred to the impact of AI personalization on citizens' reactions, has not been confirmed. The lack of a statistically significant effect may be due to the heterogeneity of the target population, as well as the fact that AI personalization works better in younger and more technologically active audience segments, as shown by previous studies.

The limitations of the study are primarily related to a small and simulated sample of 20 units, which affects the statistical strength of the model and reduces the possibility of generalizing the results. Despite these limitations, the paper contributes to the literature by quantitatively linking modern digital strategies with the potential to increase citizens' awareness and motivation in the field of recreational sport.

In addition to quantitative findings, the conclusions of this research also point to the need for a broader, strategic look at the role of digital marketing in sports organizations. Digital strategies should not only be viewed through short-term metrics such as views and reach, but also through their contribution to building a long-term relationship between sports organizations and citizens. It is particularly important to consider the potential of digital channels in an educational and motivational role, bearing in mind that sport and recreation are important social mechanisms for improving public health and quality of life. Integrating digital marketing with local sports initiatives, recreation programs, and public campaigns could further enhance its social impact. In this sense, the digital strategies of sports organizations can be seen as part of a broader system of support for active lifestyles, and not solely as a promotional tool.

On the practical side, the findings suggest that sports organizations need to optimize multi-channel strategies

skih i rekreativnih sadržaja građanima. Poisson GLM analiza ukazuje da FAST platforme ostvaruju najizraženiji pozitivan efekat na broj pregleda, što je u skladu sa industrijskim trendovima koji potvrđuju rast uticaja besplatnih streaming servisa na ponašanje šire populacije. Iako je ovaj efekat pozitivan, vrijednosti p-parametara ukazuju da se radi o trendu koji nije statistički značajan na konvencionalnom nivou, što je očekivano s obzirom na mali uzorak.

OTT platforme pokazuju umjeren, ali neznačajan efekat, dok broj digitalnih kanala bilježi slab i negativan odnos, što može ukazivati na fragmentaciju publike ili na potrebu za boljom optimizacijom digitalnog prisustva. Ovim rezultatima djelimično je potvrđena hipoteza H2, budući da je identifikovan pozitivan smjer multikanalnih efekata, ali bez statističke potvrde.

Hipoteza H2a, koja se odnosila na uticaj AI-personalizacije na reakcije građana, nije potvrđena. Nedostatak statistički značajnog efekta može biti posljedica heterogenosti ciljne populacije, kao i činjenice da AI personalizacija bolje funkcioniše u mlađim i tehnološki aktivnijim segmentima publike, što pokazuju i prethodne studije.

Ograničenja istraživanja prvenstveno se odnose na mali i simulirani uzorak od 20 jedinica, što utiče na statističku snagu modela i smanjuje mogućnost generalizacije rezultata. Uprkos ovim ograničenjima, rad doprinosi literaturi time što kvantitativno povezuje moderne digitalne strategije sa potencijalom za povećanje informisanosti i motivacije građana u oblasti rekreativnog sporta.

Pored kvantitativnih nalaza zaključci ovog istraživanja ukazuju i na potrebu šireg, strateškog sagledavanja uloge digitalnog marketinga u sportskim organizacijama. Digitalne strategije ne bi trebalo posmatrati isključivo kroz kratkoročne metrike poput pregleda i dometa, već i kroz njihov doprinos izgradnji dugoročne veze između sportskih organizacija i građana. Posebno je značajno razmotriti potencijal digitalnih kanala u edukativnoj i motivacionoj ulozi, imajući u vidu da sport i rekreacija predstavljaju važne društvene mehanizme za unapređenje javnog zdravlja i kvaliteta života. Integracija digitalnog marketinga sa lokalnim sportskim inicijativama, programima rekreacije i javnim kampanjama mogla bi dodatno osnažiti njegov društveni efekat. U tom smislu, digitalne strategije sportskih organizacija mogu se posmatrati kao dio šireg sistema podrške aktivnom načinu života, a ne isključivo kao promotivni alat.

Sa praktične strane, nalazi ukazuju da sportske organizacije treba da optimizuju multikanalne strategije i pažljivije integrišu FAST modele zbog njihovog visokog

and integrate FAST models more carefully due to their high digital reach potential. Further research should focus on larger, primary samples and more detailed measurements of user behaviour, in order to more accurately assess the actual contribution of digital platforms to the promotion of recreational activities.

potencijala digitalnog dometa. Dalja istraživanja trebalo bi da se fokusiraju na veće, primarne uzorke i detaljnija mjerenja ponašanja korisnika, kako bi se preciznije procijenio stvarni doprinos digitalnih platformi u promociji rekreativnih aktivnosti.

REFERENCES

- Digital., D. (2025). *Social media and sports*. Dellote Digital. . Preuzeto sa <https://www.deloittdigital.com/us/en/insights/perspective/social-media-strategies-sports.html>
- Kokolakis, S. (2018). *Critical success factors and their implementation in sports events organisation and management*. Doctoral dissertation, University of Stirling). Preuzeto sa https://dspace.stir.ac.uk/bitstream/1893/29216/1/Spiros_Kokolakis_PhD_Thesis_Critical_Success_Factors_April_2019.pdf
- Leite, E. T. (2024). The digital evolution of sports marketing: Strategies, technologies, and future trends. . *IRE Journals*. PDF izdanje.
- Markets, R. a. (2025). *Streaming sports in the US: The fan experience*. Reasearch and Markets.
- Matić, R. M., & Maksimović, N. (2023). *Sportski marketing*. Novi Sad: Fakultet sporta i fizičkog vaspitanja. Preuzeto sa <https://fsfvns.edu.rs/wp-content/uploads/2024/09/40-SPORTSKI-MARKETING.pdf>
- SportsPro. (2025). *The role of data in sports marketing*. Preuzeto sa SportsPro: <https://www.sportspro.com/agencies/the-role-of-data-in-sports-marketing-and-how-to-use-it-effectively/>
- Uremović, N., Landika, M., & Sredojević, V. (2025). *Odlučivanje u teoriji i praksi* (tom. 1. izdanje ISBN 987-99976-87-57-9). BanjaLuka, BiH: Panevropski univerzitet Apeiron.
- Uremović, N., Landika, M., & Sredojević, V. (2025). *Odlučivanje u teoriji i praksi* (T. 1). Banja Luka: Panevropski univerzitet Apeiron. doi:ISBN 987-99976-87-57-9

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APPLICABILITY OF MOTOR ASSESSMENTS IN MONITORING PHYSICAL EXERCISE OUTCOMES IN CHILDREN WITH AUTISM SPECTRUM DISORDER: SCOPING REVIEW

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Abstract: A neurodevelopmental disorder characterized by restricted and repetitive patterns of behavior as well as difficulties in communication and social interaction is defined as Autism Spectrum Disorders (ASD). The specific characteristics observed in children with ASD require carefully selected and methodologically justified instruments for the assessment of motor competence, i.e. the assessment of motor skills and physical abilities. The aim of this study is to broadly examine the application of test procedures (instruments) used by researchers in studies in which physical activity intervention is applied in children with ASD and to analyze the methodological justification of their choice. This scoping review was conducted following a systematic search strategy in accordance with the PRISMA Extension for Scoping Reviews guidelines. Based on the literature search and eligibility criteria, 34 papers were included in the final qualitative synthesis. The reviewed literature reveals considerable heterogeneity in the selection of instruments, with the most frequently used being the Test of Gross Motor Development-2/3, the Bruininks–Oseretsky Test of Motor Proficiency-2 and the Movement Assessment Battery for Children-2. These instruments primarily assess motor skills, although many studies also include additional measures of physical abilities for which the authors do not provide clear references regarding their source or origin, representing a methodological limitation. This review highlights the need for the development of standardized instruments that assess both motor skills and physical abilities while accounting for the unique cognitive and social characteristics of children with ASD and varying levels of support needs.

Key words: Motor competence, Motor skills, Assessment tools, Physical activity interventions, Neurodevelopmental disorder

INTRODUCTION

Motor competence (MC) is important for daily functioning, social integration, overall psychomotor development and quality of life (Bertz et al., 2022). It refers to different motor domains and reflects a child's level of motor development, which is determined by the development of motor skills (MS) and physical abilities (PA) (Luiz et al., 2017). Motor competence, as an important factor in a child's social, physical and cognitive development, results from engagement in movement activities and physical exercise. The optimal period for the development of certain motor domains is early childhood, including preschool and early school age, especially for children who have a low level of developmental abilities and skills for a given age, which is the case with children with autism spectrum disorder (ASD) (Molnar, Romanov & Milić, 2024). ASD is one of the fastest growing deviations identified in child development. Compared to children from the typical population, children with ASD are characterized by developmental differences that include difficulties in social interaction and communication, restrictive and repetitive patterns of behavior (World Health Organization, 2019), difficulties across multiple developmental domains of MC (Kodak & Bergmann, 2020), reduced initiative to engage in physical activity programs and decreased participation in motor and play activities (Gehricke et al., 2020). Deviation in motor development, which is observed in children of this population, is one of the potential early identification of ASD (Pokoski et al., 2025). Numerous authors indicate the connection of MC with the development of speech, attention, perception and other cognitive functions, as well as the skills necessary to perform everyday activities (Acar, Erol, & Cimen, 2025). Due to the clearly observed differences in motor development in children with ASD, compared to children of the typical population, experts in the field of kinesiology and related disciplines develop and apply different kinesiology programs aimed at improving motor domains. The development of various programs (physical and sports activities), as well as the monitoring of their outcomes, relies on the application of instruments, used to assess motor development and MC in children with ASD.

In the practical application of instruments, both by clinicians and researchers, a considerable variability in instrument selection can be observed, as well as limitations that affect the standardization of assessment of MC in children with ASD. A lack of methodological rationale in the selection of tests can be observed in the literature, which indicates that they are often chosen on an “ad hoc” basis (Piccolo et al, 2025). It is important to note that the motor instruments were developed according to the developmental norms of children of a typically developing children (Walters et al., 2025). Since adaptations are often required when these instruments are applied with children with ASD, especially in terms of understanding tasks, maintaining attention, motivation and general functional abilities, questions arise about the validity and suitability of the applied instruments. When instruments are used to assess the outcomes of physical activity intervention and to support the development of motor competence in children with ASD, it is important to systematically identify and analyze which instruments and test batteries researchers use to evaluate intervention outcomes. Therefore, the aim of this study is to map the application of instruments used by researchers in studies in which physical activity intervention is applied in children with ASD and to analyze the methodological rationale of their choice.

MATERIAL & METHODS

Protocol and registration

This scoping review was conducted following a systematic search strategy in accordance with the PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines (Tricco et al., 2018).

Eligibility Criteria

Eligibility criteria were defined in accordance with the PRISMA-ScR guidelines. Studies were eligible for inclusion if they: (a) were published from 2010-2025 (study with full text access); (b) employed experimental study; (c) included participants diagnosed with ASD according to established diagnostic criteria (DSM-IV, DSM-5, ICD-9, ICD-10, ICD-11) (American Psychiatric Association, 1994, 2013; World Health Organization, 1978, 1992, 2019); (d) implemented a structured physical exercise or physical activity intervention program; (e) assessed motor competence using motor assessment instruments (standardized and non-standardized); (f) involved children and adolescents aged from 3 to 21 years old; and (g) were published in English language.

Studies were excluded if they: (a) were published before 2010; (b) study with no full text access; (c) were review articles, meta-analyses, conference paper, letters, editorials, or preclinical studies; (d) studies that include other developmental disabilities than ASD; (e) studies with absence of a structured exercise program; (f) did not apply motor assessment tests; and (g) included participants under 3 years and older than 21 years old.

Information sources

A comprehensive literature search was performed up to January 13, 2026, by systematically searching the following electronic databases: Scopus, Web of Science and PubMed.

Search strategy

The search approach was customized for each database to accommodate differences in indexing systems, search interfaces and the use of controlled vocabulary. Search terms were organized into key conceptual MC domains related to the population with ASD, motor competence outcomes, physical exercise or physical activity based interventions and motor assessment instruments. Synonymous terms within each domain were combined using Boolean operators to enhance search sensitivity and specificity.

Selection process and Data collection process

Each database and study was independently screened by two authors (Š.D. and R.R.) to ensure consistent application of the eligibility criteria. In case of disagreement, a third author (B.D.) was consulted and consensus was reached through discussion. After screening titles, abstracts and full texts, agreement between Š.D. and R.R. was 95%, with remaining discrepancies resolved by B.D.

RESULTS

The initial database search yielded a total of 359 records and represented in Figure 1.

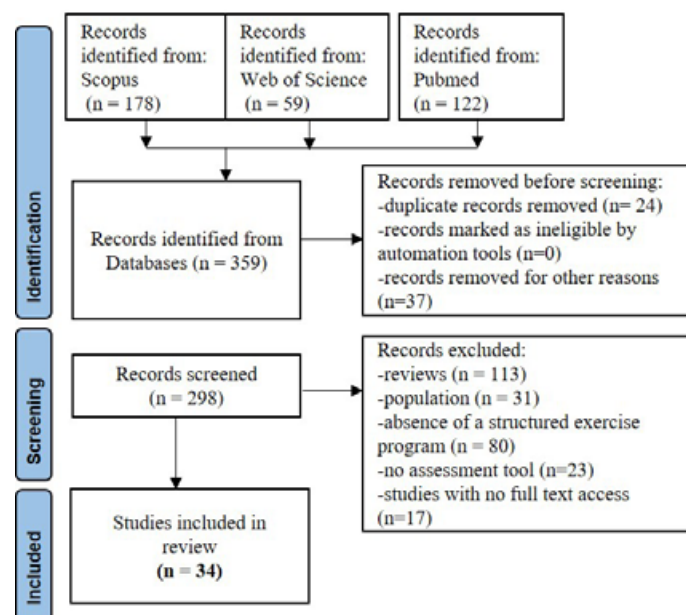


Figure 1. PRISMA flow diagram of the study selection process

After removing duplicates, studies published more than 15 years prior to the search period and non-English studies, 298 records remained for screening. During title and abstract screening, 113 records were excluded (reviews and meta-analyses), 31 due to inappropriate population, 80 due to the absence of a structured exercise program and 23 due to the lack of a motor competence assessment tool. An additional 17 studies were excluded because full texts were unavailable. Following full-text screening and application of the eligibility criteria, 34 studies were included in the final qualitative synthesis of this systematic review. Data were extracted for all assessment instruments used to evaluate motor competencies in children with ASD up to 21 years of age. Both standardized and non-standardized tools were included to capture the full spectrum of instruments currently applied by practitioners, as well as those with potential for future development. Studies involving participants older than 21 years or with other neurodevelopmental or intellectual disorders were excluded. The following data were collected for each included study: (a) study identification information (first author and year of publication), (b) intervention type, (c) participant characteristics (autism severity/intellectual level), (d) motor competence assessment instruments, (e) motor competence domains assessed, (f) study outcomes. These data are summarized in Table 1.

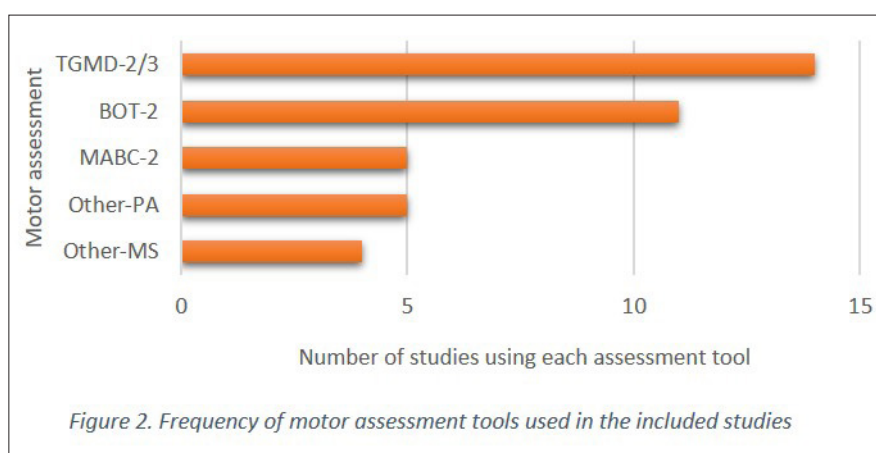
Table 1. Data collected for each included study

	Study/ year	Inter. type	Participants (Autism severity/intellectual level)	Assessment tools	Motor Outcomes
1.	Arabi & Kakhki (2025)	FMSI	n=60 children with ASD, 6–12 yrs; Mild to moderate levels ASD, non verbal, IQ>70	BOT-2-short form	Gross and fine motor skills, coordination
2.	Arabi et al. (2019)	SMI	n=60 children with ASD, 6–12 yrs; Mild to moderate levels of ASD, non-verbal IQ < 60,	TGMD-2	Locomotor and object control skills
3.	Arslan et al. (2020)	PAI	n=28 boys with ASD and TD 9-11yrs; Atypical autism (DSM-V)	BOT-2 (6 subtests); sit and reach, handgrip, Newtest 1000 reaction device	Speed and agility, balance, coordination, strength, flexibility and reaction time
4.	Bo et al. (2018)	FMSI	n=9 children with ASD, 8–13 yrs; ASD without intellectual disabilities	TGMD-3	Locomotor and object control skills

5.	Casey et al. (2015)	SBI	n=2 children with ASD, 7 and 10 yrs; High functional level	The Pediatric balance Scale, Flamingo test, The Floor to Stand Test, The timed up and Go test, Timed Up and Down Stairs test, 6 min walk test	Static, dynamic and anticipatory balance; functional mobility; walking speed, submaximal endurance
6.	Castaño et al. (2024)	FMSI	n=20 children with ASD, 4-6 yrs; Autism severity: NR	Abbreviated Development Scale -3	Gross motor and fine motor skills
7.	Chiva-Bartoll et al. (2021)	FMSI	n=25 children with ASD, 7-13 yrs High-functioning ASD, IQ > 70	MABC-2	Manual Dexterity, Aiming & Catching, Balance
8.	Colebourn et al. (2017)	FMSI	Single child with ASD, 9 yrs Receptive/expressive language & sensory integration difficulties	BOT-2 (upper limb coordination); TGMD-2 (Object Control)	Upper-limb coordination, overhand throwing skill
9.	Gaber (2025)	SMI	n=70 boys with ASD, 6-9 yrs Moderate ASD	Gross motor skills scale (GMSS) Fine motor skills scale (FMSS)	Gross and fine motor skills
10.	Hashemian et al. (2025)	FMSI	n=36 boys with ASD, 4.5–14 yrs Autism severity: NR	BOT-2	Fine Manual Control, Manual Coordination, Body Coordination, Strength & Agility
11.	Henderson (2016)	FMSI	n=37 children with ASD, 5–12 yrs; Moderate to severe autism	TGMD-2+visual support cards	Locomotor and object control skills
12.	Howells et al. (2021)	SBI	n=35 children with ASD, 5-12yrs; Autism severity: NR	MABC-2	Manual dexterity, aiming and catching, balance
13.	Imai et al. (2023)	SBI	n=9 children with ASD, 6–12 yrs; Autism-Spectrum Quotient (AQ) 26–38.	BOT-2 –Short form+BOT2 4 subtests	Bilateral Coordination, Balance, Running Speed & Agility, Strength
14.	Jia & Xie (2021)	FMSI	n=24 children with ASD Autism severity: NR	TGMD-2+visual support cards and „Basic motor skills assessment“	Locomotor and object control skills balance
15.	Kanzari et al. (2025)	SMI	n=21 children with ASD, 5–13 yrs; ASD Level 1–2 support needs – (DSM-5-TR)	BOT-2	Fine Manual Control, Manual Coordination, Body Coordination, Strength & Agility
16.	Kaplánová (2023)	FMSI	n=20 children with ASD, 5–10 yrs; Autism severity: NR	TGMD-2	Locomotor and object control skills
17.	Ketcheson et al. (2016)	FMSI	n=20 children with ASD, 4–6 yrs; Autism severity: NR	TGMD-2 + visual support cards	Locomotor and object control skills
18.	Ketcheson et al. (2021)	FMSI	n=25 children with ASD, 3–5 yrs; Autism severity: NR	TGMD-3 + 4 subtests from Brockport Physical Fitness test	Locomotor and ball skills
19.	Kozłowski et al. (2020)	PAI	n=58 children with ASD, 7–12 yrs; IQ>70	Sit and reach, push ups, sit ups, body weight squats, long jump; PACER	Flexibility, strength, power, cardiovascular endurance
20.	Lourenço et al. (2015)	SMI	n=16 children with ASD, 4–8 yrs; Autism severity: NR	BOT-2 Short form; standing long jump	Gross & fine motor skills, coordination, strength, agility
21.	Marzouki et al (2022)	SBI	n=27 children with ASF, 6-7 yrs; CARS>30; IQ ≥ 80	TGMD -2	Locomotor skills and object control skills
22.	Maussier (2025)	SBI	n=31 children with ASD, 6–10 yrs; Different levels of autism severity	TGMD-3	Locomotor and object control skills
23.	Morales et al. (2022)	SBI	n=40 children with ASD, 9-13 yrs; IQ range 55–70	TGMD-3+visual support cards	Locomotor and object control skills
24.	Özcan, Özer & Pinar (2025)	FMSI	n=34 children with ASD 3- 6 yrs; Autism severity: NR	The Peabody Motor Development Scale (PMDS)-2	Locomotor skills and manipulative skills, balance
25.	Palmer et al. (2023)	FMSI	n = 11 children 3-10yrs (ASD: n = 4; TD: n = 7) Autism severity: NR	TGMD-2 + visual support “LAMP” device	Locomotor and object control skills
26.	Pan et al. (2016)	SBI	n=22 boys with ASD, 6-12yrs High-functioning ASD	BOT-2	Fine Manual Control, Manual Coordination, Body Coordination, Strength & Agility
27.	Rafie et al. (2017)	SMI	n=20 adolescents with ASD, 9–12 yrs; Mild ASD level; IQ≥80	BOT-2	Balance, bilateral coordination, strength, agility, upper-limb coordination

28.	Rafiei Milajerdi et al. (2021)	FMSI+PAI	n=60 children with ASD, 6-10 yrs; Autism severity: NR	MABC-2	Manual Dexterity, Aiming & Catching, Balance
29.	Salvador-Garcia et al. (2021)	FMSI	n=31 children with ASD, 4-16 yrs Autism severity: NR; IQ>70	MABC-2	Manual Dexterity, Aiming & Catching, Balance
30.	Sarabzadeh et al. (2019)	SBI	n=18 children with ASD, 6-12 yrs; Autism severity: NR; Without ID	MABC-2	Manual dexterity, aiming and catching, balance
31.	Svensson et al. (2024)	SMI+ FMSI	n=10 children, 4–10 yrs Autism level 2 or 3 (DSM-V-TR) Moderate i high support needs	TGMD-3 (visual support); BOT-2 subtests	Locomotor skills, bilateral coordination, balance
32.	Touali, et al. (2025)	SMI+PAI	n=14 children with ASD aged, 6-12 yrs Moderate level of ASD (LVL 2, by DSM-5-TR)	UQAC-UQAM -test battery protocol with adaptations	Gross motor factors: limb movement speed, agility, balance, coordination and reaction time
33.	Wang et al. (2025)	FMSI	n=25 children with ASD, first-grade students, age NR; Moderate autism	TGMD-3	Locomotor and object control skills
34.	Wen & Wu (2025)	SMI	n=40 children with ASD, 6–12 yrs; SPM ≤ 30	BOT-2	Balance, coordination, fine motor control and gross motor skills

Note: ASD – Autism Spectrum Disorder; TD – Typical Development; FMSI – Fundamental Motor Skill Intervention; PAI – Physical Abilities Intervention; SMI – Sensory-Motor Intervention; SBI – Sport-Based Intervention; BOT – Bruininks-Oseretsky Test of Motor Proficiency; TGMD – Test of Gross Motor Development; MABC – Movement Assessment Battery for Children; CARS – Childhood Autism Rating Scale; NR – Not reported; EG – Experimental group; CG – Control group.

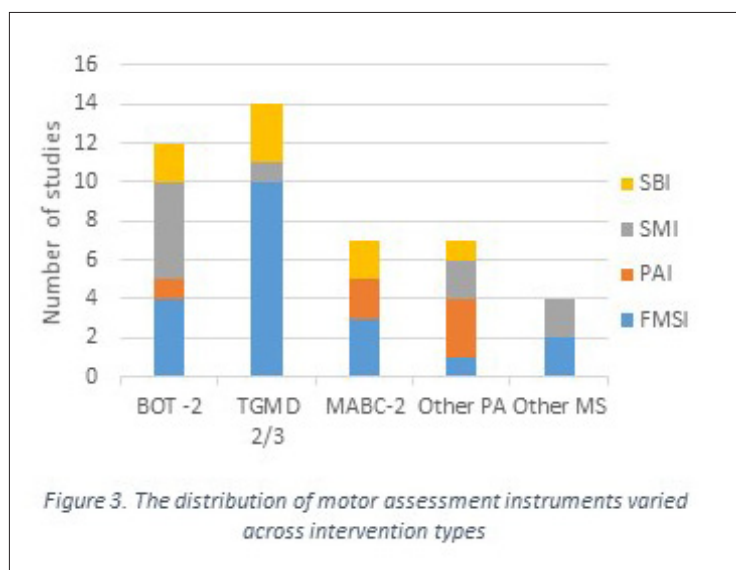


Based on the data extracted from the included studies, the most frequently used motor assessment tools are presented in Figure 2. The TGMD-2/3 was the most applied instrument, used in 14 studies, followed by the BOT-2, which was used in 11 studies. The MABC-2 was applied in five studies. Additionally, other assessments measuring physical abilities (other PA) were identified in five studies, while other instruments assessing motor skills (other MS) were reported in four studies.

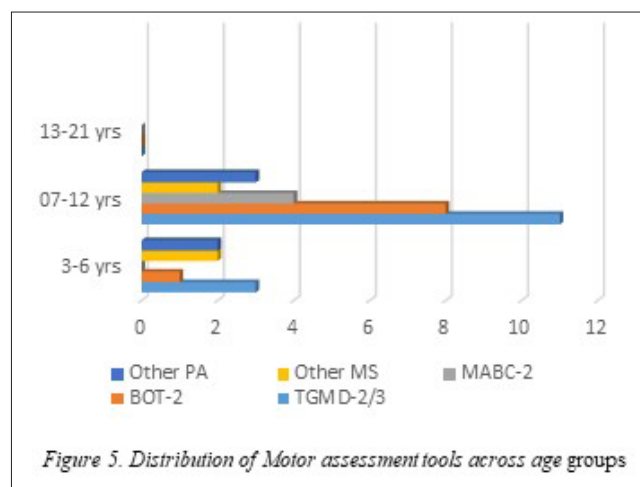
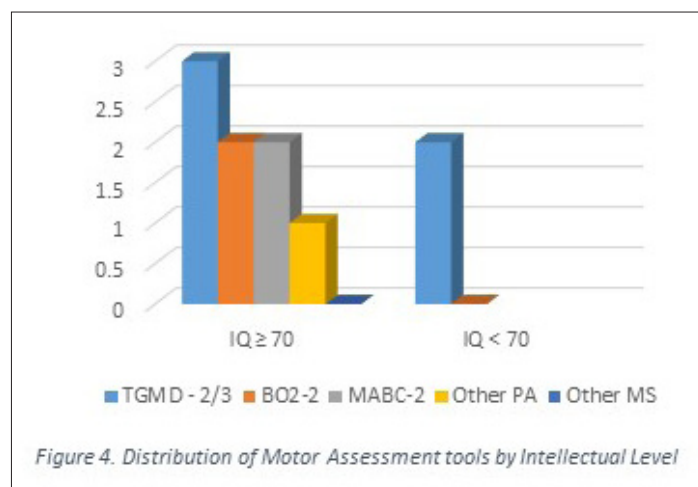
To examine the potential association between intervention type and the selection of assessment instruments, interventions were classified into four categories according to their primary motor objectives: (a) fundamental motor skills intervention (FMSI), (b) physical abilities intervention (PAI), (c) sensory-motor intervention (SMI) and (d) sport-based intervention (SBI).

Some interventions included components from more than one category. It was noted that in some of the analyzed studies, more than one instrument for assessing MC was used. The distribution of assessment tools across intervention types is presented in Figure 3.

Autism severity and intellectual level were not reported in all studies and the scales used to describe autism-related participant characteristics varied, limiting direct comparison. Among the studies that reported IQ, BOT-2, TGMD-2/3 and MABC-2 were used with similar frequency in participants with IQ ≥ 70 , whereas TGMD-2/3 was predominantly used in participants with IQ < 70 (Figure 4). Based on the available data, test selection did not show a clear correspondence with autism severity.



Regarding age-based distribution, TGMD-2/3 was most frequently applied in preschool children (3-6 years), BOT-2, TGMD-2/3 and MABC-2 appeared with similar frequency in school-age children (7-12 years) and no participants were included in the older school-age/adolescent category (13-21 years) (Figure 5.).



DISCUSSION

The aim of this study is to provide an overview of MC assessment instruments used by researchers in studies examining physical activity interventions in children with ASD and to analyze the methodological justification for their selection. The reviewed literature reveals considerable heterogeneity in the choice of instruments within this population, encompassing both standardized and non-standardized instruments. This distribution indicates the absence of a unified approach to motor assessment in the context of physical exercise intervention in children with ASD. The most frequently used tests are Test of Gross Motor Development (Second and Third edition; TGMD-2/3), Bruininks–Oseretsky Test of Motor Proficiency-2 (BOT-2) and Movement Assessment Battery for Children-2 (MABC-2). The results of this study are consistent with previous studies (Battah, Lotan & Moran, 2023; Downs et al., 2020), which report a dominant application of the TGMD-2/3 tests for ages 3 to 6 years. For ages 7 to 16, the following tests are equally applied: TGMD-2/3, BOT-2 and MAC-2. No studies with subjects older than 16 years were identified, indicating a potential lack of research in older adolescents with ASD.

The TGMD-2/3 was identified as the most frequently used instrument, being applied in studies, which may indicate its potential as „gold standard“ for assessing motor competence in children with ASD. This supported by reliability and validity studies (Clutterbuck, Ho & Dwyer, 2025; Ulrich, 2013;) conducted among children with intellectual disabilities. According to the recommendations of the test authors, when the instrument is used with children with developmental disorders, it should be administered with visual support (cards), which ensures its validity for

population of children with ASD.

In the present review, visual supports were included in the assessment instruments only in studies involving participants with moderate to severe autism (Henderson et al., 2016), mild intellectual disabilities (Morales et al., 2022), or moderate to high support needs (Svensson et al., 2024). The use of the TGMD-2/3 in this population is further supported by its applicability for intervention design, with test items also used as intervention tasks and visual cards serving as instructional support (Bo et al., 2019; Henderson et al., 2016; Ketcheson et al., 2016; Wang et al., 2025). The test stands out due to its ease of administration, established validity and sensitivity to changes following physical activity interventions, particularly in children with lower verbal and cognitive abilities (Henderson et al., 2016; Ketcheson et al., 2016; Maussier et al., 2025). This is further supported by Arabi et al. (2019), who applied TGMD-3 in children with an IQ lower than 60, whereas the BOT-2 test was used for children with an IQ above 70 (Arabi et al., 2025).

In several studies, testing procedures showed high task completion rates. Children with ASD were also observed to engage in test tasks with enjoyment and motivation (Ketcheson et al., 2016), highlighting the importance of positive experience for successful participation. Only in the study by Svensson et al. (2024) did children with high support needs fail to complete the TGMD-3 and BOT-2 tests due to difficulties in following instructions and performing the required tasks. These difficulties may be partly related to limitations in language comprehension, as research suggests that understanding visual representations and task demands in children with ASD is more strongly associated with language abilities than with non-verbal intellectual functioning (Hartley, Trainer & Allen, 2019). Svensson et al. (2024) emphasize that although these tests have been validated in children with ASD with lower support needs, their reliability and validity have not yet been confirmed with children requiring higher levels of support.

The Bruininks–Oseretsky Test of Motor Proficiency-2 (BOT-2) is designed to assess general motor proficiency, including domains such as fine manual control, manual coordination, body coordination, strength and agility (Bruininks & Bruininks, 2005). The BOT-2 has been used in several studies due to its comprehensive approach to MC, particularly in terms of performance and movement efficiency, as well as its validation in children with developmental disabilities, including high functioning ASD (Pan et al., 2016). In addition to the complete form, BOT-2 Short Form (SF) provides a quicker assessment while maintaining reliability and sensitivity (Arabi et al., 2025). The SF may represent an appropriate choice for children with ASD due to potential difficulties related to attention and motivation during testing.

In this study, it was observed that the BOT-2 was the test most supplemented with other motor assessments. Imai et al. (2020), in addition to the SF, used four other items of BOT-2 full form to assess motor skills (bilateral coordination, balance, running speed, agility and strength), as the intervention focused on activities involving gross motor skills. Arslan et al. (2020) used six items of the BOT-2 (assessing speed, agility, balance and coordination), along with additional tests of flexibility, handgrip strength and visual-auditory reactions, when enabled a comprehensive assessment of physical abilities.

On the other hand, Rafie et al. (2017) interpreted the results within the framework of perceptual-motor skills rather than motor proficiency alone, to align with the focus of the intervention. Not all subtests showed significant improvement, particularly the bilateral coordination task (drawing circles with the fingers while alternately striking with the feet or catching a falling ruler as quickly as possible). This was attributed to the complexity of the task and requirement for simultaneous coordination of the upper and lower extremities, focused attention and rapid perceptual processing. The authors also suggested that alternatives such as the MABC-2 test might be more sensitive to detect changes in this population.

However, most authors believe that the BOT-2 is capable of detecting significant changes after intervention, which confirms its sensitivity (Pan et al., 2016). The application of the BOT-2 in the analyzed studies illustrates its ability to cover a wide range of motor domains while also indicating limitations in detecting changes in the most demanding tasks.

The Movement Assessment Battery for Children-2 (MABC-2) (Henderson, Sugden, & Barnett, 2007) enables the assessment of motor skills according to developmental norms for children. It covers three age groups (3–6 years, 7–10 years and 11–16 years) and consists of eight tasks divided into three components: manual dexterity, aiming and catching and balance. In all five studies that applied this test, participants had an intellectual disability level with IQ > 70. Howells et al. (2021) reported that not all children were able to complete the grasping and fine motor tasks, as

these tasks require precise coordination and attention, which may represent a potential barrier for children with ASD and cognitive impairments (Lin et al., 2024). In addition, the results of this study were not normally distributed in relation to the identified mean values, which may be a consequence of differences in the functional level of the participants. This suggests that the test may be demanding for children with ASD with lower functional levels, as indicated by the results of this study (Figure 3), but also that these tests do not assess only the motor aspect of development and may be influenced by other domains. Rafiei Milajerdi et al. (2021) stated that a key limitation of their study was the selection of the MABC-2 test for assessing short-term changes, because the authors of the test recommend an interval of three months between two measurements. In their study, the intervention interval was shorter, which may have contributed to minimal program effects, particularly considering that children with ASD often require more time to achieve visible effects after physical exercise interventions.

The analyzed studies indicate that, in relation to the goals and characteristics of physical exercise intervention, the TGMD-2/3 test was often used to assess motor skills in programs specifically focused on learning skills. In contrast, the test was less frequently used to assess physical abilities as an outcome, which aligns with the nature of interventions. Although sensory motor interventions are theoretically based on improving basic neuromotor process (vestibular and proprioceptive integration, motor planning and body awareness), these studies indicate that the BOT-2 was predominantly used to assess these neuromotor competencies, while no study applied the MABC for the same purpose. Although the BOT-2 primarily measures motor competence rather than sensory processing as a separate construct, some of its subtests (e.g., balance, bilateral coordination and fine manual control) are functionally dependent on effective sensory integration. This may partly explain its frequent use in sensory-motor intervention research despite its broader focus on motor efficiency.

In interventions based on the development of physical abilities (PA based interventions), single tests such as push-ups, sit-ups, sit and reach, PACER, standing long jump and 6MWT were dominantly used (Arslan et al., 2020; Kozłowski et al., 2020; Touali et al., 2025), while standardizes batteries were rarely applied. Also, in the analyzed studies, the use of additional tests was observed, however, the authors did not refer to the validity of these tests although it is noticeable that some of the additional tests were taken from other test batteries such as Eurofit or Eurofit special test battery (Council of Europe, 1988; Skowroński et al., 2009). Only some studies emphasized the use of standardized instruments, such as the Brockport Physical Fitness Test or the UQAC-UQAM battery (Ketcheson et al., 2021; Touali et al., 2025). The study by Touali et al. (2025) had a dual aim: to examine the effects of intervention and to evaluate the applicability of the UQAC-UQAM protocol in children with ASD. Although the participants required a moderate level of support (level 2) and had $IQ > 70$, the protocol was adapted to their specific characteristics. The study by Touali et al. (2025) had a dual aim: to examine the effects of the intervention and to evaluate the applicability of the UQAC-UQAM protocol in children with ASD. Although the participants required a moderate level of support (level 2) and had an $IQ > 70$, the protocol was adapted to their specific characteristics. Its use was justified by its practicality, as it requires minimal space, equipment, time, and financial resources, while its validity and reliability have been supported by previous research (Touali et al., 2025). Given the positive outcomes, the UQAC-UQAM battery may represent a suitable tool for assessing physical abilities in this population, although further research across different age and clinical subgroups is needed. In sport-based interventions, TGMD-2 was the most frequently used instrument, reflecting the focus of these programs on developing fundamental motor skills. BOT-2 and MABC-2 were also used to assess broader aspects of motor competence and coordination.

CONCLUSION

This scoping review provides an overview of the application of instruments for assessing MC in children with ASD and represents a bridge between previous literature and future practice and research in this area. In the analyzed studies, TGMD-2/3, BOT-2 and MABC-2 were mapped as dominant assessment instruments. Based on the results of this study, it can be concluded that there is a clear need for further standardization and adaptation of these tests when applied to children with ASD with different levels of support needs and cognitive abilities. It was identified that alongside the dominant instruments, additional tests were applied to provide more comprehensive insights into specific MC domains. However, these tests were not always referenced, which raises questions about their validity, sensitivity and reliability. All the above points to methodological (in)justification in the choice of testing procedures for the assessment of applied interventions (physical activity, sports activity) in children with ASD. This suggests that

future researchers should align the selection of instruments with research goals but should also focus on developing instruments that consider the social and cognitive characteristics of the population of children with ASD, as well as their varying levels of motor skills and physical abilities.

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REFERENCES

- Acar, G., Erol, E., & Cimen, K. (2025). Parallels between motor skill development and language development in children. *International Journal of Holistic Health, Sports and Recreation*, 4(1), 23-36. <https://doi.org/10.5281/zenodo.15762971>
- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). American Psychiatric Association.
- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). American Psychiatric Publishing.
- Arabi, M., Saberi Kakhki, A., Sohrabi, M., Soltani Kouhbanani, S., & Jabbari Nooghabi, M. (2019). Is visuomotor training an effective intervention for children with autism spectrum disorders? *Neuropsychiatric Disease and Treatment*, 15, 3089-3102. <https://doi.org/10.2147/NDT.S214991>
- Arabi, S. M., & Saberi Kakhki, A. (2025). Comparing the effects of fine, gross and fine-gross motor exercises on the motor competence of 6–12-year-old autistic children: A quasi-experimental study with a follow-up test. *Acta Psychologica*, 254, 104842. <https://doi.org/10.1016/j.actpsy.2025.104842>
- Arslan, E., Ince, G., & Akyüz, M. (2022). Effects of a 12-week structured circuit exercise program on physical fitness levels of children with autism spectrum condition and typically developing children. *International Journal of Developmental Disabilities*, 68(4), 500-510. <https://doi.org/10.1080/20473869.2020.1819943>
- Battah, H. W., Lotan, M., & Moran, D. S. (2023). The need for a motor assessment tool for children with autism: An opinion article. *Diagnostics*, 13(12), 2095. <https://doi.org/10.3390/diagnostics13122095>
- Bo, J., Pang, Y., Dong, L., Xing, Y., Xiang, Y., Zhang, M., et al.. (2019). Does social functioning moderate the motor outcomes of a physical activity program for children with autism spectrum disorders? A pilot study. *Journal of Autism and Developmental Disorders*, 49(1), 415–421. <https://doi.org/10.1007/s10803-018-3717-4>
- Bruininks, R. H., & Bruininks, B. D. (2005). *Bruininks-Oseretsky test of motor proficiency* (2nd ed.). Pearson.
- Casey, A. F., Quenneville-Himbeault, G., Normore, A., Davis, H., & Martell, S. G. (2015). A therapeutic skating intervention for children with autism spectrum disorder. *Pediatric Physical Therapy*, 27(2), 170-177. <https://doi.org/10.1097/PEP.0000000000000139>
- Castaño, P. R. L., Suárez, D. P. M., González, E. R., et al.. (2024). Effects of physical exercise on gross motor skills in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 54, 2816-2825. <https://doi.org/10.1007/s10803-023-06031-5>
- Chiva-Bartoll, O., Maravé-Vivas, M., Salvador-García, C., & Valverde-Estevé, T. (2021). Impact of a physical education service-learning programme on ASD children: A mixed-methods approach. *Children and Youth Services Review*, 126, 106008. <https://doi.org/10.1016/j.childyouth.2021.106008>
- Clutterbuck, G. L., Ho, C., & Dwyer, G. M. (2025). The feasibility and reliability of the test of gross motor development (TGMD-3) for children with disabilities in regional Australia: A pragmatic pilot study. *Physical and Occupational Therapy in Pediatrics*, 45(4), 572–593. <https://doi.org/10.1080/01942638.2025.2463350>
- Council of Europe. (1988). *Eurofit: Handbook for the EUROFIT tests of physical fitness*. Council of Europe.
- Downs, S. J., Boddy, L. M., McGrane, B., Rudd, J. R., Melville, C. A., & Fowweather, L. (2020). Motor competence assessments for children with intellectual disabilities and/or autism: A systematic review. *BMJ Open Sport and Exercise Medicine*, 6(1). <https://doi.org/10.1136/bmjsem-2020-000902>
- Gaber, S. A., Alzahrani, A. S., Dawsari, I. A., Hamad, A. M., & Alhajri, A. S. (2025). Developing gross and fine motor skills using sensory integration in children with moderate autism spectrum disorder. *European Journal of Educational Research*, 14(1), 297–308. <https://doi.org/10.12973/eu-jer.14.1.297>
- Gehricke, J. G., Chan, J., Farmer, J. G., Fenning, R. M., Steinberg-Epstein, R., Misra, M., Parker, R. A., & Neumeyer, A. M. (2020). Physical activity rates in children and adolescents with autism spectrum disorder compared to the general population. *Research in Autism Spectrum Disorders*, 70, 101490. <https://doi.org/10.1016/j.rasd.2019.101490>
- Hartley, C., Trainer, A., & Allen, M. (2019). Investigating the relationship between language and picture understanding in children with autism spectrum disorder. *Autism*, 23(1), 187-198. <https://doi.org/10.1177/1362361317729613>
- Henderson, H., Fuller, A., Noren, S., Stout, V. M., & Williams, D. (2016). The effects of a physical education program on the motor skill performance of children with autism spectrum disorder. *Palaestra*, 30(3).
- Henderson, S. E., Sugden, D. A., & Barnett, A. L. (2007). *Movement Assessment Battery for Children-2* (2nd ed.). The Psychological Corporation.
- Imai, Y., Naruse, H., Kurita, R., Hiratani, M., & Tomori, K. (2023). A hybrid intervention combining group-based physical activity and an individual goal-oriented approach for children with developmental disabilities: A pre–post intervention study. *International Journal of Disability, Development and Education*, 70(1), 1-17. <https://doi.org/10.1080/1034912X.2020.1856793>
- Jia, W., & Xie, J. (2021). Improvement of the health of people with autism spectrum disorder by exercise. *Revista Brasileira de Medicina do Esporte*, 27(3), 282-285. https://doi.org/10.1590/1517-8692202127032021_0081
- Kanzari, C., Hawani, A., Ayed, K. B., Mrayeh, M., Marsigliante, S., & Muscella, A. (2025). The impact of a music- and movement-based intervention on motor competence, social engagement, and behavior in children with autism spectrum disorder. *Children*, 12(1), 87.

- <https://doi.org/10.3390/children12010087>
- Kaplánová, A., Šišková, N., Grznárová, T., & Vanderka, M. (2023). Physical education and development of locomotion and gross motor skills of children with autism spectrum disorder. *Sustainability*, 15(1), 28. <https://doi.org/10.3390/su15010028>
- Ketcheson, L., Hauck, J., & Ulrich, D. (2017). The effects of an early motor skill intervention on motor skills, levels of physical activity and socialization in young children with autism spectrum disorder: A pilot study. *Autism*, 21(4), 481-492. <https://doi.org/10.1177/1362361316650611>
- Ketcheson, L., Staples, K., Pitchford, E. A., & Loetzner, F. (2023). Promoting positive health outcomes in an urban community-based physical activity intervention for preschool-aged children on the autism spectrum. *Journal of Autism and Developmental Disorders*, 53, 633-647. <https://doi.org/10.1007/s10803-021-04871-7>
- Kodak, T., & Bergmann, S. (2020). Autism spectrum disorder: Characteristics, associated behaviors, and early intervention. *Pediatric Clinics of North America*, 67(3), 525-535. <https://doi.org/10.1016/j.pcl.2020.02.007>
- Kozłowski, K. F., Lopata, C., Donnelly, J. P., Thomeer, M. L., Rodgers, J. D., & Seymour, C. (2021). Feasibility and associated physical performance outcomes of a high-intensity exercise program for children with autism. *Research Quarterly for Exercise and Sport*, 92(3), 289-300. <https://doi.org/10.1080/02701367.2020.1726272>
- Lin, L. Y., Hwang, I. T., Hsu, C. F., Yu, W. H., Lai, P. C., Chen, Y. W., & Tu, Y. F. (2024). Comparing fine motor performance among young children with autism spectrum disorder, intellectual disability, ADHD, and developmental coordination disorder. *Frontiers in Pediatrics*, 12, 1372980. <https://doi.org/10.3389/fped.2024.1372980>
- Marzouki, H., Soussi, B., Selmi, O., Hajji, Y., Marsigliante, S., Bouhlel, E., Muscella, A., Weiss, K., & Knechtel, B. (2022). Effects of aquatic training in children with autism spectrum disorder. *Biology*, 11(5), 657. <https://doi.org/10.3390/biology11050657>
- Molnar, D., Romanov, R., & Milić, Z. (2024). The Effects of Adapted Physical Exercise on Gross Motor Function and Motor Abilities in Child with Multiple Disabilities. *Sport Science and Health*, 14(2), 173-178. <https://doi.org/10.7251/SSH2402173M>
- Morales, J., Pierantozzi, E., Fukuda, D. H., Garcia, V., Guerra-Balic, M., Sevilla-Sánchez, M., & Carballeira, E. (2022). Improving motor skills and psychosocial behaviors in children with autism spectrum disorder through an adapted judo program. *Frontiers in Psychology*, 13, 1067310. <https://doi.org/10.3389/fpsyg.2022.1067310>
- Pan, C. Y., Chu, C. H., Tsai, C. L., Sung, M. C., Huang, C. Y., & Ma, W. Y. (2017). The impacts of physical activity intervention on physical and cognitive outcomes in children with autism spectrum disorder. *Autism*, 21(2), 190-202. <https://doi.org/10.1177/1362361316633562>
- Piccolo, A., Raciti, C., Di Cara, M., Portaro, S., Muratore, R., De Domenico, C., et al. (2025). Motor coordination assessment in autism spectrum disorder: A systematic review. *Diagnostics*, 15(17), 2118. <https://doi.org/10.3390/diagnostics15172118>
- Pokoski, O. M., Furnier, S. M., Gangnon, R. E., Howerton, E. M., Kirby, A. V., Prothro, T., et al. (2025). Prevalence of motor milestone delays in autistic children. *JAMA Pediatrics*, 179(7). <https://doi.org/10.1001/jamapediatrics.2025.0216>
- Rafie, F., Ghasemi, A., Zamani Jam, A., & Jalali, S. (2017). Effect of exercise intervention on perceptual-motor skills in adolescents with autism. *Journal of Sports Medicine and Physical Fitness*, 57(1-2), 53-59. <https://doi.org/10.23736/s0022-4707.16.05919-3>
- Salvador-Garcia, C., Chiva-Bartoll, O., Belaire-Melià, A., & Valverde-Estève, T. (2022). Motor performance in school-aged children with autism spectrum disorder: Effects of an extracurricular physical education program and socio-ecological correlates. *Journal of Developmental and Physical Disabilities*, 34(2), 355-372. <https://doi.org/10.1007/s10882-021-09802-z>
- Sarabzadeh, M., Azari, B. B., & Helalizadeh, M. (2019). The effect of six weeks of Tai Chi Chuan training on motor skills of children with autism spectrum disorder. *Journal of Bodywork and Movement Therapies*, 23(2), 284-290. <https://doi.org/10.1016/j.jbmt.2019.01.007>
- Skowroński, W., Horvat, M., Nocera, J., Roswal, G., & Croce, R. (2009). Eurofit special: European fitness battery score variation among individuals with intellectual disabilities. *Adapted Physical Activity Quarterly*, 26(1), 54-67. <https://doi.org/10.1123/apaq.26.1.54>
- Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., & Straus, S. E. (2018). PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Annals of Internal Medicine*, 169(7), 467-473. <https://doi.org/10.7326/M18-0850>
- Ulrich, D. A. (2013). The test of gross motor development-3 (TGMD-3): Administration, scoring, and international norms. *Spor Bilimleri Dergisi*, 24(2), 27-33.
- Walters, G. W., Cooper, S., Carlevaro, F., Magno, F., Boat, R., Vagnetti, R., et al. (2025). Normative percentile values for the TGMD-3 for Italian children aged 3-11+ years. *Journal of Science and Medicine in Sport*, 28, 398-407. <https://doi.org/10.1016/j.jsams.2024.12.013>
- Wang, Q., Jia, S., Ding, F., Wang, X., Si, Y., Wang, X., & Sun, J. (2025). Effect of fundamental movement skills practice on executive function and social interaction ability in children with moderate autism: A randomized controlled trial. *BMC Complementary Medicine and Therapies*, 25(1), 354. <https://doi.org/10.1186/s12906-025-05107-2>
- Wen, L., & Wu, Z. (2025). The impact of sensory integration-based sports training on motor and social skill development in children with autism spectrum disorder. *Scientific Reports*, 15(1), 19974. <https://doi.org/10.1038/s41598-025-05393-3>
- World Health Organization. (1978). *International classification of diseases* (9th rev.). World Health Organization.
- World Health Organization. (1992). *The ICD-10 classification of mental and behavioural disorders: Clinical descriptions and diagnostic guidelines*. World Health Organization.
- World Health Organization. (2019). *International classification of diseases for mortality and morbidity statistics* (11th rev.). <https://icd.who.int/>

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COMPARING DICHOTOMOUS AND POLYTOMOUS INSTRUMENTS IN CDM-BASED SWIMMING TECHNIQUE ASSESSMENT

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Abstract: Assessing complex motor skills across physical performance domains poses distinct methodological challenges for applying the Cognitive Diagnostic Model (CDM), particularly regarding the response format of observational instruments. This study compared inter-rater reliability, model fit, diagnostic specificity, and criterion validity between dichotomous and polytomous instruments for assessing front crawl technique. A total of 280 physical education students from Universitas Negeri Surabaya participated. The dichotomous instrument (10 items, three attributes: Arm Action, Body & Leg, Breath & Synchronization) was adapted from the Crawl Technique Observation Sheet and analyzed using GDINA. The polytomous instrument (20 items, four dimensions) was analyzed using pGDINA with a three-attribute Q-matrix, after Body Position and Leg Action were mapped into a single Body & Leg attribute based on biomechanical justification, structural equivalence, and sample adequacy. The dichotomous instrument showed higher inter-rater reliability (Fleiss' $\kappa = 0.663$) than the polytomous instrument (ICC = 0.538), with a Classification Accuracy of 0.924 and higher validity against swimming speed ($p = 0.507$ vs. 0.288). The polytomous instrument produced higher diagnostic entropy (2.362 vs. 1.568 bits) and a more even latent profile distribution (largest profile 40.7% vs. 62.5%), indicating better diagnostic specificity. Cross-instrument profile consistency was low (Cohen's $\kappa = 0.370$), with 31.4% of borderline students classified differently by both instruments. A trade-off emerged: the dichotomous instrument excelled in reliability, classification accuracy, and criterion validity, whereas the polytomous instrument excelled in diagnostic depth, confirming that CDM applications in motor skill assessment face challenges distinct from cognitive education contexts.

Keywords: Cognitive Diagnostic Model; GDINA; polytomous instrument; inter-rater reliability; front crawl swimming

INTRODUCTION

Physical education has long assessed motor skills using quantitative outcomes such as speed, distance, or holistic scores. These measures capture how well a student performs but say little about why. A student who misses a target swimming time might struggle with arm coordination, body position, or breathing, yet a single total score cannot distinguish among these issues (Collares, 2022; de la Torre & Akbay, 2019; Popham, 2003; Rupp et al., 2010). This gap between performance and diagnosis has led researchers to more sophisticated measurement approaches. (de la Torre, 2011) GDINA model, part of the broader family of Cognitive Diagnostic Models (CDM), offers one such approach. Rather than placing students on a single ability continuum as Item Response Theory does, CDM classifies them according to a profile of mastered and unmastered latent attributes (Rupp et al., 2010). A swimmer might master Arm Action but not Breathing, and that distinction is precisely what makes CDM profiles useful for instructors designing targeted remediation (Collares, 2022; de la Torre & Akbay, 2019).

CDM has proven effective in cognitive academic domains such as reading, mathematics, and language (Ma & de la Torre, 2016; Meng et al., 2023), but its application to psychomotor skills remains largely untested. Front crawl swimming, which requires the simultaneous coordination of arm and leg movements, body rotation, and breathing (Maglischo, 2003), is a natural candidate because its components can be modeled as distinct yet interacting latent attributes (de la Torre, 2011; Rupp et al., 2010). GDINA accommodates this without assuming a particular interaction structure in advance (Ma & de la Torre, 2020), and its polytomous extension, pGDINA, links graded item categories to attributes via a categorical Q-matrix (Ma & de la Torre, 2016). However, forcing polytomous responses into a dichotomous mold consistently discards diagnostic information (Chen & de la Torre, 2018).

The harder problem is practical: how should qualitative, observation-based components of the technique be scored so that CDM can actually use them? Dichotomous instruments score each component as present or absent, which maps cleanly onto standard CDM (de la Torre, 2011) and underlies the Crawl Technique Observation Sheet

developed by (de Medeiros Vidal et al., 2021). By contrast, polytomous instruments use graded ordinal scales, which should, in principle, capture finer gradations in movement quality (Chen & de la Torre, 2018; Ma & de la Torre, 2016). That richness comes at a cost: ordinal judgments are harder to make consistently than binary ones (Moskal & Leydens, 2000), and Sampaio Peres et al. (2023) found that standardized observation criteria alone were insufficient to achieve adequate reliability in assessing swimming technique. Whether the theoretical advantage of polytomous instruments survives this reliability cost, and which format performs better when consistency, classification accuracy, and predictive validity are weighed together, remain open empirical questions.

This study addresses four questions: do the two instruments yield consistent attribute profiles; which yields more diagnostically specific information; how much information is lost through dichotomization; and which demonstrates stronger criterion validity relative to swimming speed and Distance Per Stroke. The findings aim to inform CDM-based assessment methodology in physical education and to offer practical guidance for researchers extending CDM into motor skill domains that remain largely unexplored in the psychometric literature.

METHOD

Ethical Approval and Participants

This study received ethical approval under Certificate No. 005/C8/G/I/2025 from the Research and Community Service Unit of STKIP PGRI Bangkalan, dated January 5, 2025. All participants provided written informed consent before participating. A total of 280 active physical education students from Universitas Negeri Surabaya participated, comprising 202 men (72.1%) and 78 women (27.9%), with a mean age of 19.4 ± 0.9 years, drawn from 18 course sections. All participants had completed coursework in basic swimming and/or aquatic instruction, and each swam 50 meters of front crawl at a self-selected, comfortable pace, following the procedure described by de Medeiros Vidal et al. (2021).

Instruments

Two instruments were used in this study. The dichotomous instrument was adapted from the Crawl Technique Observation Sheet (de Medeiros Vidal et al., 2021) and comprised 10 binary-scored items, reclassified into three latent attributes based on biomechanical relevance: Arm Action, Body & Leg, and Breath & Synchronization. Content validity of this reclassification was confirmed by seven experts using Aiken's V coefficient (Aiken, 1985), with all items deemed valid ($V = 0.857$ to 1.000). The polytomous instrument, developed specifically for this study, consists of 20 items spanning four dimensions of front crawl technique: Body Position, Leg Action, Arm Action, and Breathing. Each item was scored using a two-stage procedure: raters first assigned a broad category (Poor, Fair, or Good), then refined their judgment within that category to arrive at a final score from one to five (Moskal & Leydens, 2000).

Table 1. *Q-Matrix of the Dichotomous Instrument*

Item	Description (original wording)	A1 (AA)	A2 (BL)	A3 (BS)
1a	Hand entrance position in relation to head	1	0	0
1b	Elbow height in relation to hand in stroke recovery	1	0	0
1d	Elbow extension at end of stroke	1	0	0
1e	Elbow height in relation to hand during the stroke's propulsive phase	1	0	0
1c	Hand entrance location in relation to the body's central line	0	1	0
2a	Leg amplitude	0	1	0
3a	Horizontal alignment (body position)	0	1	0
4a	Head movement and arm coordination while breathing	0	0	1
5a	Body rolling	0	0	1
5b	Arm coordination	0	0	1

Note: AA = Arm Action; BL = Body & Leg; BS = Breath & Synchronization.

Although the polytomous instrument was designed and retained with four dimensions (Body Position, Leg Action, Arm Action, Breathing), the Q-matrix used for CDM analysis was planned around a three-attribute structure,

with the Body Position and Leg Action dimensions mapped into a single combined Body & Leg attribute pending data support. This methodological decision, made at the analysis stage rather than the instrument design stage, rested on three criteria. First, biomechanical relevance: the horizontal body position in front-crawl swimming is actively maintained by the kicking action as a stabilizer, so the two dimensions are conceptually closely linked (Maglischo, 2003). Second, structural equivalence: this mapping yields three attributes aligned with the dichotomous instrument, enabling a fair comparison between the two. Third, sample adequacy: four attributes would generate sixteen potential latent classes, requiring a much larger sample for reliable estimation than the eight latent classes produced by three attributes (Gudicha et al., 2016; Sorrel et al., 2023).

Data Collection and Performance Measurement

Data collection for the dichotomous instrument took place directly at a standard 50-meter pool, with each participant videotaped from start to finish and rated simultaneously by three trained raters; the final score for each item was determined by the mode of the three ratings (Stemler, 2004). The same videos were then scored for the polytomous instrument by ten trained raters organized into five fixed pairs, with the final score taken as the mean of each pair's two ratings, rounded to the nearest integer (Ma & de la Torre, 2016; Stevens, 1946; Zumbo & Kroc, 2019). Dichotomous raters completed three training sessions involving joint scoring of pilot videos, criterion discussion, and perceptual calibration, continuing until $\kappa \geq 0.61$ agreement was reached before actual scoring began. Polytomous raters underwent six calibration cycles using Kendall's W, with agreement rising consistently from $W = 0.085$ in the first cycle to $W = 0.538$ in the sixth, as a prerequisite before scoring the main videos.

Swimming speed and Distance Per Stroke, two valid and reliable indicators for assessing criterion validity (Jürimäe et al., 2007), were derived from the same videos. Elapsed time was measured with a manual stopwatch from start to finish over the 50-meter distance, yielding $v = 50 \text{ m} / \text{elapsed time}$. Stroke count used a separate-arm counting method, in which each right- or left-arm pull was counted as a separate stroke, so one complete cycle corresponded to two raw counts; Distance Per Stroke was calculated as $\text{DPS} = 50 \text{ m} / \text{number of cycles}$, which is algebraically equivalent to $\text{DPS} = 100 \text{ m} / \text{raw stroke count}$, as reported in the Data Analysis section. Speed reflects overall performance as the result of all technique components acting simultaneously, whereas DPS measures propulsive efficiency per cycle and is more sensitive to specific aspects of technique quality (Maglischo, 2003).

Data Analysis

Inter-rater reliability for the dichotomous instrument was computed using Fleiss' Kappa, and for the polytomous instrument, the Intraclass Correlation Coefficient was calculated with a two-way mixed, absolute agreement model. Both were computed using the irr package in R (Gamer et al., 2019). The GDINA model for the dichotomous instrument was estimated using the GDINA() function from the GDINA package (Ma & de la Torre, 2020), and the pGDINA model for the polytomous instrument was estimated using the gdina() function from the CDM package (George et al., 2016), with a 20-by-3 Q-matrix. Model fit was evaluated using M_2 , RMSEA, AIC, and BIC statistics, and classification accuracy was computed using the CA() function. Cross-instrument comparison was conducted at four levels: diagnostic specificity, assessed by the number of unique profiles and latent profile entropy; inter-attribute correlation, assessed using Spearman correlations for the dichotomous instrument and polychoric correlations for the polytomous instrument; profile consistency, assessed using Cohen's Kappa between the two instruments' attribute classifications (Cohen, 1960); and criterion validity, assessed using Spearman correlations between profile scores and both swimming speed and Distance Per Stroke.

RESULTS

Descriptive Statistics

Participants' mean swimming speed was $0.810 \pm 0.222 \text{ m/s}$ (range 0.269 to 1.736 m/s), with a mean elapsed time of 66.94 ± 20.86 seconds. Mean Distance Per Stroke was $1.805 \pm 0.395 \text{ m/cycle}$. The substantial variation in both indicators reflects a diverse range of skill levels among participants, consistent with the sample needed for diagnostic analysis.

Inter-Rater Reliability: Dichotomous and Polytomous Instruments

The dichotomous instrument showed high inter-rater reliability, with a mean Fleiss' $\kappa = 0.663$ (Substantial) across three raters. All 10 items reached the substantial category ($\kappa \geq 0.60$), except item 5a, which fell in the moderate range ($\kappa = 0.597$). The highest coefficient was observed for item 1e ($\kappa = 0.758$, Arm Action). By contrast, the polytomous instrument showed lower reliability, with a mean ICC = 0.538 (Moderate) across two raters. The Body Position dimension showed the widest variation (ICC ranging from 0.414 to 0.629), with several items falling into the poor category, while the Leg Action dimension reached the highest ICC (0.592). This substantial reliability gap between the two instruments ($\kappa = 0.663$ vs. ICC = 0.538) reflects an inherent difficulty in maintaining consistent ordinal judgments for complex motor skills.

Cognitive Diagnostic Model — Dichotomous Instrument (GDINA)

The methodological decision to map Body Position and Leg Action into a single Body & Leg attribute on the polytomous Q-matrix was empirically supported: the polychoric correlation between the two dimensions was 0.945, the highest among all attribute pairs. With $N = 280$ and three attributes yielding eight latent classes, a sample-to-class ratio of 10.4 was considered adequate for stable estimation.

The GDINA model achieved very high Classification Accuracy at both the pattern level (0.924) and the attribute level (mean 0.968). The latent profile distribution showed a dominant “masters none of the attributes” profile (0-0-0) at 62.5%, followed by the “masters all” profile (1-1-1) at 20.7%. Attribute mastery proportions followed the order Arm Action (36.4%) > Body & Leg (31.1%) > Breath & Synchronization (22.9%), indicating that breathing coordination was the most difficult component to master. The M_2 statistic could not be stably estimated due to zero cell frequencies in the bivariate item matrix, a known technical limitation for highly asymmetric response distributions (Maydeu-Olivares & Joe, 2006); therefore, model fit evaluation relied on RMSEA and individual item fit, both of which indicated adequate fit (Lei & Li, 2016).

Table 2. GDINA Model Fit and Attribute Profile Distribution (Dichotomous)

Indicator	Value	Interpretation
AIC	2,356.64	—
BIC	2,454.78	—
Pattern CA	0.924	Excellent
Attribute CA (mean)	0.968	Excellent
CA — Arm Action	0.970	Excellent
CA — Body & Leg	0.975	Excellent
CA — Breath & Sync	0.961	Excellent
Dominant profile: 0-0-0 (masters none)	62.5% (n=175)	—
Profile 1-1-1 (masters all)	20.7% (n=58)	—
Arm Action mastery proportion	36.4%	—
Body & Leg mastery proportion	31.1%	—
Breath & Sync mastery proportion	22.9%	Lowest

Cognitive Diagnostic Model — Polytomous Instrument (pGDINA)

The pGDINA model yielded a mean RMSEA of 0.079, right at the threshold for an adequate fit, with the Arm Action (0.083) and Breathing (0.084) dimensions slightly exceeding it. The latent profile distribution was more evenly distributed than for the dichotomous instrument, with the dominant 0-0-0 profile accounting for only 40.7% and the 1-1-1 profile for 27.9%. Polychoric correlations among attributes were very high (0.886–0.975), indicating substantial multicollinearity.

Table 3. *pGDINA Model Fit and Attribute Profile Distribution (Polytomous)*

Indicator	Value	Interpretation
Deviance	8,973.043	—
AIC	9,147.04	—
BIC	9,463.27	—
Mean RMSEA	0.079	Adequate (< 0.08)
RMSEA — Body & Leg	0.074	Good
RMSEA — Arm Action	0.083	Borderline
RMSEA — Breathing	0.084	Borderline
Dominant profile: 0-0-0	40.7% (n=114)	—
Profile 1-1-1 (masters all)	27.9% (n=78)	—
Body & Leg mastery	44.3%	—
Arm Action mastery	45.7%	—
Breathing mastery	40.0%	Lowest

Diagnostic Specificity and Information Loss from Dichotomization

The polytomous instrument detected all eight possible latent profiles (2³), whereas the dichotomous instrument detected only six of the eight, as profiles 0-1-0 and 0-1-1 did not appear in the data. Profile distribution entropy was substantially lower for the dichotomous instrument (1.568 bits) than for the polytomous instrument (2.362 bits, a 50.6% difference), indicating that the dichotomous distribution was far more concentrated on a single dominant profile. Mean inter-attribute correlation was much lower for the dichotomous instrument ($r = 0.751$) than for the polytomous instrument ($r = 0.928$), indicating that dichotomous attributes were more discriminable from one another. A total of 88 students (31.4%) were identified as having borderline profiles on the polytomous instrument, and their attribute classification consistency between the two instruments ranged only from 50.0% to 64.8%, confirming that dichotomization discards significant information, particularly for students at intermediate ability levels.

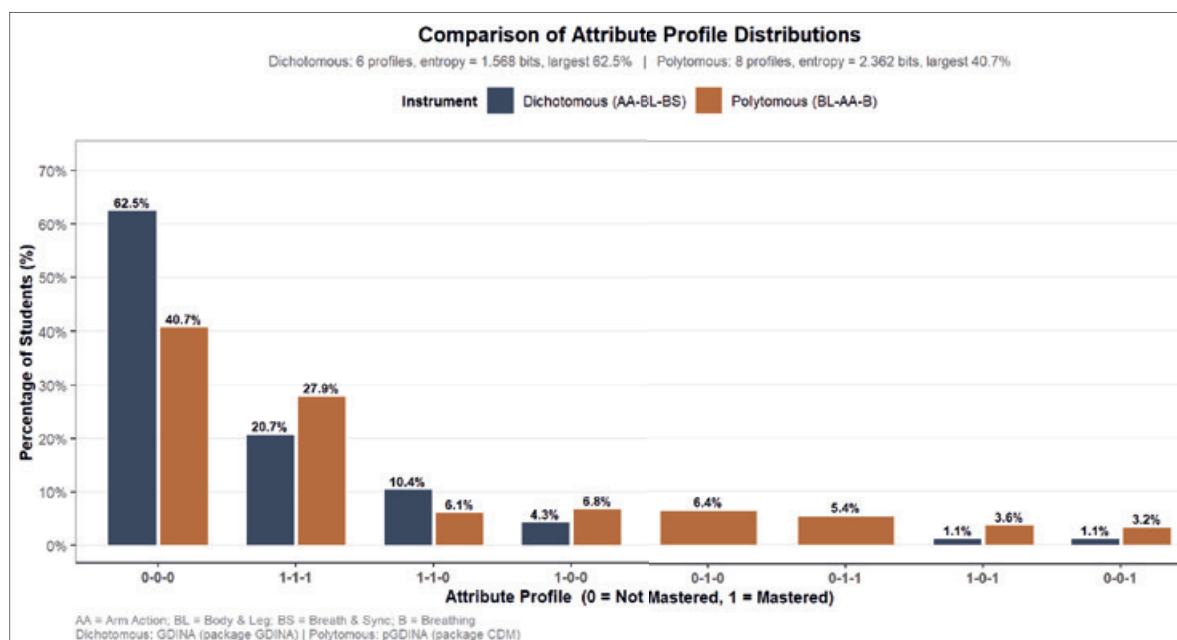


Figure 1. Comparison of attribute profile distributions from GDINA (dichotomous instrument) and pGDINA (polytomous instrument) analyses. AA = Arm Action; BL = Body & Leg; BS = Breath & Synchronization; B = Breathing. Dichotomous: 6 profiles detected, entropy = 1.568 bits, largest profile 62.5%. Polytomous: 8 profiles detected, entropy = 2.362 bits, largest profile 40.7%.

Comparative Diagnostic Performance Between Instruments

Table 4. Summary of Diagnostic Comparison

Indicator	Dichotomous	Polytomous
Inter-rater reliability	$\kappa = 0.663$ (Substantial)	ICC = 0.538 (Moderate)
Model fit (RMSEA)	Good*	0.079 (Adequate)
Classification Accuracy (pattern)	0.924	Not available†
Unique profiles detected	6 of 8	8 of 8
Diagnostic entropy	1.568 bits	2.362 bits (+50.6%)
Dominant profile (largest)	62.5%	40.7%
Inter-attribute correlation (mean)	$r = 0.751$	$r = 0.928$
Cross-instrument κ consistency	0.370 (Fair)	-
Validity vs. v (ρ)	0.507 ($p < 0.001$)	0.288 ($p < 0.001$)
Validity vs. DPS (ρ)	0.265 ($p < 0.001$)	0.255 ($p < 0.001$)
Borderline students	-	88 (31.4%)
Borderline classification consistency	54.5–64.8%	-

* M_2 could not be stably estimated due to zero cell frequencies in the bivariate item matrix, resulting from a highly uneven response distribution; fit evaluation relied on RMSEA and available item fit statistics. †The CDM package does not provide a CA function equivalent for pGDINA.

Inter-Attribute Correlation

Mean inter-attribute correlation was much lower for the dichotomous instrument ($r = 0.751$) than for the polytomous instrument ($r = 0.928$). The lower correlation for the dichotomous instrument indicates that its attributes were more discriminable from one another, a more favorable psychometric property for diagnostic purposes. The very high polychoric correlations among polytomous attributes (0.886–0.975) indicate substantial multicollinearity, which may limit the distinctiveness of diagnostic profiles.

External Criterion Validity

The dichotomous instrument showed higher criterion validity for swimming speed ($\rho = 0.507$) than the polytomous instrument ($\rho = 0.288$), although both were statistically significant ($p < 0.001$). The gap was smaller for Distance Per Stroke ($\rho = 0.265$ vs. 0.255). At the individual attribute level, Breath & Sync (dichotomous) correlated most strongly with DPS ($\rho = 0.225$), whereas Breathing (polytomous) correlated most strongly with both v ($\rho = 0.278$) and DPS ($\rho = 0.245$), confirming that breathing coordination was the technique component contributing most to swimming efficiency.

Table 5. Spearman Correlations with External Criteria

Attribute/Score	Dichotomous (ρ vs. v)	Dichotomous (ρ vs. DPS)	Polytomous (ρ vs. v)	Polytomous (ρ vs. DPS)
Total profile score	0.507***	0.265***	0.288***	0.255***
Arm Action	0.475***	0.261***	0.239***	0.194***
Body & Leg	0.470***	0.216***	0.239***	0.197***
Breath & Sync / Breathing	0.431***	0.225***	0.278***	0.245***

*** $p < 0.001$. v = swimming speed (m/s); DPS = Distance Per Stroke (m/cycle).

DISCUSSION

Diagnostic Trade-off Between Reliability and Specificity

The central finding of this study confirms a fundamental trade-off between dichotomous and polytomous instruments within a CDM framework for motor skill assessment. The dichotomous instrument excelled in reliability ($\kappa = 0.663$ vs. $ICC = 0.538$), classification accuracy ($CA = 0.924$), and criterion validity ($\rho = 0.507$ vs. 0.288 against swimming speed). By contrast, the polytomous instrument produced a more diagnostically informative profile distribution, with higher entropy (2.362 vs. 1.568 bits), more unique profiles (8 vs. 6), and a smaller dominant profile (40.7% vs. 62.5%). This trade-off has a clear theoretical basis: binary judgments are easier to make consistently because they involve only two decisions, whereas a five-point ordinal scale requires raters to draw finer distinctions, thereby increasing ambiguity and reducing agreement (Moskal & Leydens, 2000). Although the two-stage scoring procedure was designed to mitigate this, a mean ICC of 0.538 still indicates suboptimal consistency, consistent with Sampaio Peres et al. (2023) finding that standardized criteria alone are not sufficient to achieve high reliability in swimming technique assessment.

The strikingly high 0-0-0 dominant profile on the dichotomous instrument (62.5%) warrants cautious interpretation. Beyond reflecting genuinely modest skill levels among participants (consistent with a mean swimming speed of 0.810 m/s), another possibility is that the rigid binary mastery threshold misclassifies intermediate-level students as non-masters, a phenomenon known in the CDM literature as the masking effect of dichotomization (Chen & de la Torre, 2018; Ma & de la Torre, 2016). The borderline analysis supports this possibility: 31.4% of students showed intermediate profiles on the polytomous instrument, yet the dichotomous instrument failed to capture these nuances, with classification consistency for this group ranging from 50.0% to 64.8%. The implication is that the dichotomous instrument risks categorizing intermediate-level students as complete non-masters, even though they may have partially mastered certain components of the technique.

Psychometric Challenges: Multicollinearity and Criterion Validity

The very high polychoric correlations among polytomous attributes (0.886–0.975) indicate substantial multicollinearity, a psychometric challenge because CDM models struggle to distinguish each attribute's unique contribution when attributes are highly correlated, potentially yielding unstable parameter estimates and overlapping latent profiles (de la Torre, 2011). The lower inter-attribute correlation for the dichotomous instrument ($r = 0.751$) indicates more discriminable attributes, which is a favorable property for CDM analysis. The higher correlations observed for the polytomous instrument likely stem from the close biomechanical interdependence among front crawl technique components (Maglischo, 2003), as well as a possible halo effect in rater judgments that were not fully isolated across dimensions.

The dichotomous instrument's higher criterion validity relative to swimming speed ($\rho = 0.507$ vs. 0.288) is informative, since swimming speed reflects the simultaneous action of all technique components. A stronger correlation with v indicates that the attribute profile more closely reflects overall technique quality (Jürimäe et al., 2007; Maglischo, 2003). However, this higher validity may partly reflect the dichotomous instrument's more bipolar distribution, whereas the polytomous instrument captures finer gradations in movement quality that correlate less directly with overall speed (Chen & de la Torre, 2018). The merely fair cross-instrument profile consistency (Cohen's $\kappa = 0.370$) confirms that the two instruments produce substantively different diagnostic pictures, rather than simply differing in measurement scale (Landis & Koch, 1977).

Implications for Applying CDM to Motor Skill Assessment

This study has two main implications for extending CDM beyond cognitive-academic domains. First, reliability challenges in observation-based motor skill assessment exceed those typical of written cognitive testing because observational judgments are temporal and subjective, making them more susceptible to inter-rater inconsistency. This implies that substantial investment in rater training is a non-negotiable prerequisite before applying CDM to motor domains. Second, the choice of response format should be guided by the intended use: when classification accuracy and predictive validity relative to performance are the priority, the dichotomous instrument with standard GDINA performs better; when the goal is to provide more nuanced feedback on gradations in movement quality, the polytomous instrument offers richer information despite its lower reliability. The low cross-instrument profile consistency

($\kappa = 0.370$) also carries an important methodological warning: researchers should not assume that two instrument formats measure identical constructs simply because they share the same attribute labels. As a technical limitation, the M_2 statistic for the GDINA model could not be stably estimated due to zero cell frequencies in the bivariate item matrix, a known constraint for highly asymmetric response distributions (Maydeu-Olivares & Joe, 2006). This makes the exploration of alternative fit indices, such as bootstrap-based fit statistics, an important direction for future research.

CONCLUSION

This study confirms a genuine methodological trade-off between dichotomous and polytomous instruments when applying CDM to front crawl swimming assessment. The dichotomous instrument excelled in inter-rater reliability ($\kappa = 0.663$, Substantial), classification accuracy (Pattern CA = 0.924), and criterion validity against swimming speed ($\rho = 0.507$), whereas the polytomous instrument excelled in diagnostic specificity, with higher profile distribution entropy (2.362 vs. 1.568 bits) and more unique profiles detected (8 vs. 6). The merely fair cross-instrument profile consistency (Cohen's $\kappa = 0.370$), together with the finding that 31.4% of borderline-profile students were classified differently by the two instruments, confirms that response format selection is not merely a technical decision but a substantive one that fundamentally shapes diagnostic interpretation. Future research should explore rater training strategies to improve the reliability of polytomous instruments, develop hybrid approaches that integrate the strengths of both instrument types, and replicate these findings across different samples and motor skill domains. This study's primary contribution is providing empirical evidence, grounded in real rather than simulated data, on the application of CDM to motor skill assessment, a domain still rarely explored in the CDM literature, while enriching understanding of the boundaries and potential of CDM as a diagnostic assessment paradigm in physical education.

REFERENCES

- Aiken, L. R. (1985). Three Coefficients for Analyzing the Reliability and Validity of Ratings. *Educational and Psychological Measurement*, 45(1), 131–142. <https://doi.org/10.1177/0013164485451012>
- Chen, J., & de la Torre, J. (2018). Introducing the general polytomous diagnosis modeling framework. *Frontiers in Psychology*, 9. <https://doi.org/10.3389/FPSYG.2018.01474>
- Cohen, J. (1960). A Coefficient of Agreement for Nominal Scales. *Educational and Psychological Measurement*, 20(1), 37–46. <https://doi.org/10.1177/001316446002000104>
- Collares, C. F. (2022). Cognitive diagnostic modelling in healthcare professions education: an eye-opener. *Advances in Health Sciences Education*, 27(2), 427–440. <https://doi.org/10.1007/S10459-022-10093-Y>
- de la Torre, J. (2011). The Generalized DINA Model Framework. *Psychometrika*, 76(2), 179–199. <https://doi.org/10.1007/S11336-011-9207-7>
- de la Torre, J., & Akbay, L. (2019). Implementation of cognitive diagnosis modeling using the GDINA R package. *Eurasian Journal of Educational Research*, 171–192. <https://eric.ed.gov/?id=EJ1211628>
- de Medeiros Vidal, J., Tucher, G., Nogueira, L., Novaes, R. C., de Souza Vale, R. G., de Castro, M. O. R., da Silva Medeiros, N. G., & de Casio Costa Telles, S. (2021). Crawl technique observation sheet for beginning swimmers: an evaluation proposal for swimming teachers. *Motriz: Revista de Educação Física*, 27, e1021016920. <https://doi.org/10.1590/S1980-65742021016920>
- Gamer, M., Lemon, J., & Singh, I. F. P. (2019). *irr: Various coefficients of interrater reliability and agreement*. CRAN. <https://cran.r-project.org/package=irr>
- George, A. C., Robitzsch, A., Kiefer, T., Groß, J., & Ünlü, A. (2016). The R package CDM for cognitive diagnosis models. *Journal of Statistical Software*, 74(2), 1–24. <https://doi.org/10.18637/jss.v074.i02>
- Gudicha, D. W., Tekle, F. B., & Vermunt, J. K. (2016). Power and Sample Size Computation for Wald Tests in Latent Class Models. *Journal of Classification*, 33(1), 30–51. <https://doi.org/10.1007/S00357-016-9199-1>
- Jürimäe, J., Haljaste, K., Cicchella, A., Lätt, E., Purge, P., Leppik, A., & Jürimäe, T. (2007). Analysis of Swimming Performance from Physical, Physiological, and Biomechanical Parameters in Young Swimmers. *Pediatric Exercise Science*, 19(1), 70–81. <https://doi.org/10.1123/PES.19.1.70>
- Landis, J. R., & Koch, G. G. (1977). The Measurement of Observer Agreement for Categorical Data. *Biometrics*, 33(1), 159. <https://doi.org/10.2307/2529310>
- Lei, P. W., & Li, H. (2016). Performance of Fit Indices in Choosing Correct Cognitive Diagnostic Models and Q-Matrices. *Applied Psychological Measurement*, 40(6), 405–417. <https://doi.org/10.1177/0146621616647954>
- Ma, W., & de la Torre, J. (2016). A sequential cognitive diagnosis model for polytomous responses. *The British Journal of Mathematical and Statistical Psychology*, 69(3), 253–275. <https://doi.org/10.1111/BMSP.12070>
- Ma, W., & de la Torre, J. (2020). GDINA: An R package for cognitive diagnosis modeling. *Journal of Statistical Software*, 93(14), 1–26. <https://doi.org/10.18637/jss.v093.i14>
- Maglischo, E. W. (2003). *Swimming fastest*. Human Kinetics.
- Maydeu-Olivares, A., & Joe, H. (2006). Limited Information Goodness-of-fit Testing in Multidimensional Contingency Tables. *Psychometrika*, 71(4), 713–732. <https://doi.org/10.1007/S11336-005-1295-9>
- Meng, Y., Wang, Y., & Zhao, N. (2023). Cognitive diagnostic assessment of EFL learners' listening barriers through incorrect responses. *Frontiers in Psychology*, 14. <https://doi.org/10.3389/fpsyg.2023.1118848>

- tiers in *Psychology*, 14, 1126106. <https://doi.org/10.3389/FPSYG.2023.1126106>
- Moskal, B. M., & Leydens, J. A. (2000). Scoring Rubric Development: Validity and Reliability. *Practical Assessment, Research, and Evaluation*, 7(1). <https://doi.org/10.7275/Q7RM-GG74>
- Popham, W. J. (2003). *Test better, teach better: The instructional role of assessment*. ASCD.
- Rupp, A. A., Templin, J., & Henson, R. A. (2010). *Diagnostic measurement: Theory, methods, and applications*. Guilford Press.
- Sampaio Peres, M. V., Nogueira, F., Ramos, W., Cardoso, T., Nogueira, L., & Tucher, G. (2023). Effect of standardization of observation and evaluation criteria of the front crawl arm stroke technique on inter- and intra-rater reliability. *Journal of Physical Education*, 34(1). <https://doi.org/10.4025/jphyseduc.v34i1.3416>
- Sorrel, M. A., Escudero, S., Nájera, P., Kreitchmann, R. S., & Vázquez-Lira, R. (2023). Exploring Approaches for Estimating Parameters in Cognitive Diagnosis Models with Small Sample Sizes. *Psych*, 5(2), 336–349. <https://doi.org/10.3390/PSYCH5020023>
- Stemler, S. E. (2004). A Comparison of Consensus, Consistency, and Measurement Approaches to Estimating Interrater Reliability. *Practical Assessment, Research, and Evaluation*, 9(1). <https://doi.org/10.7275/96JP-XZ07>
- Stevens, S. S. (1946). On the theory of scales of measurement. *Science*, 103(2684), 677–680. <https://doi.org/10.1126/SCIENCE.103.2684.677>
- Zumbo, B. D., & Kroc, E. (2019). A Measurement Is a Choice and Stevens' Scales of Measurement Do Not Help Make It: A Response to Chalmers. *Educational and Psychological Measurement*, 79(6), 1184–1197. <https://doi.org/10.1177/0013164419844305>

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COMPARISON OF THE EFFECTS OF A 6-WEEK FIFA 11+ PROGRAM AND HARMOKNEE ON JUMPING ABILITY IMPROVEMENT IN AMATEUR FEMALE FOOTBALL PLAYERS

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Abstract: *Jumping is one of the movements in soccer that supports the technique in this sport. Jumping ability is used to win aerial duels and avoid opponent tackles. Research testing the effectiveness of the FIFA 11+ and HarmoKnee warm-up programs in improving jumping performance in female soccer players is still limited. This study aims to analyse the effect of FIFA 11+ and Harmoknee exercises on physical performance parameters, especially on the jumping performance of female amateur soccer players. This study used an experimental approach with participants divided into two experimental groups. The sample consisted of 24 female amateur soccer players. The standing long jump test data collection instrument was used. The data analysis technique for hypothesis testing used a paired t-test, and to compare the two exercises, an independent t-test. The results showed that there was an effect of the FIFA 11+ and HarmoKnee warm-up programs on jumping performance, with a significant effect ($p = 0.000 < 0.05$). There was no difference in the effect of the two exercises on jumping performance ($p = 0.963 > 0.05$), but the effect size was found to be greater in FIFA 11+ than in Harmoknee. It was concluded that the FIFA 11+ warm-up method had a slightly superior effect on improving jumping performance compared to HarmoKnee in female soccer players. However, both the FIFA 11+ and HarmoKnee warm-ups can be effectively implemented during the general preparation period of a periodized training program. Practitioners or physical trainers need to consider incorporating these programs into daily sessions during the preparation period.*

Keywords: *Warm-up, physical, power, soccer*

INTRODUCTION

Soccer players require moderate to high levels of aerobic and anaerobic power, good agility, and a variety of technical and tactical skills to increase their chances of success in the sport (Carling, 2013; Reilly et al., 2000). To respond to the physical demands of play, training components such as anaerobic power, speed, and agility must be integrated into training (Amiri-Khorasani et al., 2011). Before participating, a warm-up is generally necessary to “prepare” oneself for training or a match (Sander et al., 2013). A warm-up program is essentially a type of light or moderate exercise aimed at improving performance (Sander et al., 2013; Sotiropoulos et al., 2010; Subasi et al., 2008) by increasing blood flow and elasticity, as well as muscle neuron activity (Škof & Strojnik, 2007).

Both 11+ and HarmoKnee are multifaceted soccer-specific warm-up programs aimed at improving the general fitness of soccer players while also considering intrinsic risk factors such as strength and balance. In general, the exercises included in multifaceted warm-up programs have been shown to improve athletic performance among male soccer players (Fradkin et al., 2010). Specifically, improvements have been reported in counter-movement jump height (Sotiropoulos et al., 2010), isokinetic strength (Brito et al., 2010; Daneshjoo et al., 2012), and sprinting ability (Fletcher & Jones, 2004). Core stability training is another important component included in multifaceted warm-up programs. These core exercises have been shown to improve technical skills and game awareness (Holm et al., 2004; Leetun et al., 2004; Paterno et al., 2004). Therefore, a multifaceted warm-up program is expected to improve physical performance. Specifically, a systematic review of studies of warm-up, running speed, jumping, and skill performance (1966–2008) reported that 79% (of 32 articles) showed improvements in jump height, sprint test completion time, and technical skill performance, while only 3% showed no change (Fradkin et al., 2010).

Although the primary goal of FIFA 11+ and Harmoknee is injury prevention, knowledge of the training effects of these training programs on physical performance may help identify potential mechanisms behind the reported reduction in injury incidence (Zarei et al., 2018). Although several studies have explored the training effects of both

programs (especially FIFA 11+) on several measures of neuromuscular performance (lower limb balance (Daneshjoo et al., 2013) and core stability (Impellizzeri et al., 2013), knee proprioception (Brito et al., 2010), knee strength (Brito et al., 2010)), and sprinting and jumping ability (Bizzini et al., 2013) (which are part of the athletic physical performance spectrum), not many of these studies have used female players as samples despite being the target population of both programs.

This study is the most recent in our region, considering the limited research available on this topic. Therefore, the primary objective of this study was to analyse the effects of FIFA 11+ and Harmoknee training on physical performance parameters, particularly jumping performance, in female amateur soccer players. We hypothesised that both programs would exhibit beneficial and superior effects on physical performance (particularly jumping ability).

METHODS

This study used an experimental method to determine the effects of a treatment intentionally given by the researcher. The sample in this study was all young female soccer athletes from Batu City, East Java Province, totaling 24 people aged (19.4 ± 0.7 years). This experimental study used two groups that received different treatments, namely the FIFA 11+ method and Harmoknee. All participants understood and agreed to participate in this study with informed consent. This research was conducted following approved by the Faculty of Sports and Health Sciences of Yogyakarta State University (protocol number: B/853/UN34.16/PT.01.04/2024).

Procedure

The program was implemented on the research sample. Before being administered to the sample, the program was validated by expert lecturers to ensure its eligibility for testing. Both groups participated in the same volume and methodology of weekly soccer training (three sessions of approximately 90 minutes each and one match per week). Both groups were visited at least once a week by our research assistants to monitor whether the groups were using the same soccer training and whether the control group was using a structured injury prevention program instead of a regular warm-up.

Table 1. *Players' regular soccer training sessions during the intervention*

Exercise	Duration (min)
Technical drills (Passing exercise)	15
Tactical drills (defensive drills, offensive drills, situations)	20
Small-sided games with or without goal keeper	20
Simulated competitive games and set-pieces	15

FIFA 11+ Procedure

11+ consists of three parts. The first part includes running drills (Part 1). The second part includes six drills, all of which are at three difficulty levels, aimed at improving strength, balance, muscle control, and core stability (Part 2). The third and final part consists of advanced running drills (Part 3). The varying difficulty levels increase the program's efficiency and allow coaches and players to individually adapt the program. 11+, which replaces the typical warm-up, takes approximately 20-25 minutes to complete. All 27 drills focus on core stability, neuromuscular control, eccentric hamstring strength, and agility.

Table 2. FIFA 11+ programs

Warm Up Exercise	Exercise Component	Durasi
FIFA 11+	Part 1: Running Exercise Straight Ahead, hop out, hop in, circling partner, shoulder contact, quick forward, & backward	8 menit
	Part 2: Strenght, Plyometric, and Balance Exercise	
	The bench: one leg lift and hold Side Bench: with leg lift Hamstring: Nordic exercise Single-leg: Test your partners Squat: one leg squats Jumping: Box jump	10 Menit
	Part 3: Running Exercise Across the pitch, bounding, plant and cut	2 Menit

HarmoKnee warm-up

The HarmoKnee warm-up program includes five sections: warm-up, muscle activation, balance, strength, and core stability, all of which can be combined and performed within a regular soccer training session (Table 3). The total program duration is 20 to 25 minutes Kiani et al., 2010). Similar to the 11+ program, HarmoKnee is also performed three times per week.

Table 3. HarmoKnee Program

Warm Up Exercise	Exercise Component	Duration
HarmoKnee	Warm-up Jogging (≥4-6 min), Backward jogging on the toes (Approximately 1min), High-knee skipping (Approximately 30 s), Defensive pressure technique (Approximately 30 s), One and one (≥ 2min)	10 min
	Muscle activation Activation of calf muscles, quadriceps muscles, hamstring muscles, hip flexor muscles, groin muscles, hip and lower back muscles (6 items, each item 4s for each leg/side)	2 min
	Balance Forward and backward double leg jumps, Lateral single leg jumps, Forward and backward single leg jumps, Double leg jump with or without ball (optional), (4 items each item Approximately 30s)	2 min
	Strength Walking lunges in place, Hamstring curl (in pairs), Single-knee squat with toe raises (3 items each item Approximately 1 min)	3 min
	Core stability Sit-ups, Plank on elbows and toes, Bridging (3 items each item Approximately 1 min)	3 min

Test Procedure

To measure jumping ability, this study used the standing long jump test, which also measures leg muscle power. Participants stood behind a starting line and were instructed to push off as hard as possible and jump as far as possible. Participants were instructed to land with their feet together and remain upright. The jump distance was measured from the starting line to the back of the heel. After two familiarisation tests, participants performed three repetitions. The best score of the three repetitions was selected for analysis.

Data Analysis

Shapiro-Wilk was used to test for data normality in this study. Paired T-tests were used to test the effect of the intervention. Comparisons of the two exercises used independent t-tests. A two-way ANOVA test was used to test for interactions between Group (FIFA 11+ and HarmoKnee) × Time. If an interaction was found, further testing was performed using the Tukey test. Decision-making was based on a significance level of 5% or 0.05. The calculation of effect size in this study refers to Cohen's d analysis. Data analysis was assisted by IBM SPSS Version 26.

RESULT

After 6 weeks of intervention, there were changes in participants' jumping performance. Both exercises appeared to have an impact on players' standing long jump performance. This can be seen in Table 4.

Table 4. Changes in participants' jumping performance.

Group	n	Pre-Test Standing Long Jump (cm)	Post-test Standing Long Jump (cm)	Paired-T	Group >< Time
		M ± SD	M ± SD		
FIFA 11+	12	193.4 ± 15.1	200.1 ± 14.9	0.000*	0.484
HarmoKnee	12	190.7 ± 13.6	191.8 ± 13.1	0.000*	

Note: *significance $p < 0.05$

There was a significant main effect between pre- and post-test on the long jump ($p = 0.000$). Both effects were found in both intervention groups (FIFA 11+ and HarmoKnee). Other findings did not reveal an interaction between Group (FIFA 11+ and HarmoKnee) $\times$ Time ($p > 0.05$). The comparison between the two groups is presented in Table 5.

Table 5. The comparison between the two groups

Group	n	Mean Difference	Cohen's d	Percentage of improvement	Independent T
FIFA 11+	12	7.3	0.45	2.5%	0.963
HarmoKnee	12	1.1	0.08	0.8%	

Table 5 data shows that there was no significant difference between the two groups with a significance value ($p > 0.05$). However, the percentage change value for the FIFA 11+ group appears to be superior to the HarmoKnee value. Cohen's d effect size value for FIFA 11+ is in the medium category, while for HarmoKnee it is in the low category. Therefore, although both affect jumping ability, the FIFA 11+ group actually has a more significant influence on the jumping ability of amateur female soccer players compared to HarmoKnee.

DISCUSSION

While the FIFA 11+ Injury Prevention Programme has been highly successful, in practice, it is difficult to persuade coaches and players to implement it regularly solely for injury prevention, so the goal was to demonstrate that it also has a direct, positive impact on player performance. While the FIFA 11+ program is superior to HarmoKnee, both can improve jumping ability in female soccer players.

Jumping performance is essential in soccer to support movements such as heading, avoiding tackles, and during duels (De Oliveira et al., 2023). The results of this study illustrate the importance of developing high-level strength to improve jumping performance in soccer players. Stronger athletes tend to perform better in jumping, while weaker athletes perform worse in sprinting and jumping. Importantly, strength training has also been shown to reduce injury incidence in college soccer players (Street & Kaminski, 2021). Therefore, it is intriguing that FIFA 11+ and HarmoKnee can help improve players' muscular strength while simultaneously developing jumping skills.

The reason for this can be found in the fact that the FIFA 11+ program includes plyometric exercises in addition to neuromuscular training (Trajković et al., 2020), and includes the HarmoKnee. Furthermore, the focus in the FIFA 11+ program is on correct technique through jumping, landing, and cutting movements by providing feedback on incorrect movement patterns (Akbari et al., 2020). This improvement may be partly due to the increase in muscle temperature during the application of both programs (Ayala et al., 2017). Our findings are in line with programs that develop motor competence in early childhood, which is important for models of adolescent physical development (Sander et al., 2013).

Furthermore, studies explain that this development is due to muscle development, as reported by Bobbert and Casius, regarding changes in the length of contractile elements within the muscle-tendon structure. Specifically, the development of tendon length increases its energy storage capacity (Challis, 2000). Tendon energy storage capacity

is important in movements that utilise the stretch-shortening cycle, such as the long jump. It has been reported that in children between the ages of 12 and 16, this increase occurs naturally through maturation-related adaptations such as increased androgen concentrations, muscle fibril differentiation, and changes in resting adenosine triphosphate and creatine phosphate levels (Lloyd et al., 2015). Anatomical and physiological developments associated with maturation explain the improvements in sprinting and jumping performance that occur regardless of warm-up.

Another study demonstrated that a 10-week training period incorporating a FIFA 11+ warm-up significantly enhanced agility and long jump performance in basketball players (Sahin et al., 2018). Similarly, a study conducted by Shah Hosseini et al. (2019) explored the effects of an 8-week FIFA 11+ training program on the agility and explosive power of male collegiate volleyball players. In one study conducted on cyclists, it was observed that the average post-jump was lower than the pre-jump test, but there was a good correlation (Robert et al., 2020). Studies examining the effects of a FIFA 11+ warm-up program in adult males have shown improved jumping performance. After implementing a FIFA 11+ warm-up program for children, the children showed increased jumping ability (Pomares-Noguera et al., 2018). Akbari et al. (2020) evaluated the effect of FIFA 11+ on the vertical jump of 17-year-old soccer players and suggested that implementing a four-week FIFA 11+ warm-up program improves the physical performance of young individuals. This indicates that the program has a significant effect on jumping ability in individuals.

Limitations of this study include the short timeframe within which the effects of the FIFA 11+ and HarmoKnee programs were investigated, spanning six weeks, and the lack of follow-up. Follow-up assessments of both warm-up programs could have addressed the effects of the warm-up programs on program retention. Generalizability of the results to girls is also a limitation, as the study involved only a small sample size, so it is unknown whether the program can be applied to girls in all categories. Furthermore, the study was conducted at the end of the general and specific preparation periods, meaning some players were more prepared from the start and may have had a good baseline fitness level, potentially influencing performance changes.

However, the strength of this study lies in its ability to demonstrate the plausible effects and suitability of the FIFA 11+ and HarmoKnee warm-up programs in girls. Therefore, both FIFA 11+ and HarmoKnee warm-up programs can be implemented in training sessions for girls aged 18-20 years. This study supports previous findings that traditional routine warm-up programs can be replaced by FIFA 11+ and HarmoKnee in female soccer players based on their superior effects on jumping performance and possibly other physical components. Furthermore, these warm-up programs do not require special equipment and are easy to support the performance development of female soccer players, thus significantly contributing to injury risk reduction.

CONCLUSION

The main findings of this study indicate that implementing both the FIFA 11+ and HarmoKnee warm-up programs for 6 weeks can improve jumping performance. However, the magnitude of performance improvement with FIFA 11+ was superior to HarmoKnee. Therefore, the FIFA 11+ program can be considered appropriate for this population, as it appears sufficient to induce significant performance improvements in female soccer players. Ultimately, given the evidence-based health benefits of the FIFA 11+ warm-up program, its primary target population could be expanded to female athletes, both recreational players and schoolchildren, while also aiming to raise awareness of sports injuries. Furthermore, future research should investigate the effects of both programs over a longer duration on several physical performance variables using a randomised controlled trial design.

REFERENCES

- Akbari, H., Sahebozamani, M., Daneshjoo, A., Amiri-Khorasani, M., & Shimokochi, Y. (2020). Effect of the FIFA 11+ on landing patterns and baseline movement errors in elite male youth soccer players. *Journal of Sport Rehabilitation*, 29(6), 730–737. <https://doi.org/10.1123/JSR.2018-0374>
- Amiri-Khorasani, M., Osman, N. A. A., & Yusof, A. (2011). Acute effect of static and dynamic stretching on hip dynamic range of motion during instep kicking in professional soccer players. *The Journal of Strength & Conditioning Research*, 25(6), 1647–1652.
- Ayala, F., Pomares-Noguera, C., Robles-Palazón, F. J., Del Pilar Garcia-Vaquero, M., Ruiz-Pérez, I., Hernández-Sánchez, S., & Croix, M. D. S. (2017). Training effects of the FIFA 11+ and harmoknee on several neuromuscular parameters of physical performance measures. *International Journal of Sports Medicine*, 38(04), 278–289.
- Bizzini, M., Impellizzeri, F. M., Dvorak, J., Bortolan, L., Schena, F., Modena, R., & Junge, A. (2013). Physiological and performance responses to the “FIFA 11+”(part 1): is it an appropriate warm-up? *Journal of Sports Sciences*, 31(13), 1481–1490.
- Brito, J., Figueiredo, P., Fernandes, L., Seabra, A., Soares, J. M., Krstrup, P., & Rebelo, A. (2010). Isokinetic strength effects of FIFA’s “The 11+” injury prevention training programme. *Isokinetics and Exercise Science*, 18(4), 211–215.

- Carling, C. (2013). Interpreting physical performance in professional soccer match-play: should we be more pragmatic in our approach? *Sports Medicine*, 43, 655–663.
- Challis, J. H. (2000). Muscle-Tendon Architecture and Athletic Performance. *Biomechanics in Sport*, 33–55. <https://doi.org/10.1002/9780470693797.ch3>
- Daneshjoo, A., Mokhtar, A. H., Rahnama, N., & Yusof, A. (2012). The effects of comprehensive warm-up programs on proprioception, static and dynamic balance on male soccer players. *PloS One*, 7(12), e51568.
- Daneshjoo, A., Mokhtar, A. H., Rahnama, N., & Yusof, A. (2013). Effects of the 11+ and Harmoknee warm-up programs on physical performance measures in professional soccer players. *Journal of Sports Science & Medicine*, 12(3), 489.
- De Oliveira, F., Corrêa Neto, V. G., Barbosa, R. J. S., de Jesus, I. R. T., Novaes, J. da S., & Monteiro, E. R. (2023). Power and anaerobic capacity in female soccer: A comparison between different age-categories. *Apunts Sports Medicine*, 58(220). <https://doi.org/10.1016/J.APUNSM.2023.100421>
- Fletcher, I. M., & Jones, B. (2004). The effect of different warm-up stretch protocols on 20 meter sprint performance in trained rugby union players. *Journal of Strength and Conditioning Research*, 18(4), 885–888. <https://doi.org/10.1519/14493.1>
- Fradkin, A. J., Zazryn, T. R., & Smoliga, J. M. (2010). Effects of warming-up on physical performance: a systematic review with meta-analysis. *The Journal of Strength & Conditioning Research*, 24(1), 140–148.
- Holm, I., Fosdahl, M. A., Friis, A., Risberg, M. A., Myklebust, G., & Steen, H. (2004). Effect of Neuromuscular Training on Proprioception, Balance, Muscle Strength, and Lower Limb Function in Female Team Handball Players. *Clinical Journal of Sport Medicine*, 14(2), 88–94. <https://doi.org/10.1097/00042752-200403000-00006>
- Impellizzeri, F. M., Bizzini, M., Dvorak, J., Pellegrini, B., Schena, F., & Junge, A. (2013). Physiological and performance responses to the FIFA 11+(part 2): a randomised controlled trial on the training effects. *Journal of Sports Sciences*, 31(13), 1491–1502.
- Leetun, D. T., Ireland, M. L., Willson, J. D., Ballantyne, B. T., & Davis, I. M. C. (2004). Core stability measures as risk factors for lower extremity injury in athletes. *Medicine and Science in Sports and Exercise*, 36(6), 926–934. <https://doi.org/10.1249/01.MSS.0000128145.75199.C3>
- Lloyd, R. S., Oliver, J. L., Faigenbaum, A. D., Howard, R., De Ste Croix, M. B. A., Williams, C. A., Best, T. M., Alvar, B. A., Micheli, L. J., Thomas, D. P., Hatfield, D. L., Cronin, J. B., & Myer, G. D. (2015). Long-term athletic development, Part 2: Barriers to success and potential solutions. *Journal of Strength and Conditioning Research*, 29(5), 1451–1464. <https://doi.org/10.1519/01.JSC.0000465424.75389.56>
- Paterno, M. V., Myer, G. D., Ford, K. R., & Hewett, T. E. (2004). Neuromuscular training improves single-limb stability in young female athletes. *Journal of Orthopaedic and Sports Physical Therapy*, 34(6), 305–316. <https://doi.org/10.2519/jospt.2004.34.6.305>
- Pomares-Noguera, C., Ayala, F., Robles-Palazón, F. J., Alomoto-Burneo, J. F., López-Valenciano, A., Elvira, J. L. L., Hernández-Sánchez, S., & De Ste Croix, M. (2018). Training effects of the FIFA 11+ kids on physical performance in youth football players: A randomized control trial. *Frontiers in Pediatrics*, 6, 40. <https://doi.org/10.3389/fped.2018.00040>
- Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Sciences*, 18(9), 669–683.
- Robert, P., Cirer-Sastre, R., López-Laval, I., Matas-García, S., Álvarez-Herms, J., Julià-Sánchez, S., & Corbi, F. (2020). Relationship between jump capacity and performance in BMX cycling. In *Apunts. Educacion Fisica y Deportes* (Issue 140). [https://doi.org/10.5672/apunts.2014-0983.es.\(2020/2\).140.06](https://doi.org/10.5672/apunts.2014-0983.es.(2020/2).140.06)
- Sahin, N., Gürses, V. V., Baydil, B., Akgül, M. S., Feka, K., Iovane, A., & Messina, G. (2018). The effect of comprehensive warm up (fifa 11+ program) on motor abilities in young basketball players: A pilot study. *Acta Medica Mediterranea*, 34(3), 703–708. https://doi.org/10.19193/0393-6384_2018_3_108
- Sander, A., Keiner, M., Schlumberger, A., Wirth, K., & Schmidtbleicher, D. (2013). Effects of functional exercises in the warm-up on sprint performances. *Journal of Strength and Conditioning Research*, 27(4), 995–1001. <https://doi.org/10.1519/JSC.0b013e318260ec5e>
- Shah Hosseini, M., Rajabi, R., Minoonejad, H., & Hossein Barati, A. (2019). Effect of Eight Weeks of FIFA 11+ Training on the Agility and Explosive Power of Male College Volleyball Players. *Annals of Military and Health Sciences Research*, 17(3), e97233. <https://doi.org/10.5812/amh.97233>
- Škof, B., & Strojnik, V. (2007). The effect of two warm-up protocols on some biomechanical parameters of the neuromuscular system of middle distance runners. *Journal of Strength and Conditioning Research*, 21(2), 394–399. <https://doi.org/10.1519/R-18055.1>
- Sotiropoulos, K., Smilios, I., Christou, M., Barzouka, K., Spaias, A., Douda, H., & Tokmakidis, S. P. (2010). Effects of warm-up on vertical jump performance and muscle electrical activity using half-squats at low and moderate intensity. *Journal of Sports Science and Medicine*, 9(2), 326–331.
- Street, S. B., & Kaminski, T. (2021). Does the FIFA 11+ program prevent hamstring injuries in college-aged male soccer players? A critically appraised topic. *Journal of Sport Rehabilitation*, 30(1), 158–160. <https://doi.org/10.1123/jsr.2019-0390>
- Subasi, S. S., Gelecek, N., & Aksakoglu, G. (2008). Effects of different warm-up periods on knee proprioception and balance in healthy young individuals. *Journal of Sport Rehabilitation*, 17(2), 186–205. <https://doi.org/10.1123/jsr.17.2.186>
- Trajković, N., Gušić, M., Molnar, S., Mačak, D., Madić, D. M., & Bogataj, Š. (2020). Short-term FIFA 11+ improves agility and jump performance in young soccer players. *International Journal of Environmental Research and Public Health*, 17(6), 1–9. <https://doi.org/10.3390/ijerph17062017>
- Zarei, M., Abbasi, H., Daneshjoo, A., Barghi, T. S., Rommers, N., Faude, O., & Rössler, R. (2018). Long-term effects of the 11+ warm-up injury prevention programme on physical performance in adolescent male football players: a cluster-randomised controlled trial. *Journal of Sports Sciences*, 36(21), 2447–2454.

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DIFFERENCES IN FLEXIBILITY BETWEEN URBAN AND RURAL ELEMENTARY SCHOOL CHILDREN: A PILOT STUDY

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Abstract: Flexibility is an important component of health-related physical fitness in childhood and may be influenced by both biological and environmental factors. The aim of this pilot study was to compare flexibility levels in younger school-aged children attending urban and rural elementary schools and to explore potential sex-related differences. The sample consisted of 60 children aged 6–10 years (30 urban and 30 rural pupils; equal numbers of boys and girls). Flexibility was assessed using five standardized motor tests: Sit and Reach, Shoulder Mobility, Trunk Rotation with Stick, Deep Squat, and Wide Straddle Sit with Elbows on the Floor. An overall flexibility index was calculated as the sum of ordinal scores across all tests. Descriptive statistics, independent samples *t*-tests, and effect-size analysis (Cohen's *d*) were applied. Children attending the urban school achieved better results across all assessed flexibility tests. Statistically significant differences were observed in the Sit and Reach Test and the Wide Straddle Sit Test ($p < 0.05$). The largest between-group difference was found for the overall flexibility index (Cohen's $d = 0.95$), indicating better overall flexibility among urban children. Girls demonstrated more favourable flexibility outcomes than boys across all assessed tests. The findings suggest that flexibility outcomes may differ between children attending urban and rural schools; however, due to the pilot nature of the study and the absence of controlled variables, the results should be interpreted with caution.

Keywords: flexibility; physical fitness; school-aged children; urban-rural differences; motor performance

INTRODUCTION

Flexibility is commonly considered a component of health-related physical fitness (American College of Sports Medicine, 2021) and an important prerequisite for the effective execution of movement, maintenance of proper posture, and prevention of musculoskeletal disorders. It represents the capacity of joints to move through an optimal range of motion and is influenced by factors such as age, sex, body composition, and level of physical activity. From a health-related perspective, physical fitness in childhood, including flexibility, is increasingly recognized as an important marker of current and future health status (Ortega et al., 2008). Global trends in physical fitness in children have also been documented, indicating changes in fitness levels across populations over time (Tomkinson et al., 2019).

Childhood and early school age represent critical periods for the development of motor abilities. During this stage, growth, maturation, and environmental factors interact to shape physical fitness and movement competence. Research has shown that physical fitness develops dynamically during childhood and adolescence and is influenced by biological as well as behavioral determinants (Armstrong, 2019). At the same time, global evidence indicates that a substantial proportion of children do not meet recommended levels of physical activity, which may negatively affect their physical fitness and overall health (Guthold et al., 2020).

Sex differences in physical fitness are also well documented, with girls generally demonstrating higher flexibility than boys even at younger ages. These differences are often attributed to biological factors such as joint structure, muscle elasticity, and hormonal influences, as well as differences in physical activity patterns. Flexibility, in particular, tends to be higher in girls across childhood and adolescence, which has been consistently reported in both classical and contemporary research (Badrić, 2011; Ortega et al., 2008).

In addition to individual characteristics, the environment in which children live and attend school may influence their physical activity patterns and subsequently their level of physical fitness. Previous research suggests that physical activity in children is shaped by a complex interplay of social, environmental, and behavioral factors (Sallis et al., 2000). Differences between urban and rural environments have been associated with variations in opportunities for structured and unstructured physical activity, access to sports facilities, and lifestyle habits. Furthermore, time spent outdoors has been positively associated with physical activity levels and physical fitness in children (Gray et al., 2015).

Despite the extensive body of literature addressing physical fitness in youth, relatively little attention has been paid specifically to flexibility in relation to school environment. While many studies have focused on overall fitness levels, cardiorespiratory fitness, or physical activity patterns, fewer have examined whether the locality of the school (urban vs. rural) is associated with differences in joint mobility and flexibility in younger school-aged children.

Therefore, the aim of this study was to compare the level of flexibility in younger school-aged children (6–10 years) attending an urban and a rural elementary school in the Czech Republic. Sex-related differences were explored as a secondary objective.

MATERIAL & METHODS

Study design

The study was designed as a cross-sectional quantitative pilot study aimed at comparing flexibility levels in younger school-aged children from two different school environments. The research focused on descriptive and comparative analysis of flexibility outcomes between groups defined by school locality (urban vs. rural).

Participants

The research sample consisted of 60 primary school children aged 6–10 years. The sample included 30 pupils (15 girls and 15 boys) from an urban elementary school located in a town with approximately 25,000 inhabitants and 30 pupils (15 girls and 15 boys) from a rural elementary school situated in a village with approximately 567 inhabitants (Table 1).

Participants were selected using purposive sampling to ensure balanced representation by sex and comparable age distribution between groups. The mean age of the participants was 7.9 ± 1.3 years, with an average body height of 137.2 ± 10 cm and body weight of 31.9 ± 8.6 kg. All participants were reported as healthy and free from acute or chronic musculoskeletal disorders.

Prior to data collection, informed consent was obtained from the parents or legal guardians of all children. The study was conducted in accordance with ethical standards and approved by the Ethics Committee of the Faculty of Education, Charles University. All procedures followed the principles of the Declaration of Helsinki.

Table 1. *Characteristics of Participants*

Variable	Urban school (n=30)	Rural school (n=30)
Age, years (mean± SD)	8.1 ± 1.24	7.8 ± 1.34
Height, cm (mean± SD)	140 ± 10	135 ± 9.61
Weight, kg (mean± SD)	34.4 ± 9.01	29.6 ± 7.57
Girls, n (%)	15 (50.0)	15 (50.0)
Boys, n (%)	15 (50.0)	15 (50.0)

Flexibility assessment

Flexibility was assessed using a battery of five standardized motor tests selected with regard to the age of participants and feasibility within school conditions (Mekota & Novosad, 2005). For each participant, an overall flexibility index was calculated as the sum of scores across all five tests, with lower values indicating better overall flexibility.

The execution of individual tests is illustrated in Figures 1–5.

Sit and Reach Test: measures flexibility of the lower back and hamstrings; results were recorded in centimeters (Figure 1).

Shoulder Mobility Test: assesses shoulder flexibility by measuring the grip width (cm) required to pass a stick behind the back (Figure 2). For the purposes of the overall flexibility index, shoulder mobility performance was classified into a five-point ordinal scale (>4 cm = 1 point; 1–4 cm = 2 points; 0 to –4 cm = 3 points; –5 to –9 cm = 4 points; <-9 cm = 5 points), with lower ordinal scores indicating better flexibility.

Trunk Rotation Test with Stick: assesses trunk and shoulder girdle mobility by measuring the minimum grip width (cm) required to perform a full stick rotation around the body (Figure 3). For the purposes of the overall flexibility index, trunk rotation performance was classified into a five-point ordinal scale (<50 cm = 1 point; 50–59 cm =

2 points; 60-69 cm = 3 points; 70-79 cm = 4 points; >79 cm = 5 points), with lower scores indicating better flexibility.

Deep Squat Test: assesses lower-limb mobility based on the ability to perform a full squat while maintaining heel contact with the floor. Successful performance was assigned 1 point and unsuccessful performance 5 points (Figure 4).

Wide Straddle Sit with Elbows on the Floor: evaluates hip joint flexibility and adductor extensibility based on the ability to touch the floor with the elbows. Successful performance was assigned 1 point and unsuccessful performance 5 points (Figure 5).

Each test was demonstrated by an experienced instructor prior to execution to ensure correct technique. The children performed the tests under standardized conditions during regular physical education lessons, under comparable environmental conditions and at a similar time of day.

Individual test performances were converted into ordinal scores based on predefined performance criteria, where 1 represented the highest level of flexibility and 5 the lowest. The scoring system was applied consistently across all participants.

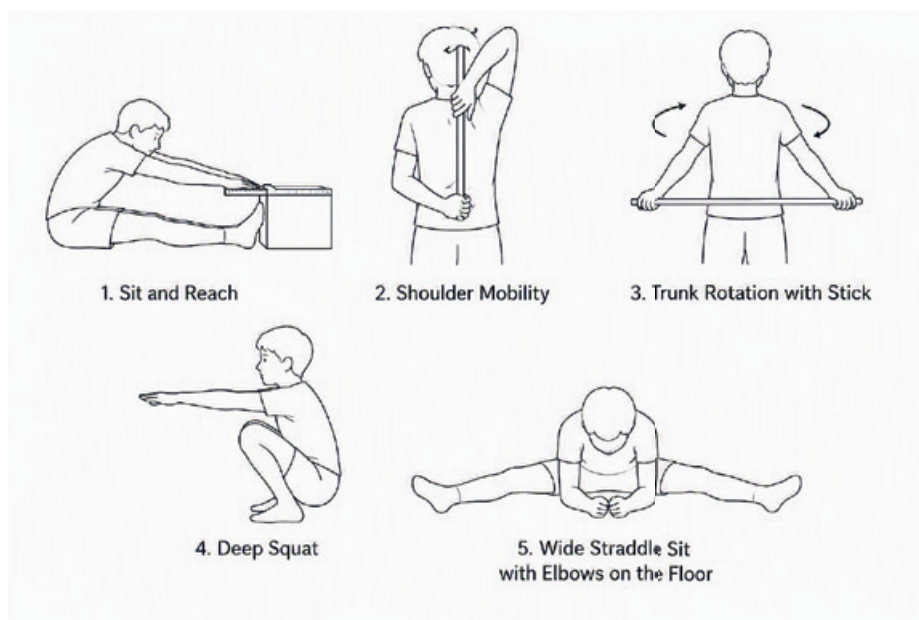


Figure 1. Battery of five standardized motor tests (Mekota & Novosad, 2005)

Statistical analysis

Data were processed using descriptive and inferential statistical methods (SPSS). Descriptive statistics included arithmetic mean and standard deviation. The normality of data distribution was verified using the Shapiro-Wilk test.

Differences between groups (urban vs. rural) were evaluated using Student's t-test for independent samples. The level of statistical significance was set at $\alpha = 0.05$. Although the flexibility scores were based on an ordinal scale, parametric tests were applied due to the approximately normal distribution of the aggregated data and for consistency with similar studies. Additional non-parametric analyses (Mann-Whitney test) yielded comparable results and did not alter the interpretation of the findings.

No additional variables such as extracurricular physical activity, socioeconomic background, or detailed characteristics of physical education lessons were controlled within the study design.

Given the pilot nature of the study and the limited sample size, the analysis should be considered primarily descriptive and exploratory. The findings should therefore be interpreted with caution.

RESULTS

The results of the flexibility tests are presented for individual test outcomes and the overall flexibility index. Comparisons are reported between children from urban and rural schools. The results of the flexibility tests are presented in Table 2.

Sit and Reach Test

Children from the urban school achieved an average value of 4.03 ± 6.74 cm in the sit and reach test, whereas children from the rural school achieved -0.10 ± 7.95 cm. The difference between groups was statistically significant ($p < 0.05$) and corresponded to a moderate effect size (Cohen's $d = 0.56$).

Shoulder Mobility Test

In the shoulder mobility test, children from the urban school achieved a mean value of -0.53 ± 6.63 cm, whereas children from the rural school achieved -1.73 ± 6.03 cm. Higher values indicate greater shoulder flexibility. The difference between groups was not statistically significant ($p > 0.05$).

Trunk Rotation Test with Stick

In the trunk rotation test, children from the urban school achieved a mean value of 55.6 ± 13.4 cm, whereas children from the rural school achieved 65.6 ± 12.2 cm. Lower values indicate better flexibility performance. According to the evaluation criteria, urban children demonstrated better trunk and shoulder girdle mobility than rural children. The between-group effect size was moderate to large (Cohen's $d = 0.78$), although the difference did not reach statistical significance ($p > 0.05$).

Deep Squat Test, Wide Straddle Sit with Elbows on the Floor

In the Deep Squat Test, successful performance was observed in 73% of urban children and 47% of rural children. Similarly, in the Wide Straddle Sit Test, 80% of urban children met the assessment criteria compared with 47% of rural children.

Overall Flexibility Index

The overall flexibility index was calculated as the sum of scores across all five tests. Urban children achieved a mean score of 10.30 ± 3.53 points, whereas rural children achieved a mean score of 13.70 ± 3.64 points, indicating better overall flexibility in the urban group. The between-group effect size was large (Cohen's $d = 0.95$).

Across all tests, girls demonstrated more favourable flexibility outcomes than boys; however, these differences were not analysed as a primary focus of the study.

Table 2. Flexibility tests performance in urban and rural school children. Values are presented as mean $\pm$ SD, median, minimum and maximum values. Cohen's d was calculated using pooled standard deviation. For the Shoulder Mobility Test and Trunk Rotation Test, lower values indicate better flexibility performance. For the Sit and Reach Test, higher values indicate better flexibility performance

Test		Urban school (n=30)	Rural school (n=30)	Cohen's d
Sit and Reach (cm)	mean $\pm$ SD	4.03 ± 6.74	-0.10 ± 7.95	0.56
	median	2.5	2.5	
	min	-12	-22	
	max	19	13	
Shoulder mobility (cm)	mean $\pm$ SD	-0.53 ± 6.63	-1.73 ± 6.03	0.19
	median	1.5	1	
	min	-23	-20	
	max	8	5	
Trunk rotation with stick (cm)	mean $\pm$ SD	55.6 ± 13.4	65.6 ± 12.2	0.78
	median	54	64.5	
	min	38	33	
	max	79	92	

	mean± SD	10.30 ± 3.53	13.70 ± 3.64	0.95
Overall flexibility index (points)	median	10	13.5	
	min	5	7	
	max	21	20	

DISCUSSION

The findings indicate that children from the urban school achieved better flexibility outcomes across all assessed tests. The largest difference was observed for the overall flexibility index (Cohen's $d = 0.95$), indicating a large effect in favour of urban children. Moderate differences were also found in the Trunk Rotation Test with Stick ($d = 0.78$) and the Sit and Reach Test ($d = 0.56$). Girls demonstrated higher flexibility levels than boys across all assessed tests.

The present findings suggest that flexibility outcomes may differ between children attending urban and rural schools. Children from the urban school achieved better results across all assessed flexibility tests, with the largest difference observed for the overall flexibility index (Cohen's $d = 0.95$). Although statistically significant differences were identified only for selected tests, the consistency of the observed pattern across all assessments suggests that the difference was not limited to a single dimension of flexibility. Previous research has shown that children's physical activity behaviour is influenced by a complex interaction of environmental, social, and behavioural determinants (Sallis et al., 2000). Similarly, opportunities for outdoor play and physical activity have been associated with higher levels of physical fitness (Gray et al., 2015). However, because flexibility was the primary outcome of the present study and detailed information regarding physical activity participation was not collected, the mechanisms underlying the observed differences remain unclear.

Although rural environments are frequently perceived as favourable for spontaneous physical activity, the relationship between living environment and physical fitness appears to be more complex. Physical activity alone may not fully explain flexibility development, which is likely influenced by the type, frequency, and specificity of movement experiences. It is therefore possible that differences in participation in organised sports or movement programmes contributed to the observed outcomes. However, these factors were not assessed in the present study and should be considered as possible explanations rather than established causes.

Girls demonstrated more favourable flexibility outcomes than boys across all assessed tests. This observation is consistent with previous findings reporting higher flexibility levels in girls during childhood and adolescence (Badrić, 2011). Differences between sexes have commonly been attributed to anatomical and physiological factors, including differences in joint structure, connective tissue characteristics, and muscle elasticity. The present findings are therefore in agreement with broader evidence showing that sex-related differences in physical fitness components emerge already in early school age (Ortega et al., 2008).

The effect-size analysis suggests that the observed differences were not only statistically detectable but also practically meaningful. The largest effect was found for the overall flexibility index (Cohen's $d = 0.95$), while moderate effects were observed for the Trunk Rotation Test with Stick ($d = 0.78$) and the Sit and Reach Test ($d = 0.56$). These findings indicate a relatively consistent advantage of the urban group across different flexibility assessments despite the limited sample size and exploratory nature of the study.

The present findings should be interpreted in the context of several limitations. First, the study was conducted with a relatively small sample of children from only two schools, which limits the generalizability of the results. In addition, the inclusion of only one urban and one rural school limits the external validity of the findings and prevents broader generalization to urban and rural child populations. Second, the study design did not include control of potentially important variables such as extracurricular physical activity, socioeconomic background, or the content and quality of physical education. These factors may have influenced the observed differences between groups. Third, flexibility was assessed using a set of field-based tests evaluated on an ordinal scale, which, although practical for school conditions, may limit the precision of measurement. Finally, the cross-sectional and pilot nature of the study does not allow for causal interpretation of the findings.

Despite these limitations, the study provides an initial contribution to the understanding of flexibility differences in younger school-aged children in relation to school environment. The results highlight that differences in flexibility may exist even within relatively small and homogeneous populations and emphasize the importance of considering

contextual factors when evaluating motor abilities in children. Further research with larger and more diverse samples, as well as with more comprehensive assessment of physical activity and environmental variables, is needed to better understand the determinants of flexibility in this age group.

CONCLUSIONS

The present pilot study examined differences in flexibility between younger school-aged children attending urban and rural elementary schools and explored potential sex-related differences. Children from the urban school achieved better results across all assessed flexibility tests, with statistically significant differences observed in the Sit and Reach Test and the Wide Straddle Sit Test. In addition, girls demonstrated more favourable flexibility outcomes than boys across all assessed tests.

The most pronounced difference between groups was observed for the overall flexibility index, which showed a large effect size (Cohen's $d = 0.95$), indicating better overall flexibility among children attending the urban school. These findings suggest that flexibility outcomes may be associated with environmental and contextual factors related to the school setting. However, due to the pilot and exploratory nature of the study, the small sample size, and the absence of controlled variables, the findings should not be interpreted as evidence of a causal relationship.

The study contributes to the limited body of research addressing flexibility in younger school-aged children in relation to school locality and highlights the potential importance of contextual influences on flexibility development. Future research should include larger and more diverse samples and incorporate additional variables, such as physical activity participation, socioeconomic factors, and characteristics of school physical education, to provide a more comprehensive understanding of the determinants of flexibility in this age group.

Conflicts of interest

The authors declare that they have no conflicts of interest.

REFERENCES:

- American College of Sports Medicine. (2021). *ACSM's guidelines for exercise testing and prescription* (11th ed.). Wolters Kluwer.
- Armstrong, N. (2019). Youth aerobic fitness. *Pediatric Exercise Science*, 31(2), 137–143. <https://doi.org/10.1123/pes.2019-0039>
- Badrić, M. (2011). Differences in motor abilities of male and female fifth and sixth grade pupils. *Croatian Journal of Education*, 13, 82–107.
- Gray, C., Gibbons, R., Larouche, R., Sandseter, E. B. H., Bienenstock, A., Brussoni, M., Chabot, G., Herrington, S., Janssen, I., Pickett, W., Power, M., Stanger, N., Sampson, M., & Tremblay, M. S. (2015). What is the relationship between outdoor time and physical activity, sedentary behaviour, and physical fitness in children? A systematic review. *International Journal of Environmental Research and Public Health*, 12(6), 6455–6474. <https://doi.org/10.3390/ijerph120606455>
- Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1.6 million participants. *The Lancet Child & Adolescent Health*, 4(1), 23–35. [https://doi.org/10.1016/S2352-4642\(19\)30323-2](https://doi.org/10.1016/S2352-4642(19)30323-2)
- Mekota, K., & Novosad, J. (2005). *Motor tests in physical education and sport*. Hanex.
- Ortega, F. B., Ruiz, J. R., Castillo, M. J., & Sjöström, M. (2008). Physical fitness in childhood and adolescence: A powerful marker of health. *International Journal of Obesity*, 32(1), 1–11. <https://doi.org/10.1038/sj.ijo.0803774>
- Sallis, J. F., Prochaska, J. J., & Taylor, W. C. (2000). A review of correlates of physical activity among children and adolescents. *Medicine & Science in Sports & Exercise*, 32(5), 963–975. <https://doi.org/10.1097/00005768-200005000-00014>
- Tomkinson, G. R., Lang, J. J., & Tremblay, M. S. (2019). Temporal trends in the cardiorespiratory fitness of children and adolescents representing 19 high-income and upper middle-income countries between 1981 and 2014. *British Journal of Sports Medicine*, 53(8), 478–486. <https://doi.org/10.1136/bjsports-2017-097982>

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EFFECTS OF AN ADAPTED PHYSICAL ACTIVITY PROGRAM INTEGRATED WITH APPLIED BEHAVIOR ANALYSIS IN CHILDREN AND ADOLESCENTS WITH AUTISM SPECTRUM DISORDER: A PILOT STUDY

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Abstract: Adapted Physical Activity (APA) represents an area of growing interest within rehabilitation pathways for individuals with Autism Spectrum Disorder (ASD), as it enables the integration of motor, behavioural, and socio-relational dimensions within structured educational contexts. The present pilot study aims to examine the functional impact and ecological validity of an APA protocol integrated with the principles of Applied Behaviour Analysis (ABA). Twenty participants diagnosed with ASD, aged between 3 and 17 years, took part in the study and were involved in a 10-week training programme. Outcome assessment was carried out using a mixed observational design, integrating caregivers' perceptions collected through a post-intervention questionnaire and systematic observations conducted by ABA practitioners using a structured checklist. The results highlight an overall positive impact of the intervention, with significant improvements in motor functioning, active participation, and emotional and behavioural regulation. The findings suggest that APA integrated with ABA constitutes an ecologically valid and potentially effective intervention for promoting adaptive skills in individuals with ASD, confirming the central role of movement within integrated rehabilitation pathways.

Keywords: Emotional self-regulation, Social interaction, Engagement, Setting.

INTRODUCTION

In recent decades, scientific and pedagogical interest in the inclusion of individuals with autism spectrum disorder (ASD) in educational, sport, and rehabilitation contexts has promoted the development of integrated and multidimensional intervention models aimed at enhancing global well-being and adaptive skills (Ceruso et al., 2024a,b). A substantial body of literature has shown that children and adolescents with ASD frequently present difficulties in motor coordination, action planning, and sensory modulation, with significant repercussions on communication, social skills, and functional autonomy (Fournier et al, 2010; Bhat et al, 2011; Taleb et al, 2021). These characteristics have progressively encouraged the adoption of an educational and rehabilitative perspective that recognizes the body not merely as an executive tool, but as a privileged space for cognitive, emotional, and relational mediation (D'Elia et al, 2020; Raiola et al., 2025). Within this theoretical framework, adapted physical activity (APA) assumes a central role as an educational and rehabilitative tool capable of integrating motor, cognitive, and socio-affective dimensions (Altavilla et al, 2022; Cascone et al, 2020). APA is not limited to compensating for physical difficulties but is configured as an intentional intervention aimed at supporting the development of executive functions, attention, emotional and behavioral regulation, and adaptive skills through the structuring of contexts and activities tailored to the functional characteristics of each individual (Pan, 2011; Bremer et al, 2016). The playful and motivational dimension of intervention represents a key element in fostering active engagement among individuals with ASD and in promoting meaningful and lasting learning processes, facilitating the transfer of acquired skills to everyday life contexts (D'Elia et al, 2023, Raiola et al, 2018). The effectiveness of APA is further enhanced when it is integrated with evidence-based methodologies, including Applied Behavior Analysis (ABA), which allows the training intervention to be structured according to principles of gradual progression, positive reinforcement, modeling, and generalization of learning (Lovaas, 1987; Cooper et al, 2007). In line with recent national guidelines, the integration of motor-based approaches and behavioral analysis represents a particularly relevant perspective, as it promotes self-regulation, active participation, and the development of social skills within structured settings characterized by predictability, routines, and clarity of demands (D'Isanto et al, 2022; Aliberti et al, 2025). Considering these premises, the present

pilot study aims to examine the ecological validity and functional impact of an APA protocol integrated with the ABA method and designed for children and adolescents with autism spectrum disorder (Altavilla, 2019). The objective is to evaluate the effects of the intervention on motor skills, adaptive abilities, and behaviors by adopting a dual analytical perspective that integrates parent and caregiver perceptions, collected through questionnaires, with systematic observations conducted by ABA practitioners using checklists focused on participation, self-regulation, and social interaction. This methodological approach makes it possible to combine subjective and observational dimensions, offering a more comprehensive and context-sensitive evaluation of intervention outcomes within a clinical and rehabilitative setting. Based on supporting scientific evidence, it is hypothesized that participation in an integrated specialized motor program may lead to improvements in behavioral self-regulation, accompanied by a reduction in stereotyped, oppositional, and frustration-related behaviors. An increase in active participation and interest in motor activity is also expected, along with greater confidence and competence in movement. Finally, it is hypothesized that structuring the intervention in small groups may foster the development of social skills, with an increase in imitative behaviors and spontaneous social and communicative interactions, as perceived by caregivers and observed by practitioners.

Purpose of the research

Overall, the study also aims to assess the sustainability and acceptability of the protocol, contributing to the definition of integrated, replicable intervention models that are consistent with the functional needs of individuals with ASD.

MATERIALS AND METHODS

Study participants

Children and adolescents ($n = 20$) with a diagnosis of autism spectrum disorder (ASD), recruited through the reference rehabilitation service. The sample was selected according to a convenience criterion, based on accessibility to treatment and the availability of families to participate in the study. Participants ranged in age from 3 to 17 years, with a higher representation of preschool and school-age children. With regard to the level of support according to DSM-5 classification, the sample was distributed among individuals with level 1 and level 2 support needs, both accounting for 40 percent of the sample, while the remaining 20 percent consisted of individuals with level 3 support needs. This distribution reflects the functional variability typically observed in clinical and rehabilitative settings and allows for a differentiated interpretation of the effects of the intervention. Inclusion criteria included the presence of an ASD diagnosis, active enrollment in the center's motor program, the ability to participate in the proposed activities with or without individualized support, and the availability of parents or legal guardians to provide informed consent for participation in the research. No specific inclusion criteria related to cognitive level, verbal language, or the presence of comorbidities were applied, in order to ensure greater adherence to real-world rehabilitative conditions. Participants presenting medical or physical conditions incompatible with the proposed physical activity, such as acute orthopedic or neurological disorders, were excluded from the study. Cases characterized by irregular attendance at the program, such as compromising intervention continuity and the observability of effects, were also excluded. Additional exclusion criteria included failure to obtain informed consent or interruption of treatment before completion of the observation period. With regard to ethical aspects and data protection, families were not required to provide detailed clinical documentation, such as medical certifications or diagnostic codes. In line with the principles of data minimization established by Regulation (EU) 2016/679 (GDPR) and current national legislation, only information regarding the level of support according to DSM-5 was collected, as it was considered sufficient and relevant to the exploratory aims of the study. Participation in other parallel physical or rehabilitative activities was recorded as a descriptive variable and did not constitute an exclusion criterion.

Study design

The present observational pilot study examined the ecological validity and functional impact of an APA protocol integrated with the principles of ABA within a real clinical and rehabilitative context. All participants took part in a standardized training program consisting of two weekly sessions lasting 60 minutes each, over a total period of 10 weeks. The intervention was conducted in small groups within a structured and predictable setting consistent

with ABA principles, in order to promote participation, behavioral regulation, and generalization of learning. The objective of the study was to examine the impact of the APA-ABA protocol on the functional profile of children and adolescents with autism spectrum disorder, considering both observable changes within the rehabilitative context and those perceived in daily life. To this end, a mixed-methods approach was adopted (D'Elia et al., 2022), integrating the perspective of parents and caregivers with systematic observations conducted by ABA practitioners involved in the treatment. Outcome evaluation was based, on the one hand, on the administration of a questionnaire addressed to parents and caregivers, aimed at detecting perceived changes in motor skills, self-regulation behaviors, and social abilities, and, on the other hand, on the use of an observational checklist completed by practitioners during sessions, designed to document the evolution of motor, regulatory, and social behaviors within the rehabilitative setting. The integration of observational data and caregiver-reported perceptions is consistent with the national guidelines of the Italian Society of Child and Adolescent Neuropsychiatry (SINPIA, 2022), which recommend a multidimensional approach to the assessment of adaptive and social skills in individuals with ASD. This methodological framework allows for capturing the complexity of functional changes by valuing both the objective dimension of observed behavior and the subjective dimension of family experience (Di Domenico et al., 2024; Esposito et al., 2024a). It should be noted that the absence of a pre-intervention assessment does not allow for a direct pre-post comparative analysis. However, given the exploratory and pilot nature of the study, the combined use of structured systematic observations and caregiver perceptions still allows for an ecologically valid evaluation of intervention effects, which is particularly relevant in real clinical settings. The duration of the program, set at 10 weeks, is also consistent with existing literature regarding the effectiveness of medium-term interventions for the promotion and stabilization of adaptive behavioral patterns in individuals with autism spectrum. The APA sessions were designed to promote the development of motor, socio-relational, and self-regulatory skills in children and adolescents with ASD. Each session lasted 60 minutes and was organized in small groups in order to ensure targeted intervention and optimal management of attention and social interactions. The proposed physical activities included exercises for hand-eye and gross motor coordination, static and dynamic balance exercises, circuits organized into stations with progressive tasks, imitative games, collaborative activities, and ball-passing games. Task complexity was adjusted according to participants' level of support, encouraging active participation and the gradual development of autonomy in task execution. From a pedagogical perspective, the sessions followed ABA-based protocols, including strategies such as graduated prompting, modeling, shaping, natural reinforcement, and token economy, which were used to support skill acquisition, attention maintenance, and generalization of learning (Esposito et al., 2024b). Each session was structured into three main phases: an initial welcoming and activation phase, including light stretching and imitation exercises; a central phase characterized by structured games, circuits, and group activities; and a final phase focused on cool-down, symbolic processing of activities, and positive reinforcement of observed behaviors. The setting was organized according to principles of predictability, with clear visual structuring, management of activity and break times, reduction of sensory overload, and visually accessible materials. Data collection was carried out at the end of the intervention using two structured assessment tools, aimed at capturing, on the one hand, caregiver perceptions of changes observed in the child and on the other hand, behavioral performance displayed during sessions through direct observation. The use of differentiated tools allowed for the integration of perceptual evaluation with observational assessment, enabling a more articulated interpretation of intervention outcomes. The first instrument was a post-intervention questionnaire administered to parents or caregivers. The questionnaire was designed to assess perceived benefits of the program across specific areas of child functioning and consisted of items organized into five domains: motor skills, behavior and self-regulation, social interaction, participation in activities, and overall perception of change. The structure of the questionnaire, the domains investigated, and the purpose of the items are reported in Table 1. Items related to motor skills investigated aspects such as movement control, coordination, and engagement in the proposed physical activities. The behavior and self-regulation domain included items related to the ability to maintain attention, manage transitions, and modulate behavioral responses. The social interaction domain explored modes of interaction with peers and adults and participation in group-based activities. The participation domain assessed the level of involvement and continuity of engagement during sessions. Finally, the overall perception domain allowed caregivers to express a global evaluation of changes observed following the intervention.

Table 1. *Structure of the questionnaire for caregivers*

Area of investigation	Description of the items	Purpose
Motor skills	Movement control, coordination, involvement in physical activities	Detect perceived changes in motor skills
Behavior and self-regulation	Attention, management of transitions, regulation of behavioral responses	Assess self-regulation ability
Social skills	Interaction with peers and adults, participation in group activities	Analyze social skills
Participation	Involvement and continuity of engagement during sessions	Estimate the level of engagement
General perception	Overall evaluation of observed changes	Identify the caregivers' overall judgment

The second instrument consisted of an observational checklist completed by the practitioners during the sessions. The checklist is structured into items divided into four observation areas, as illustrated in Table 2, and is aimed at the systematic assessment of the child's behavioral performance in an ecological setting. Observations focus on the level of participation in activities, self-regulation abilities, patterns of social interaction, and responses to sensory stimuli present in the environment. The checklist was completed by experienced staff with ABA training, based on direct observations conducted during the sessions, in order to ensure consistency and reliability in behavioral assessment.

Table 2. *Structure of the practitioners' observational checklist*

Observation area	Observed behaviors	Assessment method
Participation and motivation	Active involvement and task persistence	Direct observation
Self-regulation and behavior	Management of behavior and waiting	Direct observation
Social skills and communication	Interaction, cooperation, and response to instructions	Direct observation
Sensory processing	Response and adaptation to sensory stimuli	Direct observation

Both instruments adopt a five-point Likert rating scale, with values ranging from 1 to 5, where 1 indicates "Not observed/Not applicable" and 5 indicates "Always." The use of the same rating scale for both the questionnaire and the checklist allowed for greater uniformity in data interpretation and facilitated descriptive comparisons between caregivers' evaluations and those recorded by practitioners. Although the instruments used in the present study were developed ad hoc to address the specific aims of the intervention, the investigated areas and reference constructs are consistent with those explored by validated instruments reported in the literature. In particular, the assessment of adaptive behaviors, self-regulation, and social skills is aligned with standardized measures such as the Child Behavior Checklist (Achenbach & Ruffle, 2000) and the Adaptive Behavior Assessment System (Oakland & Harrison, 2011), while the evaluation of social competencies and relational difficulties is consistent with the constructs assessed by the Social Responsiveness Scale (Bruni, 2014). Similarly, the dimensions related to self-regulation and sensory responsiveness are in line with specific tools developed for the observation of these aspects in developmental age (Altavilla et al., 2024; D'Isanto et al., 2024). These theoretical and psychometric references guided the definition of the items in order to ensure adequate content validity of the instruments used. Data collected through the caregiver questionnaire and the practitioners' checklist were analyzed using descriptive statistics. For each item, the arithmetic mean, standard deviation, and minimum and maximum values were calculated to describe the distribution of responses across the different areas of investigation. A descriptive comparison was also conducted between the scores obtained from the questionnaire and those derived from the observational checklist, in order to explore the consistency between caregivers' subjective perceptions and the observational evaluation of performance during the sessions. With regard to ethical aspects, the study was conducted in accordance with principles for the protection of participants. Prior to the start of the program, all caregivers provided informed consent to participate after receiving clear information about the aims of the study, the methods of data collection and processing, and the guarantee of anonymity. Each participant was assigned an anonymous alphanumeric code, used exclusively for data linkage purposes. Data were stored in a secure manner for a maximum period of twelve months and subsequently deleted, in compliance with current regulations on personal data protection.

RESULTS

Data analysis highlights an overall positive impact of APA across the investigated areas, with particularly relevant results in the motor, participation, and behavioral self-regulation domains. The evaluations provided by caregivers and the observations conducted by practitioners show good convergence, strengthening the interpretation of the findings. With regard to the physical domain, caregivers report a positive perception of the changes observed in children at the end of the program. As shown in Table 3, interest in movement is high ($M = 4.15$), as is the perception of increased physical confidence ($M = 4.10$). Particularly noteworthy is the result related to the generalization of physical behavior, with the item “Is more active also outside the center” showing the highest mean within the area ($M = 4.25$). These findings suggest that the intervention affected not only motor skills per se, but also motivation and the propensity for physical activity in contexts other than the structured setting.

Table 3. *Caregivers perceived benefits in the physical domain*

Item	M	SD	Min	Max
Shows interest in movement	4.15	1.21	3	5
Accepts initiating the activity	3.90	1.25	3	5
Moves with greater confidence	4.10	1.04	3	5
Follows the practitioner's instructions	4.15	0.59	3	5
Is more active also outside the center	4.25	1.04	3	5

Practitioners' observations confirm these results, highlighting high levels of participation and motivation during the sessions. As reported in Table 4, children enter the activity space without opposition ($M = 4.10$), accept initiating the activity ($M = 4.10$), and maintain attention throughout the duration of the proposed tasks ($M = 4.30$). These data suggest that the structured APA setting facilitates activity initiation and supports sustained engagement over time.

Table 4. *Practitioners' observations on participation.*

Item	M	SD	Min	Max
Enters the space without opposition	4.10	0.44	3	5
Accepts initiating the activity	4.10	0.30	4	5
Maintains attention	4.30	0.50	3	5
Completes the activity	4.19	0.51	3	5

Regarding sensory responsiveness, practitioners reported good acceptance of environmental stimuli and materials used during activities. The item related to acceptance of different materials showed a mean of $M = 4.05$, while marked discomfort in response to noise or tactile contact was limited. These findings are consistent with the adopted environmental structure, characterized by controlled progression of stimuli and continuous educational mediation. Turning to behavioral and self-regulation outcomes, the most relevant results of the entire study emerge. Caregivers report a marked improvement in emotional regulation, with the item “Calmer after the activity” reaching the highest overall mean ($M = 4.60$), accompanied by a low standard deviation ($SD = 0.60$), indicating high response homogeneity. Improvements in frustration management and reductions in oppositional behaviors were also rated positively ($M = 4.05$ for both items).

Table 5. *Caregivers' perceived effects on behavior and self-regulation*

Item	M	SD	Min	Max
Calmer after the activity	4.60	0.60	3	5
Better compliance with rules	4.20	1.23	3	5
Shows less opposition	4.05	1.09	3	5
Manages frustration better	4.05	0.60	3	5

Practitioners' observations are consistent with these perceptions. Compliance with basic rules (stop, turn-taking, waiting) and tolerance of task difficulty both show a mean of $M = 4.21$, while reductions in oppositional behaviors observed during sessions reach $M = 4.05$. These findings indicate that APA appears to promote greater behavioral stability and improved management of task demands. With respect to social functioning, the data show more evident improvements in indirect interactions and those mediated by motor tasks. Practitioners report good levels of participation in dyadic or group activities ($M = 4.05$) and high levels of motor imitation ($M = 4.35$), while initiative toward peers reaches a mean of $M = 4.00$. From the caregivers' perspective, improvements are observed in the ability to observe peers to understand what to do ($M = 4.05$), whereas direct imitation of movements is slightly lower ($M = 3.55$). The item related to direct communication ("Communicates more during/after the activity") shows the lowest mean within this domain ($M = 3.40$), suggesting that observed social improvements do not automatically translate into an equivalent increase in verbal communication. Finally, caregivers' overall perception of the intervention is extremely positive. Perceived usefulness of the program, overall satisfaction, and organizational satisfaction all reach a mean of $M = 4.50$, with responses concentrated at the upper end of the scale. Qualitative analysis of open-ended responses confirms these findings, highlighting perceived benefits particularly in the physical and emotional regulation domains. In parallel, practitioners' qualitative observations indicate that approximately 80% of participants show greater task tolerance, increased spontaneous social interaction, and improved acceptance of turn-taking with peers.

DISCUSSION

The results of the pilot study confirm that APA, when integrated with ABA principles, has a positive and cross-cutting impact on motor, behavioral, and socio-relational dimensions in children and adolescents with ASD. The most evident effect concerns emotional self-regulation and behavioral management, with particular emphasis on the reduction of post-activity agitation, suggesting that APA may act as an emotional stabilizer and facilitate stress level regulation within structured contexts (Anderson-Hanley et al, 2011; Penedo & Dahn, 2005). These findings are especially relevant for profiles characterized by sensory atypicalities, in which emotional dysregulation often underlies oppositional behaviors (Williams et al, 2021; Esposito, 2024). The intervention also promoted active participation and motivation, as highlighted by practitioner observations and caregiver perceptions. This supports the hypothesis that a predictable and structured setting, combined with ABA strategies such as contingent reinforcement, graduated prompting, modeling, and task analysis, facilitates not only the acquisition of complex motor skills, but also attention maintenance, tolerance of challenges, and generalization of adaptive behaviors (Hansen et al, 2022). The evidence suggests that APA can create an enabling educational context in which activity structuring and controlled stimulus progression allow participants to consolidate motor, social, and self-regulatory skills in a consistent and reproducible manner. From a socio-relational perspective, the most significant improvements emerged in task-mediated interactions, motor imitation, and joint attention, while direct verbal communication showed more gradual progress. This phenomenon confirms the role of embodied interaction as a privileged channel for the development of social skills in individuals with ASD, highlighting how shared movement and motor synchrony may represent relational modalities that are less dependent on linguistic mediation (Gallese, 2001; Rizzolatti & Sinigaglia, 2010). Caregiver reports support these findings, indicating perceived benefits not only in motor skills and emotional regulation, but also in socialization and participation in non-sport contexts, thereby confirming the generalization of adaptive behaviors and the effectiveness of the ABA approach. While acknowledging the importance of these results, the methodological limitations of the study must be considered. The absence of a pre-intervention assessment does not allow for a formal pre-post comparison, limiting the ability to establish causal relationships between the intervention and observed changes. The small sample size and pilot nature of the study further limit the generalizability of the findings to other ASD populations. The use of ad hoc instruments, although consistent with standardized scales and appropriate for the clinical context, may reduce comparability with previous studies. Finally, post-intervention data collection based on caregiver subjective perceptions and practitioner observations may introduce evaluative bias. However, convergence between these two sources increases the reliability of the collected evidence. To further enhance effects on verbal communication, it may be useful to integrate specific protocols of Augmentative and Alternative Communication (AAC). Overall, these findings support the consideration of APA not as an ancillary activity, but as a central component of continuous rehabilitation and habilitation pathways for individuals with ASD.

CONCLUSION

This pilot study confirms that APA, when integrated with ABA strategies, promotes significant improvements in emotional regulation, management of oppositional behaviors, and participation in physical activities, with generalization of adaptive behaviors also occurring in non-sport contexts. Social improvements emerge primarily in task-mediated interactions and motor imitation, while direct verbal communication shows more gradual gains. Although limited by the absence of a pre-intervention assessment, the small sample size, and the use of ad hoc instruments, the study suggests that APA represents a central rehabilitative intervention within rehabilitation pathways for individuals with ASD and should be integrated with specific communication-focused strategies in order to maximize overall effectiveness.

REFERENCES

- Achenbach, T. M., & Ruffle, T. M. (2000). The Child Behavior Checklist and related forms for assessing behavioral/emotional problems and competencies. *Pediatrics in Review*, 21(8), 265-271.
- Aliberti, S., D'Elia, F., Giardullo, G., & Raiola, G. (2025). Agonism and performance in adolescent football players in informal physical education settings. *Frontiers in Sports and Active Living*, 7, 1511719.
- Altavilla, G. (2019). Monitoring training to adequate the teaching method in training: An interpretative concepts. *Journal of Physical Education and Sport*, 19, 1763-1766.
- Altavilla, G., Ceruso, R., Esposito, G., Raiola, G., & D'Elia, F. (2022). *Physical education teaching in Italian primary school: theoretical lines and operational proposals*. *Pedagogy of Physical Culture and Sports*, 26(3), 151-157.
- Altavilla, G., Aliberti, S., & D'Elia, F. (2024). Assessment of Motor Performance and Self-Perceived Psychophysical Well-Being in Relation to Body Mass Index in Italian Adolescents. *Children*, 11(9), 1119.
- Anderson-Hanley, C., Tureck, K., & Schneiderman, R. L. (2011). Autism and exergaming: effects on repetitive behaviors and cognition. *Psychology Research and Behavior Management*, 129-137.
- Bhat, A. N. (2021). Motor impairment increases in children with autism spectrum disorder as a function of social communication, cognitive and functional impairment, repetitive behavior severity, and comorbid diagnoses: A SPARK study report. *Autism Research*, 14(1), 202-219.
- Bremer, E., Crozier, M., & Lloyd, M. (2016). A systematic review of the behavioural outcomes following exercise interventions for children and youth with autism spectrum disorder. *Autism*, 20(8), 899-915.
- Bruni, T. P. (2014). Test review: Social responsiveness scale-Second edition (SRS-2). *Journal of Psychoeducational Assessment*, 32(4), 365-369.
- Cascone, C., De Cesare, G., & D'Elia, F. (2020). Physical education teacher training for disability. *Journal Of Human Sport and Exercise*, 15, 634-644.
- Ceruso, R., Focetola, G., Sferlazza, M. C., & Raiola, G. (2024a). Influence of Generalist Teachers Views on Training and Experience in Inclusive Education of Students with Autism Spectrum Disorder. *Collegium Antropologicum*, 48(4), 269-274.
- Ceruso, R., Giardullo, G., Di Lascio, G., Cusano, P., & Sannicandro, I. (2024b). Physical Activity Monitoring Model to Measure the Appropriateness of Weekly Physical Activity for the World Health Organization's Physical Well-Being and Health Claims. *Physical Education Theory and Methodology*, 24(6), 905-911.
- Cooper, J. O., Heron, T. E., & Heward, W. L. (2007). *Applied behavior analysis* (Vol. 2, pp. 37-46). Pearson/Merrill-Prentice Hall.
- D'Elia, F., Di Domenico, F., D'Isanto, T., Altavilla, G., & Raiola, G. (2020). From biomechanics to motor learning. *Acta Medica Mediterranea*, 36, 3073-3078.
- D'Elia, F., Altavilla, G., Esposito, G., Aliberti, S., & Raiola, G. (2022). Perceptions and benefits of static and dynamic stretching in dancers: Qualitative and quantitative aspects. *Journal of Physical Education*, 33, e3339.
- D'Elia, F., D'Isanto, T., Esposito, G., Altavilla, G., & Raiola, G. (2023). Physical activity and sports science in Italian scientific research products. *Health, sport, rehabilitation*, 9(2), 38-47.
- D'Isanto, T., Altavilla, G., Esposito, G., D'Elia, F., & Raiola, G. (2022). Heuristic Learning and Sport: Theoretical Lines and Operational Proposals. *Encyclopaideia*, 69-80.
- D'Isanto, T., Aliberti, S., Raiola, G., & D'Elia, F. (2024). Assessment of motor skills in 5-6 year old Italian children using the MABC-2: a preliminary study. *Physical Activity Review*, 12(1).
- Di Domenico, F., Ceruso, R., Aliberti, S., & Esposito, G. (2024). Analyzing the Perception of the Impact of Sports Practice on Students in School Settings. *Physical Education Theory and Methodology*, 24(2), 276-282.
- Esposito, G., Di Domenico, F., Ceruso, R., Aliberti, S., & Raiola, G. (2024). Perceptions/opinions about the formation of the bachelor program in exercise and sports science by students aimed at the new professional profile of the basic kinesiologist. *Sport Sciences for Health*, 20(2), 659-664.
- Esposito, G., Ceruso, R., Aliberti, S., & Raiola, G. (2024). Ecological-dynamic approach vs. traditional prescriptive approach in improving technical skills of young soccer players. *Journal of Functional Morphology and Kinesiology*, 9(3), 162.
- Esposito, G. (2024). Effects of competitiveness in rhythmic gymnastics: a qualitative research. *Acta Kinesiologica*, 18(4), 54-63.
- Fournier, K. A., Hass, C. J., Naik, S. K., Lodha, N., & Cauraugh, J. H. (2010). Motor coordination in autism spectrum disorders: a synthesis and meta-analysis. *Journal of autism and developmental disorders*, 40(10), 1227-1240.
- Gallese, V. (2001). The 'shared manifold' hypothesis. From mirror neurons to empathy. *Journal of Consciousness Studies*, 8(5-6), 33-50.
- Hansen, S., Drew, C., Etchison, H., & Demarco, J. (2022). Using applied behavior analysis to teach adaptive skills. In *Handbook of autism and pervasive developmental disorder: Assessment, diagnosis, and treatment* (pp. 845-873). Cham: Springer International Publishing.
- Lovaas, O. I. (1987). Behavioral treatment and normal educational and intellectual functioning in young autistic children. *Journal of consulting*

and clinical psychology, 55(1), 3.

- Oakland, T., & Harrison, P. L. (Eds.). (2011). Adaptive behavior assessment system-II: Clinical use and interpretation. *Academic Press*.
- Pan, C. Y. (2011). The efficacy of an aquatic program on physical fitness and aquatic skills in children with and without autism spectrum disorders. *Research in Autism Spectrum Disorders*, 5(1), 657-665.
- Penedo, F. J., & Dahn, J. R. (2005). Exercise and well-being: a review of mental and physical health benefits associated with physical activity. *Current opinion in psychiatry*, 18(2), 189-193.
- Raiola, G., D'Elia, F., & Altavilla, G. (2018). Physical activity and sports sciences between European Research Council and academic disciplines in Italy. *Journal of Human Sport and Exercise*, 13, 283-295.
- Raiola, G., Esposito, G., Aliberti, S., D'Elia, F., & D'Isanto, T. (2025). Physical Exercise and Psychophysical Learnings on Basic Strength Development. *Methods and Protocols*, 8(2), 40.
- Rizzolatti, G., & Sinigaglia, C. (2010). The functional role of the parieto-frontal mirror circuit: interpretations and misinterpretations. *Nature Reviews Neuroscience*, 11(4), 264-274.
- SINPIA. (2022). Clinical guidelines for autism: Psychoeducational, rehabilitative and pharmacological interventions. Italian Society of Child and Adolescent Neuropsychiatry. https://sinpia.eu/wp-content/uploads/2023/03/Sinpia_3_22_def.pdf
- Taleb, M., Aliberti, S., & D'Isanto, T. (2021). Core training to reduce the performance gap between abled and disabled athletes in the canoe discipline. *Journal of Human Sport and Exercise*, 16(3), 1039-1044.
- Williams, K. L., Kirby, A. V., Watson, L. R., Sideris, J., Bulluck, J., & Baranek, G. T. (2018). Sensory features as predictors of adaptive behaviors: A comparative longitudinal study of children with autism spectrum disorder and other developmental disabilities. *Research in Developmental Disabilities*, 81, 103-112.

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EFFECTS OF DIFFERENT GROUP FITNESS PROGRAMS ON BODY COMPOSITION AND FUNCTIONAL CAPACITY

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Abstract: Group fitness programs are widely used as non-pharmacological interventions for improving body composition and functional capacity in women. However, limited evidence directly compares the effectiveness of different group exercise modalities under identical experimental conditions. Objective: To compare the effects of Zumba, women's fitness, and Pilates programs on body composition and aerobic capacity in adult women. A total of 101 healthy women were assigned to four groups: Zumba ($n = 23$), women's fitness ($n = 31$), Pilates ($n = 26$), and control ($n = 21$). Experimental groups participated in supervised training programs three times per week for 12 weeks (60 min/session), while the control group maintained habitual activities. Body composition was assessed using bioelectrical impedance analysis, and aerobic capacity was estimated through the UKK 2-km Walk Test. Mixed-design ANOVA and Cohen's d effect sizes were used to evaluate intervention effects. Significant group $\times$ time interactions were observed for all analyzed variables ($p < 0.01$). The Zumba group achieved the greatest reductions in body weight (-4.4 kg) and body fat percentage (-4.9%), alongside the largest increase in VO_{2max} ($+6.3$ ml $\cdot$ kg $^{-1}\cdot$ min $^{-1}$). The fitness group also demonstrated significant improvements in body composition and aerobic capacity, although to a lesser extent. Pilates produced moderate but significant improvements, while the control group showed negligible changes. Effect size analysis revealed large effects for Zumba in body fat reduction ($d = 1.09$), body water percentage ($d = 1.21$), and VO_{2max} ($d = 1.46$). Women's fitness showed large effects for VO_{2max} ($d = 1.01$), whereas Pilates generated small-to-moderate effects across variables. All three exercise programs positively influenced body composition and functional capacity in women. However, Zumba produced the most pronounced improvements in reducing adiposity and enhancing aerobic fitness, suggesting that high-volume aerobic group exercise may represent the most effective strategy for improving health-related fitness in adult women.

Keywords: Aerobic exercise, VO_{2max} , body fat percentage, women, Pilates, Zumba

INTRODUCTION

A reduced level of physical activity and an increase in obesity today are important health problems that negatively affect body composition (increase in the proportion of fat tissue and decrease in the proportion of muscle) and increase the risk of chronic diseases. The World Health Organization recommends that adults get at least 150–300 minutes of moderate-intensity or 75–150 minutes of high-intensity aerobic activity per week, including strength training, to improve functional capacity and general health. One of the popular forms of exercise, especially among women, are group fitness programs. These programs often include choreographed dance moves to music (eg, aerobics, Zumba®, combination workouts) and are supervised by instructors, making them engaging and fun for a wide range of participants. The main purpose of group fitness is to improve body composition (decreasing fat tissue, increasing muscle mass) and cardiorespiratory endurance, strength and flexibility.

Some studies show that group fitness programs can have a positive effect on body composition and health. For example, Barranco-Ruiz et al. (2019) found in a 16-week study that women who regularly participated in choreographed group training (Zumba and Zumba with body weight exercises) had significant improvements in parameters of body composition and cardiovascular health. Similarly, Špirtović et al. (2023) in a 12-week intervention with mixed aerobics recorded a decrease in body mass by about 2.5%, waist diameter by 3.4% and the percentage of fat tissue by 10.6%, with a significant increase in the proportion of muscle mass. Recent research by Špirtović et al. (2025) confirmed that different types of group aerobic programs (mix aerobics, kickboxing aerobics, step aerobics) during 12 weeks significantly reduce body mass and the proportion of fat tissue and improve the lipid profile in obese

young women. These results show that structured group training can lead to improvements in body composition and cardiometabolic status.

However, findings on the impact of group fitness programs are not always consistent. For example, Delestrat et al. (2015) reported that an 8-week Zumba intervention significantly increased maximal aerobic capacity (VO_{2max}) of participants but did not lead to significant changes in body composition. In other words, women achieved better results on endurance tests after the Zumba program (VO_{2max} +3.6%), but there was no statistically significant reduction in body fat. We find similar contradictory results in other studies: some (Bjelica, 2020) show improvements in body composition after Zumba and fitness training, while others (Delestrat et al., 2015) do not find significant changes in fat deposits.

In addition to aerobic dance programs, popular group fitness programs also include methods such as Pilates, which combines strength, stability and flexibility exercises. Gökalp and Kirmizigil (2025) showed that an 8-week reformer Pilates program in obese and overweight women significantly improved body composition and increased muscle strength and endurance. These results indicate that programs like Pilates, although less focused on cardio, can work to reduce fat content and increase muscle mass, which favors better functional ability of the exerciser.

Functional capacity, and thus cardiovascular performance, is often measured by estimating VO_{2max} . In field conditions, e.g. UKK 2-kilometer walking test, in which the subject walks 2 km as fast as he can, with time and heart rate measured at the end of the test. According to Otinwa (2005), based on the obtained values, the UKK Institute's formula is applied to calculate the fitness index (Fitness Index) or estimate VO_{2max} . This provides an objective indicator of the aerobic endurance of the exerciser, which can be compared with norms and progress can be monitored.

In light of the above findings, it is clear that group fitness programs can have a beneficial effect on body composition and functional capacity, but with certain limitations and variability of effects. Previous research shows that changes in body composition in women participating in group training are often modest and that they differ depending on the type of program, intensity and length of the intervention. Furthermore, increases in aerobic capacity were observed already after several weeks of exercise (eg a significant increase in VO_{2max} after 8 weeks of Zumba). Further systematic research comparing different group fitness programs – from dynamic aerobic training to strength and flexibility programs – is needed to more precisely determine their impact on weight loss, body fat percentage and improvement in fitness.

METHOD

Sample of participants

A total of 101 female participants participated in the research, divided into four groups: Zumba group ($n=23$), Fitness group ($n=31$), Pilates group ($n=26$) and control group ($n=21$). All subjects were healthy, with no recorded chronic diseases, injuries or medical conditions that could limit participation in exercise programs. Participation in the research was voluntary, and all respondents signed an informed consent before inclusion.

The average age of the subjects in the Zumba group was 32 ± 4.8 years, in the Fitness group 31 ± 5.1 years, in the Pilates group 29 ± 4.6 years, while in the control group the average age was 31 ± 5.0 years.

The average body height of the subjects was uniform between the groups. In the Zumba group it was 167.1 ± 5.8 cm, in the Fitness group 166.8 ± 6.2 cm, in the Pilates group 167.4 ± 5.6 cm, and in the control group 166.9 ± 5.9 cm, which indicates a high degree of sample homogeneity in terms of basic anthropometric characteristics.

The research is planned to be carried out in the fitness centers “Sparta” and “Elite Fit” in Pale, where the subjects from the experimental groups will attend organized group exercise programs, while the control group will continue with their usual daily activities without participating in a structured training program.

Sample of measuring instruments

The body composition of the test subjects was assessed using a multi-frequency body composition analyzer Tanita MC-545N (Tanita Corp., Tokyo, Japan), based on the bioelectrical impedance analysis (BIA) method. The device was used to determine body mass (kg), body fat percentage (%), muscle mass (kg), total body water (%) and metabolic age. All measurements were carried out according to the manufacturer's recommendations, under standardized laboratory conditions.

Aerobic capacity was assessed using the UKK 2-km Walk Test, a validated field test for assessing the cardio-

spiratory fitness of adults. During the test, the time needed to cover the distance of 2 km and the heart rate immediately after the end of the test were recorded.

Maximum oxygen uptake values ($\text{VO}_{2\text{max}}$; $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) were calculated using the standard UKK equation for women: $\text{VO}_{2\text{max}} = 116.2 - (2.98 \times \text{time}) - (0.11 \times \text{heart rate}) - (0.14 \times \text{age}) - (0.39 \times \text{BMI})$

In doing so, the body mass index (BMI) was used exclusively as a constituent element of the aforementioned equation for estimating $\text{VO}_{2\text{max}}$, and was not analyzed as a separate research variable.

Experimental program

The experimental program lasted 12 weeks, with a frequency of three training sessions per week, which makes a total of 36 training sessions per group. The duration of each training session was 60 minutes and included the introductory part (10 min), the main part (45 min) and the final part with stretching and relaxation exercises (5 min). The intensity of the exercise varied depending on the characteristics of the program and ranged from 65–85% of maximum heart rate (HRmax) in the Zumba group, 60–80% of HRmax in the Fitness group, and 50–70% of HRmax in the Pilates group. During the experimental period, the principle of progressive loading was applied through a gradual increase in the complexity of the exercises, the volume of work and the intensity of the load. Accordingly, the programs were organized through three consecutive phases: adaptation (weeks 1–4), development (weeks 5–8), and progressive phase (weeks 9–12). The characteristics and progression of the experimental programs are shown in Table 1.

Table 1. *Progression of experimental programs over 12 weeks*

Program phase	Zumba	Fitness	Pilates
S1–S4 Adaptation phase	Salsa, Merengue, Cumbia and Reggaeton basic steps; simple choreography; continuous aerobic work (65–70% HRmax)	Aerobic exercises, squats, lunges, thrusts, rowing with elastic bands; 2×12–15 repetitions; 60–65% HRmax	Hundred, Roll-Up, Single Leg Stretch, Spine Stretch; breathing control and activation of the body center; 50–60% HRmax
S5–S8 Development phase	More complex choreographies; changes in the direction of movement; longer aerobic intervals; 70–80% HRmax	Step aerobics, circuit training, squats, lunges, push-ups and rowing with dumbbells (1-3 kg); 3×12–15 repetitions; 65–75% HRmax	Double Leg Stretch, Shoulder Bridge, Side Kick Series, Swan; prolonged isometric contractions; 55–65% HRmax
S9–S12 Progressive phase	High-energy Zumba sequences; Salsa-Reggaeton-Cumbia combinations; shorter recovery intervals; 75–85% HRmax	Circuit training with aerobic and resistance exercises; squats, lunges, push-ups, push-ups, rows and trunk exercises; increased volume of work; 70–80% HRmax	Plank, Side Plank, Swimming, Teaser modifications and advanced stabilization exercises; 60–70% HRmax

Statistical data processing

Statistical data analysis was performed using the IBM SPSS Statistics 26.0 software package (IBM Corp., Armonk, NY, USA). Basic descriptive statistics were calculated for all analyzed variables, including arithmetic mean (M) and standard deviation (SD).

Before conducting inferential statistical procedures, the normality of data distribution was checked using the Shapiro–Wilk test, while the homogeneity of variances was assessed using Levene’s test. Considering that all the analyzed data met the requirements for the application of parametric statistical procedures, the results of the mentioned tests are not presented in the paper in order to avoid unnecessary load on the tabular presentation.

To evaluate the effects of the experimental treatment, an analysis of variance with repeated measurements (Mixed-design ANOVA) was used, where the time factor included two levels (initial and final measurement), while the group factor included four levels (Zumba, Fitness, Pilates and control group). The main effects of time and group were analyzed, as well as the interaction effect of group × time.

In order to assess the practical significance of the changes between the initial and final measurements, the effect size was calculated using Cohen’s coefficient (Cohen’s d). The obtained values were interpreted according to standard criteria: $d < 0.20$ negligible effect, $0.20–0.49$ small effect, $0.50–0.79$ moderate effect and ≥ 0.80 large effect. The level of statistical significance was set at $p < 0.05$.

RESULTS

The results of the initial measurement indicate a high degree of homogeneity between the experimental and control groups in all observed variables. The average values of body height ranged from 167.0 cm in the Zumba group, 168.5 cm in the Fitness group, 166.5 cm in the Pilates group and 167.8 cm in the Control group. Based on the graph

shown, a decrease in the value of the body mass index (BMI) can be observed in all experimental groups after the implemented exercise program. The largest decrease was recorded in the Zumba group ($24.8 \rightarrow 23.3$), followed by the Fitness group ($24.6 \rightarrow 23.4$), while the smallest change was registered in the Pilates group ($25.3 \rightarrow 24.7$). The control group showed a minimal reduction in BMI values ($24.8 \rightarrow 24.6$), which indicates a greater effect of organized exercise programs compared to no intervention.

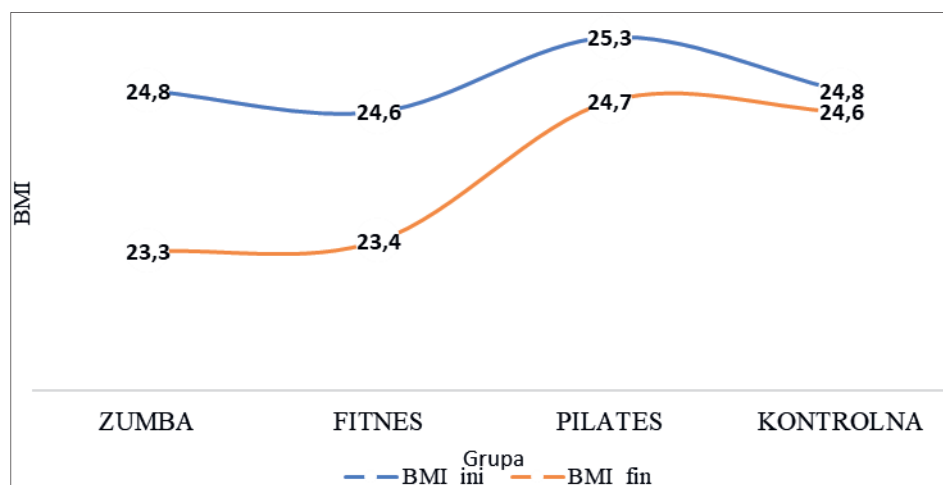


Chart 1. Tendency of change in BMI during the experimental treatment

The values of the total percentage of body fat were almost identical between the groups (34.5–35.1%). A similar pattern was observed in muscle mass, percentage of body water, metabolic age and total energy requirements. Initial values of VO_2max ranged between 31.1 and $31.8 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, which further confirms the comparable aerobic capacity of the subjects before the start of the intervention. This distribution of initial results enables a reliable assessment of the effects of applied programs during the experimental period.

Table 2. Descriptive parameters from the initial measurement

Variable	Zumba (n=23) M±SD	Fitness (n=31) M±SD	Pilates (n=26) M±SD	Control (n=21) M±SD
Body weight (kg)	69.3±9.6	69.8±10.4	70.1±8.9	69.9±9.8
Total fat (%)	34.8±4.6	35.1±4.9	34.5±4.2	34.9±4.8
Muscle mass (kg)	25.6±3.2	25.4±3.5	25.7±3.0	25.5±3.4
Water (%)	45.2±3.1	45.0±3.4	45.4±3.0	45.1±3.2
Metabolic years	43.8±6.3	44.2±6.5	43.6±5.9	44.0±6.2
Total requirements (kcal)	2038±212	2047±224	2029±205	2035±218
VO_2max ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$)	31.5±4.2	31.1±4.5	31.8±4.0	31.4±4.3

After the end of the intervention period, differences between the groups were evident in almost all analyzed variables. The most pronounced changes were recorded in the Zumba group, which achieved the lowest average body weight ($69.9 \pm 8.8 \text{ kg}$), the lowest body fat percentage ($29.9 \pm 4.2\%$) and the highest VO_2max value ($37.8 \pm 4.4 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). The fitness program also resulted in significant improvements, while the changes in the Pilates group were more moderate. The control group showed minimal oscillations between the initial and final measurements, with all values remaining almost unchanged. Observed between the groups, the results indicate a superior effect of the Zumba program in improving the body composition and functional abilities of the subjects.

Table 3. Descriptive parameters from the final measurement

Variable	Zumba (n=23) M±SD	Fitness (n=31) M±SD	Pilates (n=26) M±SD	Control (n=21) M±SD
Body weight (kg)	64.9±8.8	66.5±9.8	68.5±8.6	69.3±9.7
Total fat (%)	29.9±4.2	31.6±4.5	32.8±4.0	34.5±4.7
Muscle mass (kg)	27.8±3.3	27.1±3.4	26.6±3.0	25.6±3.3

Water (%)	49.0±3.0	47.8±3.2	46.8±2.9	45.2±3.1
Metabolic years	38.2±5.8	39.9±6.0	41.0±5.6	43.7±6.0
Total requirements (kcal)	2118±225	2102±219	2078±208	2032±216
VO ₂ max (ml·kg ⁻¹ ·min ⁻¹)	37.8±4.4	35.6±4.2	33.9±3.8	31.5±4.2

Analysis of the group $\times$ time interaction showed statistically significant effects for all analyzed variables ($p < 0.01$), which confirms that the changes during the experimental period depended on the type of applied program. The largest reduction in body weight was achieved in the Zumba group (-4.4 kg), followed by the Fitness (-3.3 kg) and Pilates group (-1.6 kg), while the control group recorded a minimal change (-0.6 kg). A similar trend was registered for body fat percentage, where the Zumba program led to the greatest reduction (-4.9%), with $F = 12.31$ $ip = .001$. The most pronounced increase in aerobic capacity was achieved in the Zumba group (+6.3 ml·kg⁻¹·min⁻¹), then in the Fitness (+4.5 ml·kg⁻¹·min⁻¹) and Pilates group (+2.1 ml·kg⁻¹·min⁻¹), while no practically significant change was registered in the control group. The highest F value was obtained precisely for VO₂max ($F = 15.86$; $p = .001$), which indicates that this variable was the most sensitive to the applied interventions.

Table 4. Mixed ANOVA (group $\times$ time)

Variable	Zumba ini/fin	Fitness ini/fin	Pilates ini/fin	Control ini/fin	F	Sig.
Body weight (kg)	-4.4	-3.3	-1.6	-0.6	8.94	.001
Total fat (%)	-4.9	-3.5	-1.7	-0.4	12.31	.001
Muscle mass (kg)	+2.2	+1.7	+0.9	+0.1	7.48	.001
Water (%)	+3.8	+2.8	+1.4	+0.1	9.85	.001
Metabolic years	-5.6	-4.3	-2.6	-0.3	6.72	.001
Total requirements (kcal)	+80	+55	+49	-3	4.11	.009
VO ₂ max (ml·kg ⁻¹ ·min ⁻¹)	+6.3	+4.5	+2.1	+0.1	15.86	.001

The effect size analysis showed clear differences in the effectiveness of the applied programs. The Zumba program achieved the greatest effects in all analyzed variables, with large effects registered for total fat ($d = 1.09$), body water ($d = 1.21$), metabolic age ($d = 0.89$) and especially VO₂max ($d = 1.46$). The fitness program also showed significant adaptations, with large effects for VO₂max ($d = 1.01$) and body water percentage ($d = 0.84$), while the effects on other variables were mostly moderate. The Pilates program produced small to moderate effects, with the largest effect recorded for VO₂max ($d = 0.53$). In contrast, the control group showed negligible effects in all analyzed indicators ($d = 0.02$ – 0.08), which confirms that the observed changes are the result of the applied experimental programs. Observing the overall pattern of results, it can be concluded that Zumba was the most effective modality for improving the body composition and functional capacities of the test subjects.

Table 5. Effect size (Cohen's d) for pre-post changes in anthropometric and functional variables across study groups

Variable	Zumba	Fitness for women	Pilates	Control
Body weight	0.48**	0.32**	0.18*	0.06*
Total fat (%)	1.09****	0.73***	0.39**	0.08*
Muscle mass (kg)	0.67***	0.50***	0.30**	0.03*
Water (%)	1.21****	0.84****	0.47**	0.04*
Metabolic years	0.89****	0.61***	0.42**	0.05*
Total requirements (kcal)	0.38**	0.25**	0.16*	0.02*
VO ₂ max (ml·kg ⁻¹ ·min ⁻¹)	1.46****	1.01****	0.53***	0.02*

Legend: Cohen's $d < 0.20$ = negligible effect*; Cohen's $d = 0.20$ – 0.49 = small effect**; Cohen's $d = 0.50$ – 0.79 = moderate effect***; Cohen's $d \geq 0.80$ = large effect****

The graphic display additionally confirms the results obtained by statistical analysis. The largest relative changes were recorded in the Zumba group, which achieved a 5.8% reduction in body mass, a 14% reduction in body fat and a 20% increase in VO_2max . The fitness program led to somewhat smaller but still pronounced adaptations, including a 14.5% increase in aerobic capacity and a 10% decrease in body fat. The Pilates group achieved moderate improvements in all observed indicators, while the changes in the control group were minimal and without practical significance. Viewed as a whole, the graph clearly shows that the intensity of positive changes was proportional to the demands and metabolic load of the applied programs, with Zumba achieving the most favorable adaptive response.

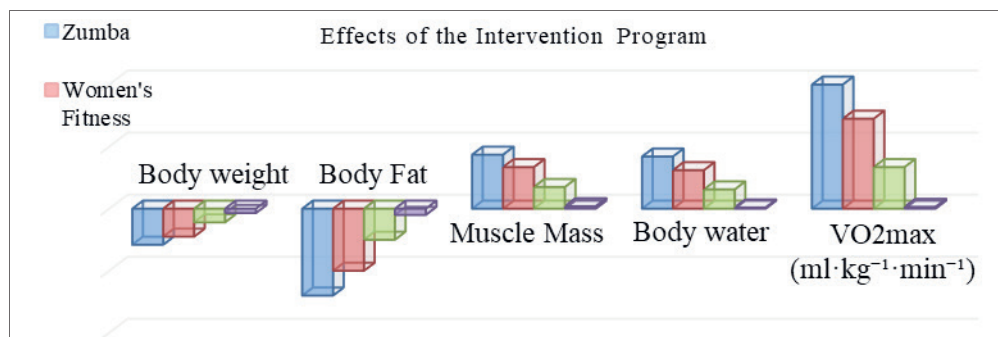


Chart 2. Changes Following the Intervention Program Between Groups

DISCUSSION

The results of this research showed that all three experimental programs led to positive changes in the parameters of body composition and functional abilities of women, with the greatest effect achieved in the Zumba group. The most pronounced changes were registered in the reduction of body fat percentage, increase in muscle mass, increase in body water and improvement of aerobic capacity. Such findings confirm earlier research indicating that group aerobic exercise programs are an effective strategy for improving the health status of women (Ljubojević et al., 2022).

The biggest changes in this research were recorded in the respondents included in the Zumba program. The decrease in body mass and percentage of body fat, with a simultaneous increase in VO_2max values, agree with the results of previous studies that showed that Zumba training leads to significant improvements in cardiorespiratory endurance and body composition in women of different ages (Donath et al., 2014; Ljubojević et al., 2022). A possible explanation for such results lies in the fact that Zumba involves continuous aerobic work of medium and high intensity with the engagement of large muscle groups for a long period of time.

The increase in VO_2max value was one of the most significant changes in this research. The obtained results confirm the findings of Donath et al. (2014), who state that Zumba training can produce significant cardiorespiratory adaptations due to high energy expenditure and the intermittent nature of the load. Also, a systematic review by Tsugusi et al. (2019) showed that regular participation in Zumba programs significantly improves aerobic capacity and reduces risk factors associated with a sedentary lifestyle.

The obtained results are additionally supported by a recent meta-analysis that showed that Zumba programs achieve a significant reduction in fat tissue and an increase in VO_2max values in adult women, with the greatest effects registered in programs lasting at least eight weeks (Chavarrias et al., 2021). These findings almost identically follow the results obtained in this research, where the biggest changes were recorded precisely in the parameters of aerobic capacity and body composition.

The fitness program for women also led to significant improvements in the analyzed variables. The obtained results support recommendations that highlight the benefits of combined aerobic-strength training for improving body composition and functional abilities of adult women (Garber et al., 2011). The simultaneous decrease in fat tissue and increase in muscle mass indicate a favorable adaptive response of the organism, which is also confirmed by the results of the meta-analysis by Schwingshackl et al. (2013).

The increase in muscle mass registered in the Fitness group can be explained by the combination of aerobic and resistance exercises, which represent a strong stimulus for muscle hypertrophy and preservation of lean body mass.

A systematic review by Zouit et al. (2023) showed that programs that include strength training components lead to significant improvements in muscle mass, body composition, and functional ability in women.

The Pilates program led to statistically significant, but slightly smaller changes compared to the other two experimental treatments. Similar results were reported by Cruz-Ferreira et al. (2011), who determined that Pilates improves functional abilities, body posture and muscular endurance, but has a smaller effect on fat tissue reduction compared to programs with a dominant aerobic component. Smaller effects in this research are probably a consequence of the lower energy expenditure characteristic of Pilates training.

Although the effects of the Pilates program were smaller compared to Zumba and the Fitness program, the results are in line with modern systematic reviews that indicate that Pilates can significantly improve certain parameters of body composition, especially the reduction of body mass and the percentage of fat tissue, but the effects are usually of moderate intensity (Pereira et al., 2022; Silva et al., 2022). Similarly, Parveen et al. (2023) conclude that Pilates is an effective intervention for improving women's health, especially in the domain of postural control, functional ability and quality of life, while changes in body composition are generally less pronounced than with higher intensity aerobic programs.

A particularly significant finding is the increase in muscle mass in all experimental groups. These results suggest that the reduction in body mass was not the result of a loss of lean body mass, but primarily of a reduction in adipose tissue. This finding is of practical importance because it confirms that properly programmed recreational activity can simultaneously improve body composition and preserve the muscular status of the organism (Garber et al., 2011).

The main contribution of this research is reflected in the direct comparison of three widely represented recreational programs in women using an identical experimental design. The obtained results indicate that all analyzed programs can represent effective models for improving women's health, with Zumba achieving the greatest effects on body composition and cardiorespiratory abilities.

The results of this research confirm the modern trend in the literature according to which programs with a dominant aerobic component have the greatest effects on reducing fat tissue and increasing cardiorespiratory fitness, while programs like Pilates show more significant effects in the domain of functional stability, posture and neuromuscular control. This pattern has been confirmed in several recent studies during the last few years (Pereira et al., 2022; Parveen et al., 2023; Chavarrias et al., 2021).

CONCLUSION

The results of this research show that Zumba, fitness and Pilates programs during 12 weeks led to statistically significant improvements in body composition and functional capacity of women. All experimental groups achieved a decrease in body mass and percentage of fat tissue, an increase in muscle mass and an improvement in aerobic capacity, while no significant changes were recorded in the control group.

The most pronounced effects were achieved in the Zumba program, which resulted in the greatest reduction in body mass and fat tissue and the greatest increase in VO_2max . The fitness program showed significant and practically important effects on most of the analyzed indicators, while Pilates led to moderate, but statistically significant improvements. The obtained findings indicate that programs with a dominant aerobic component achieve greater effects on improving body composition and cardiorespiratory capacity compared to programs with a lower metabolic load.

The practical value of this research is reflected in the confirmation that different forms of group fitness are effective models for improving the health status of women, whereby Zumba can be recommended as the most effective program for reducing fat tissue and improving aerobic fitness. Future research should include longer intervention periods, control of eating habits and monitoring of long-term maintenance of the achieved effects in order to further clarify the mechanisms of adaptation to different group fitness programs.

REFERENCES

- Barranco-Ruiz, Y., Ramírez-Vélez, R., Martínez-Amat, A., & Villa-González, E. (2019). Effect of two choreographed fitness group-workouts on the body composition, cardiovascular and metabolic health of sedentary female workers. *International Journal of Environmental Research and Public Health*, 16(24), 4986. <https://doi.org/10.3390/ijerph16244986>
- Bjelica, B. (2020). Effects of group fitness programs on the body composition of women. *Facta Universitatis Series: Physical Education and Sport*, 18(2), 345 – 354.
- Bull, FC, Al-Ansari, SS, Biddle, S., Borodulin, K., Buman, MP, Cardon, G., ... Willumsen, JF (2020). World Health Organization 2020 guidelines on physical activity and sedentary behavior. *British Journal of Sports Medicine*, 54(24), 1451–1462. <https://doi.org/10.1136>

bjsports-2020-102955

- Chavarrias, M., Villafaina, S., Lavín-Pérez, AM, Carlos-Vivas, J., Merellano-Navarro, E., & Pérez-Gómez, J. (2021). Zumba®, fat mass and maximum oxygen consumption: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, 18(1), 105. <https://doi.org/10.3390/ijerph18010105>
- Cruz-Ferreira, A., Fernandes, J., Gomes, D., Bernardo, LM, Kirkcaldy, BD, & Barbosa, TM (2011). Effects of Pilates-based exercise on life satisfaction, physical self-concept and health status in adult women. *Women & Health*, 51(3), 240–255. <https://doi.org/10.1080/03630242.2011.563417>
- Delextrat, A., Warner, S., Graham, S., & Neupert, E. (2015). An 8-week exercise intervention based on Zumba® improves aerobic fitness and psychological well-being in healthy women. *Journal of Physical Activity and Health*, 13(2), 125–131. <https://doi.org/10.1123/jpah.2014-0535>
- Donath, L., Roth, R., Hohn, Y., Zahner, L., & Faude, O. (2014). The effects of Zumba training on cardiovascular and neuromuscular function in healthy women. *European Journal of Sport Science*, 14(6), 569–577. <https://doi.org/10.1080/17461391.2013.866168>
- Garber, CE, Blissmer, B., Deschenes, MR, Franklin, BA, Lamonte, MJ, Lee, I.-M., Nieman, DC, & Swain, DP (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Medicine & Science in Sports & Exercise*, 43(7), 1334–1359. <https://doi.org/10.1249/MSS.0b013e318213febf>
- Gökalp, Ö., & Kırmızıgül, B. (2025). Effects of reformer Pilates on body composition, strength, and psychosomatic factors in overweight and obese women: A randomized controlled trial. *Scientific Reports*, 15, 23602. <https://doi.org/10.1038/s41598-025-09683-8>
- Ljubojević, A., Jakovljević, V., Popržen, M., & Drapšin, M. (2023). Effects of Zumba fitness program on body composition in women. *Healthcare*, 11(1), 72. <https://doi.org/10.3390/healthcare11010072>
- Otinwa, GO (2005). Adoption of the UKK walk test in the assessment of cardiorespiratory fitness of women. *Journal of the International Council for Health, Physical Education, Recreation, Sports and Dance*, XLI(3), 22–26.
- Parveen, A., Kalra, S., & Jain, S. (2023). Effects of Pilates on health and well-being of women: A systematic review. *Bulletin of the Faculty of Physical Therapy*, 28, 17. <https://doi.org/10.1186/s43161-023-00128-9>
- Pereira, MJ, Dias, G., Mendes, R., Mendes, RS, Martins, F., Gomes, R., Gama, J., Castro, MA, & Vaz, V. (2022). Efficacy of Pilates in functional body composition: A systematic review. *Applied Sciences*, 12(15), 7523. <https://doi.org/10.3390/app12157523>
- Schwingshackl, L., Dias, S., Strasser, B., & Hoffmann, G. (2013). Impact of different training modalities on anthropometric and metabolic characteristics in overweight and obese subjects. *PLoS ONE*, 8(12), e82853. <https://doi.org/10.1371/journal.pone.0082853>
- Silva, LL, Silva, KBM, Sousa, L., & Rocha, CP (2022). Is the Pilates method efficient to cause changes in the body composition of healthy individuals? A systematic review. *Journal of Bodywork and Movement Therapies*, 32, 51–59. <https://doi.org/10.1016/j.jbmt.2022.04.005>
- Špirtović, O., Caprić, I., Katanić, B., Govindasamy, K., Geantă, VA, Ardelean, VP, ... Stanković, M. (2025). Group aerobic exercise improves body composition and lipid profile in young women with elevated BMI: A randomized controlled trial. *Applied Sciences*, 15(13), 7489. <https://doi.org/10.3390/app15137489>
- Špirtović, O., Caprić, I., Stanković, M., & Društvo, M. (2023). The effects of preventive aerobics mix on body composition in healthy adult women. *Frontiers in Physiology*, 14, 1132619. <https://doi.org/10.3389/fphys.2023.1132619>
- Tsugusi, L., Manca, A., Bergamin, M., Di Blasio, A., Yeo, TJ, Crisafulli, A., & Mercuro, G. (2019). Zumba fitness and women's cardiovascular health: A systematic review. *Journal of Cardiovascular Medicine*, 20(10), 735–741. <https://doi.org/10.2459/JCM.0000000000000858>
- Zećirović, A., Čeremidžić, D., Joksimović, A., Čeremidžić, T., Joksimović, D., Aksović, N., ... Tobijašin, R. (2025). The effects of group fitness programs Zumba and MoFit on body composition parameters in women. *Life*, 15(8), 1225. <https://doi.org/10.3390/life15081225>
- Zouita, A., Darragi, M., Bousselmi, M., Sghaier, Z., Clark, CCT, Hackney, AC, Granacher, U., & Zouhal, H. (2023). The effects of resistance training on muscular fitness, muscle morphology, and body composition in elite female athletes: A systematic review. *Sports Medicine*, 53(8), 1709–1735. <https://doi.org/10.1007/s40279-023-01859-4>

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ENHANCING SHORT-PASS PERFORMANCE AND ENGAGEMENT THROUGH 5 V 5 SMALL-SIDED GAMES IN YOUNG FOOTBALL ATHLETES

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Abstract: This study aimed to examine the impact of 5v5 small-sided games on the short-pass performance and engagement of young football athletes aged 13 to 15. The study employed a one-group pretest and posttest design, consisting of 30 young football athletes. Every participant in the study underwent a six-week intervention consisting of three sixty-minute sessions per week. Each session began with a warm-up, followed by a ten-minute passing technique drill and a thirty-minute small-sided game with new rules to engage all participants. The research data was analyzed using an independent sample *t*-test. The results showed a statistically significant improvement in short-pass performance following the intervention ($t = -20.694$, $df = 29$, $p < 0.001$). In addition, engagement levels showed a statistically significant increase ($t = -13.861$, $df = 29$, $p < 0.001$) across all measured dimensions. These findings indicate that the 5 vs 5 small-sided games training program is effective in enhancing both short-pass performance and engagement. In conclusion, small-sided games can serve as an effective and practical training strategy to simultaneously develop skill performance and engagement. Practically, coaches can incorporate 5 vs 5 small-sided games into training sessions to simultaneously enhance short-pass performance and increase athletes' engagement.

Keywords: engagement, short pass, football, young athletes

INTRODUCTION

The ability to execute basic techniques is a crucial factor that needs to be considered in empowering the potential of young football athletes. The first technique a young athlete needs to master is short passing skills. This technique is crucial because it determines accuracy, timing, and tactical success during both offensive and defensive play (Hakman et al., 2018). Young athletes who possess good short passing skills will demonstrate consistent performance, quick decision-making, and the ability to adapt to various situations during training and matches (Wang et al., 2024). However, it is known that young athletes often struggle to execute consistent short passes under pressure, particularly in tight spaces or during critical moments that require quick decisions.

Relevant research indicates that a team's success is primarily determined by its mastery of passing skills (Tim & Ali, 2023). For young athletes, mastering short passing skills is crucial because it supports technical skills and tactical awareness in the game. The training program implemented by the coach is a significant factor in the level of short-passing mastery achieved by the athletes they coach. Traditional training programs are still predominantly implemented by coaches, thus failing to accommodate the real needs during matches. Traditional passing drills are generally done outside of an actual game, so they don't really show what it's like to be under pressure and how the game changes (Lindsay & Spittle, 2024).

Young athletes usually already have some fundamental technical skills, but they don't employ them consistently when the pressure is on. Athletes frequently fail to comprehend the game situation, make erroneous decisions, and lack precision in passing. Young athletes necessitate authentic game stimuli for the effective transfer of technical talents to a competitive environment. Therefore, conventional training models based on static drills are no longer adequate for the demands of the modern game. Thus, short-pass development must be designed through contextual training and close to real match situations (Clemente & Sarmiento, 2020).

Small-sided games (SSG) are a training methodology empirically demonstrated to enhance the technical, tactical, physiological, and physical abilities of young athletes (Clemente et al., 2021). The 5v5 SSG format offers high-

intensity play, more touches of the ball, and more frequent game interactions (Clemente et al., 2022). A study by (Anwar et al., 2024) shown that a diminished number of players necessitates quicker and more precise short passes owing to the constricted playing area. This situation provides an ideal environment for developing short-passing skills. Coaches can change the size of the field, the number of players, and the regulations of the game to fit their needs. These modifications enable players to engage with the ball and one another more intensely, facilitating rapid decision-making and enhancing their ability to manage stress during training (Machado et al., 2024).

Beyond technical aspects, player engagement in training also plays a crucial role (Zou et al., 2024). Engagement is a determining factor in successful learning because it influences an individual's focus, effort, and persistence (Wan et al., 2025). The impact of low athlete engagement in training is reduced creativity, competitiveness, and decreased motivation, ultimately affecting the quality of performance (Jiang et al., 2025). SSG, including the 5v5 format, has been shown to increase player cognitive and emotional engagement by providing a realistic challenge, natural competition, and a match-like rhythm (Yılmaz et al., 2025).

SSG has a favorable effect on both technical and psychological improvement. However, there is a gap in the literature regarding the specific impact of this approach on short-passing performance and athlete engagement. Research investigating the impact of SSG on short passing and engagement among young athletes within a singular intervention is evidently required. The research question, as defined above, is whether small-sided games can improve the short-pass performance and engagement of young football athletes. This study aims to investigate the impact of 5v5 SSG on the short-passing performance and engagement of young football athletes.

MATERIAL AND METHODS

This research employed an experimental method to investigate the effect of 5v5 SSG on short pass performance and engagement in young football athletes. The research design used a one-group pretest-posttest design, with a pre-test to assess baseline levels before treatment and a posttest to determine levels after treatment (Capili & Anastasi, 2024). This allowed for more accurate comparisons because it enabled comparisons between the before- and after-treatment periods.

Participants

Participants in this study were 30 young football athletes, selected using a purposive sampling technique (Campbell et al., 2020). Sampling criteria included volunteering and actively participating in training for at least six months, as well as being between 13 and 15 years of age. No sports injuries, and obtaining parental/guardian permission. All participants underwent a six-week intervention, consisting of three 60-minute sessions per week. Each session consisted of a warm-up, a 10-minute passing technique drill, and a 30-minute main training session (5v5 SSG), with modified rules to increase engagement.

Instruments

The short-pass performance test used in this study was adapted from a wall-volley soccer skill test, which requires players to perform repeated passes against a rebound surface (Johnson, 1962). The athlete waits behind the boundary line while holding the ball. The athlete kicks the ball against the backboard and bounces back towards him or the ball becomes uncontrollable. The athlete performs this movement as many times as possible within 39 seconds. The ball must be kicked from behind the boundary line using several kicking techniques learned in soccer. When the ball cannot be controlled, the athlete takes the spare ball that has been prepared, rather than chasing the uncontrolled ball.

The athlete engagement questionnaire was used to assess athlete engagement before and after participating in the SSG. This instrument consists of 20 statements divided into four indicators: cognitive engagement, emotional/affective engagement, behavioral engagement, and agentic engagement, which are widely recognized in the literature as core components of engagement (Reeve et al., 2025). Consists of five statements with a Likert scale (strongly disagree to strongly agree). The mean corrected item-total correlation value was 0.52. The reliability analysis revealed a Cronbach's alpha coefficient of 0.89.

Data analysis

Data normality was tested using the Shapiro–Wilk test, and data homogeneity was tested using the Levene test. A paired-sample t-test was subsequently conducted to determine whether the intervention resulted in a statistically significant difference between pre-test and post-test scores.

RESULTS

The results of this study are presented in several tables, which clearly demonstrate the improvement in athletes' engagement and short-pass performance through the use of SSG training.

Table 1. Descriptive data on short pass performance

Test	Mean	Median	Variance	Std deviation	Minimum	Maximum
Pre	28.43	29	18.94	4.35	22	36
Post	38.50	38	13.57	3.68	31	45

Based on the descriptive statistical data presented in Table 1, consistent positive developments in the short passing performance of athletes after receiving the SSG intervention can be identified. The pretest results showed an average score of 28.43 (SD = 4.35) with a score range of 22 to 36; most athletes fell into the moderate to low category. The posttest results showed a significant increase, with an average score of 38.5 (SD = 3.68) and a score range of 31 to 45. This increase indicates that the athletes' abilities have moved into the good and excellent categories. After participating in the SSG training program, there was an increase in ability and performance consistency among athletes. This is indicated by a decrease in the variance value from 18.94 to 13.57.

Table 2. Tests of Normality

	Shapiro-Wilk		
	statistic	df	Sig.
Pre	.944	30	.115
Post	.969	30	.507

Table 2 shows the results of the normality test using the Shapiro-Wilk test. Before starting the parametric analysis, this test is needed to ensure that the data meet the assumptions of a normal distribution. The results of the test show that the pretest has a statistical value of 0.944 with df of 30 and a significance value of p of 0.115. In contrast, the posttest has a statistical value of 0.969 with df = 30 and a significance value of p = 0.507. Both the pretest and posttest measurements have a normal distribution, as indicated by the significance values, which are above the alpha threshold of 0.05. These results indicate that the data meet one of the main requirements for the success of the paired sample t-test.

Table 3. Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
1.662	1	58	.208

Table 3 presents the results of the Levene test for homogeneity of variance, applied to the short pass performance data. This test is conducted to ensure that the variance between the two data groups (pretest and posttest) is the same or homogeneous. The test results show a Levene statistic value of 1.662 with degrees of freedom of 1 (df1) and 58 (df2), respectively, and a significance value of p of 0.208. There is no significant variance between the pretest and posttest data, as indicated by a significance value greater than 0.05. Therefore, the variance in both data groups is homogeneous. Thus, the data meet the requirements for analysis using a paired sample t-test. Therefore, the variance in both data groups is homogeneous. Thus, the data meet the criteria for analysis using a paired sample t-test.

Table 4. Paired Sample t-test

t	df	Sig. (2-tailed)
-20.694	29	.000

Paired test results, a sample t-test to determine the difference in short pass performance between the pretest and posttest, are shown in Table 4. The results of the analysis show a t-value of -20.694, with degrees of freedom is 29, and the significance value (2-tailed) is 0.000. These results statistically demonstrate that the 5 v 5 format SSG training program is efficacious in improving short-pass performance in young athletes.

Table 5. Descriptive data on athlete engagement

Test	Mean	Median	Variance	Std deviation	Minimum	Maximum
Pre	68.9	68	17.33	4.16	62	79
Post	77.8	77.5	24.85	4.96	70	88

Table 5 presents descriptive statistics of athlete engagement before and after participating in the SSG training program. With a mean of 68.9 and a median of 68, pretest measures revealed a comparatively symmetrical distribution of data. Athletes' levels of engagement varied quite uniformly, with a variation of 17.33 and a standard deviation of 4.16. Posttest results showed an increase, with a minimum score of 62 and a maximum of 79, indicating that the athletes' initial engagement level fell within the good category. After six weeks of the SSG intervention, posttest results showed an increase with a mean of 77.8 and a median of 77.5. The variance increased to 24.85 and the standard deviation to 4.96, indicating greater variation among athletes in the program. Engagement levels changed from the better to very good category, with a minimum score of 70 and a maximum score of 88.

Table 6. Tests of Normality

	Shapiro-Wilk		
	statistic	df	Sig.
Pre	.960	30	.304
Post	.961	30	.335

Table 6 shows the results of the normality test using the Shapiro-Wilk test for athlete engagement data. The data were tested to meet the normal distribution assumption required for parametric analysis. The results showed that the pretest statistical value was 0.960 with $df = 30$ and sig 0.304. The posttest statistical value was 0.961 with a $df = 30$ and sig = 0.335. Athlete engagement data in the pretest and posttest measurements were normally distributed, as indicated by two significance values above the alpha threshold of 0.05. These results indicate that the data meet the requirements for paired sample t-test analysis and validate the use of parametric tests.

Table 7. Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
.680	1	58	.413

Table 7 presents the results of Levene's test for homogeneity of variance, applied to the athlete engagement data. This is a crucial assumption in parametric statistical analysis, and the purpose of this test is to verify that the variance between the pretest and posttest data groups is homogeneous. A significance value significantly greater than 0.05 indicates that there is no significant variance between the pretest and posttest athlete engagement data. Therefore, it can be concluded that the variance in both data groups is homogeneous, which meets the assumption of homogeneity and validates the use of the paired-sample t-test for further analysis.

Table 8. Paired Sample t-test

t	df	Sig. (2-tailed)
-13.861	29	.000

Table 8 showed that the 5 vs 5 format SSG training program is effective in increasing athletes' cognitive, emotional, behavioral, and agentic engagement during the training process. The 5v5 SSG intervention makes a statisti-

cally significant and valuable difference in the development of young football athletes. The SSG training program can be an effective strategy for training young athletes.

DISCUSSION

The findings of this study underscore the importance of implementing 5v5 SSG to improve short pass performance and engagement in young soccer athletes aged 13-15 years. The 5v5 SSG structure increases ball-touch intensity, speed of decision-making, and technical quality, making the implementation of the 5v5 SSG structure effective in improving short pass in young football athletes (Anwar et al., 2024). With a smaller field and fewer players, players engage more frequently in actions such as receiving, controlling, and passing the ball (Halouani et al., 2019). This leads to natural repetition, which significantly improves the quality of short passes. According to other studies, SSG has a significantly higher level of player interaction compared to conventional training methods (Clemente, 2025). Ultimately, this leads to improvements in technical abilities such as passing speed and accuracy (Gunawan & Rahman, 2023).

Additionally, the 5v5 SSG structure creates more tangible time and space pressure, forcing players to scan, control the ball, and pass in a shorter amount of time. These limited conditions help players understand the game situation and choose fast, progressive, or safe passing paths (Xu et al., 2024). Players must also maintain proper body orientation to enable effective ball control and a quality first touch. It has been shown that good ball control under pressure is crucial for improving the quality of short passes (Coutinho et al., 2023).

From a tactical perspective, the 5v5 game has small interaction patterns such as triangles, walls pass, and supporting play. These patterns teach players how to open up space, maintain distance, and create effective passing lanes (Zlojutro et al., 2023). The abilities of players who frequently face situations like this improve when they use short passes to maintain the rhythm of the game. In addition, because the entire team interacts with each other at closer range, communication between players improves, which results in more coordination in short ball play (Sarmiento et al., 2018).

Overall, the 5 vs 5 SSG structure creates a training environment full of technical and tactical pressure, while remaining relevant to real-life match situations. SSG is an excellent technique for improving short passing skills in young football athletes due to its high intensity, technical repetition, game pressure, and quick decision-making (Ferraz et al., 2025). Empirical evidence shows that SSG improves technique and accelerates skill transfer from training to matches (Sgrò et al., 2018). Therefore, implementing 5 vs 5 is an effective and proven method for improving short passing performance in youth athlete training.

Because this game format creates an active, intense, and meaningful learning environment, the implementation of SSG has been shown to increase player engagement in young soccer athletes (Pop et al., 2022). Each player in an SSG has more opportunities to participate in technical actions such as passing, dribbling, shooting, moving without the ball, and making tactical decisions (Clemente et al., 2021). The increased physical, cognitive, and emotional engagement during training is directly influenced by the higher frequency of activity (Fernandez-Espinola et al., 2020). SSG ensures that almost all players are involved in the game at all times, unlike 11 vs. 11 games, which tend to make some players less active during particular phases.

In smaller spaces, players must constantly move, communicate, position themselves, and work together to cooperate. This compact game environment keeps players continually engaged, leaving them little time to wait for the ball or be passive (Entezari et al., 2023). Due to the high frequency of actions per minute, SSG significantly increases players' physical and technical stimulation (Han et al., 2025). This is a key factor in boosting engagement: players feel more "in the game," more active, and more mentally and emotionally involved.

For motivation, SSG fosters a friendly yet competitive atmosphere. Young players can become more motivated by playing games that resemble real matches but are scaled down in size, as they can encounter difficulties that are appropriate for their skill level and receive immediate feedback on the game's progress (Romdhani et al., 2023). Other studies suggest that SSG can improve team cohesion, competency, and emotions of autonomy (Yilmaz et al., 2025). These three psychological elements are essential for the best possible participation in sports. Young players are more motivated, concentrated, and willing to take chances when they receive training.

Additionally, SSG increases cognitive engagement, particularly in decision-making (Couto et al., 2022). Rapidly changing game situations require players to constantly study the movements of their opponents and teammates,

activate options, and strategize. This condition keeps players mentally alert and fully engaged in the game. Cognitive engagement is crucial for young players because it accelerates the development of play intelligence, also known as game intelligence, which is difficult to develop with statistical drill techniques (Machado et al., 2024).

Overall, SSG creates a training environment that allows players to engage in more activities, encourages them to do so, and increases their attention levels. SSG is a great way to increase engagement in young soccer athletes due to the high intensity of activity, quick decisions, lots of ball contact, and an enjoyable playing experience (Gok et al., 2023). The learning process and development of technical and tactical skills are also more effective and sustainable with high engagement (Paun et al., 2025).

The results of this study add to the scientific literature on how SSG helps young football athletes with skills and psychology. However, several limitations of this study should be considered. First, generalizability may be limited to a broader group of young athletes due to the small sample size and lack of a control group. Second, the use of a conventional questionnaire instrument to measure athlete engagement may introduce bias. Additionally, because of the brief length of the intervention, this study was unable to evaluate long-term changes associated with engagement development and short-term pass improvement.

These restrictions do not limit its applicability in the actual world. This study demonstrates to coaches that SSG implementation may be a crucial tactic in programs designed to develop young athletes. Coaches can change match formats to alter technical focus, intensity, and engagement. Additionally, this study suggests that incorporating SSG into regular training regimens can help young athletes enhance training efficacy while maintaining the quality of their educational experiences.

CONCLUSION

Small-sided games with a 5v5 format are an innovative training model for enhancing short-pass performance and engagement in young soccer athletes aged 13-15. However, several limitations of this study should be considered. First, generalizability may be limited to a broader group of young athletes due to the small sample size and lack of a control group. Second, the use of a conventional questionnaire instrument to measure athlete engagement may introduce bias. Additionally, because of the brief length of the intervention, this study was unable to evaluate long-term changes associated with engagement development and short-term pass improvement. Further research is recommended to include decision-making variables, comparisons with other small-sided game formats, and longer durations.

REFERENCES

- anwar, G. M., Hanief, Y. N., Supriatna, S., Azidin, R. M. F. R., Amiq, F., Muslim, B. A., & Carmen, M. (2024). Examining the influence of eight weeks of small-sided games (SSGs) enhancing pass accuracy and eye-foot coordination: a factorial experimental design. *Journal of Physical Education and Sport*, 24(2), 275–282. <https://doi.org/10.7752/jpes.2024.02033>
- Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., Bywaters, D., & Walker, K. (2020). Purposive sampling: complex or simple? Research case examples. *Journal of Research in Nursing*, 25(8), 652–661. <https://doi.org/10.1177/1744987120927206>
- Capili, B., & Anastasi, J. K. (2024). An Introduction to Types of Quasi-Experimental Designs. *American Journal of Nursing*, 124(11), 50–52. <https://doi.org/10.1097/01.NAJ.0001081740.74815.20>
- Clemente, F. M. (2025). The enjoyment of small-sided games: a narrative review. *Human Movement*, 26(1), 1–14. <https://doi.org/10.5114/hm/197230>
- Clemente, F. M., Ramirez-campillo, R., & Sarmiento, H. (2021). Effects of Small-Sided Game Interventions on the Technical Execution and Tactical Behaviors of Young and Youth Team Sports Players: A Systematic Review and. *Frontiers in Psychology*, 12, 1–13. <https://doi.org/10.3389/fpsyg.2021.667041>
- Clemente, F. M., & Sarmiento, H. (2020). The Effects Of Small-Sided Soccer Games On Technical Actions And Skills: A Systematic Review. *Human Movement*, 21(3), 100–119. doi: 10.5114/hm.2020.93014
- Clemente, F. M., Silva, A. F., Kawczyński, A., Yıldız, M., & Chen, Y. S. (2022). Physiological and locomotor demands during small-sided games are related to match demands and physical fitness? A study conducted on youth soccer players. *BMC Sports Science, Medicine and Rehabilitation*, 14, 1–10. <https://doi.org/10.1186/s13102-022-00535-w>
- Coutinho, D., Kelly, A. L., Santos, S., Figueiredo, P., Pizarro, D., & Travassos, B. (2023). Exploring the Effects of Tasks with Different Decision-Making Levels on Ball Control, Passing Performance, and External Load in Youth Football. *Children*, 10(220), 1–16. <https://doi.org/10.3390/children10020220>
- Couto, M., Rodrigues, J., Figueiredo, L. S., Andre, C., Lira, B. De, Conti, G. De, & Costa, T. (2022). Cognitive processes in small-sided games (Procesos cognitivos en pequeños juegos). *Retos: Nuevas Tendencias En Educación Física*, 44, 897–906. <https://doi.org/10.47197/retos.v44i0.90369>
- Entezari, M., Shams, A., & Bahram, A. (2023). Effectiveness of Small-Sided Games (SSG) Training on Mental Toughness, Physical Activity Enjoyment and Performance of Soccer Players. *Sport Psychology Studies*, 12(44), 73–96. https://spsyj.sscc.ac.ir/article_2578.html?lang=en
- Fernandez-Espinola, C., Robles, A. M. T., & Fuentes-Guerra, F. J. (2020). Small-Sided Games as a Methodological Resource for Team Sports

- Teaching : A Systematic Review. *International Journal of Environmental Reserach and Public Health*, 17, 1–21. <https://doi.org/10.3390/ijerph17061884>
- Ferraz, M., Garganta, J., Bagatin, R., & Barreira, D. (2025). Assessing physical , technical , and tactical performance of youth football players in small-sided games : a systematic review. *Retos: Nuevas Tendencias En Educación Física*, 66, 206–225. doi: 10.47197/retos.v66.110366
- Gok, Y., Suel, E., & Soylu, Y. (2023). Effects of different small-sided games on psychological responses and technical activities in young female basketball players. *Acta Gymnica*, 53, 1–6. <https://doi.org/10.5507/ag.2023.006>
- Gunawan, G., & Rahman, A. (2023). Effect of 5 VS 5 Small Sided Games (SSGs) Training on Passing Accuracy of U-16 Football Athletes. *Journal of Physical and Outdoor Education*, 5(2), 50–59. <https://doi.org/10.37742/jpoe.v5i2.204>
- Hakman, A., Vaskan, I., Kljus, O., Liasota, T., Palichuk, Y., & Yachniuk, M. (2018). Original Article Analysis of the acquisition of expertise and mastery of physical skills for performing techniques by young footballers. *Journal of Physical Education and Sport*, 18(2), 1237–1242. <https://doi.org/10.7752/jpes.2018.s2184>
- Halouani, J., Ghattasi, K., Bouzid, M. A., Rosemann, T., Nikolaidis, P. T., Chtourou, H., & Knechtel, B. (2019). Physical and Physiological Responses during the Stop-Ball Rule During Small-Sided Games in Soccer Players. *Sports*, 1(117), 1–8. <https://doi.org/10.3390/sports7050117>
- Han, X., Li, L., Chen, J., Xu, W., Trybulski, R., & Clemente, F. M. (2025). Comparing The Effects of Small-Sided and Medium-Sided Soccer Games on Physical Fitness Adaptations in Untrained Men : A Randomized Controlled Study. *Journal of Sports Science and Medicine*, 24, 142–153. doi: 10.52082/jssm.2025.142
- Jiang, C., Razak, N. A., & Rasyid, N. M. (2025). Need-supportive coaching and engagement in Chinese high school football players : a serial mediation model. *Frontier in Psychology*, January, 1–12. <https://doi.org/10.3389/fpsyg.2024.1466985>
- Johnson, J. R. (1962). *The development of a single-item test as a measure of soccer skill*.
- Lindsay, R., & Spittle, M. (2024). The adaptable coach – a critical review of the practical implications for traditional and constraints-led approaches in sport coaching. *International Journal of Sports Science & Coaching*, 19(3), 1240–1254. <https://doi.org/10.1177/17479541241240853>
- Machado, G., González-villora, S., Roca, A., & Teoldo, I. (2024). Developing cognitive and motor decision-making skills through tactical principles and small-sided games in youth soccer. *International Journal of Performance Analysis in Sport*, 24(5), 444–463. <https://doi.org/10.1080/24748668.2024.2321039>
- Paun, G., Enoiu, R. S., & Dima, M. D. (2025). Small-Sided Games in Youth Football : Advancing Technical – Tactical Performance and Social Inclusion for Sustainable Development. *Sustainability*, 17, 1–18. <https://doi.org/10.3390/su17219563>
- Pop, R.-M., Grosu, V. T., Grosu, E. F., Zadic, A., Mata, L., & Dobrescu, T. (2022). The Effects of Small-Sided Games and Behavioral Interventions on the Physical and Motivational Outcomes of Youth Soccer Players. *International Journal of Environmental Research and Public Helath*, 19, 1–12. <https://doi.org/10.3390/ijerph192114141>
- Reeve, J., Basarkod, G., & Ryen, H. (2025). Specialized Purpose of Each Type of Student Engagement : A Meta - Analysis. In *Educational Psychology Review* (Vol. 37, Issue 1). Springer US. <https://doi.org/10.1007/s10648-025-09989-z>
- Romdhani, Z., Ceylan, H. I., Hammami, R., Sahli, F., Dhahbi, W., Souissi, N., Zghibi, M., Oliveira, R., Morgans, R., & Nikolaidis, P. T. (2023). Small-sided-games with coaches ' verbal encouragement have a positive effect on aerobic performance , mood state , satisfaction and subjective effort in male semi-professional soccer players. *Journal of Mens 's Health*, 20(2), 1–10. <https://doi.org/10.22514/jomh.2024.018>
- Sarmento, H., Clemente, F. M., Harper, L. D., Teoldo, I., Owen, A., Figueiredo, A. J., Sarmento, H., Clemente, F. M., Harper, L. D., Costa, T., Owen, A., & Figueiredo, A. J. (2018). Small sided games in soccer – a systematic review. *International Journal of Performance Analysis in Sport*, 1–57. <https://doi.org/10.1080/24748668.2018.1517288>
- Sgrò, F., Bracco, S., Pignato, S., & Lipoma, M. (2018). Small-Sided Games and Technical Skills in Soccer Training: Systematic Review and Implications for Sport and Physical Education Practitioners. *Journal of Sports Science*, 6, 9–19. <https://doi.org/10.17265/2332-7839/2018.01.002>
- Tim, T., & Ali, A.-Y. (2023). Greater numbers of passes and shorter possession durations result in increased likelihood of goals in 2010 to 2018 World Cup Champions. *PLoS ONE*, 18(1), 1–12. <https://doi.org/10.1371/journal.pone.0280030>
- Wan, B., Huang, H., Sha, X., Zhong, C., & Shui, Y. (2025). Adolescent Athlete Engagement and Team Cohesion in Football : A Moderated Mediation Model with Gender-Based Insights. *Behavioral Sciences*, 15(9), 1–17. <https://doi.org/10.3390/bs15091264>
- Wang, B., Wan, B., Chen, S., Zhang, Y., Bai, X., Xiao, W., Tang, C., & Long, B. (2024). A Systematic review of the factors that affect soccer players ' short - passing ability — based on the Loughborough Soccer Passing Test. *BMC Sports Science, Medicine and Rehabilitation*, 16(96), 1–17. <https://doi.org/10.1186/s13102-024-00880-y>
- Xu, Q., Silva, R. M., Qi, K., Ma, D., Li, T., & Clemente, F. M. (2024). Physiological and locomotor variations of 3v3 and 5v5 small-sided games soccer formats : A 4-month study on sedentary young adults. *Sports Science, Exercise, and Helath*, 107(1), 1–16. <https://doi.org/10.1177/00368504231224606>
- Yılmaz, O., Jahrami, H., Batalik, L., Trabelsi, K., Ammar, A., & Soylu, Y. (2025). Verbal encouragement in coaching : enhancing small-sided game performance in youth basketball players. *Frontiers in Psychology*, 16, 1–9. <https://doi.org/10.3389/fpsyg.2025.1512803>
- Zlojutro, N., Eler, S., Joksimovic, M., Eler, N., Markovic, S., Kukric, A., & Goranovic, K. (2023). Kinematic parameters and metabolic power in elite soccer players : A small sided a large sided games comparison. *Frontiers in Physiology*, 14(April), 1–8. <https://doi.org/10.3389/fphys.2023.1150713>
- Zou, Y., Wang, Z., Zhang, S., Hu, J., Liu, H., & Silva, G. (2024). Development and initial validation of the Engagement in Athletic Training Scale. *Frontier in Psychology*, 1–14. <https://doi.org/10.3389/fpsyg.2024.1402065>

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EVALUATION OF FOREHAND AND BACKHAND TECHNIQUE: AN EXPERIMENTAL STUDY OF TRAINING EFFECTIVENESS IN TABLE TENNIS

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Abstract: Various techniques in the game of table tennis are studied in depth to improve the performance of athletes. The research focuses on the analysis of aspects of the game such as technical skills, biomechanics, and the level of effectiveness. This study was to look at the effectiveness of forehand and backhand skills in table tennis games. This research is included in the type of ex post facto research, where the measurement or testing of forehand and backhand hitting skills in table tennis games is carried out on students who have participated in table tennis lectures for 16 meetings, with a total of 24 participants. The learning process was conducted through structured sessions, ensuring that all participants received equal opportunities for practice using adequate facilities. Skill assessment was administered after the completion of the instructional program. Data analysis involved testing the normality of the data distribution, followed by the application of both parametric and non-parametric statistical approaches to compare forehand and backhand performance. The findings revealed that forehand performance tended to follow a normal distribution, while backhand performance showed slight deviations from normality. However, the results from both statistical approaches consistently indicated that there was no significant difference between forehand and backhand skills. Visual analysis further supported these findings, showing that forehand data aligned more closely with the expected distribution pattern, whereas backhand data demonstrated minor irregularities. In conclusion, beginner students exhibit relatively balanced development of forehand and backhand skills following structured learning. These findings suggest that the instructional approach applied in the learning process is effective in promoting proportional skill acquisition. The study emphasizes the importance of balanced technical training in early stages of learning and highlights the need for further research to explore additional factors that may influence skill development in table tennis.

Keywords: Table Tennis; Performance Sport; Training Method

INTRODUCTION

The technique of playing table tennis has been studied extensively to improve the performance of the players. The research is focused on the analysis of various aspects of the game, including technical skills, biomechanics, and effectiveness. The main techniques identified included spin, block, chop, push, and drive, with spin being the most dominant (44.179%) in high-level play (Yulianto, 2015). Biomechanical studies have compared fast break and curving ball techniques, which reveal differences in racket speed during different phases of the stroke (Mao, 2012). Evaluation of the effectiveness of elite players' techniques has led to the development of formulas and criteria for assessing performance, with Chinese players generally excelling in most techniques compared to their international counterparts (Zhang et al., 2013). These studies provide valuable insights for players and coaches, highlighting the importance of mastering certain techniques and understanding their biomechanical aspects to achieve a high level of performance in table tennis.

Recent studies on table tennis playing techniques reveal significant differences between male and female players at a high level. Men tend to prefer forehand techniques and offensive shots, specifically flips, while women use defensive punches and backhand techniques more (Malagoli Lanzoni et al., 2024; Pradas de la Fuente et al., 2023). Women generally play more shots per rally and game compared to men (Malagoli Lanzoni et al., 2024). Top players show versatile technical skills, with attack after serve being an important technique for scoring points (Sung, 2019). The heart rate response during the match showed an average rate of 142.69 bpm and a peak rate of 167.26 bpm,

with forehand shots accounting for 57.88% of the total strokes (Picabea et al., 2022). Service placement usually targets areas close to the net, while subsequent shots are often directed to backhand corners (Malagoli Lanzoni et al., 2024). These findings highlight the importance of tailoring training sessions to address gender-specific playstyles and technical-tactical needs.

Recent studies on table tennis strokes have revealed important insights into technique, performance, and neural activity. Gender differences in punch kinematics were observed, with men using larger muscle groups and achieving higher hand acceleration compared to women (Bańkosz et al., 2020). The non-playing hand was found to move symmetrically with the playing hand during the topspin forehand, which could potentially support the punch (Winiarski et al., 2021). Neural efficiency in experts is demonstrated through lower cortical activation compared to beginners during forehand and backhand strokes, despite superior performance (Carius et al., 2023). To improve backhand accuracy in beginner players, external focus of attention (on the ball or table target) has been shown to be more effective than internal focus (on the hand), which supports the benefit of external cues in skill acquisition (Niżnikowski et al., 2022). These findings contribute to our understanding of stroke mechanics, skill-related differences, and effective training strategies in table tennis.

Table tennis is a popular sport among students that develops a wide range of skills, including coordination, speed, and accuracy (Zhukovskyi et al., 2020). For beginners, innovative teaching methods can enhance learning. Video analysis of forehand techniques helps students understand proper movements and correct mistakes (Chichenova, 2021). Reflective board devices have been shown to effectively improve forehand and backhand drive skills in beginner players (Hanim & Tomoliyus, 2019). Structured lessons typically include warm-ups, main exercises, and cool-downs, with coordination exercises placed at the beginning of the session (Zhukovskyi et al., 2020). The Confederation of Table Tennis Brazil and the University of Campinas have developed a comprehensive entry-level course that includes Olympic and Paralympic table tennis (Belli & Galatti, 2021). This approach can help beginners develop proper technique and improve their overall performance in table tennis. The main objective of this study is to see the effectiveness of table tennis learning on forehand and backhand shots.

METHOD

Design

This research is ex post facto research, where this research method examines the cause-effect relationship in events or events that have occurred (Darajat & Abduljabar, 2014). The measurement or test of forehand and backhand hitting skills in table tennis games was carried out on table tennis lecture students who had carried out lectures for 16 meetings with a total of 24 students, consisting of male and female students who were beginner students or had never played table tennis.

Instrument

The instrument used in this study is the backboard test in table tennis games. The backboard test has a validity value of 0.615 and a reliability value of 0.738; the purpose of this test is to measure beginner table tennis playing skills (Rumondor et al., 2022). The test backboard is a test where the testee makes a shot independently by reflecting the results of the shots to the wall of the table tennis table that is arranged vertically. The testee took the test for 30 seconds with a chance of 3 times, and the highest score was taken.

Procedure

The following is the research procedure carried out in this study, where the respondents carried out and participated in table tennis learning for many as 16 meetings. Table tennis learning is carried out for 2 x 50 minutes in each session with the number of tables used as many as 6 ping pong tables so that each student has the same opportunity to do treats. The skills test was conducted at the 17th meeting after the learning was completed.

RESULT

Here is a description of the test results of forehand and backhand skills in table tennis learning, as seen in table 1.

Table 1. Description of Forehand and Backhand Skill Results Data

	Types of Strokes	N	Mean	Hours of deviation	Std. Error Mean
Table tennis skills	Forehand	24	43.67	15.85	3.23
	Backhand		49.42	17.81	3.63

The results of the table tennis skills test in table 1 show the test score results of 24 respondents with an average forehand score of 43.67, a standard deviation of 15.85, and a standard error of 3.23. As for the backhand shot, it shows an average score of 49.42, with a standard deviation of 17.81 and a mean standard error of 3.63. Looking at the average score in Table 1 shows that the average score of the backhand shot has a higher success effectiveness than the forehand shot.

Furthermore, to see if there is a significant difference in the effectiveness of table tennis learning on forehand and backhand strokes, an independent samples test was conducted. Table 2 shows the results of the statistical test of independent samples by using SPSS.

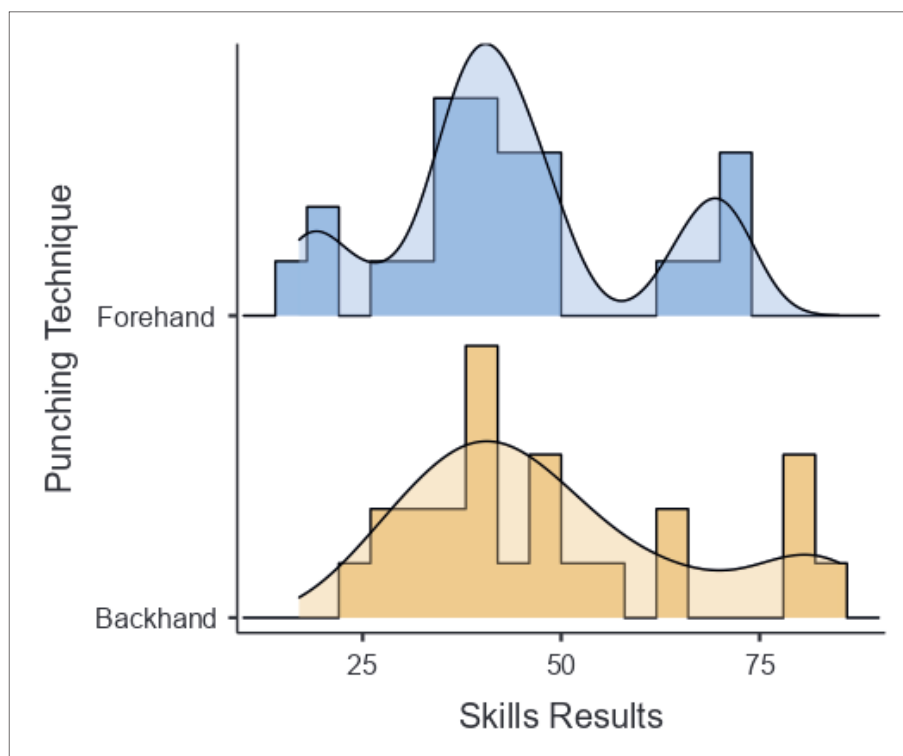


Figure 1. Density and histogram of test result data

Figure 1 show the distribution of skill results based on forehand and backhand stroke techniques exhibited distinct characteristics. For the forehand technique, data were spread over a fairly wide range, with a tendency toward a less symmetrical distribution and mild multimodality. The largest concentration of scores was in the mid-range (around 40–55), but there were also clusters of high scores, indicating variation in performance between subjects. Meanwhile, the backhand distribution tended to be more centralized and formed a unimodal pattern with a peak in the 35–50 range. Nevertheless, variation was still evident through the spread of scores into the high range, albeit with a lower frequency. Overall, both techniques had relatively similar score ranges, but forehand showed greater variation than backhand. This indicates that forehand ability is more heterogeneous among individuals, while backhand tends to be more consistent. Furthermore, both distributions did not fully follow a normal pattern, as indicated by skewness and uneven data distribution. These findings suggest the need for more specific training approaches for each technique to optimize overall skill mastery.

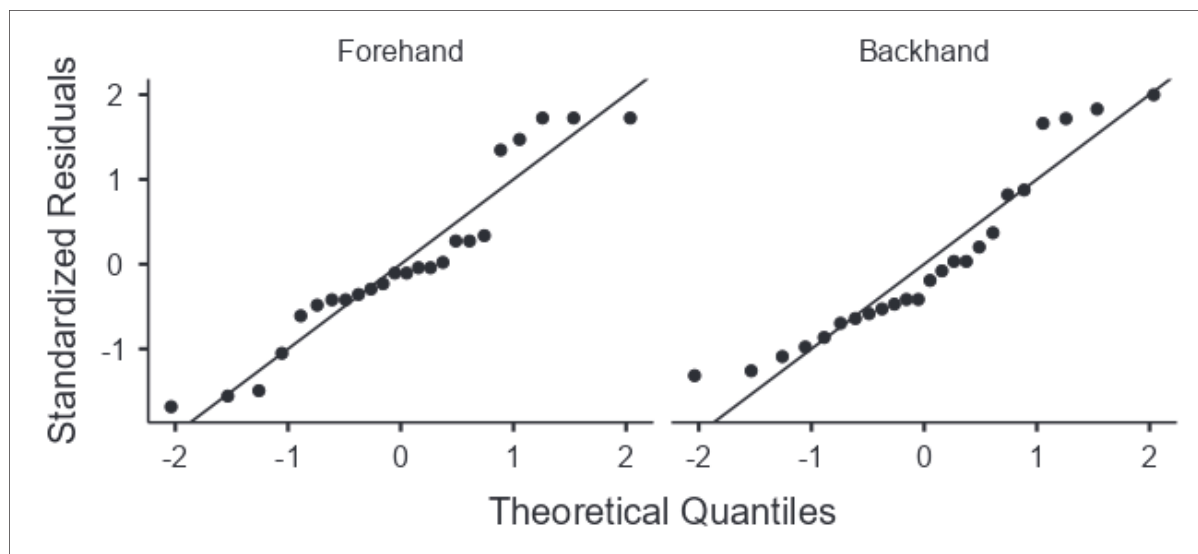


Figure 2. Assumption of data normality

The figure 2 shows the Q-Q plot (Quantile–Quantile Plot) of standardized residuals on the forehand and backhand variables used to evaluate the assumption of data normality. In the forehand plot, the data points tend to follow the diagonal line with slight deviations in the tails, indicating that the data distribution is close to normal, and therefore the assumption of normality is acceptable. In contrast, in the backhand plot, although some points are located around the diagonal line, there are more obvious deviations, especially in the lower tail and some points that are far from the reference line, indicating that the data distribution does not meet the assumption of normality. These visual findings are consistent with the results of the Shapiro–Wilk test, which obtained a W statistic value of 0.918 for the forehand and 0.905 for the backhand, with significance values (p-values) of 0.052 and 0.027, respectively. Based on the decision-making criteria ($\alpha = 0.05$), a p-value > 0.05 for the forehand indicates that the data are normally distributed, while a p-value < 0.05 for the backhand indicates that the data are not normally distributed. Thus, it can be concluded that the normality assumption is only met for the forehand variable, while the backhand variable requires a non-parametric analysis approach or data transformation before further analysis is carried out.

Table 2. Non Parametrik Independent Samples Test Forehand And Backhand Skills

		Statistic	df	p
Skills Results	Student's t	-1.18	46.0	0.243
	Mann-Whitney U	243		0.358

Note: $H_a: \mu_{Forehand} \neq \mu_{Backhand}$

Based on Table 2, which displays the results of the test for differences between forehand and backhand skills, two analytical approaches were used, namely the parametric test (independent samples t-test) and the non-parametric test (Mann–Whitney U). The t-test results show a statistical value of -1.18 with a degree of freedom (df) of 46 and a significance value (p) of 0.243. Meanwhile, the Mann–Whitney U test produces a statistical value of 243 with a significance value (p) of 0.358. Referring to the decision-making criteria ($\alpha = 0.05$), both p-values are greater than 0.05, so there is no significant difference between forehand and backhand skills. Thus, the alternative hypothesis ($H_a: \mu_{forehand} \neq \mu_{backhand}$) is rejected, which means that statistically forehand and backhand skills are at a relatively similar level.

DISCUSSION

The analysis results showed no significant difference between forehand and backhand skills, based on both parametric (independent samples t-test) and non-parametric (Mann–Whitney U) tests, with significance values of 0.243 and 0.358, respectively ($p > 0.05$). This finding indicates that statistically, the abilities of both types of strokes are at a relatively equal level. This condition may reflect that the training process given to the subjects has been able

to develop technical skills in a balanced manner between the forehand and backhand sides. In addition, the absence of significant differences may also be influenced by the homogeneous characteristics of the sample or a relatively uniform level of playing experience. From a methodological perspective, the results of the previous normality test showed that only forehand data were normally distributed, while backhand data were not, so the use of non-parametric tests is relevant to strengthen the analysis results. The consistency of the results between the two test methods strengthens the validity of the finding that there is no significant difference. The implication is that coaches or sports practitioners can maintain a balanced training approach but still need to conduct a more in-depth evaluation of certain technical aspects to improve specific performance, especially if there are individual variations that were not statistically detected in this study.

Recent studies have explored various approaches to improve the learning of forehand and backhand shots of table tennis. The scientific approach applied in the junior high school setting produced excellent learning outcomes for both strokes, with 68% of students achieving high proficiency (Mappaompo et al., 2023). Video-based learning media and apps significantly improve forehand and backhand skills among students (Fufu et al., 2020; Siregar et al., 2023). For elementary school students, the app-based learning model for forehand drive punches shows a modest skill improvement (Kurniadi et al., 2023). At the university level, a study on table tennis skills revealed that 46% of students showed excellent backhand shots, while 21% showed excellent forehand shots after a series of learning sessions (Azmi, 2024). These findings suggest that diverse teaching methods can effectively support the development of table tennis forehand and backhand skills across different age groups and education levels. The discovery learning style has shown a significant effect on improving basic techniques for students (Sari, 2020). Video-based self-recording during practice has been found to improve learning outcomes, with key skills including bouncing the ball, tapping the board, and forehand and backhand rallies (Sookhanaphibarn & Sookhanaphibarn, 2018). A survey of table tennis athletes revealed varying levels of proficiency in a variety of basic techniques, such as serving, attacking, defending, and certain types of strokes (Anwar et al., 2022). These findings suggest that a combination of innovative teaching methods, technology-assisted learning, and targeted skill development can contribute to improving basic table tennis skills for players at different levels.

In addition, various learning approaches are also very important to improve table tennis skills. Virtual reality (VR) training has shown promising results, with significant improvements in table tennis performance in the real world compared to the control group (Michalski et al., 2019; Oagaz et al., 2021). These studies show that the complex skills learned in VR can be transferred to the real world. Moreover, the *rich media platform for table tennis learning* (RMPTTL) has been found to improve advanced skills and participation motivation in young players (Zou et al., 2021). From a socio-ecological perspective, individual factors, such as intrinsic interests, have the most significant impact on adolescents' table tennis skills, followed by social support and physical environment (Gumilar, 2024; Gumilar et al., 2023; Xiao et al., 2020). To improve table tennis skills, it is recommended to cultivate intrinsic interests, encourage peer and parent support, provide adequate facilities, and incorporate innovative training methods such as VR and rich media platforms alongside traditional training techniques.

Another factor that favors table tennis performance and training is physical and physiological condition. Physical demands in tennis vary by court surface, performance level, and gender, with elite players exhibiting superior physical fitness and hitting performance compared to sub-elite players (Lambrich & Muehlbauer, 2022; Pluim et al., 2023). Sports training interventions have shown positive effects on physical fitness and stroke speed in young and adult tennis players, with varying effectiveness across different components (Lambrich & Muehlbauer, 2023). Specifically, large improvements were observed in agility, lower extremity muscle strength, upper extremity muscle strength, balance, and stroke speed. Age-specific differences in training adaptations were noted, with adult players showing greater potential for improvement in certain areas. In addition, research on transcranial direct current stimulation (tDCS) suggests that high-definition tDCS can offer superior behavioral and neurophysiological effects compared to conventional tDCS in visuomotor processing tasks (Sehatpour et al., 2021).

CONCLUSION

Based on the analysis results, it can be concluded that forehand and backhand skills do not show statistically significant differences, either through parametric tests (independent samples t-test) or non-parametric tests (Mann-Whitney U), with significance values greater than 0.05 for each. The normality test showed that the forehand data

were normally distributed, while the backhand was not, so a non-parametric analysis approach was used to ensure the reliability of the results. The consistency of the findings from both analysis methods indicates that forehand and backhand technical abilities are at a relatively balanced level. Thus, this study provides empirical evidence that there are no significant differences in ability between the two types of skills in the studied sample. The implications of these findings emphasize the importance of a proportional and integrated training approach in developing technical skills and open opportunities for further research to explore other factors that may influence performance variations in more depth.

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REFERENCE

- Anwar, K., Handayani, H. Y., & Himawan, A. (2022). Survey of Basic Technical Skills of Table Tennis Game Athletes Ptmsi Puslatkab Bangkalan. *Nusantara Sports Page: Journal of Sports Science*, 5(1), 350–361.
- Azmi, S. A. (2024). *PROFILE OF STUDENTS' TABLE TENNIS PLAYING SKILLS*. University of Education Indonesia.
- Bañkosz, Z., Winiarski, S., & Malagoli Lanzoni, I. (2020). Gender differences in kinematic parameters of topspin forehand and backhand in table tennis. *International Journal of Environmental Research and Public Health*, 17(16), 5742.
- Belli, T., & Galatti, L. (2021). *Development of table tennis coaching beginners*. Campinas: Unicamp.
- Carius, D., Herold, F., Clauß, M., Kaminski, E., Wagemann, F., Sterl, C., & Ragert, P. (2023). Increased cortical activity in novices compared to experts during table tennis: A whole-brain fNIRS study using threshold-free cluster enhancement analysis. *Brain Topography*, 36(4), 500–516.
- Chichenova, O. (2021). An innovative technique for teaching beginners to the technical stroke of table tennis during physical education. *Physical Education, Sport and Human Health*, 20, 61–64.
- Darajat, J., & Abduljabar, B. (2014). Statistical Application in Penjas. *Bandung: CV. Warliartika Star*.
- Fufu, R. D. A., Tajuddin, A. I., & Ladjar, M. B. (2020). THE INFLUENCE OF VIDEO LEARNING MEDIA ON FOREHAND AND BACKHAND SHOTS IN TABLE TENNIS GAMES. *Journal Of Physical Education Health And Sport Sciences*, 1(1), 9–17.
- Gumilar, A. (2024). *Positive Youth Development: The Integration of Life Skills in Softball*.
- Gumilar, A., Ma'Mun, A., Nuryadi, N., KN, J. D., & Hambali, B. (2023). Life skills of youth softball athletes. *Patriot Journal*, 5(4), 177–185. <https://doi.org/https://doi.org/10.24036/patriot.v5i4.1012>
- Hanim, M. U., & Tomoliyus, T. (2019). Design of Table Tennis Tool for Drive Stroke Drill Training to Beginner. *Proceedings of the International Conference of Science and Technology for the Internet of Things*. <https://api.semanticscholar.org/CorpusID:129938581>
- Kurniadi, A., Hernawan, H., & Nuraini, S. (2023). Table Tennis Forehand Drive Learning Model for Application based Elementary School Students. *Kinesthetics: Scientific Journal of Physical Education*, 7(3), 824–832.
- Lambrich, J., & Muehlbauer, T. (2022). Physical fitness and stroke performance in healthy tennis players with different competition levels: A systematic review and meta-analysis. *PloS One*, 17(6), e0269516.
- Lambrich, J., & Muehlbauer, T. (2023). Effects of athletic training on physical fitness and stroke velocity in healthy youth and adult tennis players: A systematic review and meta-analysis. *Frontiers in Sports and Active Living*, 4.
- Malagoli Lanzoni, I., Cortesi, M., Russo, G., Bankosz, Z., Winiarski, S., & Bartolomei, S. (2024). Playing style of women and men elite table tennis players. *International Journal of Performance Analysis in Sport*, 24(5), 495–509.
- Mao, B. J. (2012). Biomechanical analysis of two techniques performed in table tennis. *Applied Mechanics and Materials*, 182, 1658–1661.
- Mappaompo, A., Aprilio, I., & Said, P. (2023). Analysis of Table Tennis Forehand and Backhand Learning Results: Independent Learning Curriculum with A Scientific Approach. *Journal of Physical and Outdoor Education*, 5(1), 107–116.
- Michalski, S. C., Szpak, A., Saredakis, D., Ross, T. J., Billingham, M., & Loetscher, T. (2019). Getting your game on: Using virtual reality to improve real table tennis skills. *PloS One*, 14(9), e0222351. <https://doi.org/10.1371/journal.pone.0222351>
- Niżnikowski, T., Luba-Arnista, W., Arnista, P., Porter, J. M., Makaruk, H., Sadowski, J., Mastalerz, A., Niżnikowska, E., & Shaw, A. (2022). An external focus of attention enhances table tennis backhand stroke accuracy in low-skilled players. *Plos One*, 17(12), e0274717.
- Oagaz, H., Schoun, B., & Choi, M.-H. (2021). Performance Improvement and Skill Transfer in Table Tennis Through Training in Virtual Reality. *IEEE Transactions on Visualization and Computer Graphics*.
- Picabea, J. M., Cámara, J., & Yanci, J. (2022). Heart Rate Response, Temporal Structure and the Stroke Technique Distribution in Table Tennis National Category Matches. *International Journal of Environmental Research and Public Health*, 20(1), 739.
- Pluim, B. M., Jansen, M. G. T., Williamson, S., Berry, C., Camporesi, S., Fagher, K., Heron, N., van Rensburg, D. C. J., Moreno-Perez, V., & Murray, A. (2023). Physical demands of tennis across the different court surfaces, performance levels and sexes: a systematic review with meta-analysis. *Sports Medicine*, 53(4), 807–836.
- Pradas de la Fuente, F., Ortega-Zayas, M. Á., Toro-Román, V., & Moreno-Azze, A. (2023). Analysis of technical–tactical actions in high-level table tennis players: differences between sexes. *Sports*, 11(11), 225.
- Rumondor, W. I. A., Safari, I., & Akin, Y. (2022). Comparison of bounce to wall exercises with shadow exercises against increased backhand drive strokes of table tennis. *SPORTIVE*, 4(1), 421–430.
- Sari, D. N. (2020). The Effect of Discovery Teaching Style on Basic Techniques of Table Tennis Skills at SMP Semen Padang. *1st Progress in*

- Social Science, Humanities and Education Research Symposium (PSSHERS 2019)*, 212–214.
- Sehatpour, P., Dondé, C., Adair, D., Kreither, J., Lopez-Calderon, J., Avissar, M., Bikson, M., & Javitt, D. C. (2021). Comparison of cortical network effects of high-definition and conventional tDCS during visuomotor processing. *Brain Stimulation: Basic, Translational, and Clinical Research in Neuromodulation*, 14(1), 33–35.
- Siregar, S., Faridah, E., & Hasibuan, R. (2023). Applications-Based Learning Media to Improve Students' Table Tennis Basic Skills: Viewing its Effectiveness. *AL-ISHLAH: Jurnal Pendidikan*. <https://api.semanticscholar.org/CorpusID:258155508>
- Sookhanaphibarn, T., & Sookhanaphibarn, K. (2018). Enhancing table-tennis learning outcome using video-based self-recording during play and practice. *2018 IEEE 7th Global Conference on Consumer Electronics (GCCE)*, 647–648.
- Sung, C.-Y. (2019). A smart analysis of technical skills of top male table tennis players. *Smart Science*, 7(4), 231–238.
- Winiarski, S., Malagoli Lanzoni, I., & Bańkosz, Z. (2021). The role of the non-playing hand during topspin forehand in table tennis. *Symmetry*, 13(11), 2054.
- Xiao, Y., Huang, W., Lu, M., Ren, X., & Zhang, P. (2020). Social-ecological analysis of the factors influencing shanghai adolescents' table tennis skills: A cross-sectional study. *Frontiers in Psychology*, 11, 1372.
- Yulianto, F. R. P. (2015). Study analysis of the skill of playing sports branch of table tennis games. *Journal of Sports Health*, 3(1), 201–206.
- Zhang, H., Liu, W., Hu, J., & Liu, R.-Z. (2013). Evaluation of elite table tennis players' technique effectiveness. *Journal of Sports Sciences*, 31, 1526–1534. <https://api.semanticscholar.org/CorpusID:23650085>
- Zhukovskiy, Y., Kruk, M., & Shokhanov, O. (2020). Scientific and Methodological Foundation of Improvement of the Students' Coordination Abilities at the Table Tennis Training Lessons. *Scientific Journal of National Pedagogical Dragomanov University. Series 15. Scientific and Pedagogical Problems of Physical Culture (Physical Culture and Sports)*, 3(3(123)), 56–60. [https://doi.org/10.31392/npu-nc-series15.2020.3\(123\).10](https://doi.org/10.31392/npu-nc-series15.2020.3(123).10)
- Zou, J., Liu, K., & Han, L. (2021). The impact of a rich media platform to table tennis learners' performance and participation motivation. *Interactive Learning Environments*, 29(6), 1006–1018.

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IMPACT OF SPORTING EVENTS ON DESTINATION TOURISM OFFER: CASE STUDY OF PANNONIAN CHALLENGE AND DOBRO WORLD CUP

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Abstract: This paper analyses the impact of sporting events on a destination's tourism offer, with a particular focus on the city of Osijek and two international events: the Pannonian Challenge and the DOBRO World Cup. The study is grounded in the theoretical framework of sport and event tourism, which highlights the role of events in generating tourism demand, strengthening destination image, and extending the tourism season. The empirical part of the research is based on the analysis of secondary data on tourist overnight stays generated by events held in Osijek during 2023, as well as on tourism statistics on arrivals and overnight stays recorded during the week of the international gymnastics competition DOBRO World Cup in April 2025. Descriptive statistics, correlation analysis, and regression analysis were applied to examine the relationship between domestic and international tourism demand and to assess the tourism effects of sporting events. The results indicate that sporting events generate a significant level of tourism demand, with the analysed events producing a total of 28,214 overnight stays in 2023. The structure of tourism demand shows a relatively balanced relationship between domestic and foreign tourists, suggesting an increasing internationalisation of tourism associated with events. A strong positive relationship between domestic and foreign overnight stays was also identified, indicating that event attractiveness simultaneously influences both tourism markets. Furthermore, the analysis of the DOBRO World Cup shows that foreign tourists record a longer average length of stay compared with domestic visitors. The findings highlight the importance of sporting events as strategic tourism products and underline the need to integrate them into destination tourism development and management strategies.

Key words: sport tourism; event tourism; sporting events; destination development; tourism demand

INTRODUCTION

Sports tourism is one of the more dynamic segments of contemporary tourism, and major sporting events are increasingly used as instruments for destination branding, season extension, and demand generation. In the literature, event tourism is described as a field that encompasses both professional practice and scientific research on the impacts of events on the economy and society, with sporting events occupying a particularly important position due to their wide media visibility and their ability to attract visitors (Getz, 2008). In the context of sports tourism, travel may be motivated either by active participation in sport or by spectating, with expenditure directed toward accommodation, hospitality services, transport, and related activities (Gibson, 1998).

Although mega-events such as the Olympic Games or world championships are the most visible, regional events can also have an important impact on the tourism offer, particularly in destinations outside the main tourism flows. In recent years, Osijek has been developing a profile as a centre for sports and sport-cultural events. Events such as the Pannonian Challenge (action sports) and the DOBRO World Cup (artistic gymnastics) attract participants and visitors from both domestic and international markets, creating measurable effects on tourist traffic and potentially strengthening the city's image.

The aim of this paper is to analyse the impact of sporting events on the tourism offer of Osijek through a literature review and an empirical analysis of secondary data on overnight stays by event in 2023, as well as reports for the week during which the DOBRO World Cup was held in 2025.

THEORETICAL BACKGROUND AND LITERATURE REVIEW

Sports tourism represents one of the most significant areas of contemporary tourism, and its development is closely linked to the globalization of sport, increased mobility of populations, and growing demand for experiential forms of travel. According to Gibson (1998), sports tourism includes travel motivated by active participation in sport,

spectating at sporting events, or visiting sport-related attractions, with sporting events representing one of the most important segments of this form of tourism. Weed and Bull (2004) further emphasize that sports tourism is not only a form of physical movement of visitors but also a complex social and economic phenomenon involving the interaction between sport, tourism, and destination development. Research in this field highlights that sport tourism activities may include both active participation and spectator experiences, creating various forms of tourism demand that contribute to destination development (Ritchie & Adair, 2004). Within event tourism, sporting events occupy a special position due to their ability to generate significant tourism demand and create long-term development effects. Getz (2008) defines event tourism as the systematic planning, development, and management of events with the aim of generating tourism and economic benefits for a destination. In this context, sporting events act as catalysts for tourism development by attracting visitors, increasing tourism expenditure, and contributing to the international promotion of destinations. Getz and Page (2016) highlight that contemporary research on sporting events has evolved from simple measurements of economic impacts toward analysing their broader influence on destination image, competitiveness, and sustainable development.

One of the key theoretical concepts in the study of sporting events is the concept of event tourism impacts, which includes economic, social, and infrastructural dimensions. Economic impacts relate to increased tourism expenditure, employment, and revenue in the tourism sector (Gratton & Taylor, 2000). Daniels and Norman (2003) emphasize that sporting events generate additional demand for accommodation, hospitality services, and transportation, thereby directly contributing to the local economy. In addition to direct economic impacts, sporting events also generate indirect effects through destination promotion and increased international recognition (Hall, 1992). Early research on hallmark events highlighted their ability to strengthen the identity and image of host destinations and to attract visitors over a longer period of time (Ritchie, 1984). Hall (1992) further developed this concept by emphasizing that hallmark events become strongly associated with a particular destination and play an important role in its tourism development. A particularly important concept in the literature is the legacy of sporting events, referring to the long-term effects of events on a destination. Preuss (2007) defines event legacy as all planned and unplanned, positive and negative, tangible and intangible effects that remain after the event has concluded. These effects include infrastructure development, increased tourism demand, and the strengthening of the destination's image. Thomson, Schlenker, and Schulenkorf (2013) further conceptualize sport event legacy as a multidimensional phenomenon that includes economic, social, environmental, and institutional outcomes that persist after the event. Smith (2012) also points out that sporting events can contribute to urban development and city revitalization, particularly when they are integrated into broader destination development strategies.

Depending on their size and significance, sporting events can be classified into several categories, including mega-events, hallmark events, and local events. Mega-events, such as the Olympic Games, have global reach and significant economic impacts (Matheson, 2006). Horne (2007) notes that mega-events are characterized by their large scale, global media coverage, and significant economic and social impacts on host destinations. Zimbalist (2006) also highlights that major sporting events can generate substantial tourism demand, although their long-term benefits depend on effective management and strategic planning. While mega-events have received the greatest scholarly attention, research increasingly indicates that smaller and medium-scale events can also generate meaningful tourism impacts, particularly in smaller or medium-sized destinations (Higham & Hinch, 2009). An important aspect of sporting events is their role in destination marketing. Chalip (2004) emphasizes that sporting events represent an effective tool for destination promotion because they enable the creation of positive emotions and experiences associated with the destination. This process, known as leverage, involves using sporting events to achieve long-term tourism and economic benefits. Fourie and Santana-Gallego (2011) empirically demonstrated that sporting events have a statistically significant positive impact on tourist arrivals, particularly when accompanied by effective promotional strategies.

Despite the many positive effects, the literature also highlights methodological challenges in assessing the impacts of sporting events. Crompton (1995) argues that economic impact estimates are often overestimated due to methodological limitations, while Preuss (2007) emphasizes the need to use objective and long-term tourism indicators. In their meta-analysis, Li and Jago (2013) conclude that sporting events generally have a positive but variable impact on tourism, depending on factors such as event size, location, and the level of international participation. In addition to economic effects, sporting events may also influence residents' perceptions and social attitudes toward tourism development. Kim and Petrick (2005) found that local residents often perceive major sporting events as opportunities

for improving destination reputation, infrastructure development, and community pride, although potential negative impacts such as congestion or increased costs may also occur. In recent years, increasing attention has been given to the sustainability of sports tourism. UN Tourism (2025) emphasizes that sporting events should be integrated into destination sustainable development strategies in order to maximize benefits and minimize negative impacts. Sustainable management of sporting events involves cooperation between event organizers, tourism organizations, and local communities in order to create long-term tourism benefits. In the context of continental destinations, sporting events have particular importance because they contribute to reducing the seasonality of tourism demand and diversifying the tourism offer. Higham and Hinch (2009) point out that sporting events can play a key role in tourism development in destinations that lack traditional tourism resources such as coastal or mountain attractions. In such destinations, sporting events become a key tourism product and an important element of the competitive strategy.

Based on the theoretical and empirical insights presented above, it can be concluded that sporting events represent an important instrument of tourism development, influencing increased tourism demand, strengthening destination image, and enhancing the tourism offer. However, their actual impact depends on a number of factors, including event size, the level of international participation, and the quality of destination management. The theoretical foundations of sports tourism point to the multidimensional nature of the phenomenon: sport may represent the primary motivation for travel, but it may also serve as an additional element within a broader tourism experience (Weed & Bull, 2004). In research, events are often viewed both as drivers of tourism demand and as platforms for generating intangible values such as destination image, emotions, and social capital (Chalip, 2004). Consequently, sporting events represent an increasingly important strategic instrument for tourism development and destination competitiveness.

RESEARCH PROBLEM, OBJECTIVES, HYPOTHESES AND CONCEPTUAL RESEARCH MODEL

Despite the extensive body of literature on the impact of sporting events on tourism, most existing studies focus primarily on large international and mega-events such as the Olympic Games and world championships (Preuss, 2007; Fourie & Santana-Gallego, 2011). In contrast, significantly fewer studies analyse the effects of smaller but regularly held international sporting events on tourism demand in medium-sized continental destinations. In particular, their influence on the structure of tourism demand—such as the relationship between domestic and international tourists and differences in their behaviour and length of stay—remains insufficiently explored.

Furthermore, many previous studies rely on estimates of the overall economic impact of events, while fewer focus on analysing specific tourism performance indicators such as the number of arrivals and overnight stays, which represent more objective and reliable measures of tourism impact (Li & Jago, 2013). In the context of medium-sized continental destinations such as Osijek, empirical studies examining the role of sporting events in the development of the tourism offer and the internationalisation of tourism demand are particularly limited. Accordingly, a research gap can be identified in the lack of empirical studies examining the impact of international sporting events on tourism demand in medium-sized continental destinations, with particular emphasis on the structure of tourism demand and the differences between domestic and foreign tourists.

In line with this gap, the main objective of this paper is to empirically analyse the impact of sporting events on tourism demand in the city of Osijek, with a particular focus on the events **Pannonian Challenge** and **DOBRO World Cup**, and to determine their contribution to overall tourism performance and the internationalisation of tourism demand.

Based on the theoretical framework and the identified research gap, the following research questions are formulated:

RQ1: To what extent do sporting events contribute to an increase in tourism demand in the destination?

RQ2: Is there a statistically significant relationship between domestic and foreign tourist overnight stays during sporting events?

RQ3: Are there differences in the tourism behaviour of domestic and foreign tourists during international sporting events?

Based on these research questions, the following hypotheses are proposed:

H1: Sporting events have a statistically significant positive impact on tourism demand in the destination.

H2: There is a statistically significant positive relationship between the number of domestic and foreign tourist overnight stays during sporting events.

H3: Foreign tourists achieve a longer average length of stay in the destination during international sporting events compared to domestic tourists.

Based on theoretical insights and the defined hypotheses, the conceptual framework of this study assumes that sporting events represent a key independent factor influencing tourism demand in the destination. Within the model, sporting events are expected to contribute to an increase in the total number of overnight stays, an increase in the number of international tourists, a longer average length of stay, and the internationalisation of tourism demand. At the same time, a positive relationship is assumed between domestic and international tourism demand, reflecting the overall attractiveness and market reach of sporting events. Finally, increased tourism demand contributes to strengthening the destination's tourism offer and competitiveness.

RESEARCH METHODOLOGY

The empirical part of this study is based on the analysis of secondary data on tourism demand related to sporting events in the city of Osijek. Tourism data used in this research were obtained from official tourism statistics and reports of the City of Osijek Tourism Board. The data were collected from official statistical sources and consist of two datasets. The first dataset refers to tourist overnight stays recorded during 18 events held in Osijek in 2023. The data include the number of overnight stays by domestic and foreign tourists for each individual event, as well as the total number of overnight stays. This dataset enables the analysis of the tourism impact of individual events and a comparison of the structure of tourism demand. The second dataset relates to tourist arrivals and overnight stays recorded during the period from 7 to 13 April 2025, which coincides with the organization of the international gymnastics competition DOBRO World Cup. These data allow for a more detailed analysis of the structure of tourism demand during the period of a major international sporting event, including differences between domestic and foreign tourists and their average length of stay.

For the purposes of analysis, methods of descriptive and inferential statistics and correlation analysis were applied. Descriptive statistics were used to calculate basic statistical indicators, including the total number of overnight stays, arithmetic mean, median, standard deviation, and the shares of domestic and foreign overnight stays. These indicators provide insight into the scope and structure of tourism demand related to sporting events. To analyse the relationship between domestic and foreign overnight stays, the Pearson correlation coefficient (r) was used. This method enables the assessment of the strength and direction of the linear relationship between two variables and is frequently used in tourism research (Field, 2018). Statistical significance was tested at a significance level of $p < 0.05$.

Additionally, in order to further examine the relationship between domestic and foreign overnight stays, a simple linear regression analysis was conducted, in which the number of foreign overnight stays represents the dependent variable and the number of domestic overnight stays the independent variable. Regression analysis allows for an assessment of the extent to which domestic overnight stays can explain variation in foreign overnight stays and provides additional insight into the structure of tourism demand associated with sporting events. To further examine differences between domestic and foreign overnight stays by event, a paired samples t-test was applied. This method enables the assessment of whether a statistically significant difference exists between two related groups of data (Field, 2018). Since the sample includes a relatively small number of events, the results were additionally verified using the non-parametric Wilcoxon test, which does not require the assumption of normal data distribution.

The variables included in the research are:

- total number of overnight stays per event
- number of overnight stays by domestic tourists
- number of overnight stays by foreign tourists
- share of foreign overnight stays
- number of tourist arrivals
- average length of stay

Data analysis was performed using Statistica statistical software, and the results are presented in tables and graphs to facilitate interpretation.

Despite its analytical value, the study has certain limitations. First, the analysis is based on secondary data that do not include information about tourists' travel motivations, expenditure, or socio-demographic characteristics. In addition, the research is limited to a single destination, which may restrict the generalizability of the results to other

destinations. However, despite these limitations, the data used represent a reliable and objective indicator of the tourism impact of sporting events, as they are based on actually recorded tourist arrivals and overnight stays.

RESULTS

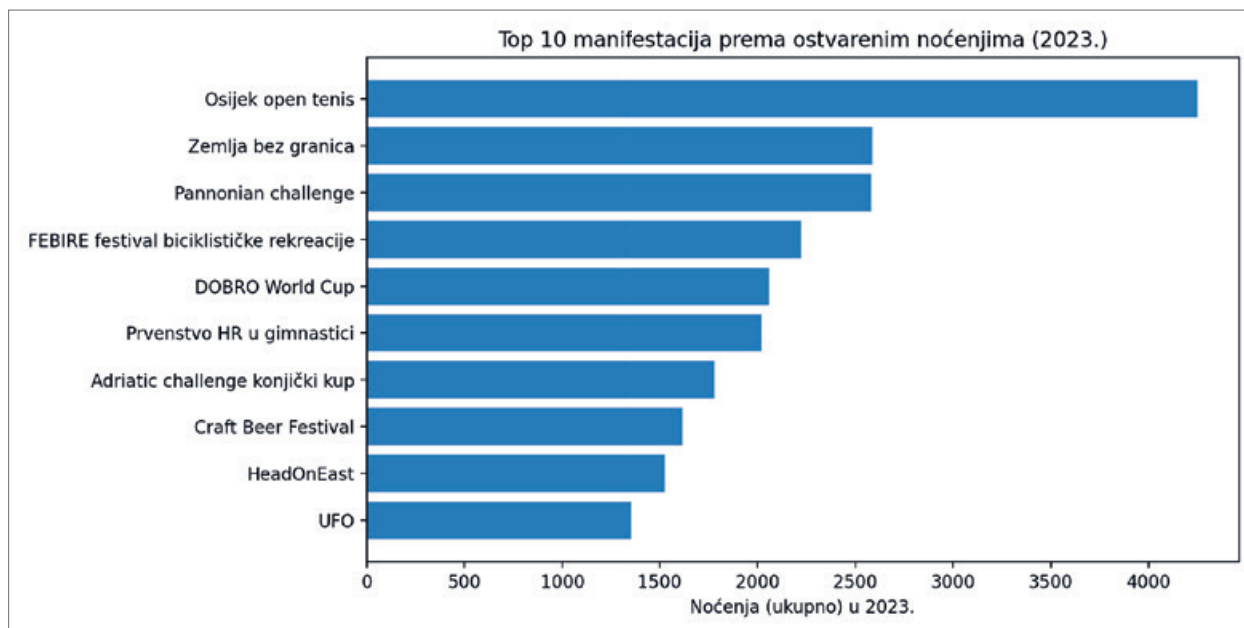


Figure 1: Top 10 Events by Number of Overnight Stays (2023)

Source: Authors' research

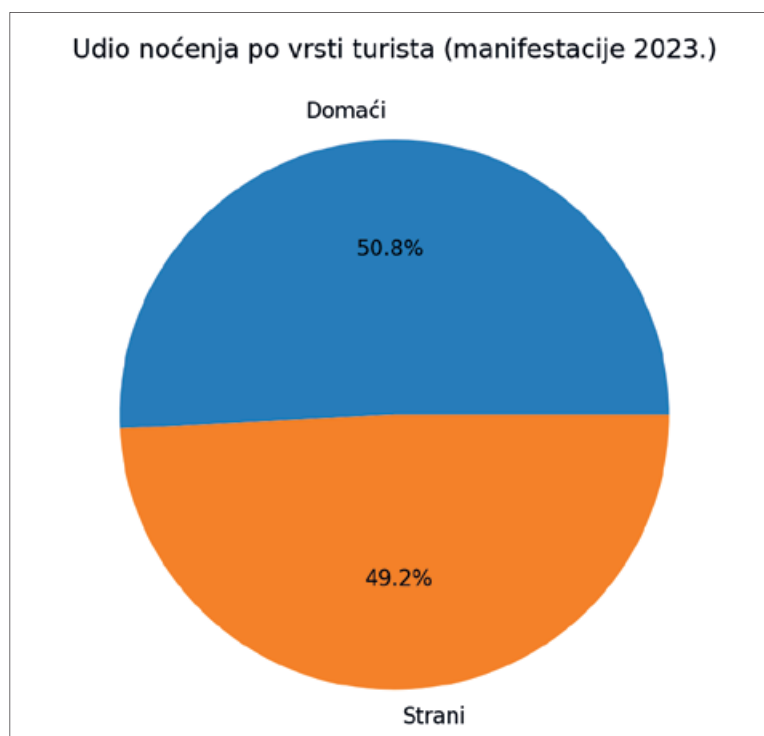


Figure 2: Share of Overnight Stays by Tourist Type (Events 2023)

Source: Authors' research

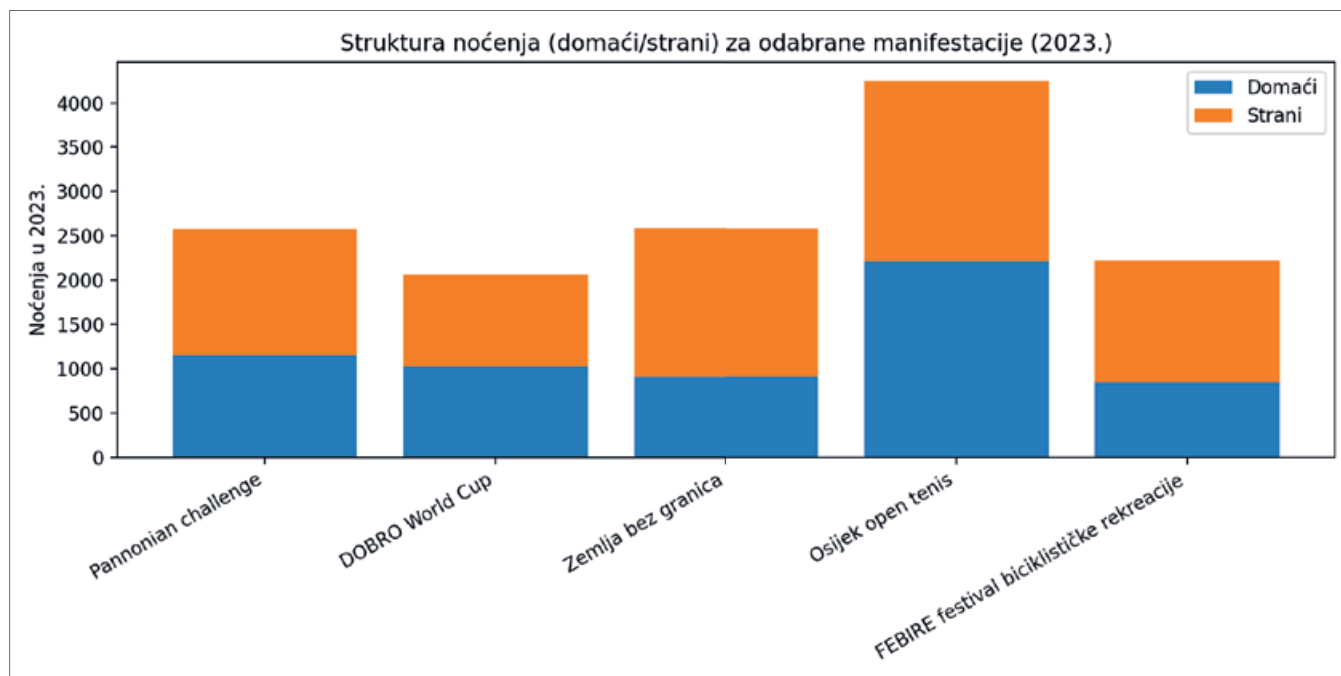


Figure 3: Structure of Overnight Stays (Domestic vs. Foreign Tourists) for Selected Events (2023)

Source: Authors' research

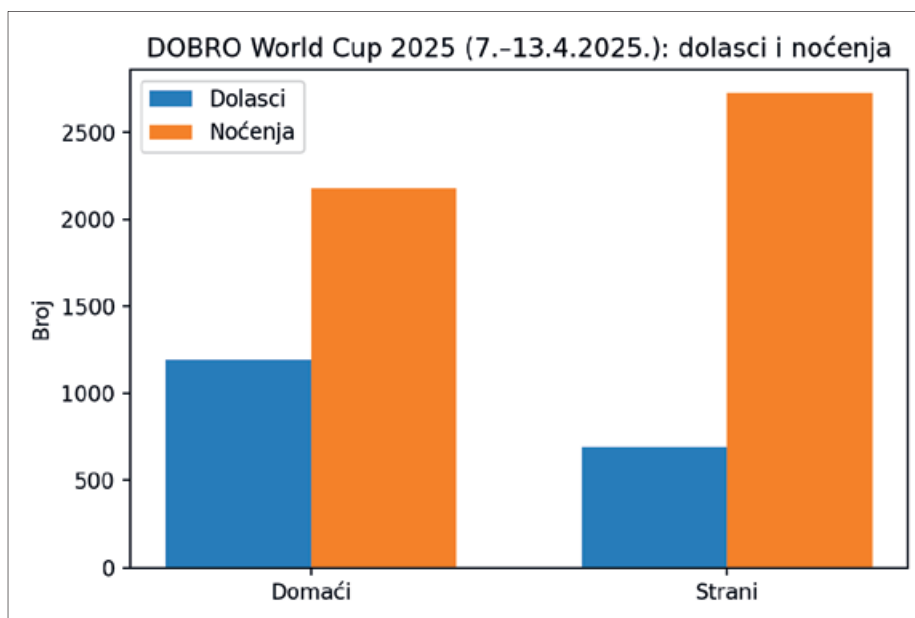


Figure 4: DOBRO World Cup 2025 (7–13 April 2025): Comparison of Tourist Arrivals and Overnight Stays by Tourist Type

Source: Authors' research

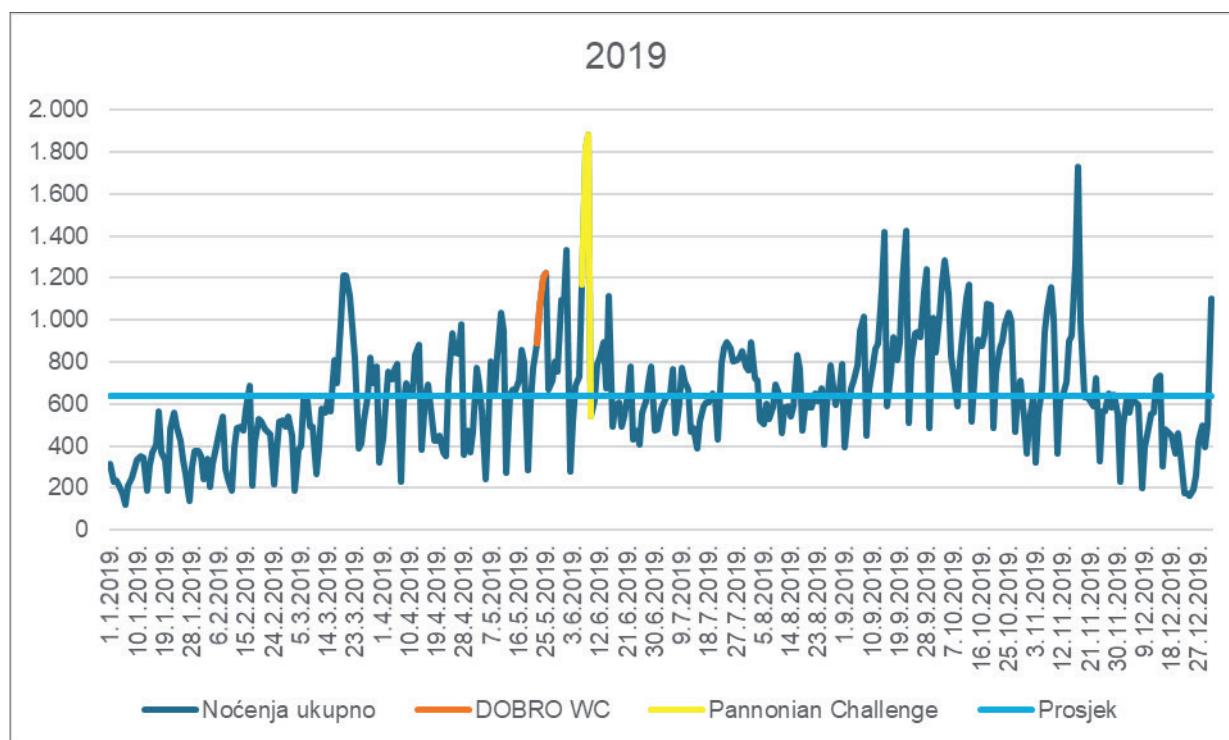


Figure 5: Impact of Pannonian Challenge and DOBRO World Cup on Overnight Stays in 2019

Source: Authors' research

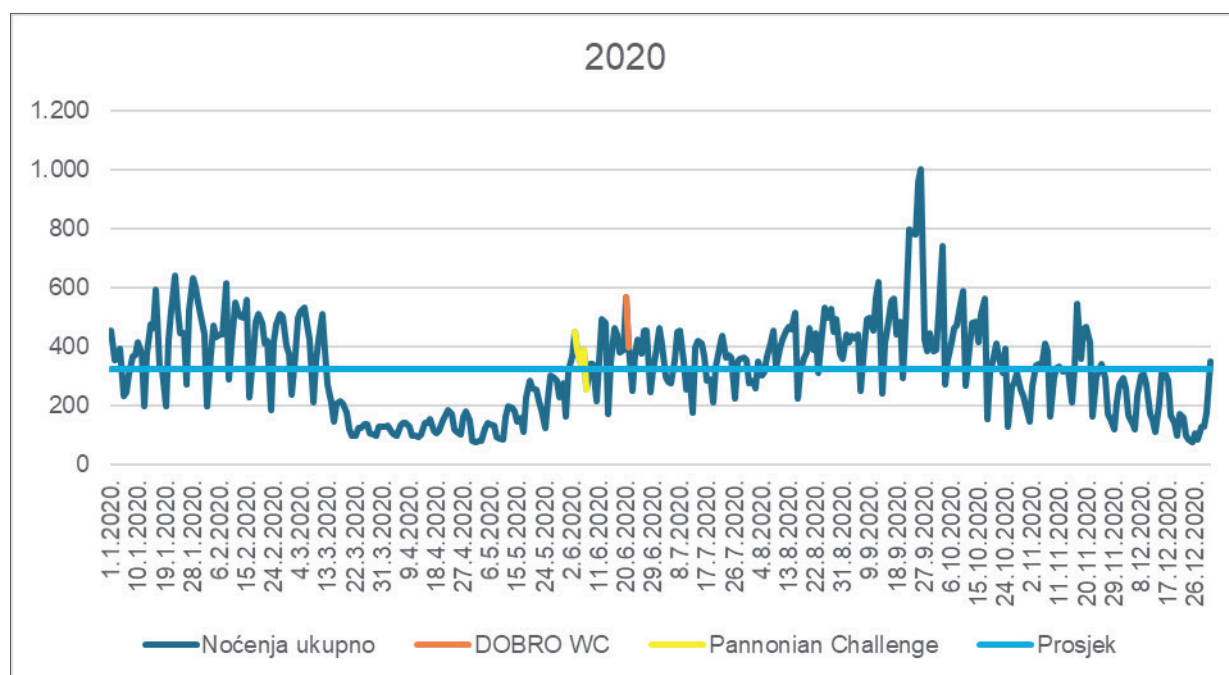


Figure 6: Impact of Pannonian Challenge and DOBRO World Cup on Overnight Stays in 2020

Source: Authors' research

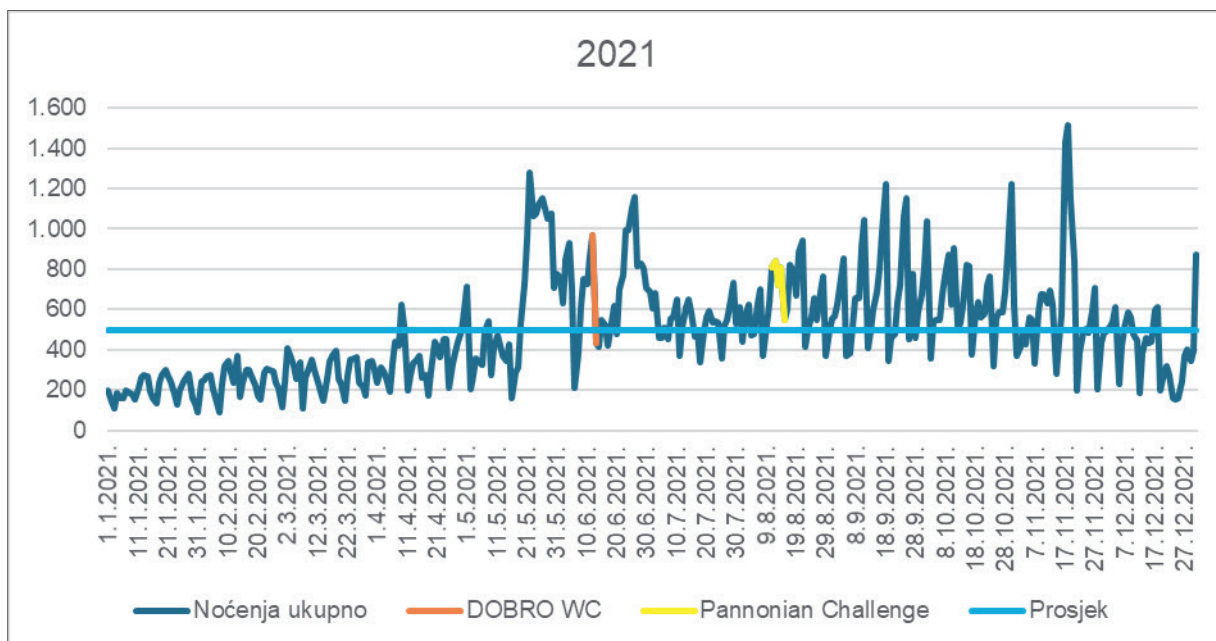


Figure 7: Impact of Pannonian Challenge and DOBRO World Cup on Overnight Stays in 2021

Source: Authors' research

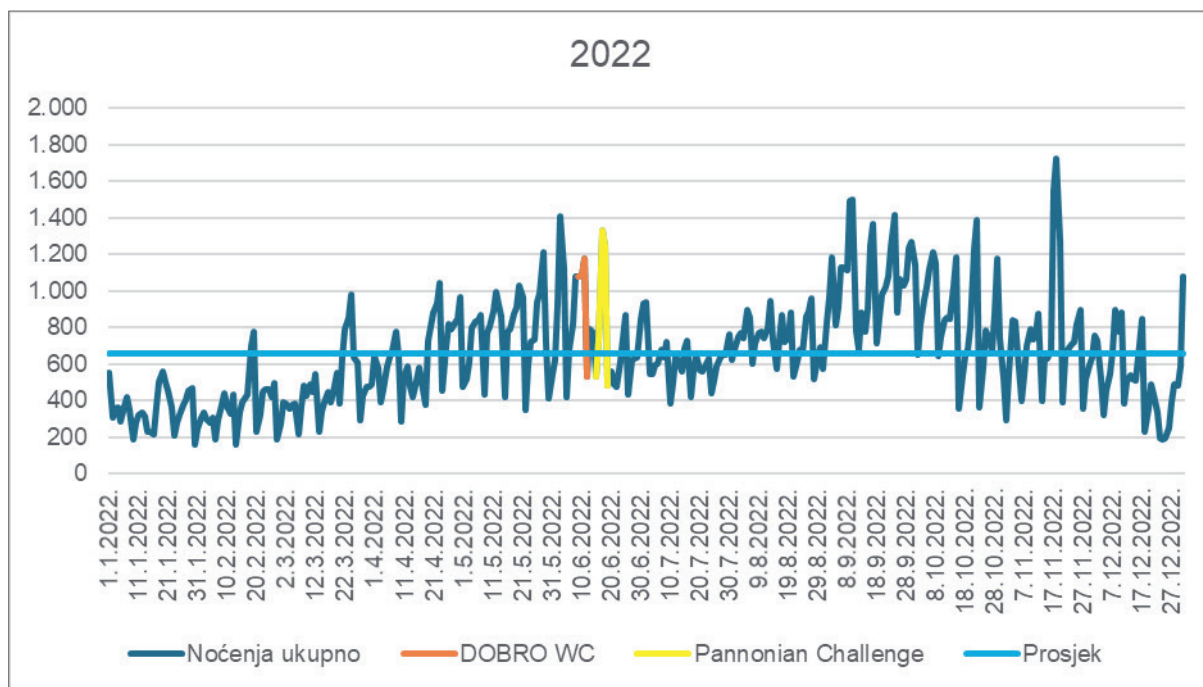


Figure 8: Impact of Pannonian Challenge and DOBRO World Cup on Overnight Stays in 2022

Source: Authors' research

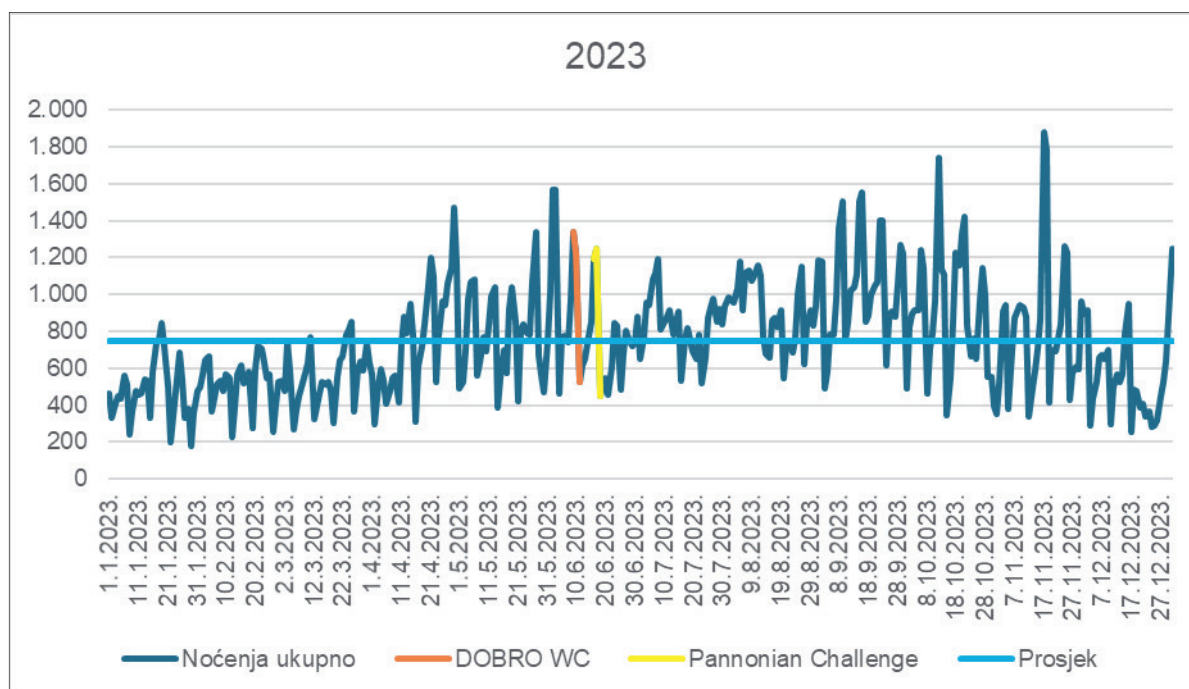


Figure 9: Impact of Pannonian Challenge and DOBRO World Cup on Overnight Stays in 2023

Source: Authors' research

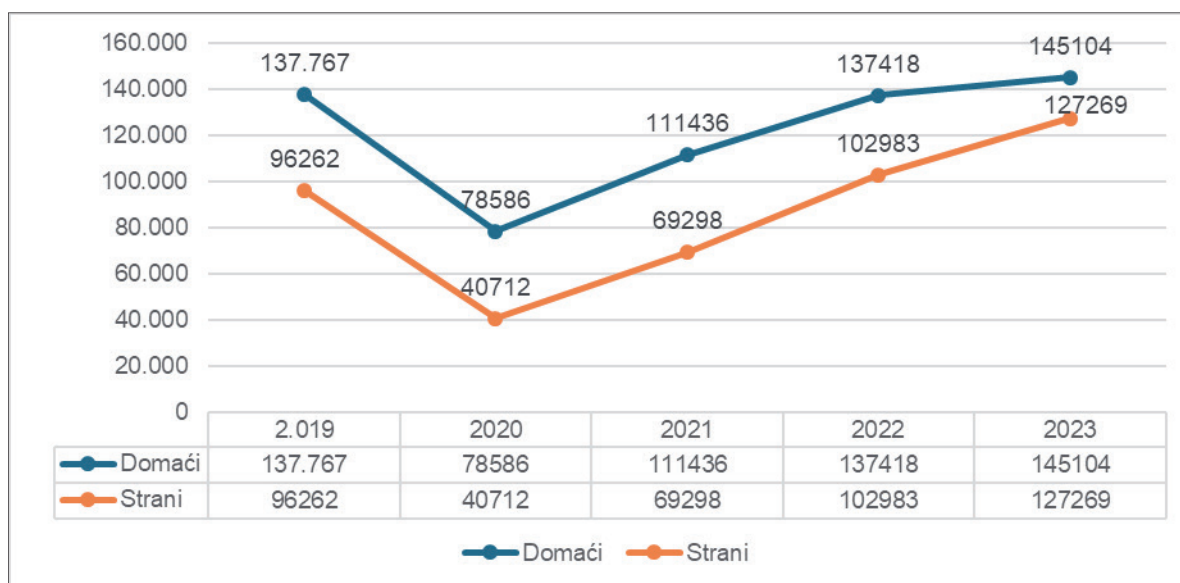


Figure 10: Comparison of Domestic and Foreign Tourist Overnight Stays

Source: Authors' research

Table 1: Tourist Arrivals and Overnight Stays in Osijek During the DOBRO World Cup Week (7–13 April 2025)

Tourist Type	Arrivals	Overnight Stays	Average Length of Stay (days)	Share of Arrivals (%)	Share of Overnight Stays (%)
Domestic	1191	2175	1.83	63.3	44.4
Foreign	691	2721	3.94	36.7	55.6
Total	1882	4896	2.60	100.0	100.0

Source: Authors' research

Table 2: Top 10 Events by Number of Overnight Stays in Osijek (2023)

Event	Event Date	Domestic Overnight Stays	Foreign Overnight Stays	Total Overnight Stays	Share of Foreign Overnight Stays (%)
Osijek Open Tennis	24–30 Apr	2212	2038	4250	48.0
Zemlja bez granica (Land Without Borders Festival)	21–24 Sep	912	1676	2588	64.8
Pannonian Challenge	15–19 Jun	1152	1428	2580	55.3
FEBIRE Cycling Recreation Festival	21–23 Sep	850	1373	2223	61.8
DOBRO World Cup	9–12 Jun	1032	1027	2059	49.9
Croatian Gymnastics Championship	2–4 Jun	1441	580	2021	28.7
Adriatic Challenge Equestrian Cup	29 Jun–2 Jul	864	915	1779	51.4
Craft Beer Festival	15–16 Sep	651	966	1617	59.7
HeadOnEast	6–8 Oct	865	662	1527	43.4
UFO Festival	8–9 Sep	550	801	1351	59.3

Source: Authors' research

Table 3: Test of Differences Between Domestic and Foreign Overnight Stays by Event (2023)

Test	Statistic	p-value	Interpretation
Paired t-test	t = -0.134	p = 0.897	No statistically significant difference between domestic and foreign overnight stays across events
Wilcoxon signed-rank test	W = 25.0	p = 0.846	Non-parametric confirmation of the same result

Source: Authors' research

Table 4: OLS Regression Model: Foreign Overnight Stays = $a + b \times$ Domestic Overnight Stays (2023)

Parameter	Coefficient	SE	p	R ²
Intercept (a)	240.58	-	-	
Domestic overnight stays (b)	0.765	-	0.018	0.52

Source: Authors' research

DISCUSSION

The study's findings provide strong empirical support for the assumption that sporting events exert a positive influence on tourism demand and contribute to the development of the destination's tourism offer. The analysis presented in Figure 1 (Top 10 Events by Number of Overnight Stays, 2023) shows that the largest tourism effect was generated by the Osijek Open tennis tournament, with 4,250 overnight stays, followed by Zemlja bez granica and the Pannonian Challenge, each with approximately 2,600 overnight stays. The observed gap between the leading events and the remainder indicates a concentration of event-generated tourism demand in a relatively small number of "anchor" events, which is typical of event tourism and corresponds to the role of flagship or hallmark events in destination development (Getz, 2008; Hall, 1992). At the same time, the presence of both sporting and socio-cultural events among the top-performing manifestations suggests a diversified event portfolio, which may contribute to a more stable distribution of tourism demand throughout the year.

The structure of tourism demand shown in Figure 2 (Share of Overnight Stays by Tourist Type, Events 2023) reveals an almost balanced relationship between domestic and foreign tourists (50.8% vs. 49.2%), which represents an important indicator of the internationalisation of tourism demand associated with events in Osijek. This ratio is particularly relevant for medium-sized continental destinations that traditionally rely more heavily on the domestic market, as it indicates the ability of events to attract international audiences while maintaining a strong national visitor base. The strong presence of domestic tourists simultaneously confirms the role of sporting events in the development of the national market and regional travel flows, which is consistent with theoretical approaches to sports tourism that highlight participants, accompanying persons, and spectators as key demand segments (Gibson, 1998; Weed & Bull, 2004). Furthermore, Figure 3 (Structure of Overnight Stays – Domestic vs. Foreign Tourists for Selected Events, 2023) indicates pronounced heterogeneity in the demand structure across events. Certain events, such as Zemlja bez

granica (64.8% foreign overnight stays) and the FEBIRE Cycling Recreation Festival (61.8%), demonstrate a high level of international attractiveness, whereas nationally oriented events, such as the Croatian Gymnastics Championship, record a substantially lower share of foreign overnight stays (28.7%). This pattern confirms that the degree of internationalisation, event reach, and visibility are important determinants of the structure of tourism demand, with international competitions generally producing stronger tourism effects than nationally oriented events (Getz, 2008; Higham & Hinch, 2009). The correlation analysis further supports these findings, showing a statistically significant positive relationship between domestic and foreign overnight stays ($r = 0.724$, $p = 0.018$). This result suggests that both segments of tourism demand respond to similar factors related to event attractiveness, organisation quality, and destination appeal. In practical terms, events that successfully attract domestic visitors also tend to attract foreign tourists, indicating that the attractiveness of sporting events simultaneously influences both tourism markets. Such a pattern supports the theoretical assumption that successful sporting events generate multiplicative effects on tourism demand rather than targeting a single market segment (Getz & Page, 2016).

A particularly clear insight into demand structure during an international event is provided by Table 1 (Tourist Arrivals and Overnight Stays in Osijek During the DOBRO World Cup Week, 7–13 April 2025). During the observed week, 1,882 arrivals and 4,896 overnight stays were recorded, with an average length of stay of 2.60 days. Although foreign tourists represent a minority of arrivals (36.7%), they account for the majority of overnight stays (55.6%) due to a substantially longer average stay (3.94 days) compared with domestic tourists (1.83 days). The visual comparison in Figure 4 (DOBRO World Cup 2025: Comparison of Tourist Arrivals and Overnight Stays by Tourist Type) further confirms this pattern. This finding points to the higher economic value of foreign visitors during international sporting events, as longer stays are typically associated with higher tourism expenditure. Consequently, international sporting events may generate disproportionately large economic impacts even when the number of foreign arrivals is not dominant (Preuss, 2007). The long-term impact of key sporting events is illustrated in Figures 5–9 (Impact of Pannonian Challenge and DOBRO World Cup on Overnight Stays, 2019–2023). Both events demonstrate continuity in generating tourism demand, with the exception of 2020, which was marked by the COVID-19 pandemic. Following the pandemic, a relatively rapid recovery is evident, indicating the resilience of event tourism. This continuity confirms that the Pannonian Challenge and the DOBRO World Cup have become recognisable elements of the city's tourism identity and can be considered hallmark events with long-term value for the destination (Hall, 1992; Getz, 2008). The comparison of total domestic and foreign overnight stays in Figure 10 (Comparison of Domestic and Foreign Tourist Overnight Stays) further confirms a generally balanced demand structure, with a slight predominance of domestic overnight stays, which contributes to tourism stability by reducing dependence on a single tourism market.

The empirical framework is further summarised in Table 2 (Top 10 Events by Number of Overnight Stays in Osijek, 2023), according to which the analysed events generated a total of 28,214 overnight stays. The mean per event is 1,567, the median is 1,439, and the standard deviation of 975 overnight stays indicates substantial variability in the tourism impact of events. This suggests that a relatively small number of events generate the largest share of tourism demand, confirming the importance of flagship events in the structure of event tourism demand. The difference tests presented in Table 3 (Test of Differences Between Domestic and Foreign Overnight Stays by Event, 2023) provide additional insight into the structure of tourism demand. The results of the paired samples *t*-test ($t = -0.134$, $p = 0.897$) indicate that there is no statistically significant difference between domestic and foreign overnight stays across events. This finding is further confirmed by the Wilcoxon signed-rank test ($W = 25.0$, $p = 0.846$), which also shows no statistically significant differences. These results reinforce the conclusion that sporting events in Osijek generate a relatively balanced demand structure across domestic and international markets. Finally, the regression analysis presented in Table 4 (OLS Regression Model: Foreign Overnight Stays = $a + b \times$ Domestic Overnight Stays) indicates that the coefficient of domestic overnight stays is statistically significant ($p = 0.018$), while the coefficient of determination ($R^2 = 0.52$) shows that domestic overnight stays explain approximately 52% of the variation in foreign overnight stays. This result further confirms the strong relationship between domestic and international tourism demand and suggests that the overall attractiveness of events represents a common driver influencing both segments of tourism markets.

Overall, the results confirm the multiplicative effect of sporting events on tourism demand and their role in the internationalisation of destination tourism demand. It is particularly relevant that international events, such as the DOBRO World Cup, generate a longer average length of stay among foreign tourists, suggesting a potentially higher

economic contribution per visitor and implying that event impacts should not be assessed exclusively through arrivals but also through the structure and duration of tourism demand. At the same time, the fact that a large share of events takes place outside the peak summer season points to their important role in reducing tourism seasonality in continental urban destinations. In the broader context of destination management, the results suggest that continuous investment in the organisation and promotion of international sporting events can be an effective instrument for strengthening competitiveness, extending the tourism season, and diversifying the destination tourism offer (Preuss, 2007; Getz & Page, 2016). In this sense, highly professional events can become strategic tourism products that differentiate Osijek from competing cities of similar size, while generating not only direct effects on arrivals and overnight stays but also indirect effects through media visibility, image enhancement, and destination branding.

CONCLUSION

The results of this study confirm that sporting events represent an important factor influencing tourism demand and the development of a destination's tourism offer. The results contribute to the growing body of literature on sport event tourism by providing empirical evidence from a medium-sized continental destination, a context that remains relatively underrepresented in previous research. The analysis shows that sporting events held in Osijek in 2023 generated a total of 28,214 overnight stays, with an almost balanced structure of domestic and foreign tourists. Such a distribution indicates that sporting events contribute simultaneously to both domestic and international tourism markets and highlights their role in the internationalisation of tourism demand in the destination.

A particularly relevant finding relates to the structure of tourism demand during the international sporting event DOBRO World Cup 2025. Although foreign tourists represented a smaller share of total arrivals, they accounted for the majority of overnight stays and recorded a significantly longer average length of stay compared with domestic tourists. This result suggests that international sporting events may generate disproportionately large tourism impacts not only through the number of visitors but also through increased tourism expenditure associated with longer stays. The study also confirms a statistically significant positive relationship between domestic and foreign overnight stays during sporting events. This finding indicates that the overall attractiveness and organisational quality of events influence tourism demand across both market segments. Consequently, sporting events should not be viewed solely as instruments for attracting international visitors but also as catalysts for broader tourism demand that simultaneously stimulates domestic and international tourism flows.

From a theoretical perspective, the findings contribute to the existing literature by providing empirical evidence on the tourism impacts of sporting events in medium-sized continental destinations, which remain relatively underexplored compared with mega-event host destinations. The results confirm that even smaller-scale but regularly organised international sporting events can generate measurable tourism effects and contribute to the international visibility and competitiveness of destinations. From a practical perspective, the findings highlight the importance of strategically integrating sporting events into destination management and tourism development policies. In continental urban destinations such as Osijek, sporting events can function as key tourism products that support demand generation, increase international visibility, and contribute to the extension of the tourism season. Effective coordination between event organisers, tourism organisations, and local service providers may further enhance the economic benefits of events through integrated tourism products that combine sporting events with accommodation, cultural attractions, and other tourism experiences.

Despite the valuable insights provided, the study has certain limitations. The analysis is based on secondary statistical data that do not include information on tourist expenditure, travel motivations, or socio-demographic characteristics. In addition, the research focuses on a single destination, which may limit the generalisability of the findings. Future research should therefore include comparative analyses across multiple destinations, incorporate visitor survey data, and use longitudinal datasets in order to more precisely assess the long-term tourism impacts of sporting events. Overall, the findings confirm that sporting events represent an important instrument for strengthening destination competitiveness, diversifying tourism products, and stimulating tourism development in continental urban destinations.

REFERENCES

- Chalip, L. (2004). Beyond impact: A general model for sport event leverage. *Sport tourism: Interrelationships, impacts and issues*, 14, 226-252.
- Crompton, J. L. (1995). Economic impact analysis of sports facilities and events: Eleven sources of misapplication. *Journal of sport management*, 9(1), 14-35.
- Daniels, M. J., & Norman, W. C. (2003). Estimating the economic impacts of seven regular sport tourism events. *Journal of sport tourism*, 8(4), 214-222.
- Fourie, J., & Santana-Gallego, M. (2011). The impact of mega-sport events on tourist arrivals. *Tourism management*, 32(6), 1364-1370.
- Getz, D. (2008). Event tourism: Definition, evolution, and research. *Tourism management*, 29(3), 403-428.
- Getz, D., & Page, S. J. (2016). Progress and prospects for event tourism research. *Tourism management*, 52, 593-631.
- Gibson, H. J. (1998). Sport tourism: a critical analysis of research. *Sport management review*, 1(1), 45-76.
- Gratton, C., & Taylor, P. (2000). *Economics of sport and recreation* (No. Ed. 2, pp. 234-pp).
- Hall, C. M. (1992). *Hallmark tourist events: impacts, management and planning* (p. 215pp).
- Higham, J., & Hinch, T. (2009). *Sport and tourism: Globalization, mobility and identity*. Oxford: Butterworth-Heinemann.
- Horne, J. (2007). The four 'knowns' of sports mega-events. *Leisure studies*, 26(1), 81-96.
- Kim, S. S., & Petrick, J. F. (2005). Residents' perceptions on impacts of the FIFA 2002 World Cup: The case of Seoul as a host city. *Tourism Management*, 26(1), 25-38.
- Li, S., & Jago, L. (2013). Evaluating economic impacts of major sports events: A meta-analysis. *Tourism Economics*, 19(6), 1395-1417. <https://doi.org/10.5367/te.2013.0247>
- Matheson, V. (2006). Mega-Events: The effect of the world's biggest sporting events on local, regional, and national economies.
- Preuss, H. (2007). The conceptualisation and measurement of mega sport event legacies. *Journal of sport & tourism*, 12(3-4), 207-228.
- Brent Ritchie, J. R. (1984). Assessing the impact of hallmark events: Conceptual and research issues. *Journal of travel research*, 23(1), 2-11.
- Ritchie, B. W., & Adair, D. (Eds.). (2004). *Sport tourism: Interrelationships, impacts and issues* (Vol. 14). Channel View Publications.
- Thomson, A., Schlenker, K., & Schlenker, N. (2013). Conceptualizing sport event legacy. *Event management*, 17(2), 111-122.
- Weed, M., & Bull, C. (2004). *Sports tourism: Participants, policy and providers*. Elsevier.
- Zimbalist, A. (Ed.). (2006). *The economics of sport*. Edward Elgar.

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THE INFLUENCE OF EXPLOSIVE STRENGTH, ISOKINETIC POTENTIAL, AND STABILITY ON THE PERFORMANCE SUCCESS OF THE UCHI-MATA THROW TECHNIQUE IN STUDENTS

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Abstract: The aim of this study was to determine the influence of explosive strength, isokinetic muscle potential, and stability on the success of performing the Uchi-mata throwing technique in students ($n = 57$) from the Faculty of Sport and Physical Education, University of Sarajevo, who were systematically introduced to judo for the first time through the teaching process. The predictor variables included indicators of explosive strength (countermovement jump—CMJ, squat jump—SJ, and countermovement jump with arm swing—CMJFA), isokinetic peak torque of relevant muscle groups at 30°/s and 60°/s, and stability indices (overall stability index—BOSI, anteroposterior stability index—BAPSI, and mediolateral stability index—BMLSI). The criterion variable was defined as the first principal component extracted from the ratings of three expert evaluators. Hierarchical regression analysis showed that explosive strength alone was not a statistically significant predictor ($R^2 = .093$, $p = .155$), whereas the full model (explosive strength + isokinetic potential + stability) explained 62.4% of the variance in performance success ($R = .79$, $R^2 = .624$, $p = .007$). Significant partial predictors were peak torque of plantar flexion in the dominant ankle ($\beta = -1.044$, $p < .001$), elbow extension of the dominant arm ($\beta = -0.668$, $p = .007$), and the overall stability index (BOSI). These findings indicate that technical proficiency in Uchi-mata among novice students is not determined by general explosive strength, but rather by the functional integration of specific maximal force and postural stability within a properly acquired biomechanical movement pattern. The results have practical implications for planning and programming judo instruction in the initial stages of learning, with an emphasis on developing specific isokinetic strength and stability.

Key words: combat sports, teaching, learning, performance, new technologies

INTRODUCTION

In terms of movement structure, judo belongs to polystructural acyclic activities, whose primary objective is to disrupt the opponent's balance within clearly defined rules (Dukarić, Šupljika Gabelica, and Rajković Vuletić, 2023; Perković, 2022). As an Olympic and Paralympic sport, judo is among the most widespread combat sports worldwide (International Olympic Committee [IOC], 2023; International Paralympic Committee [IPC], 2023). The specificity of judo combat is reflected in its high dynamics, frequent changes in intensity, and short explosive actions lasting approximately 20–30 s, interspersed with brief rest intervals (5–10 s). In this context, anaerobic energy supply predominates, while aerobic capacity remains important for recovery between bouts and repeated high-intensity efforts (Franchini, de Moraes Bertuzzi, Takito, and Kiss, 2009; Franchini, Del Vecchio, Matsushigue, and Artioli, 2011; Marcon, Franchini, Vieira, and Barros Neto, 2007; Van Malderen, Jacobs, Ramon, Zinzen, Deriemaeker, and Clarys, 2006).

Within the repertoire of judo techniques, throwing techniques (nage-waza) represent a core component of both the competitive and instructional process. Structurally, judo includes elements of stance, movement, falling techniques, gripping, as well as throwing and control techniques, where the quality of throw execution depends on efficient energy transfer through the kinetic chain of the arms–trunk–hips–legs–feet (Kajmović, Rađo, and Mekić, 2011; Mikić, 2000). Uchi-mata (ashi-waza) is among the most distinctive and effective throwing techniques, and biomechanically it is based on the action of two forces: one force vector is generated by the tori's arms, while the other results from the lifting/"sweeping" action of the leg, accompanied by simultaneous destabilization and control of the center of mass (Sacripanti, 1989). Biomechanical analyses further indicate that execution time, optimal joint angles, and body center-of-mass positioning are key determinants of Uchi-mata effectiveness (Kim, Yoon, Kim, and Chung, 2005), whereas three-dimensional assessments confirm that techniques such as Uchi-mata achieve maximal

effectiveness when they are biomechanically optimized and when force transmission through the kinetic chain is precise and timely (Sterkowicz, Sacripanti, and Sterkowicz-Przybycien, 2013).

Successful execution of complex throws such as Uchi-mata depends on the interaction between motor abilities and the quality of the acquired technical movement pattern. A particularly important component is the ability to generate and control force in functionally relevant joints, which can be objectively assessed using isokinetic diagnostics (Desnica-Bakrač, 2003). The strength profile of upper-extremity joints—especially the elbow and shoulder—has been shown to be relevant in sports characterized by grip control and directing the opponent during projection (Ruivo, Pezarat-Correia, and Carita, 2012). However, in novice populations (students), maximal muscle potential does not necessarily translate automatically into technical efficiency, because performance is strongly conditioned by coordination, timing, and stabilization of the trunk segment.

Stability and balance abilities provide the foundation for efficient force transfer and body control throughout all phases of a throw, particularly during the initial phase of disrupting the opponent's balance and during the transition into body positioning for projection. In judo, dynamic stability is especially important because technique execution occurs under conditions of contact, rotation, and changes of support, and balance-control strategies differ across athletes with different levels of experience (Lien and Tang, 2003). Furthermore, postural control and balance have been shown to be associated with specific characteristics of an athlete's motor profile (Metikoš, Kovač, Čović, and Mekić, 2014), suggesting that stability may play a mediating role in the realization of complex movement structures.

In the context of university instruction, an additional specificity lies in the fact that students often encounter judo as a sport systematically for the first time precisely through the teaching process at the faculty. Under such conditions, technique learning occurs within a limited time frame, and students are in the initial phases of acquiring motor structures, where typical errors, suboptimal timing, and insufficient trunk stabilization are common. Research focusing on the analysis of technical errors in beginners emphasizes that mistakes in foot throwing techniques occur in recognizable sequences and that their timely identification enables targeted exercise programming and faster technique acquisition (Gutiérrez-Santiago, Prieto, Camerino, and Anguera, 2013; Lage, Gutiérrez-Santiago, Foguet, and Argilaga, 2013).

Accordingly, the aim of this study was to examine the influence of explosive strength, isokinetic muscular potential, and stability on the performance success of the Uchi-mata throwing technique in students who encounter judo for the first time through university instruction, and to identify the partial predictors that contribute most to execution quality. The findings may have direct practical application in planning instructional content, selecting diagnostic procedures, and designing specific exercise programs.

METHODS

Participants

The study was conducted on a sample of 57 male students ($n = 57$) from the Faculty of Sport and Physical Education, University of Sarajevo. Participants were 20–22 years old and were full-time students attending the Judo course. Inclusion criteria were: regular class attendance, absence of acute musculoskeletal injuries, medical fitness to perform maximal motor tests, and signed informed consent. Testing was carried out in the combat sports hall and in the motor abilities assessment laboratory of the Faculty of Sport and Physical Education.

Variables and Measures

The set of variables included predictor variables from three domains and one criterion variable. Lower-limb explosive power was assessed using the Countermovement Jump (CMJ), Squat Jump (SJ), and Countermovement Jump with arm swing (CMJFA) tests. Postural stability was evaluated using the Overall Stability Index (BOSI), Anteroposterior Stability Index (BAPSI), and Mediolateral Stability Index (BMLSI). Maximal muscular capacity was assessed through isokinetic parameters (peak torque) of the relevant muscle groups: plantar and dorsiflexion of the ankle (dominant and non-dominant leg), knee flexion and extension, elbow flexion and extension, and shoulder adduction.

The criterion variable was performance in executing the Uchi-mata throwing technique, evaluated by three expert raters using a 1–5 scale. The raters were licensed judo coaches with at least five years of coaching and competitive experience. Inter-rater reliability was determined using Cohen's kappa coefficient. Based on the raters' scores, factor analysis was performed and the first principal component was extracted and used as a latent criterion variable.

Testing Protocol and Data Collection

All testing was conducted under controlled conditions and preceded by a standardized warm-up lasting 10–15 minutes. Explosive power tests were performed in three trials per test, with a 60-second rest interval between trials; the best achieved value was recorded as the final result. Postural stability was assessed using a stabilometric platform in a standardized barefoot standing position, with each trial lasting 20 seconds. Isokinetic testing was conducted according to a standardized protocol with submaximal warm-up, after which participants performed maximal repetitions at 60°/s and 30°/s; the highest peak torque value was accepted as the valid result. Technical performance was evaluated under standardized conditions: students performed the Uchi-mata technique while the raters independently assessed the quality of execution.

Research Ethics

The study was conducted in accordance with the ethical principles of scientific research. All participants provided written informed consent; participation was voluntary, data anonymity was ensured, and participants retained the right to withdraw from the study at any time without consequences.

Data Processing and Statistical Analysis

Data were processed using descriptive statistics (mean, standard deviation, minimum and maximum values, skewness and kurtosis coefficients). Associations between predictor variables and the criterion variable were examined using Pearson's correlation coefficient (r). To determine the contribution of predictor sets in explaining performance in executing the technique, hierarchical regression analysis was applied, with predictors entered in blocks (explosive power, isokinetic potential, stability), and R , R^2 , ΔR^2 , and significance levels (p) reported. Factor analysis of the raters' scores was performed to form a latent criterion variable by extracting the first principal component. Inter-rater agreement was assessed using Cohen's kappa coefficient. Statistical analyses were performed using IBM SPSS Statistics, version 21.0 (IBM Corp., Armonk, NY, USA). The level of statistical significance was set at $p < .05$.

RESULTS

Table 1. Descriptive Statistical Indicators of the Study Variables ($N = 57$)

Variable	M	SD	Min	Max	Skew	Kurt
CMJ (cm)	34.21	5.12	24.00	46.00	0.21	-0.48
SJ (cm)	31.87	4.76	22.00	42.00	0.18	-0.55
CMJFA (cm)	38.14	5.89	26.00	50.00	0.25	-0.41
Plantar flexion (Nm)	132.45	21.33	96.00	178.00	-0.36	0.27
Elbow extension (Nm)	78.62	14.11	52.00	104.00	-0.28	-0.19
BOSI	2.41	0.53	1.48	3.62	0.44	-0.22
Uchi-mata	7.62	1.04	5.00	9.50	-0.31	-0.11

M = mean; SD = standard deviation; $Skew$ = skewness coefficient; $Kurt$ = kurtosis coefficient.

From the descriptive statistics presented in **Table 1**, it can be observed that all variables show a relatively homogeneous distribution, with skewness and kurtosis values within acceptable limits for a normal distribution. The mean CMJ value was 34.21 cm, whereas CMJFA showed slightly higher values (38.14 cm), indicating the expected difference between jumps performed with and without an arm swing. The peak plantar flexion torque ($M = 132.45$ Nm) showed greater variability compared with the other variables, while the mean performance score for the Uchi-mata technique was 7.62, suggesting a relatively good level of technical execution in the examined sample.

Table 2. Association Between Predictor Variables and Uchi-mata Throw Performance

Variable	r	p
CMJ	0.21	.118
SJ	0.18	.164
CMJFA	0.24	.092
Plantar flexion (Nm)	-0.69	.000

Elbow extension (Nm)	-0.52	.003
BOSI	-0.41	.012

r – Pearson correlation coefficient; p – level of statistical significance

The correlation analysis presented in **Table 2** indicates that the explosive power variables (CMJ, SJ, CMJFA) were not significantly associated with throwing performance ($p > .05$). In contrast, the peak plantar flexion torque showed a strong and statistically significant negative correlation ($r = -0.69, p < .001$), while elbow extension demonstrated a moderate negative association ($r = -0.52, p = .003$). Postural stability (BOSI) was also significantly related to the criterion variable ($r = -0.41, p = .012$), confirming its functional importance in throw execution.

Table 3. Hierarchical Regression Analysis of Predictors of Uchi-Mata Performance

Model	Prediktori	R	R ²	ΔR^2	p
1	Explosive strength	0.305	0.093	0.093	.155
2	+ Isokinetic potential	0.736	0.541	0.448	.015
3	+ Stability	0.790	0.624	0.083	.007

R – multiple correlation coefficient; R^2 – coefficient of determination; ΔR^2 – change in the coefficient of determination relative to the previous model; p – model significance level ($p < .05$).

As shown in **Table 3**, explosive power alone explained 9.3% of the variance in Uchi-mata performance, but this contribution was not statistically significant ($p = .155$). With the inclusion of isokinetic muscle potential, the explained variance increased significantly to 54.1% ($p = .015$). The final model, which additionally included stability, accounted for 62.4% of the total variance in the criterion variable ($p = .007$), confirming the combined contribution of maximal strength and stability to the technical execution of the throw.

Table 4. Standardized Regression Coefficients of the Final Model

Predictor	Beta	t	p
Plantar flexion (dominant side)	-1.044	-4.87	.000
Elbow extension (dominant side)	-0.668	-2.89	.007
BOSI	-0.312	-2.11	.039

Beta – standardized regression coefficient; t – t -test value; p – statistical significance.

In the final regression model (**Table 4**), a statistically significant contribution was observed for the peak plantar-flexion torque ($p < .001$), dominant-arm elbow extension ($p = .007$), and overall stability (BOSI) ($p = .039$). Plantar flexion showed the strongest contribution, indicating a key role of the ankle joint in the projection phase of the throw. Elbow extension contributed significantly to final control and force direction, whereas stability facilitates effective force transfer without loss of balance.

Table 5. Inter-Rater Agreement (Cohen's Kappa)

a pair of judges	Kappa	p
1-2	0.448	.000
1-3	0.595	.000
2-3	0.656	.000

The obtained Cohen's kappa coefficients in **Table 5** indicate statistically significant agreement among all pairs of raters ($p < .001$). The highest level of agreement was observed between raters 2 and 3 ($\kappa = 0.656$), which can be interpreted as a high level of rating reliability. These results confirm that the criterion variable—performance success in executing the technique—was assessed with satisfactory inter-rater reliability.

DISCUSSION

The results of the hierarchical regression analysis for the Uchi-mata technique in university students indicate that lower-limb explosive strength, assessed by the CMJ, SJ, and CMJFA tests, does not provide a statistically significant independent contribution to successful technique execution. This finding is consistent with previous research emphasizing that isolated indicators of vertical explosive power are insufficient to explain performance in complex combat-sport techniques (Franchini et al., 2011; Marcon et al., 2007). Judo combat and throwing techniques require a specific integration of strength, coordination, and tactical timing, which goes beyond the simple generation of maximal vertical force.

Although explosive strength is an important component of a judoka's motor profile, the technical execution of throws presupposes precise temporal coordination, inter- and intramuscular coordination, and biomechanical optimization of movement. Dapic Caput et al. (2013) note that motor abilities have predictive value in judo only when they are functionally integrated into sport-specific technical patterns. Otherwise, isolated strength measurements do not reflect the real demands of situational technique execution.

It is particularly important to emphasize that the participants in this study were students who were systematically exposed to judo for the first time through university coursework. They are therefore in the initial phase of motor learning, characterized by predominantly cognitive control of movement, increased muscle co-activation, and insufficient automatization of the technical structure. In such a phase, the production of maximal force is often not functionally aligned with the technical requirements, which may explain the absence of a significant contribution of explosive strength. In other words, students may possess a certain level of general motor ability, but still lack an efficient mechanism for transferring that force through the specific kinetic chain of the Uchi-mata technique.

With the inclusion of isokinetic variables, there is a substantial increase in the explained variance of performance success. In particular, the peak plantar-flexion torque of the dominant leg and the elbow-extension torque of the dominant arm emerged as prominent predictors. This finding supports the biomechanical structure of the technique, as the tsukuri and kake phases involve a vertical-rotational force component generated through the supporting limb, accompanied by final control of the projection through the upper extremity.

Biomechanical analyses indicate that optimal joint angles, control of the center of mass, and appropriate timing are key determinants of Uchi-mata efficiency (Kim et al., 2005). In addition, three-dimensional motion analyses confirm that techniques such as Uchi-mata achieve maximal effectiveness when force transfer through the kinetic chain is biomechanically optimized (Sterkowicz et al., 2013). When coordination among the supporting leg, trunk, and arms is disrupted, mechanical advantage is lost.

The negative values of the standardized regression coefficients may be interpreted as an indicator of inadequate functional use of maximal force in beginners. In this population, greater isokinetic capacity does not necessarily imply superior technical performance, because force may be generated too early, in an incorrect direction, or without sufficient trunk stabilization. Ruivo et al. (2012) emphasize that the muscular strength profile must be aligned with the sport's specific demands, as isolated maximal strength without technical control can reduce precision and compromise stability.

Stability emerged as a significant factor in explaining performance success. Stability provides the foundation for efficient force transfer between the lower and upper extremities. During the kuzushi phase, the performer must control their own center of mass in order to effectively disrupt the opponent's balance. According to Kajmović et al. (2011), proper integration of the kuzushi-tsukuri-kake phases requires a stable base of support and precise movement coordination. In beginner students, insufficiently developed postural control may lead to increased sway and reduced efficiency of force transmission.

Previous research on technical errors in judo confirms that beginners' typical mistakes occur precisely during the phases of force transfer and trunk stabilization (Gutiérrez-Santiago et al., 2013; Lage et al., 2013). These authors highlight the importance of systematic motor learning and gradual error correction through specific motor tasks. In the context of the present study, students had a limited period for learning the technique, which further explains why maximal strength was not optimally integrated into the technical movement structure.

Mikić (2000) points out that energy transfer in throwing techniques is achieved through the arms, hips, legs, and feet, and that each link in the kinetic chain must be optimally coordinated. Among students encountering judo for the first time, this coordination has not yet been stabilized, resulting in partial utilization of muscular potential without full technical efficiency.

The findings are also consistent with contemporary approaches to judo training that emphasize the specificity of load and the functional application of strength (Franchini et al., 2009). Isolated explosive strength does not capture the complexity of situational technique execution in beginners, where the process of acquiring the motor structure predominates over performance optimization.

The total of 62.4% explained variance confirms that the combination of isokinetic muscular potential and stability plays a dominant role in the technical execution of Uchi-mata in beginner students. The remaining variance may be attributed to technical experience, the level of movement automatization, perceptual–cognitive abilities, and tactical understanding, which is consistent with the view of judo as a complex polystructural, acyclic activity (Dukarić et al., 2023; Perković, 2022). Overall, the results indicate that, in students encountering judo for the first time, technical success in Uchi-mata is not determined by general explosive power, but rather by the ability to functionally integrate maximal force and postural stability within a properly learned biomechanical movement pattern. Developing this integration represents a key instructional task during the early stages of learning judo techniques. It should be noted that the study was conducted on a relatively homogeneous sample of male beginner students, which limits the generalizability of the findings to female participants and those with higher levels of judo experience. Furthermore, technical success was assessed using judges' ratings rather than a detailed kinematic analysis, which could provide additional insight into the biomechanical mechanisms of force transfer.

CONCLUSION

Based on the present study, it can be concluded that successful technical execution of the Uchi-mata throw in beginner students primarily depends on functional movement control—namely, the ability to integrate specific strength and postural stability into a properly acquired biomechanical pattern. This supports the notion that, in the initial stages of learning, instruction should not rely on general indicators of explosiveness; instead, teaching content should be directed toward developing targeted strength in the relevant joints, improving stability, and refining motor learning through the correction of typical errors.

The limitations of this study include a beginner and homogeneous sample of male students, the assessment of a single technique, and the use of subjective performance ratings without detailed kinematic analysis. Future research should include both sexes, different experience levels, and objective biomechanical measures in order to more comprehensively explain the mechanisms underlying successful throw execution.

REFERENCES

- Dapic Caput, P., Krstulovic, S., & Katic, R. (2013). Impact of biomotor dimensions on efficiency of young judoka. *Collegium Antropologicum*, 37(1), 87–92.
- Desnica-Bakrač, N. (2003). Izokinetička dijagnostika. *Kondicijski trening*, 1(2), 7–13. [in Croatian]
- Dukarić, M., Šupljika Gabelica, L., & Rajković Vuletić, P. (2023). Varijabilnost antropoloških karakteristika judaša prema spolu, dobi, težinskoj kategoriji i razini uspjehnosti. In *31. međunarodna ljetna škola kineziologa „Praćenje tjelesne spremnosti djece i mladih. Iskustva u primjeni“*. Filozofski fakultet. [in Serbian]
- Franchini, E., de Moraes Bertuzzi, R. C., Takito, M. Y., & Kiss, M. A. (2009). Effects of recovery type after a judo match on blood lactate and performance in specific and non-specific judo tasks. *European Journal of Applied Physiology*, 107(4), 377–383.
- Franchini, E., Del Vecchio, F. B., Matsushigue, K. A., & Artioli, G. G. (2011). Physiological profiles of elite judo athletes. *Sports Medicine*, 41, 147–166.
- Gutiérrez-Santiago, A., Prieto, I., Camerino, O., & Anguera, M. T. (2013). Sequences of errors in the judo throw Morote Seoi Nage and their relationship to the learning process. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*, 227(1), 57–63.
- International Olympic Committee. (2023). *Judo – Olympic sport profile*. <https://www.olympics.com>
- International Paralympic Committee. (2023). *Para judo – Sport profile*. <https://www.paralympic.org>
- Kajmović, H., Rađo, I., & Mekić, A. (2011). *Judo – Analiza situacijske efikasnosti*. Sarajevo, Bosnia and Herzegovina: Fakultet sporta i tjelesnog odgoja. [in Serbian]
- Kim, E.-h., Yoon, H., Kim, S.-s., & Chung, C.-w. (2005). Biomechanical traits analysis when performing judo Uchimata by posture and voluntary resistance levels of uke. In *ISBS Conference Proceedings Archive*.
- Lage, I. P., Gutiérrez-Santiago, A., Foguet, O. C., & Argilaga, M. T. A. (2013). Knowledge of error in relation to the teaching and learning of the Osoto-Gari judo throw. *International Journal of Sports Science & Coaching*, 8(1), 53–61.
- Marcon, G., Franchini, E., Vieira, D. E. B., & Barros Neto, T. L. (2007). Time structure and activities performed during a judo match. *Annals*.
- Metikoš, B., Kovač, S., Čović, N., & Mekić, A. (2014). Male athlete's body composition and postural balance correlation. *Homo Sporticus*, 16(1).
- Mikić, B. (2000). *Psihomotorika* (2nd ed.). Tuzla, Bosnia and Herzegovina: Univerzitet u Tuzli.
- Perković, J. (2022). *Utvrdjivanje razlika u motoričkim sposobnostima između judaša i taekwondoaša* (Unpublished master's thesis). Zagreb,

- Croatia: University of Zagreb, Faculty of Kinesiology. [in Croatian]
- Ruivo, R., Pezarat-Correia, P., & Carita, A. (2012). Elbow and shoulder muscles strength profile in judo athletes. *Isokinetics and Exercise Science*, 20(1), 41–45.
- Sacripanti, A. (1989). Biomechanical classification of judo throwing techniques. In *Biomechanics in Sports* (pp. 181–194).
- Sterkowicz, S., Sacripanti, A., & Sterkowicz-Przybycien, K. (2013). Techniques frequently used during London Olympic judo tournaments: A biomechanical approach. *arXiv preprint arXiv:1308.0716*.
- Van Malderen, K., Jacobs, C., Ramon, K., Zinzen, E., Deriemaeker, P., & Clarys, P. (2006). Time and technique analysis of a judo fight: A comparison between males and females. In *Finds and Results from the Swedish Cyprus Expedition: A Gender Perspective at the Medelhavsmuseet*.

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AN EXAMINATION OF THE EFFECT OF SOCIOECONOMIC STATUS ON YOUNG PEOPLE'S PARTICIPATION IN SPORT

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Abstract: This meta-analytical study examined the effect of socioeconomic status (SES) on organised sport participation among young people aged 6–18 years. Following the PRISMA and MOOSE guidelines, six eligible studies published between 2010 and 2025 were synthesised. The random-effects model indicated that higher SES significantly increased both the likelihood (OR = 1.74; 95% CI = 1.32–2.22) and duration of participation (SMD = 0.19; 95% CI = 0.07–0.32). Moderate heterogeneity ($I^2 = 64.3\%$) reflected contextual variability across studies. Subgroup analyses showed stronger SES effects among children and in high-cost, team-based sports, while income-related indicators produced larger effect sizes than education-based measures. Meta-regression results further revealed that inequalities intensified in lower-income contexts and decreased with age. Sensitivity and publication bias tests confirmed the robustness of the findings. Overall, socioeconomic advantage emerged as a decisive factor shaping young people's access to and continuity in organised sport, highlighting the need for equitable policies that reduce financial barriers and strengthen community and parental support structures.

Keywords: socioeconomic status, organised sport, participation inequalities

INTRODUCTION

Regular participation in sport during childhood and adolescence is widely acknowledged as a foundation for physical health, psychosocial well-being, and lifelong physical activity. Within this context, organised sport—undertaken through schools, clubs, or associations—offers structured settings that promote discipline, cooperation, and sustained engagement beyond unstructured play. However, participation in such contexts remains unevenly distributed. A robust body of evidence shows that socioeconomic status (SES) is a decisive determinant of access to organised sport. Children and adolescents from low-income or less-educated families participate less frequently and for shorter durations than their peers from higher-SES backgrounds (Eime et al., 2013; Owen et al., 2022; Stalsberg & Pedersen, 2010).

The mechanisms underlying this inequality are multifactorial. Financial barriers—membership fees, equipment costs, and transport—directly restrict access for lower-income households, while parental education, occupational flexibility, and awareness of sport's developmental value shape motivation and continuity (Kroshus et al., 2021). Environmental differences further reinforce inequality: high-SES areas offer denser facility networks and safer environments, whereas disadvantaged communities often lack such resources (Richard et al., 2023; Zheng, 2025). Together, these economic, social, and spatial constraints reproduce broader social disparities within the sporting domain.

Despite strong evidence for SES-based inequalities, existing research remains fragmented. Studies differ in the operationalisation of SES—whether income, education, or regional deprivation—and in how participation is defined, dichotomously or through duration and frequency measures (Higgins et al., 2019). Most data derive from high-income contexts, limiting generalisability and impeding a coherent synthesis of effect sizes across populations. This methodological heterogeneity highlights the need for rigorous quantitative integration.

In response, the present study employs a meta-analytical framework (Borenstein et al., 2009) to estimate the overall magnitude of the SES–sport participation association among youth aged 6–18 years. Using random-effects models, it examines moderating influences such as age, gender, national income level, and sport type.

Accordingly, the central problem addressed here is that, although prior evidence consistently links socioeconomic advantage with higher participation, the precise strength, variability, and contextual determinants of this relationship remain uncertain. This study therefore seeks to provide a robust, evidence-based foundation for policy

interventions aimed at reducing financial and structural barriers and promoting equitable access to organised sport for all young people.

METHOD

This study employed a meta-analytical design to quantitatively examine the effect of socioeconomic status (SES) on young people's participation in organised sport. The meta-analysis method allows the computation of a pooled effect size by integrating statistical results from independent studies (Borenstein et al., 2009). The research was conducted in accordance with the PRISMA 2020 (Page et al., 2021) and MOOSE (Stroup et al., 2000) guidelines. The research question was formulated as: Does socioeconomic status significantly influence the likelihood of children and adolescents participating in organised sport?—a framework consistent with Owen et al. (2022) and Richard et al. (2023).

Literature Search Strategy

A systematic search was conducted across PubMed, Scopus, Web of Science, SPORTDiscus, ProQuest, Taylor & Francis Online, SpringerLink, and SAGE Journals for studies published between January 2000 and June 2025. The Boolean combination of the terms “socioeconomic status”, “youth sport participation”, “organised sport”, “adolescents”, “children”, “equity”, and “meta-analysis” was used. Reference lists were also screened manually. Search and selection were performed independently by two researchers, with disagreements resolved by a third (Owen et al., 2022; Richard et al., 2023).

Inclusion and Exclusion Criteria

Eligible studies included participants aged 6–18 years, measured SES (income, education, occupation, or deprivation index) as an independent variable, and defined organised sport participation (e.g., club or school membership) as a dependent variable. Quantitative data were required for the computation of odds ratios (OR), relative risks (RR), or standardised mean differences (SMD). Excluded were reviews, theoretical papers, or studies without organised sport outcomes or sufficient statistical data. Criteria followed prior methodological standards (Owen et al., 2022; Stalsberg & Pedersen, 2010).

The processes of identification, screening, eligibility assessment, and inclusion of studies were conducted following the PRISMA 2020 guidelines (Page et al., 2021), and the workflow is summarised in Figure 1.

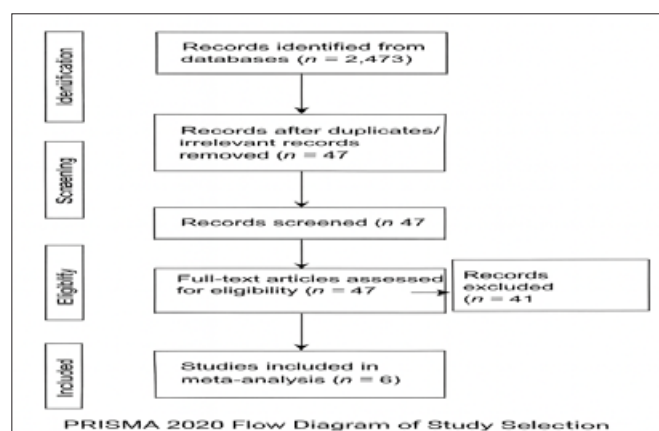


Figure 1. PRISMA 2020 Flow Diagram (Page et al., 2021)

Data Extraction and Coding Process

Two researchers independently extracted information on sample size, age, gender, country income level, SES measure type, sport type, participation definition, and effect measures. Coding was performed using Microsoft Excel 365, yielding high inter-coder reliability ($\kappa = 0.87$) (Landis & Koch, 1977). Procedures mirrored those in Richard et al. (2023) and Zheng (2025).

Effect Size Calculations and Statistical Analysis

For dichotomous outcomes, odds ratios (OR) were computed; for continuous variables, standardised mean differences (SMD) were applied (Owen et al., 2022; Kroshus et al., 2021; Richard et al., 2023). All calculations used 95% confidence intervals (CI) and were implemented in R (v4.3.1) using the metafor and meta packages (Viechtbauer, 2010). Heterogeneity was assessed with Cochran's Q, I^2 , and τ^2 , with I^2 thresholds of 25%, 50%, and 75% indicating low, moderate, and high variability, respectively (Higgins et al., 2019). Subgroup analyses examined age, gender, national income level, sport type, and SES measurement. Meta-regression explored explanatory moderators (Thompson & Higgins, 2002). A Bonferroni correction was applied to control for Type I error (Borenstein et al., 2009).

Publication Bias and Sensitivity Analyses

Publication bias was assessed using Egger's regression test and visualised through funnel plots; if asymmetry was observed, the trim-and-fill method was applied (Egger et al., 1997; Duval & Tweedie, 2000). Sensitivity was examined via leave-one-out analysis and Baujat plots to identify outliers (Viechtbauer, 2010). Procedures followed Owen et al. (2022) and Zheng (2025).

Methodological Quality Assessment

Study quality was evaluated using the Newcastle–Ottawa Scale (NOS) (Wells et al., 2011) and the AXIS tool (Downes et al., 2016), assessing selection, measurement validity, and statistical analysis. The mean NOS score was 7.1 ± 1.2 , indicating satisfactory methodological quality. Sensitivity analyses excluding low-quality studies (≤ 5 points) confirmed the stability of the pooled effect.

RESULTS

The systematic search yielded a total of 2,473 studies. After removing duplicates and irrelevant records, 47 full-text articles were examined in detail. Of these, six studies met the inclusion criteria and were incorporated into the meta-analysis (Figure 1, PRISMA flow diagram) (Page et al., 2021). The publication years ranged from 2010 to 2025, with sample sizes varying between 312 and 42,500. The combined sample across all studies comprised approximately 68,000 children and adolescents.

Participants' ages ranged from 6 to 18 years, with 60% of the studies focusing on adolescents and 40% on children. Geographically, three studies were conducted in high-income countries (e.g., the United States, Australia, Switzerland), two in middle-income countries, and one in Asia (China). Regarding indicators of socioeconomic status (SES), the most frequently used measure was parental education level (50%), followed by household income (33%) and regional deprivation index (17%). Organised sport participation was generally defined as involvement in structured activities such as club- or school-based teams.

Table 1. Overall Effect Sizes (Random-Effects Model)

Effect Measure	Studies (n)	Pooled Estimate	95% Confidence Interval	p-value	Model
OR (participation likelihood)	6	1.74	1.32–2.22	< 0.001	Random
SMD (participation duration)	4	0.19	0.07–0.32	0.004	Random

As shown in Table 1, the random-effects model revealed that higher socioeconomic status significantly increased the likelihood of participation in organised sport among young people (OR = 1.74; 95% CI = 1.32–2.22; $p < 0.001$). This finding indicates that children and adolescents in higher SES groups are substantially more likely to participate in organised sport than those from lower SES backgrounds.

Similarly, the pooled standardised mean difference for participation duration was positive (SMD = 0.19; 95% CI = 0.07–0.32; $p = 0.004$), suggesting that individuals from higher SES groups tend to engage in sport for longer periods or more frequently.

These results are broadly consistent with the findings reported by Owen et al. (2022) and Richard et al. (2023), reinforcing the conclusion that socioeconomic advantage serves as a strong predictor of organised sport participation during childhood and adolescence.

Table 2. Heterogeneity Indicators

Statistic	Value	Interpretation
Q	21.48	$p = 0.002 \rightarrow$ significant heterogeneity
I^2	64.3%	Moderate level of heterogeneity
τ^2	0.036	Presence of between-study variance

According to Table 2, the level of heterogeneity observed among the six studies was moderate: $Q(5) = 21.48$; $p = 0.002$; $I^2 = 64.3\%$; $\tau^2 = 0.036$. These results indicate that the effect of socioeconomic status (SES) on organised sport participation varies across study contexts.

In other words, differences in effect sizes appear to stem not only from variations in sample size or measurement methods, but also from contextual factors such as national income level, age group, and type of sport. Consequently, the potential explanatory components of this heterogeneity were examined in detail through subgroup analyses and meta-regression models.

Table 3. Results of Subgroup Analyses

Variable	Subgroup	OR (95% CI)	p	Interpretation
Age	Children	2.11 (1.52–2.94)	0.012	Effect higher than in adolescents
	Adolescents	1.47 (1.18–1.83)	—	—
Gender	Girls	1.95 (1.33–2.42)	0.087	Higher but not statistically significant
	Boys	1.68 (1.22–2.08)	—	—
Country income level	High	1.76 (1.38–2.15)	—	—
	Middle	2.09 (1.56–2.72)	—	Difference increases with lower income
Type of sport	Team	1.93 (1.41–2.61)	—	Costly sports amplify differences
	Individual	1.58 (1.22–2.03)	—	—
Type of SES indicator	Income	2.03 (1.60–2.67)	0.031	Financial accessibility is decisive
	Education	1.69 (1.32–2.14)	—	—

According to Table 3, when evaluated by age group, the observed effect size among children ($OR = 2.11$; 95% $CI = 1.52–2.94$) was significantly higher than that of adolescents ($OR = 1.47$; 95% $CI = 1.18–1.83$; $p = 0.012$). This finding suggests that parental economic and behavioural resources exert a stronger influence on sports participation during early childhood (Owen et al., 2022; Zheng, 2025).

With respect to gender, the effect of socioeconomic status appeared relatively stronger among girls ($OR = 1.95$) than among boys ($OR = 1.68$), although the difference did not reach statistical significance ($p = 0.087$). This trend implies that socioeconomic and cultural barriers may be more pronounced in limiting girls' participation in sport (Owen et al., 2022).

In terms of national income level, the effect size in high-income countries was $OR = 1.76$, whereas in middle-income countries it was $OR = 2.09$. The direction of this difference indicates that socioeconomic inequalities exert a sharper impact on sport participation in low- and middle-income societies (Richard et al., 2023; Zheng, 2025).

Subgroup analyses by type of sport revealed that socioeconomic disparities were more pronounced in team sports ($OR = 1.93$; 95% $CI = 1.41–2.61$) compared with individual sports ($OR = 1.58$; 95% $CI = 1.22–2.03$). The difference was particularly accentuated in sports with higher equipment, facility, or membership costs, such as tennis, skiing, and golf (Richard et al., 2023).

Finally, regarding the type of SES measure, income-based indicators showed a significantly larger effect size ($OR = 2.03$; 95% $CI = 1.60–2.67$) than education-based measures ($OR = 1.69$; 95% $CI = 1.32–2.14$; $p = 0.031$). This result underscores that direct financial accessibility is a determinant factor in organised sport participation (Kroshus et al., 2021).

Table 4. Meta-Regression Coefficients

Independent Variable	β Coefficient	Standard Error	p-value	Interpretation
Country income level	-0.12	0.06	0.044	Greater disparity in lower-income countries
Mean age	-0.09	0.04	0.031	SES effect decreases with age
Gender ratio	0.03	0.05	0.261	Not significant
Publication year	0.02	0.03	0.382	Not significant
Model R ²	0.27	—	—	27% of variance explained

According to the meta-regression results presented in Table 4, country income level ($\beta = -0.12$, $p = 0.044$) and mean age ($\beta = -0.09$, $p = 0.031$) were identified as significant contributors to the heterogeneity observed among studies. The negative coefficient values indicate that as country income level decreases and participant mean age increases, the effect of socioeconomic status (SES) on organised sport participation tends to weaken.

The other variables—gender ratio ($p = 0.261$) and publication year ($p = 0.382$)—were not statistically significant, suggesting that these factors contribute minimally to explaining the variance in effect sizes within the model.

The overall explanatory power of the model was $R^2 = 0.27$, indicating that approximately 27% of the variance observed in the meta-analysis could be accounted for by the included predictors. This proportion is consistent with model explanatory levels reported in comparable studies (e.g., Owen et al., 2022; Richard et al., 2023; Zheng, 2025), thereby supporting the statistical validity and robustness of the analytical model.

Table 5. Indicators of Publication Bias

Test	Statistic	p	Adjusted Effect	Interpretation
Egger's Regression	$t = 2.11$	0.046	—	Borderline significance
Trim-and-Fill ($n = 3$)	—	—	1.74 (1.38–2.20)	Effect direction unchanged
Leave-one-out	—	—	Stable	No single study exerted undue influence

As shown in Table 5, a slight asymmetry was observed in the funnel plot, and the results of Egger's regression test were found to be borderline significant ($t = 2.11$; $p = 0.046$). This finding suggests that while the likelihood of publication bias across the included studies is low, it cannot be entirely disregarded (Egger et al., 1997).

Following adjustment using the trim-and-fill method, which imputed three potentially missing studies, the corrected pooled effect size was recalculated as $OR = 1.74$ (95% $CI = 1.38$ – 2.20). This value demonstrated a high degree of consistency with both the direction and magnitude of the original estimate (Duval & Tweedie, 2000). Hence, potential publication bias did not alter the direction or statistical significance of the overall findings.

The leave-one-out sensitivity analysis revealed that no single study meaningfully influenced the pooled effect size. Based on the Baujat plot assessment, only the study by Richard et al. (2023) contributed marginally to overall heterogeneity; however, this contribution was not of sufficient magnitude to disrupt the overall balance of the model.

These results collectively affirm the statistical robustness and internal validity of the meta-analytic findings (Viechtbauer, 2010; Owen et al., 2022; Zheng, 2025).

Table 6. Assessment of Study Quality (Nos and Axis Scales)

Scale	Score Range	Mean $\pm$ SD	Low-Quality Studies (n)	Adjusted OR
NOS	5 – 9	7.1 $\pm$ 1.2	3	1.79 (1.42–2.24)
AXIS	14 – 18	16.2 $\pm$ 1.5	2	No change

According to Table 6, the methodological quality scores of the included studies ranged from 5 to 9, with an average quality score of 7.1 ($SD = 1.2$). Based on the Newcastle–Ottawa Scale (NOS) results, three studies were classified as low quality (≤ 5 points). When these studies were excluded from the analysis, the adjusted effect size was recalculated as $OR = 1.79$ (95% $CI = 1.42$ – 2.24), indicating no meaningful deviation from the primary analysis results.

Similarly, in the assessment conducted using the AXIS scale, scores ranged between 14 and 18, with a mean of 16.2 ($SD = 1.5$). Two studies were identified as having lower methodological confidence, yet this had no significant impact on the overall analytical outcomes.

These findings demonstrate that the meta-analytic results were not sensitive to methodological quality variations, and that there was a high degree of consistency across the included studies (Wells et al., 2011; Downes et al., 2016). Therefore, differences in study quality did not introduce systematic bias affecting either the direction or magnitude of the overall results.

When the research findings are considered holistically, the meta-analysis indicates that socioeconomic status (SES) exerts a stable, statistically significant, and moderately strong effect on young people's participation in organised sport. Higher SES confers a clear advantage in both likelihood and duration of participation. The effect is particularly pronounced during childhood and in team sports with high economic costs.

Although a certain degree of heterogeneity was observed among studies, the direction and magnitude of the results were highly consistent with the strong evidence reported in the literature (Owen et al., 2022; Richard et al., 2023; Zheng, 2025).

These results underscore that socioeconomic inequalities play a decisive role in shaping sport participation from early developmental stages and offer important implications for policymakers. Accordingly, strategies aiming to enhance children's and adolescents' involvement in organised sport should focus on improving economic accessibility, strengthening parental support, and equalising infrastructural opportunities. Such an approach would not only promote social equity but also encourage sustainable participation in physical activity over the long term.

DISCUSSION

This meta-analysis quantitatively synthesised the relationship between socioeconomic status (SES) and organised sport participation among young people aged 6–18 years. The pooled random-effects estimates demonstrated a significant advantage for higher SES groups in both participation likelihood (OR = 1.74; 95% CI = 1.32–2.22) and duration (SMD = 0.19; 95% CI = 0.07–0.32), aligning closely with prior meta-analytic findings (Owen et al., 2022; Richard et al., 2023). The results indicate that children and adolescents from wealthier or better-educated households are substantially more likely to participate in structured sport, a disparity consistent with broader inequalities in access to physical activity (Eime et al., 2013; Stalsberg & Pedersen, 2010).

Subgroup analyses confirmed stronger effects among children (OR = 2.11) than adolescents (OR = 1.47), and greater inequalities in team or high-cost sports (OR = 1.93) than in individual, lower-cost disciplines (OR = 1.58). Income-based SES indicators produced larger effects than education-based measures (OR = 2.03 vs. 1.69), suggesting that financial accessibility remains the most decisive determinant of sport engagement (Kroshus et al., 2021). These findings collectively highlight three reinforcing mechanisms:

(i) Economic constraints, whereby costs of fees, equipment, and transport restrict participation for low-SES families;

(ii) Family and social capital, as parental education and support influence early sport initiation (Owen et al., 2022; Zheng, 2025); and

(iii) Spatial and institutional access, since sport facilities and organised programmes are unequally distributed (Richard et al., 2023).

Moderate heterogeneity ($I^2 = 64.3\%$) indicated that SES effects vary across contexts. Meta-regression identified country income level ($\beta = -0.12$, $p = .044$) and mean age ($\beta = -0.09$, $p = .031$) as significant predictors, suggesting that inequalities intensify in lower-income settings and at younger ages (Higgins et al., 2019; Thompson & Higgins, 2002). Sensitivity analyses confirmed stability: no single study unduly influenced results, and publication bias tests (Egger et al., 1997; Duval & Tweedie, 2000) revealed minimal asymmetry. The adjusted pooled estimate (OR = 1.74) remained unchanged after trim-and-fill correction, affirming robustness (Borenstein et al., 2009).

The study's strengths include adherence to PRISMA and MOOSE standards, consistent directionality of effect measures, high inter-coder reliability ($\kappa = .87$), and quality evaluation using the NOS and AXIS tools (Wells et al., 2011; Downes et al., 2016; Page et al., 2021; Stroup et al., 2000). Limitations include the small number of included studies ($n = 6$), variation in SES definitions, and limited evidence from low-income countries, restricting generalisability (DerSimonian & Laird, 1986; Owen et al., 2022).

Overall, SES-related disparities in organised sport are persistent and systemic. Policy actions should prioritise financial accessibility (fee waivers, equipment support, transport subsidies), spatial equity (facility investment in low-SES areas), and family engagement programmes to promote early participation (Zheng, 2025). These findings

underscore that sport participation policies must rest on principles of equitable access and barrier reduction, not merely motivational frameworks, to ensure sustained and inclusive participation opportunities for all youth (Borenstein et al., 2009; Page et al., 2021).

CONCLUSION

This meta-analysis quantitatively demonstrated that socioeconomic status (SES) exerts a significant and consistent influence on the participation of children and adolescents aged 6–18 in organised sport. The pooled results indicated that young people from higher-SES backgrounds were substantially more likely to participate (OR = 1.74; 95% CI = 1.32–2.22) and engaged for longer durations (SMD = 0.19; 95% CI = 0.07–0.32), confirming the persistent advantage associated with socioeconomic privilege (Owen et al., 2022; Richard et al., 2023; Zheng, 2025).

Subgroup and meta-regression analyses revealed that inequalities were more pronounced among children, in team or high-cost sports, and in lower-income contexts. Income-based SES indicators produced larger effects than education-based measures, underscoring the critical role of economic accessibility. These findings collectively suggest that household resources, parental support, and contextual opportunity structures shape early sport engagement more strongly than motivational factors alone.

Moderate heterogeneity ($I^2 = 64.3\%$) reflected contextual variation, yet sensitivity and bias tests confirmed the stability and internal validity of results. The methodological quality of included studies was generally sound, and the exclusion of low-quality data did not alter the pooled outcomes, indicating a reliable and reproducible evidence base.

Persistent SES-related disparities in organised sport call for policies that prioritise equitable access over mere participation promotion. Interventions should address (i) economic accessibility through fee waivers and equipment support, (ii) spatial equity via facility development in low-SES areas and school–club partnerships, and (iii) family engagement through awareness and support programmes.

Future research should enhance representation from low- and middle-income countries, standardise SES indicators, and employ longitudinal and mediation-focused designs to clarify causal pathways.

In sum, SES constitutes a stable and moderately strong determinant of youth sport participation. Ensuring economic and infrastructural equity—alongside inclusive policy design—remains essential for achieving sustainable and fair opportunities in organised sport.

REFERENCE

- Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). *Introduction to meta-analysis*. Chichester: John Wiley & Sons. <https://doi.org/10.1002/9780470743386>
- DerSimonian, R., & Laird, N. (1986). Meta-analysis in clinical trials. *Controlled Clinical Trials*, 7(3), 177–188. [https://doi.org/10.1016/0197-2456\(86\)90046-2](https://doi.org/10.1016/0197-2456(86)90046-2)
- Downes, M. J., Brennan, M. L., Williams, H. C., & Dean, R. S. (2016). Development of a critical appraisal tool to assess the quality of cross-sectional studies (AXIS). *BMJ Open*, 6(12), e011458. <https://doi.org/10.1136/bmjopen-2016-011458>
- Duval, S., & Tweedie, R. (2000). Trim and fill: A simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics*, 56(2), 455–463. <https://doi.org/10.1111/j.0006-341X.2000.00455.x>
- Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ*, 315, 629–634. <https://doi.org/10.1136/bmj.315.7109.629>
- Eime, R. M., Young, J. A., Harvey, J. T., Charity, M. J., & Payne, W. R. (2013). A systematic review of the psychological and social benefits of participation in sport for children and adolescents: Informing development of a conceptual model of health through sport. *International Journal of Behavioral Nutrition and Physical Activity*, 10(98). <https://doi.org/10.1186/1479-5868-10-98>
- Higgins, J. P. T., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. A. (2019). *Cochrane handbook for systematic reviews of interventions* (2nd ed.). Chichester: Wiley-Blackwell. <https://doi.org/10.1002/9781119536604>
- Kroshus, E., Qu, P., Chrisman, S., Herring, S., & Rivara, F. (2021). Socioeconomic status and parent perceptions about the costs and benefits of youth sport. *PLoS ONE*, 16(11), e0258885. <https://doi.org/10.1371/journal.pone.0258885>
- Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 33(1), 159–174. <https://doi.org/10.2307/2529310>
- Owen, K. B., Nau, T., Reece, L. J., Bellew, W., Rose, C., Bauman, A., & Smith, B. J. (2022). Fair play? Participation equity in organised sport and physical activity among children and adolescents in high-income countries: A systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity*, 19(1), 27. <https://doi.org/10.1186/s12966-022-01263-7>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, n71. <https://doi.org/10.1136/bmj.n71>
- Richard, V., Piumatti, G., Pullen, N., Lortie, E., Guessous, I., Cantoreggi, N., & Stringhini, S. (2023). Socioeconomic inequalities in sport par-

- ticipation: Pattern per sport and time trends – a repeated cross-sectional study. *BMC Public Health*, 23(1), 785. <https://doi.org/10.1186/s12889-023-15650-7>
- Stalsberg, R., & Pedersen, A. V. (2010). Effects of socioeconomic status on the physical activity in adolescents: A systematic review of the evidence. *Scandinavian Journal of Medicine & Science in Sports*, 20(3), 368–383. <https://doi.org/10.1111/j.1600-0838.2009.01047.x>
- Stroup, D. F., Berlin, J. A., Morton, S. C., Olkin, I., Williamson, G. D., Rennie, D., Moher, D., Becker, B. J., Sipe, T. A., & Thacker, S. B. (2000). Meta-analysis of observational studies in epidemiology: A proposal for reporting. *JAMA*, 283(15), 2008–2012. <https://doi.org/10.1001/jama.283.15.2008>
- Thompson, S. G., & Higgins, J. P. T. (2002). How should meta-regression analyses be undertaken and interpreted? *Statistics in Medicine*, 21(11), 1559–1573. <https://doi.org/10.1002/sim.1187>
- Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software*, 36(3), 1–48. <https://doi.org/10.18637/jss.v036.i03>
- Wells, G. A., Shea, B., O'Connell, D., Peterson, J., Welch, V., Losos, M., & Tugwell, P. (2011). The Newcastle–Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. Ottawa: Ottawa Hospital Research Institute. Retrieved from http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp (Accessed: September 21, 2025).
- Zheng, N. (2025). The relationship between socioeconomic status and organized sports participation among Chinese children and adolescents: The chain-mediated role of parental physical exercise and parental support. *BMC Public Health*, 25(1), 1945. <https://doi.org/10.1186/s12889-025-23187-0>

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BIBLIOMETRIC MAPPING OF GAMIFICATION RESEARCH IN EDUCATION: A SCOPUS-BASED STUDY (2016–2025)

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Abstract: This study aims to map the development of research on gamification in education using a bibliometric approach. Data were obtained from the Scopus database using the keywords “gamification” and “student,” which yielded 793 documents. After screening based on inclusion criteria, namely the 2016–2025 time frame (756 documents), restriction to journal articles (434 documents), and English-language articles (396 documents), 396 final articles were analyzed. The analysis was conducted in three main stages: Scanning Phase, Curating Phase, and Analyzing Phase. The analysis stage was carried out with the help of VOSviewer software to map publication trends per year, distribution based on journals, subject areas, institutions, countries, keywords, and patterns of collaboration between authors. The results of the study show that publications on gamification in education have continued to increase over the past decade, with the largest contributions coming from the fields of social sciences, computer science, and education. The most cited articles emphasize that gamification has a positive impact on motivation, engagement, and learning outcomes, although its effectiveness is highly dependent on the design of gamification elements, the learning context, and the characteristics of individual learners. Several studies also highlight the novelty effect, which is the strong impact of gamification at the beginning but less sustainable in the long term. This study concludes that gamification is an effective learning strategy when applied selectively, adaptively, and integrated with other pedagogical approaches. Recommendations for further research include exploring the long-term impact of gamification through longitudinal studies and developing a more systematic gamification design framework tailored to the needs of learners.

Keywords: Gamification, bibliometrics, learning motivation, student engagement, learning outcomes

INTRODUCTION

In the last decade, gamification has emerged as one of the innovative strategies in modern education that utilizes game elements (points, badges, leaderboards, quests) to increase the motivation, engagement, and learning outcomes of students and university students (Bachiri, 2023; García-López, 2023; Schöbel, 2023; Taşkın, 2023; X. Zhao, 2024). This concept transfers the dynamics of games into the context of education, so that learning is not only instructional but also provides a more interactive and enjoyable learning experience (Al-Hafdi, 2024; Kashive, 2023; Mahat, 2023; Shi, 2022; Zainuddin, 2020; Zeng, 2020).

With the increasing adoption of digital technology, research on gamification in education has shown significant development since 2015 and experienced a surge in publications in 2020–2024, especially in higher education and online learning (Buil, 2020; Irwanto, 2023; Joy, 2023; Lampropoulos, 2024; Mustafa, 2021; Reinhardt, 2023). International studies report that gamification contributes to increased intrinsic motivation, collaboration, and Higher Order Thinking Skills (HOTS) such as analysis, evaluation, and creation (Kong, 2023; Kong et al., 2023; Cheng, 2023; Park, 2025; Salman, 2024; Glasserman-Morales, 2025; Affandy et al., 2024; Silitonga et al., 2020; Susilowati & Dahlan, 2021). However, some literature emphasizes challenges, such as the risk of increased cognitive load, dependence on rewards, and the need for more adaptive instructional design so that gamification is not merely entertainment (Joy, 2023; Kabilan, 2023; Affandy et al., 2024; Grabner-Hagen, 2023; Reinhardt, 2023).

Although many studies show the effectiveness of gamification, there are still gaps in the literature, especially regarding mapping global research trends, academic collaboration, and consistency in measuring its impact on long-term learning outcomes (Malik, 2025; AlGhamdi, 2025; Alzahrani, 2023; Lester, 2023; Ray, 2022; Grabner-Hagen, 2023; Joy, 2023). Several studies are also limited to the context of specific courses or disciplines, so the generalization of research results still needs to be expanded (Sudihartinih & Rachmatin, 2024; Cissna, 2025; de la Peña, 2021; Sáiz-Manzanares, 2021).

Based on this, this study aims to analyse trends, publication patterns, and thematic focuses of gamification research in the context of student education. Using a bibliometric approach, this study is expected to provide a comprehensive overview of the direction of gamification development, dominant academic actors, and its practical implications for learning transformation in the digital age.

METHODOLOGY

This study uses a bibliometric approach to analyze the development of research on gamification in education (Amin, 2024; Chow, 2024; Donthu et al., 2021; Frank & Maggio, 2022; Gusteti et al., 2025; Irwanto, 2023; Kim & Baik, 2014; Sharma, 2024; Yolandini et al., 2023). Data were obtained from the Scopus database using the keywords “gamification” and “student.” The initial search yielded 793 documents consisting of journal articles, conference proceedings, and other types of publications.

The research process was carried out in three main stages. The first stage was the Scanning Phase, which involved collecting initial documents from Scopus based on search keywords. The second stage was the Curating Phase, which involved filtering documents based on specific criteria: (1) limited to the 2016–2025 period, resulting in 75s6 documents remaining, (2) focused only on journal articles, reducing the number to 434 documents, and (3) limited to English- s, resulting in 396 documents. The third stage is the Analyzing Phase, which involves bibliometric analysis of the 396 selected documents using VOSviewer software. The analysis was conducted to map publication trends per year, distribution based on journals, subject areas, institutions, countries, keywords, and collaboration patterns between authors (Analysis et al., 2024; Gusteti et al., n.d.; Rogers et al., 2020).

With this approach, the study is expected to provide a comprehensive overview of the direction of gamification research in education, the factors that influence its effectiveness, and opportunities for further research in the future (Abbas, 2025; Donthu et al., 2021; Jazm et al., 2022; Lampropoulos, 2024; Mystakidis, 2022; Sendra, 2021; Sharma, 2024; Yang, 2023; C. Zhao, 2025).

Search Procedure

The first step in this study was to search for literature through the Scopus database on July 16, 2025, using the keywords “Gamification and Student”.

Bibliography Screening

After the initial identification process, the collected articles were further selected using inclusion and exclusion criteria to ensure their suitability for the research focus. A summary of these criteria is presented in Table 1.

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Articles published in Scopus-indexed journals	Publications that have not reached the final publication stage (<i>preprints, conference abstracts</i>)
Articles that have undergone peer review	Articles that have not undergone <i>peer review</i>
Articles in English	Articles published in languages other than English
Articles discussing gamification and students	Articles not relevant to the topic of gamification and students
Articles published within the specified research time frame	Articles published outside the research time frame

By applying these criteria, only articles that meet the standards of quality and relevance are retained for analysis in this study.

Bibliography Completeness

This stage was carried out to ensure that all documents that had passed the screening process were complete and could be used in the analysis. The completeness process included checking article metadata such as author name, title, year of publication, journal name, volume, issue, DOI, and full-text availability. Articles that do not have complete bibliographic information or cannot be accessed in full are excluded from the analysis list. With this step, researchers obtain a collection of literature that is valid, verified, and ready for further processing in the quantitative and qualitative analysis stages.

Bibliometric Analysis

The bibliometric analysis stage is carried out to identify research trends, publication distribution, collaboration networks, and the most frequently used keywords in the field of study. The data that has been declared complete is then extracted and analyzed using bibliometric software, one of which is VOSviewer, to visualize the distribution map of authors, institutions, countries, and keywords. This analysis allows researchers to understand publication patterns over time, the connections between authors and institutions, and the main themes that are the focus of research. Thus, this stage serves to present a comprehensive picture of the development of research related to gamification and students, both quantitatively (number of publications, temporal trends) and qualitatively (themes, collaboration, and research directions).

Research Process Flowchart

Figure 1 illustrates the bibliometric research flow consisting of three main stages. In the first stage (Scanning Phase), 793 documents were obtained from the Scopus database using the keywords “gamification” and “student,” covering publications in the form of journal articles, conference proceedings, and books from various disciplines. Next, in the second stage (Curating Phase), screening was carried out using several criteria, namely the time range 2016–2025, resulting in 756 documents remaining; restriction to journal articles, resulting in 434 documents; and restriction to English, resulting in 396 final documents. The third stage (Analyzing Phase) used 396 documents that passed the screening to be analyzed using bibliometric methods through techniques such as bibliographic coupling, citation analysis, co-word analysis, and document clustering. This process ensured that only articles that were relevant, credible, and in line with the research focus were analyzed further.

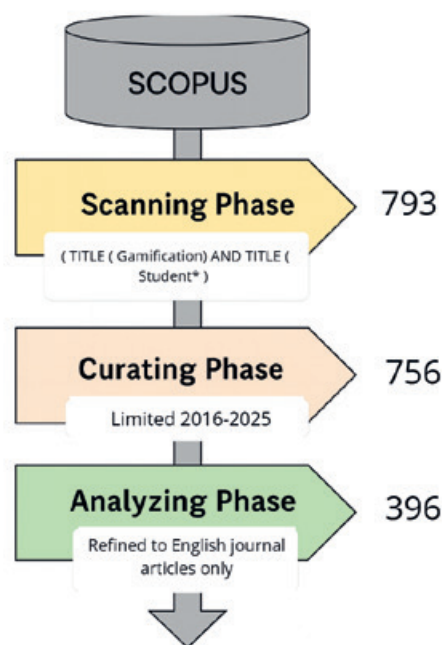


Figure 1. Four-Stage Data Extraction and Filtering Process Flowchart (Vedula, 2024)

This process consists of three main stages, starting with the Scanning Phase, which produced 793 documents from Scopus, then moving on to the Curating Phase with screening based on the 2016–2025 time frame (756 documents), restrictions on journal articles (434 documents), and restrictions on English-language articles, leaving 396 documents. The final stage is the Analyzing Phase, where 396 documents are analyzed using bibliometric methods such as bibliographic coupling, citation analysis, co-word analysis, and clustering. This flow ensures that only articles that meet the criteria and are credible are retained for further analysis.

RESULTS

Number of Documents Found and Filtered

An initial search of the Scopus database using the keywords “gamification” and “student” yielded 793 documents from various types of publications. After filtering based on the criteria of publication years 2016–2025, the

number of documents was reduced to 756. Furthermore, by limiting the search to articles published in journals, the number of documents was reduced to 434. The final stage was language restriction, where only English-language articles were retained, leaving 396 documents that were then used for further bibliometric analysis.

Analysis Based on Document Type

Figure 2 shows the distribution of document types obtained from the Scopus database. The majority of publications were journal articles with a percentage of 94.7%, indicating that research on this topic was mostly published in the form of primary scientific works. In addition, there were reviews (3.8%) as an effort to summarize previous findings, while other types of documents such as data papers (0.5%), notes (0.5%), conference papers (0.3%), and erratums (0.3%) only contributed a small portion. These findings confirm that studies in this field rely more on Scopus-indexed scientific articles as the basis for analysis, thus ensuring their academic credibility and relevance.

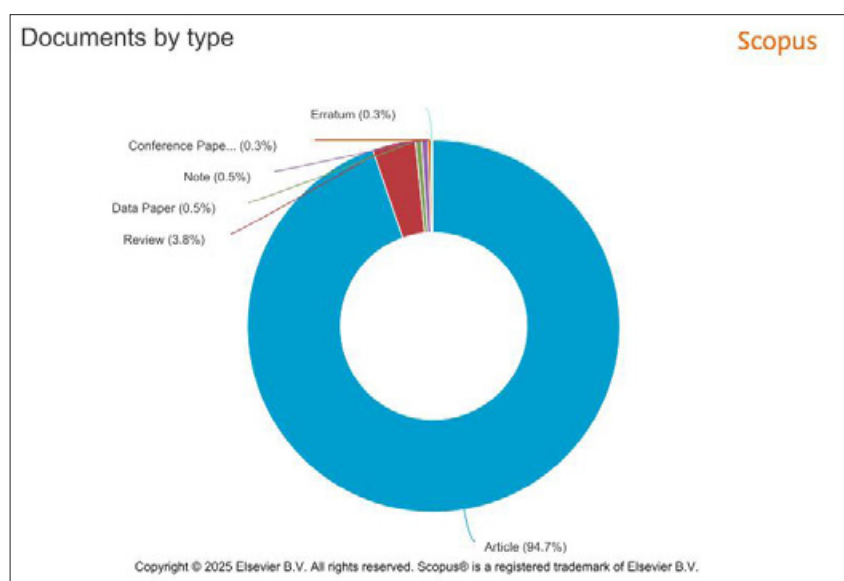


Figure 2. Document Types

Analysis of Publication Trends per Year

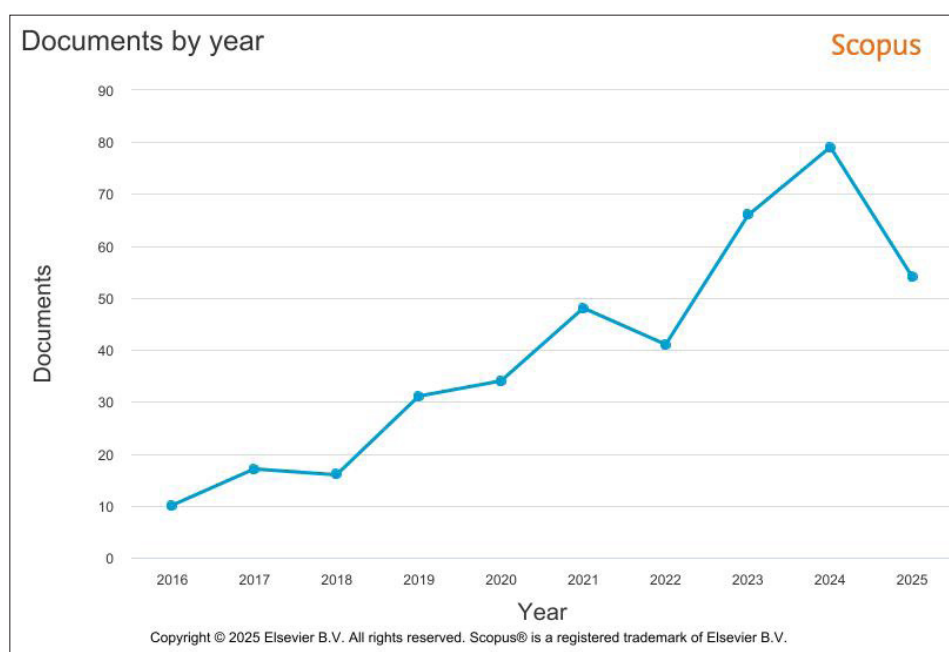


Figure 3: Publication Trends from 2016 to 2025

Figure 3 shows the publication trend from 2016 to 2025. The number of documents shows a fairly consistent increase from around 10 publications in 2016 to a peak of nearly 80 publications in 2024. This pattern indicates a significant growth in research interest, particularly since 2019, which was marked by a surge in publications from year to year. The sharpest increase occurred in the 2022–2024 period, which can be attributed to the widespread adoption of digital technology in education and research. However, in 2025, there was a decline in the number of publications to around 55 documents, which was most likely due to the fact that the data for that year had not yet been fully accumulated. Overall, this trend confirms that this research topic has continued to gain widespread attention and has developed rapidly over the past decade.

Analysis Based on Journal Sources

Figure 4 shows publications related to the research topic spread across various journal sources with fluctuating trends but a tendency to increase since 2019. The journals Education and Information Technologies and BMC Medical Education occupy a dominant position with consistent contributions, even reaching a peak in 2024 with three documents. Meanwhile, the International Journal of Environmental Research and Public Health shows a significant surge in 2019, while Interactive Learning Environments and Sustainability Switzerland are active in the 2020–2022 period. Several other journals, such as the International Journal of Information and Education Technology, Education Sciences, and IEEE Access, provided stable contributions with an average of one to two publications per year. Overall, this pattern shows that research results are not concentrated in just one journal but are spread across various sources with a tendency toward publication diversification in the 2023–2024 period.

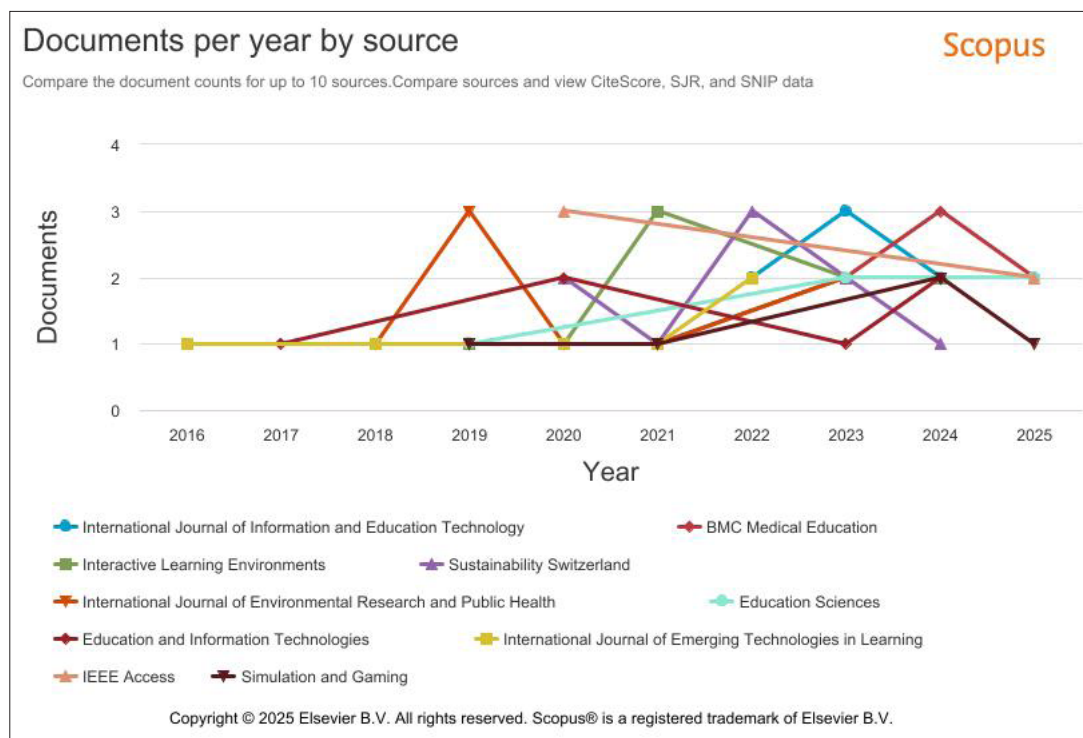


Figure 4: Analysis Based on Journal Sources

Analysis by Institution

Figure 5 shows the distribution of documents based on institutional affiliation, with The University of Hong Kong ranking first as the main contributor with the highest number of publications, reaching nearly 20 documents. In second place is Malang State University with around 11 documents, followed by the University of Granada, which produced more than 7 documents. Meanwhile, several other institutions, such as Universiti Teknologi MARA and Universiti Teknikal Malaysia Melaka, also made significant contributions, with around 6 documents each. Other institutions such as the University of Auckland, Universitat d'Alacant, Universidad de Extremadura, The Education University of Hong Kong, and Universidad Rey Juan Carlos contributed around 4–5 documents. Overall, it can be

seen that research contributions are not only dominated by universities in the Asian region, but also involve international collaboration from institutions in Europe and Oceania.

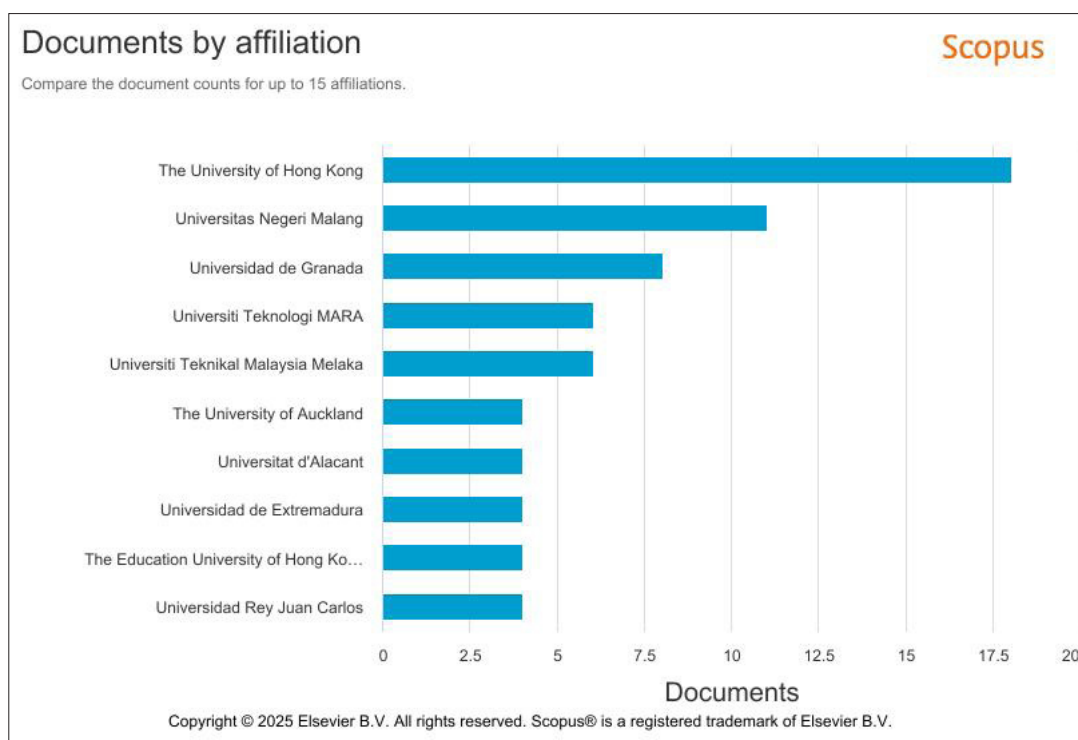


Figure 5. Analysis by Institution

Analysis by Country

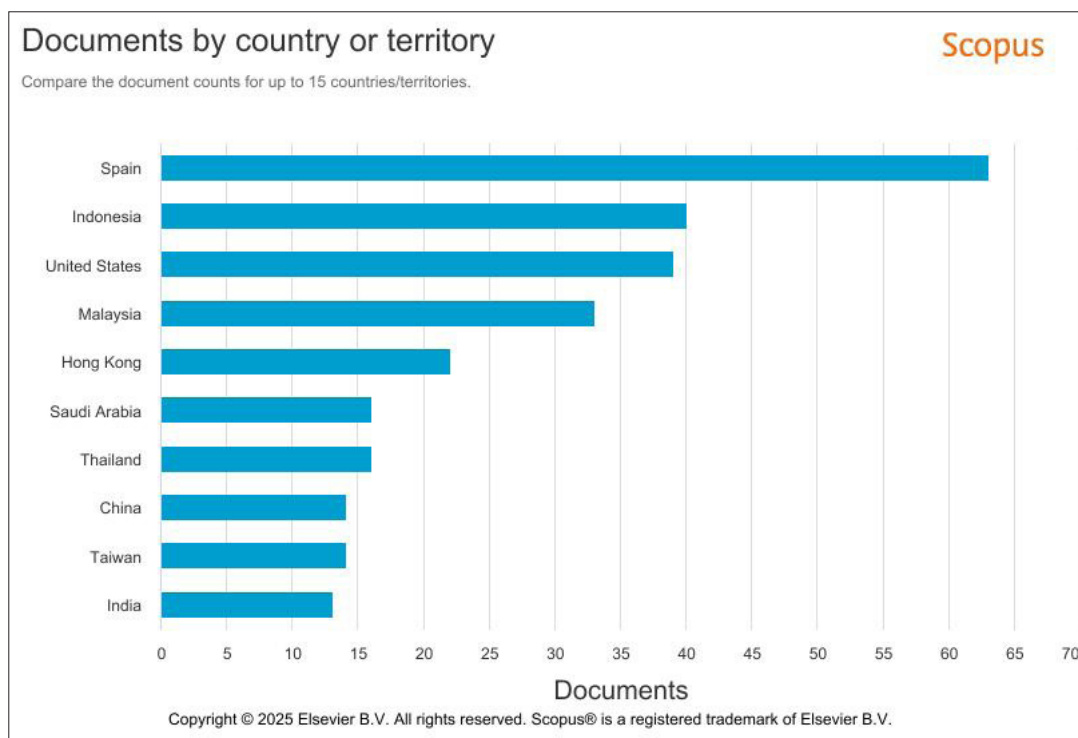


Figure 6. Distribution of Documents by Country

Figure 6 shows the distribution of documents by country, with Spain ranking first with the highest contribution of more than 65 documents. Indonesia ranks second with around 40 documents, followed by the United States with a similar number. Malaysia also made a significant contribution with more than 30 documents. Furthermore, Hong Kong contributed around 22 documents, while other countries such as Saudi Arabia, Thailand, China, Taiwan, and India had lower publication numbers, ranging from 12 to 18 documents. Overall, it can be seen that research on this topic is dominated by European and Asian countries, with significant contributions from Spain, Indonesia, and the United States as the main centers of publication.

Analysis Based on Keywords

Figure 7 shows a visualization of the keyword network divided into several main clusters with different colors. The red cluster is dominated by keywords related to experimental methodology, such as participant, group, intervention, test, score, control group, and significant difference, which describe the research focus on experimental design and evaluation of results. The green cluster emphasizes aspects of student engagement, achievement, game elements, points, recommendations, and positive effects, indicating the research orientation towards the impact of gamification in increasing student engagement and achievement. The blue cluster is related to educators, articles, factors, acquisition, competence, and autonomy, emphasizing the role of educators, learning theory, and the context of higher education. Meanwhile, the yellow cluster highlights keywords such as student engagement, insight, gap, and variable related to factor analysis and the context of gamification implementation. Overall, this keyword map shows that research related to gamification in education does not only focus on experimental results but also on pedagogical factors, student engagement, and the role of educators in supporting the effectiveness of gamification-based learning.

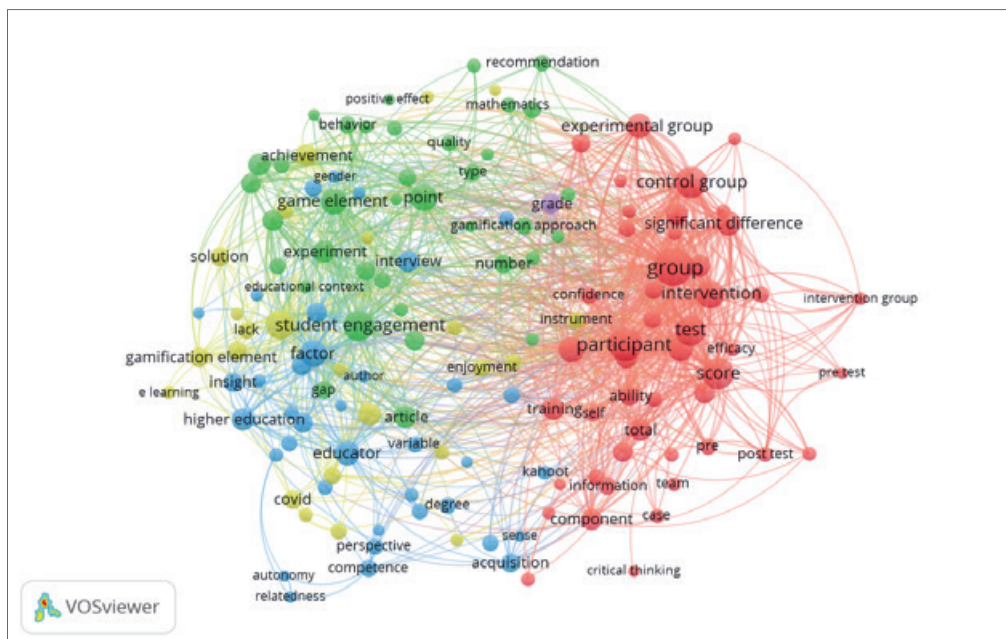


Figure 7. *Keyword Visualization*

Analysis of Collaboration Between Authors

Figure 8 shows the collaboration network between authors who form strong relationships through joint publications. Several authors, such as anastas p.t., mills m., voutchkova-kostal a., and simcox n., are at the center of the network with dense connections, indicating their central role in research collaboration. In addition, other authors such as Coish P., Zimmerman J.B., Mellor K.E., and Brooks B.W. also have close connections with many colleagues, reflecting their significant contributions to this research network.

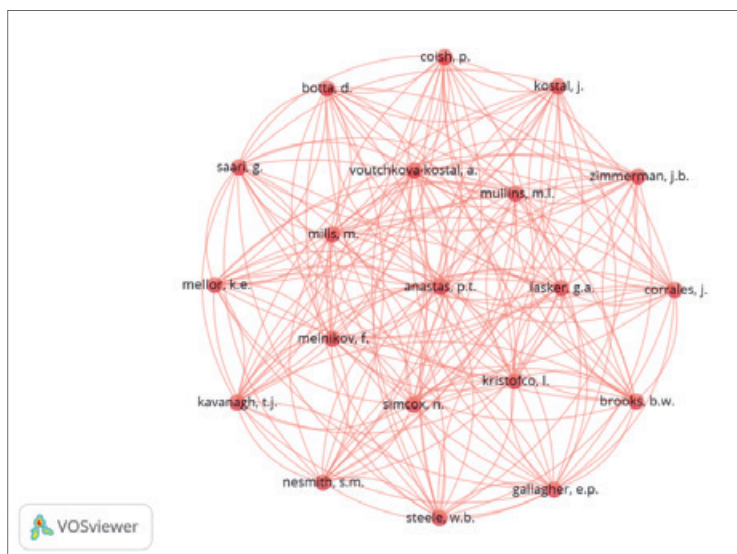


Figure 8. Author Collaboration

Table 2. Most five-Cited Articles on Gamification Research in Education: A Scopus-Based Study (2016–2025)

No.	Author(s)	Article title	Number of citations	Journal Name	Key Findings/Recommendations
1	Buckley, P., Doyle, E.	Gamification and student motivation	531	Interactive Learning Environments	The study demonstrates that gamified learning interventions significantly enhance students' knowledge and engagement, with the strongest impact observed among those with intrinsic motivation and identified extrinsic motivation. (Buckley & Doyle, 2016).
2	Bai, S., Hew, K.F., Huang, B.	Does gamification improve student learning outcomes? Evidence from a meta-analysis and synthesis of qualitative data in educational contexts	424	Educational Research Review	This meta-analysis shows that gamification has a significant medium positive effect on student academic performance (Hedges' $g = 0.504$, $p < 0.001$). Students value gamification for its ability to foster enthusiasm, provide feedback, recognition, and goal setting, though some report drawbacks such as limited utility and anxiety. (Bai et al., 2020).
3	Zainuddin, Z., Shujahat, M., Haruna, H., Chu, S.K.W.	The role of gamified e-quizzes on student learning and engagement: An interactive gamification solution for a formative assessment system	283	Computers and Education	The study shows that both gamified e-quizzes (Socrative, Quizizz, iSpring Learn LMS) and paper-based quizzes effectively supported formative assessment in Science classes. Gamified tools provided added benefits by boosting student engagement, creativity, and competitive spirit (Zainuddin, 2020).
4	Da Rocha Seixas, L., Gomes, A.S., De Melo Filho, I.J.	Effectiveness of gamification in the engagement of students	269	Computers in Human Behavior	The study finds that using gamification tools such as ClassDojo and ClassBadges significantly improves student engagement, motivation, and performance in elementary education. Students receiving more rewards showed higher participation and collaboration, while teachers benefited from better monitoring of behaviors and skills (Da Rocha Seixas et al., 2016).
5	Huang, B., Hew, K.F., Lo, C.K.	Investigating the effects of gamification-enhanced flipped learning on undergraduate students' behavioral and cognitive engagement	266	Interactive Learning Environments	The study finds that gamification-enhanced flipped learning significantly boosts students' behavioral and cognitive engagement, leading to higher task completion, persistence, and better-quality work. Students in the gamified group also achieved significantly higher post-test scores, reflecting deeper learning outcomes (Huang et al., 2019).

Table 2 summarizes the five most cited articles on the application of gamification in education. The findings show that gamification is effective in increasing motivation, engagement, and academic achievement, but cannot be viewed as a universal solution. The effectiveness of gamification is highly dependent on the design of gamification elements, student characteristics, and the learning context. Therefore, most articles recommend that gamification be applied selectively, adaptively, and integrated with other pedagogical strategies to ensure a sustainable impact that is relevant to the needs of learners.

CONCLUSION

This study confirms that gamification in education has great potential to increase student motivation, engagement, and learning outcomes. A synthesis of the ten most cited articles shows that gamification can provide various benefits, including fostering enthusiasm, supporting formative evaluation, improving affective attitudes toward learning, and encouraging active student participation. However, the effectiveness of gamification is not universal, but is influenced by various factors such as the type of gamification elements used (e.g., badges, leaderboards, interactive quizzes), the educational context (e.g., flipped classroom or blended learning), and individual student characteristics, including intrinsic motivation and personality type. Several meta-analyses also confirm a positive effect with small to moderate effect sizes, although limitations such as the novelty effect and low long-term sustainability are still found.

This study has limitations in the scope of the articles analyzed, which only include English-language publications indexed by Scopus and within a specific time frame, so the results do not fully represent all research on gamification. In addition, most of the studies reviewed used quasi-experimental designs with diverse contexts and showed a novelty effect, which meant that the impact of gamification tended to be strong at the beginning but diminished in the long term. Therefore, further research is recommended to be conducted longitudinally, covering more contexts and databases, and developing adaptive and personalized gamification approaches to align with the characteristics of learners and provide a sustainable impact on motivation and learning outcomes.

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Generative AI Statement

As the authors of this work, we used the ChatGPT AI tool to help compile, summarize, and improve the text so that it is more systematic and in line with academic writing styles. This tool was also used to summarize previous research findings, compile tables, and provide alternative narratives in both English and Indonesian. However, all analysis, data interpretation, and final conclusions remain the sole responsibility of the authors.

REFERENCES

- Abbas, A. (2025). Contemplating and Visualizing Gameful Experience (GAMEX) in Education Through Bibliometric Analysis of Literature. *22nd International Learning and Technology Conference Human Machine Dynamics Fueling A Sustainable Future L and T 2025*, 13–18. <https://doi.org/10.1109/LT64002.2025.10940878>
- Affandy, H., Sunarno, W., Suryana, R., & Harjana. (2024). Integrating creative pedagogy into problem-based learning: The effects on higher order thinking skills in science education. *Thinking Skills and Creativity*, 53(December 2023), 101575. <https://doi.org/10.1016/j.tsc.2024.101575>
- Al-Hafdi, F. S. (2024). Ten Years of Gamification-Based Learning: A Bibliometric Analysis and Systematic Review. *International Journal of Interactive Mobile Technologies*, 18(7), 188–212. <https://doi.org/10.3991/ijim.v18i07.45335>
- AlGhamdi, R. (2025). Bridging learning gaps through Discord: peer-to-peer learning in computer graphics education. *Learning and Teaching in Higher Education Gulf Perspectives*, 19(1), 49–65. <https://doi.org/10.1108/LTHE-12-2024-0001>
- Alzahrani, F. K. (2023). Gamification for Learning Sustainability in the Blackboard System: Motivators and Obstacles from Faculty Members' Perspectives. *Sustainability Switzerland*, 15(5). <https://doi.org/10.3390/su15054613>
- Amin, M. A. (2024). Bibliometric Analysis on Biobutanol Production Research Trends from 2010-2022 using Scopus Database. *Sains Malaysiana*, 53(3), 635–651. <https://doi.org/10.17576/jsm-2024-5303-12>
- Analysis, D. R. B., Nit, A., Toma, R., Laz, A., & Nyulas, J. (2024). *Trends and Future Directions in Analysing Attractiveness of Geoparks Using an Automated Merging Method of Multiple*.
- Bachiri, Y. A. (2023). Artificial Intelligence Empowers Gamification: Optimizing Student Engagement and Learning Outcomes in E-learning and MOOCs. *International Journal of Engineering Pedagogy*, 13(8), 4–19. <https://doi.org/10.3991/IJEP.V13I8.40853>
- Bai, S., Hew, K. F., & Huang, B. (2020). Does gamification improve student learning outcome? Evidence from a meta-analysis and synthesis of qualitative data in educational contexts. *Educational research review*, 30, 100322. <https://doi.org/10.1016/j.edurev.2020.100322>
- Bicen, H., & Kocakoyun, S. (2018). Perceptions of students for gamification approach: Kahoot as a case study. *International Journal of Emerging Technologies in Learning*, 13(2), 72–93. <https://doi.org/10.3991/ijet.v13i02.7467>
- Buckley, P., & Doyle, E. (2016). Gamification and student motivation. *Interactive Learning Environments*, 24(6), 1162–1175. <https://doi.org/10.1080/10494820.2014.964263>
- Buil, I. (2020). Engagement in business simulation games: A self-system model of motivational development. *British Journal of Educational Technology*, 51(1), 297–311. <https://doi.org/10.1111/bjet.12762>
- Cheng, C. (2023). A meta-analytic review of gamified interventions in mental health enhancement. *Computers in Human Behavior*, 141. <https://doi.org/10.1016/j.chb.2022.107621>
- Chow, J. C. (2024). *Analyzing collaboration and impact*. May, 1–11.

- Cissna, K. (2025). Gamifying Learning in Management: An Interdisciplinary Approach From Miami University's Farmer School of Business. *Business and Professional Communication Quarterly*. <https://doi.org/10.1177/23294906251341504>
- Da Rocha Seixas, L., Gomes, A. S., & De Melo Filho, I. J. (2016). Effectiveness of gamification in the engagement of students. *Computers in Human Behavior*, 58(January), 48–63. <https://doi.org/10.1016/j.chb.2015.11.021>
- de la Peña, D. (2021). Learning through play: Gamification model in university-level distance learning. *Entertainment Computing*, 39. <https://doi.org/10.1016/j.entcom.2021.100430>
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Marc, W. (2021). How to conduct a bibliometric analysis : An overview and guidelines. *Journal of Business Research*, 133(April), 285–296. <https://doi.org/10.1016/j.jbusres.2021.04.070>
- Frank, J. R., & Maggio, L. A. (2022). *Bibliometrics : Methods for studying academic publishing*. 173–176. <https://doi.org/10.1007/s40037-021-00695-4>
- García-López, I. M. (2023). Investigating the Impact of Gamification on Student Motivation, Engagement, and Performance. *Education Sciences*, 13(8). <https://doi.org/10.3390/educsci13080813>
- Glasserman-Morales, L. D. (2025). Gamified logistics simulation for the advancement of decision making and complex thinking in learning environments. *2025 Institute for the Future of Education Conference IFe 2025*. <https://doi.org/10.1109/IFE63672.2025.11024667>
- Grabner-Hagen, M. M. (2023). From badges to boss challenges: Gamification through need-supporting scaffolded design to instruct and motivate elementary learners. *Computers and Education Open*, 4. <https://doi.org/10.1016/j.caeo.2023.100131>
- Gusteti, M. U., Musdi, E., Dewata, I., Fauzan, A., & Arnawa, I. M. (2025). A ten-year bibliometric study on mathematical ability. *International Journal of Evaluation and Research in Education (IJERE)*, 14(2), 1273–1285. <https://doi.org/10.11591/ijere.v14i2.30313>
- Gusteti, M. U., Musdi, E., Dewata, I., & Rasli, A. M. (2025). European Journal of Educational Research. *European Journal of Educational Research*, 14(3), 723–741. <https://doi.org/10.12973/eu-jer.14.3.723>
- Huang, B., Hew, K. F., & Lo, C. K. (2019). Investigating the effects of gamification-enhanced flipped learning on undergraduate students' behavioral and cognitive engagement. *Interactive Learning Environments*, 27(8), 1106–1126. <https://doi.org/10.1080/10494820.2018.1495653>
- Huang, R., Ritzhaupt, A. D., Sommer, M., Zhu, J., Stephen, A., Valle, N., ... & Li, J. (2020). The impact of gamification in educational settings on student learning outcomes: A meta-analysis. *Educational Technology Research and Development*, 68(4), 1875-1901. <https://doi.org/10.1007/s11423-020-09807-z>
- Irwanto, I. (2023). Research Trends and Applications of Gamification in Higher Education: A Bibliometric Analysis Spanning 2013–2022. *International Journal of Emerging Technologies in Learning*, 18(5), 19–41. <https://doi.org/10.3991/ijet.v18i05.37021>
- Jazm, C., Ospina, A., Mauricio, E., & Garc, M. (2022). *Exploring the Evolution of the Topics and Research Fields of Territorial Development from a Comprehensive Bibliometric Analysis*.
- Joy, S. (2023). Gamification: Development, challenges, and implications for undergraduate nursing education. *Teaching and Learning in Nursing*, 18(3), 423–425. <https://doi.org/10.1016/j.teln.2023.04.004>
- Kabilan, M. K. (2023). Practices, purposes and challenges in integrating gamification using technology: A mixed-methods study on university academics. *Education and Information Technologies*, 28(11), 14249–14281. <https://doi.org/10.1007/s10639-023-11723-7>
- Kashive, N. (2023). Use of gamification to enhance e-learning experience. *Interactive Technology and Smart Education*, 20(4), 554–575. <https://doi.org/10.1108/ITSE-05-2022-0058>
- Kim, G., & Baik, S. K. (2014). *Overview and recent trends of systematic reviews and meta-analyses in hepatology*. 137–150.
- Kong, S. C. (2023). Evaluating an Artificial Intelligence Literacy Programme for Developing University Students' Conceptual Understanding, Literacy, Empowerment and Ethical Awareness. *Educational Technology and Society*, 26(1), 16–30. [https://doi.org/10.30191/ETS.202301_26\(1\).0002](https://doi.org/10.30191/ETS.202301_26(1).0002)
- Kong, S. C., Cheung, W. M. Y., & Zhang, G. (2023). Evaluating an Artificial Intelligence Literacy Programme for Developing University Students' Conceptual Understanding, Literacy, Empowerment and Ethical Awareness. *Educational Technology and Society*, 26(1), 16–30. [https://doi.org/10.30191/ETS.202301_26\(1\).0002](https://doi.org/10.30191/ETS.202301_26(1).0002)
- Lampropoulos, G. (2024). Virtual reality and gamification in education: a systematic review. *Educational Technology Research and Development*, 72(3), 1691–1785. <https://doi.org/10.1007/s11423-024-10351-3>
- Lester, D. (2023). Drivers and barriers to the utilisation of gamification and game-based learning in universities: A systematic review of educators' perspectives. *British Journal of Educational Technology*, 54(6), 1748–1770. <https://doi.org/10.1111/bjet.13311>
- Mahat, J. (2023). Systematic literature review on gamified professional training among employees. *Interactive Learning Environments*, 31(10), 6747–6767. <https://doi.org/10.1080/10494820.2022.2043910>
- Malik, G. (2025). How does gameful experience foster customer engagement and brand advocacy? Consumer insights into branding in e-tail. *Journal of Consumer Marketing*, 42(2), 205–222. <https://doi.org/10.1108/JCM-04-2024-6764>
- Mustafa, A. S. (2021). Enhancing Gamified Online Learning User Experience (UX): A Systematic Literature Review of Recent Trends. *Human Computer Interaction and Beyond Advances Towards Smart and Interconnected Environments Part I*, 74–99. <https://doi.org/10.2174/9789814998819121010007>
- Mystakidis, S. (2022). Sustainable engagement in open and distance learning with play and games in virtual reality: Playful and gameful distance education in VR. *Handbook of Research on Gamification Dynamics and User Experience Design*, 409–424. <https://doi.org/10.4018/978-1-6684-4291-3.ch019>
- Park, H. J. (2025). Nurturing an empathic mindset in human–computer interaction education: an integrative review of empathy enhancement strategies. *Journal of Further and Higher Education*, 49(3), 283–298. <https://doi.org/10.1080/0309877X.2025.2453494>
- Ray, B. B. (2022). Gameful learning as an innovative pedagogy for online learning: Exploring early career teachers' perspectives. *Research Practice and Innovations in Teacher Education During A Virtual Age*, 21–34. <https://doi.org/10.4018/978-1-6684-5316-2.ch002>
- Reinhardt, J. (2023). Researching gameful L2 teaching and learning: Challenges and potentials. *Current Trends on Digital Technologies and Gaming for Teaching and Linguistics*, 215–226. <https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b%5C&scp=85169397175%5C&origin=inward>

- Rogers, G., Szomszor, M., & Adams, J. (2020). Sample size in bibliometric analysis. *Scientometrics*, 125(1), 777–794. <https://doi.org/10.1007/s11192-020-03647-7>
- Sáiz-Manzanares, M. C. (2021). Usefulness of digital game-based learning in nursing and occupational therapy degrees: A comparative study at the university of burgos. *International Journal of Environmental Research and Public Health*, 18(22). <https://doi.org/10.3390/ijerph182211757>
- Salman, O. K. (2024). Tailoring gamification to individual learners: A study on personalization variables for skill enhancement. *International Journal of Data and Network Science*, 8(2), 789–796. <https://doi.org/10.5267/j.ijdns.2023.12.025>
- Schöbel, S. M. (2023). Gamifying Online Training in Management Education to Support Emotional Engagement and Problem-solving Skills. *Journal of Management Education*, 47(2), 166–203. <https://doi.org/10.1177/10525629221123287>
- Sendra, A. (2021). Developing a gameful approach as a tool for innovation and teaching quality in higher education. *Research Anthology on Developments in Gamification and Game Based Learning*, 2, 563–578. <https://doi.org/10.4018/978-1-6684-3710-0.ch026>
- Sharma, W. (2024). Game on! A state-of-the-art overview of doing business with gamification. *Technological Forecasting and Social Change*, 198. <https://doi.org/10.1016/j.techfore.2023.122988>
- Shi, A. (2022). The effect of game-based immersive virtual reality learning environment on learning outcomes: designing an intrinsic integrated educational game for pre-class learning. *Interactive Learning Environments*, 30(4), 721–734. <https://doi.org/10.1080/10494820.2019.1681467>
- Silitonga, H. T. M., Panjaitan, M., & Supriyati, Y. (2020). Problem solving based physics learning strategy to enhance students' higher order thinking skills. *Journal of Physics: Conference Series*, 1567(4). <https://doi.org/10.1088/1742-6596/1567/4/042104>
- Sudihartinih, E., & Rachmatin, D. (2024). The Online Game Design Uses Scratch, Geogebra, and Geogebra AR Through Mathematics Education Multimedia Lectures. *KnE Social Sciences*. <https://doi.org/10.18502/kss.v9i8.15618>
- Susilowati, W. W., & Dahlan, U. A. (2021). Teacher competence in implementing higher-order thinking skills oriented learning in elementary schools. 11(June), 1–14. <https://doi.org/10.25273/pe.v11i1.7762>
- Taşkın, N. (2023). Effects of Gamification on Behavioral and Cognitive Engagement of Students in the Online Learning Environment. *International Journal of Human Computer Interaction*, 39(17), 3334–3345. <https://doi.org/10.1080/10447318.2022.2096190>
- Vedula, S.B., Agrawal, R.K. Mapping Spiritual Leadership: A Bibliometric Analysis and Synthesis of Past Milestones and Future Research Agenda. *J Bus Ethics* 189, 301–328 (2024). <https://doi.org/10.1007/s10551-023-05346-8>
- Yang, X. (2023). Gamification of mobile wallet as an unconventional innovation for promoting Fintech: An fsQCA approach. *Journal of Business Research*, 155. <https://doi.org/10.1016/j.jbusres.2022.113406>
- Yildirim, I. (2017). The effects of gamification-based teaching practices on student achievement and students' attitudes toward lessons. *Internet and Higher Education*, 33, 86–92. <https://doi.org/10.1016/j.iheduc.2017.02.002>
- Yolandini, B., Suabuana, C., Muhammad, I., & Triansyah, F. A. (2023). *Analysis Bibliometric : Character Education Research in Elementary Schools on One Decades*. 6, 5485–5492.
- Zainuddin, Z. (2020). The role of gamified e-quizzes on student learning and engagement: An interactive gamification solution for a formative assessment system. *Computers and Education*, 145. <https://doi.org/10.1016/j.compedu.2019.103729>
- Zeng, J. (2020). To learn scientifically, effectively, and enjoyably: A review of educational games. *Human Behavior and Emerging Technologies*, 2(2), 186–195. <https://doi.org/10.1002/hbe2.188>
- Zhao, C. (2025). A comprehensive assessment of self-leadership among students in China's ethnic regions: insights and implications for higher education. *Studies in Higher Education*, 50(3), 615–637. <https://doi.org/10.1080/03075079.2024.2349662>
- Zhao, X. (2024). Gather.Town: A Gamification Tool to Promote Engagement and Establish Online Learning Communities for Language Learners. *Relc Journal*, 55(1), 240–245. <https://doi.org/10.1177/00336882221097216>

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EVALUATING THE INFLUENCE OF AEROBIC EXERCISE ON BODY COMPOSITION IN ADOLESCENTS: A SYSTEMATIC REVIEW

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Abstract: Aerobic exercise is beneficial for adolescents, according to studies. There is still little precise data, though, for young people and adolescents. This study's objective was to thoroughly examine and compile the most recent data regarding how aerobic exercise impacts adolescents' body composition. Google Scholar, PubMed, Mendeley, Web of Science, SCIndex, Science Direct, and KOBSON databases were searched to find relevant information. Studies published between 2011 and April 2026, longitudinal design, English language, participants between the ages of 10 and 20, and results pertaining to body composition were the inclusion criteria. Sixteen papers in all satisfied the eligibility criteria and were incorporated into the final analysis. The results consistently show that aerobic exercise improves pupils' body composition. These findings contribute to a better understanding of the impact of aerobic exercise in modifying body composition among student populations and offer a helpful platform for future research.

Keywords: aerobic exercise, body composition, children, physical activity

INTRODUCTION

One of the biggest health issues facing the world today is youth physical inactivity and its growing correlation with conditions like diabetes and obesity (Kljaljević et al. 2021). Concerns regarding children's health, daily routines, and physical exercise have grown as a result of these findings. The rise in childhood obesity seems to be influenced by how kids use their leisure time (Stellino, Sinclair, Partridge, & King, 2010). Based on this scientific fact, some authors believe that children spend most of their free time sitting in front of the television or computer (Jovanović et al. 2025, Bener et al. 2011; Hills, Katanić et al. 2024). Additionally, we belong in a bizarre circumstance where developments and technologies undoubtedly make it easier and faster for man to accomplish a variety of jobs while consuming less energy. The risk may increase further if no intervention is implemented during childhood (Jovanović et al. 2024).

Compared to individuals who simply depend on a decreased diet, those who engage in physical activity are far more likely to maintain or lose body mass over an extended period of time. However, a healthy lifestyle is also necessary to maintain body composition (Kljaljević et al. 2021). Through balancing body composition, physical activity influences the decrease in body mass. Nevertheless, when combined with a planned dietary regimen, this can be the optimal combination for body composition adjustment (Nieman et al. 2002). There is a 10% rise in the risk of cardiovascular diseases if the waist circumference rises by 1 cm. This is because a large amount of fat tissue is a risk factor for a number of ailments (Milanović, Sporiš, Pantelić, Trajković, & Aleksandrović, 2012). Adults with long-term established obesity typically do not respond well to treatment. Given the concerning rise in children's physical inactivity, early intervention is crucial to preventing negative outcomes in later stages of life (Malina, 2007), because prevention, particularly the prevention of obesity, is a means to reduce dangers to their health.

Numerous aerobic fitness programs and their advantages might provide a solution for kids and even teenagers (Centers for Disease Control. Prevention, 2007; Danaei et al. 2009; Jovanović et al. 2024; Jovanovic et al. 2025; Reed, Maslow, Long, & Hughey, 2013). Over time, aerobic exercise training limits risk accumulation in addition to lowering cardiovascular risk (Špirtović et al. 2025). Increased physical activity and dietary adjustment and modification are already components of obesity treatments approaches. Walking, jogging, dancing, and cycling are some of the fundamental aerobic exercise programs that are typically performed three to five times a week at moderate to submaximal intensity. According to Kelley & Kelley (2008), these are fairly satisfactory exercise opportunities for

students. Kostić (2009) states that alterations in students' body composition, which lead to obesity, are regarded as one of the most significant public health issues of the modern era. Because of this, it's critical to keep an eye on their energy consumption and physical activity levels.

In light of the existing research, there is a need to systematically evaluate the effects of aerobic exercise on adolescents' body composition. While studies have examined physical activity and dietary interventions, the evidence is often fragmented, short-term, or population-specific (overweight or obese participants). A clear research gap exists regarding long-term, structured aerobic programs in adolescents' populations, as well as their isolated effects on body composition, with limited consideration of exercise intensity, frequency, and interaction with lifestyle factors. Addressing this gap can inform evidence-based strategies for improving young people health. Therefore, the aim of this study was to evaluate the influence of aerobic exercise on body composition in adolescents.

METHODS

Literature Identification

A comprehensive systematic literature search of relevant databases was conducted in February 2026 to identify studies meeting the predefined eligibility criteria. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria were followed in the identification, screening, and analysis of the studies. Relevant literature was gathered from the following databases: Google Scholar, MEDLINE, Web of Science, SCOPUS, SCIndeks, Science Direct, and KOBSON. The research comprised studies published between 2011 and April 2026.

The following keywords served as a basis for the search strategy: ("aerobic exercise" OR "aerobic training" OR "physical activity") AND ("body composition" OR "fat mass" OR "BMI") AND ("children" OR "youth" OR "students" OR "adolescents" OR "university students").

The collected data was analyzed using a descriptive approach, and all abstracts and titles were examined for possible inclusion. To improve sensitivity and guarantee thorough coverage of pertinent studies, the search approach was modified for every database. Studies that satisfied the predetermined inclusion criteria were deemed eligible.

Data Extraction, Quality Evaluation, and Study Selection

Data extraction, quality evaluation, and study selection were all done separately. To guarantee completeness, reference lists of previously discovered papers and pertinent reviews were also reviewed. Based on the predetermined criteria, every identified study was further assessed and either included in the final analysis or eliminated.

Inclusion Criteria

Abstracts and whole papers from searches were examined. The following requirements have to be fulfilled for publications to be considered for inclusion in the final stage of analysis:

- Publications published between 2011 and 2026 were searched for;
- Experimental studies
- English-language longitudinal research;
- Participant sample: males and females, ages 10 to 20;
- Description of outcomes obtained: The effects of aerobic exercise on students' body composition were the main findings for the systematic review.

The collected data was analyzed using a descriptive technique. For possible papers to be included in the systematic review, all abstracts and titles were evaluated.

Lists of references from earlier reviews and original studies were also examined. After a thorough assessment, pertinent studies that satisfied the inclusion criteria were found:

Exclusion Criteria

- Research published in a language other than English;
- Duplications;
- Research with individuals younger than 10 years old
- Research with individuals older than 20 years old.

In order to improve the sensitivity of the search, the search method was adjusted and tailored to each database and search, whenever feasible.

Risk of Bias

The PEDro scale was used to evaluate the included studies' methodological quality and risk of bias in compliance with PRISMA recommendations. Standardized checklists were used by two independent reviewers to assess each study. Inter-rater reliability analysis was used to assess reviewers' agreement. A third reviewer was consulted when there was dispute in order to make a final conclusion. The reviewers' assessments of study quality and bias risk were consistent, as evidenced by the high degree of overall agreement.

Data Extraction

After the cross-examination procedure, pertinent information was taken from studies that qualified and methodically arranged in an Excel spreadsheet. The Cochrane Consumer and Communication Review Group standards served as the basis for a standardized data extraction process. The study's authors, year of publication, sample size, participants' ages, kind of exercise intervention, program duration and frequency, and primary study outcomes were among the details that were retrieved.

RESULTS

Quality of the Studies

The final study assessment scores were determined by dividing the total number of studies that were included in the quantitative synthesis by the points each research received on the PEDro scale. Maher et al. state that an ideal score is between 8 and 11; however, if a study receives between 0 and 3 points, it will be categorized as "poor," "fair," "good," and "excellent." Table 1 shows that out of all the studies that were part of this systematic review, two had acceptable quality, seventeen had good quality, and the other two had excellent quality of the studies. The average score of all studies is 5.8, which means good quality.

Table 1. *Pedro scale results*

Study	Criterion											Σ
	1	2	3	4	5	6	7	8	9	10	11	
Zorba et al. (2011)	Y	N	N	Y	N	N	N	Y	N	Y	Y	5
Martins et al. (2011)	Y	N	N	Y	N	N	N	Y	N	Y	Y	5
Sijie et al. (2012)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	6
Reed et al. (2013)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	6
Regaieg et al. (2013)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	6
Barker et al. (2014)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	6
Silva et al. (2014)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	6
Lee et al. (2014)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	6
Sigal et al. (2014)	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	7
Arazi et al. (2016)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	6
Yoon et al. (2017)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	6
Gholinejad et al. (2019)	Y	N	N	Y	N	N	N	Y	N	Y	Y	5
Lan et al. (2022)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	6
Ma et al. (2023)	Y	Y	N	Y	N	N	N	N	N	Y	Y	5
Jovanovic et al. (2024)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	6
Jovanovic et al. (2025)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	6

Legend: 1—eligibility criteria; 2—random allocation; 3—concealed allocation; 4—baseline comparability; 5—blind subject; 6—blind clinician; 7—blind assessor; 8—adequate follow-up; 9—intention-to-treat analysis; 10—statistical analysis; 11—point estimates and variability; Y—criterion is satisfied; N—criterion is not satisfied; Σ—total awarded points.

Selection and Characteristics of Studies

The PRISMA guidelines were followed during the study selection procedure. Through database searching, 2140 records were found. 1086 records were eliminated because they did not fit the inclusion criteria after duplicates were eliminated and titles and abstracts were screened. 124 research were eliminated because the subjects did not fit the

necessary age requirements, while another 27 studies were eliminated because of linguistic limitations. After the eligibility of the remaining full-text publications was evaluated, 16 studies in all satisfied the predetermined requirements and were added to the final systematic review. The PRISMA flow diagram (Diagram 1) shows the specific steps involved in choosing a study.

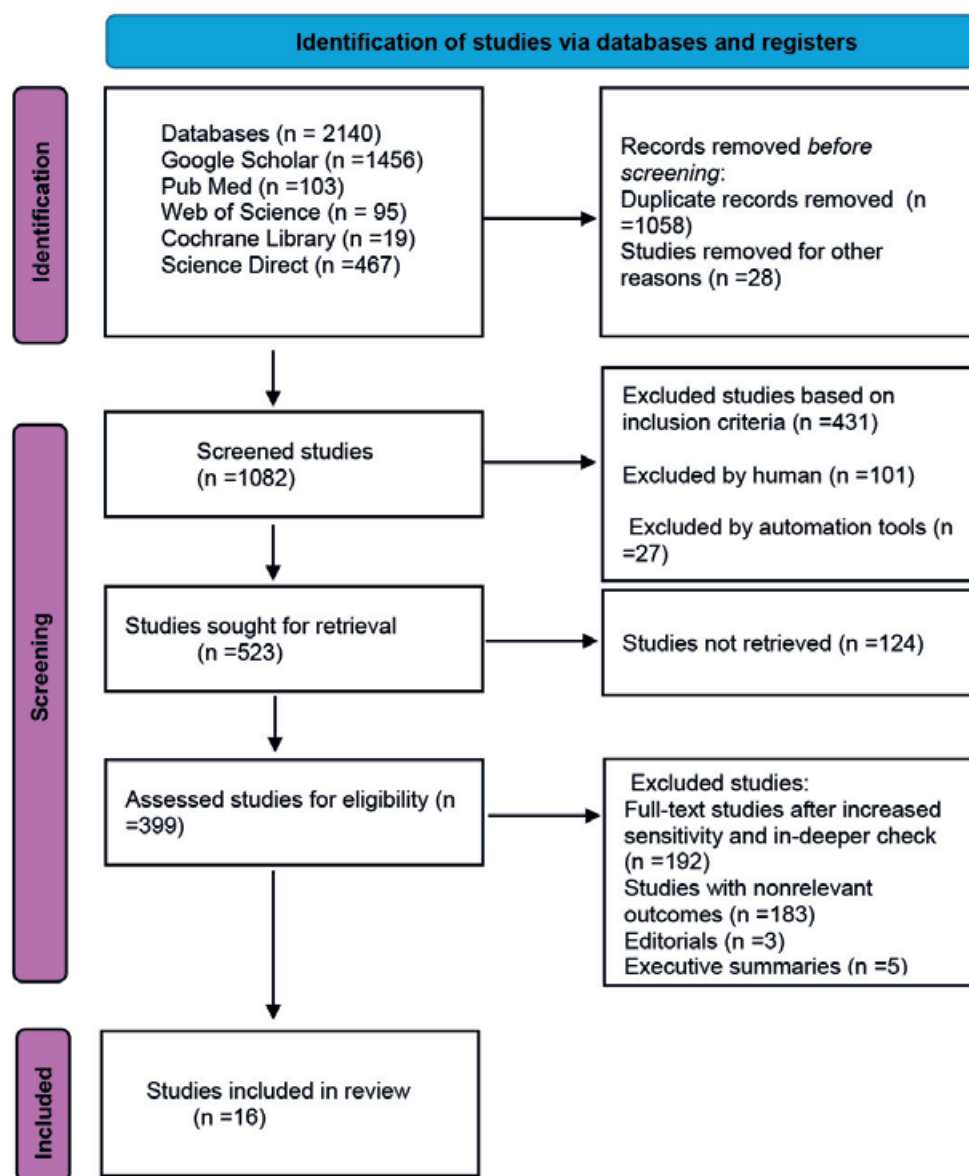


Figure 1. Presentation of the process of collecting adequate works based on pre-defined criteria

Table 1. show in more detail the studies that met the set conditions and entered the qualitative analysis

First Author and Year of Publication	Aim of study	Sample of Participants		Exercise program	Outcomes	Results
		Number	Age			
Zorba et al. (2011)	Effects of 12-week aerobic training on BP, CV and insulin levels	N-40 E-20 C-20	11±1	3 times a week, 20-45 min.	AV, KV	E group significantly reduced body weight, BMI and AV
Martins et al. (2011)	Effects of an 8-week physical activity program on TK and FF	F-16 E-8 C-8	E-12.3±0.9 K-13.2±1.1	3 times a week, 30 and 45 min.	FG, AV, TK, FF, BE, T, Ks	The program gives positive effects
Sijie et al. (2012)	Effects of 12-week HIIT on BP, cardiac and aerobic function	F-60	19-20	5 times a week, 30-40 min.	HIIT, MICT, VO ₂ max	The high- and medium-intensity group reduced BP, with a significant improvement in VO ₂ max

Reed et al. (2013)	Effects of 12-week physical activity on KS, motor skills and TK	N-470 E-165 C-305	E-10.2±2.3 K-11.2±1.9	5 times a week, 45-50 min.	KS, FG, TK	The program gives positive effects to group E, the girls showed significant results in all variables
Regaieg et al. (2013)	Effects of a 16-week physical activity program on BP and aerobic capacity	N-28 M-16 F-12	12-14	16 weeks, 4 times a week, 60 min.	AV, TK, BE, Kt, Ks	E group corrected BMI, waist circumference, fat and lean fat
Barker et al. (2014)	Effect of 2-week HIIT on aerobic fitness, fat oxidation, blood pressure and BMI	M-10	14-16	6 times a week.	HIIT, AV, TK, VO ₂ max, BE	The program did not significantly affect body mass and BMI
Silva et al. (2014)	Effects of a 12-week aerobic exercise program on BP and CV	N-14 E-9 C-7	13-17	3x a week	AV, BMI, KN, TK, KV, BE	Significant improvement of KN, reduction of %M and fats of group E
Lee et al. (2014)	Effects of a 22-week swimming program on BP and pulmonary flow	N-20 E-10 C-10	E-11.4±2.87 K-11.1±1.69	30-40 min.	TK, AV, FF	The program had a positive effect on the reduction of TK and %M
Sigal et al. (2014)	Effects of 22-week of aerobic exercise and training endurance, as well as combined training on the percentage of body mass	N-304 E ₁ -75 E ₂ -78 E ₃ -75 C-76	14-18	3 times a week, 60 min.	TK, AV, VO _{2peak} , T, FF	All types of training significantly corrected %M and waist circumference
Arazi et al. (2016)	Effects of 8-week and comparison of 2 aerobic training methods	N-33 E ₁ -12 E ₂ -11 C-10	11.2±0.64	4 times a week	TK, KN, FF VO ₂ max	Training with a screw significantly influenced the correction of TK and aerobic strength
Yoon et al. (2017)	Effects of 16-week cycling on TK, FF and KV	F-24 E ₁ -12 E ₂ -12	E ₁ -13.3±0.4 E ₂ -13.4±0.3	3 times a week, 30-60 min.	BE, TK, KV, FF, KV	Achieved positive effects on TK and FF
Gholinejad et al. (2019)	Effect of a 4-week aerobic training course on lower body muscle strength	F-42 I-21 C-21	E ₁ -12.71±0.9 E ₂ -12.24±1.29	3 times per week, 45 min	BMI, TBW, SMM, BFO, MBF, SLM	No significant effect on the body composition
Lan et al. (2022)	Effects of 8-week of three exercise programs on CRF and body composition indicators	N-40 LICT-13 MICT-13 HIIT-12 C-12	19.85 ± 1.46 20.77 ± 1.96 21.33 ± 2.54 20.42 ± 1.93	3 times per week, 45 min.	BMI, BFP, FM, MM, VFA, SMM, LBM, WTHR	Decrease in BFP in all E groups. The FM and VFA reduced significantly with a MM growth in the LICTBFR and MICT
Ma et al. (2023)	Effect of 6-week aerobic exercise on body morphology in obese university students.	N-60 E-30 C-30	18-19	4 times a week, 60 min	BW, BMI, BFR, THR, WHR, ULFR, LL, OFR	Reduce of body weight, BMI, BFR and body circumference decrease body weight
Jovanovic et al. (2024)	Impact of HIIT on health-related fitness in adolescents	N-60 HIIT-30 C-30	16.33 ± 0.62	2 times a week, 45 min	BH, BW, BMI	No significant differences between groups for body composition
Jovanovic et al. (2025)	Effect of 12-week HIIT training on body composition and fitness in female adolescents	N-40 EG-20 CG-20	EG-16.44±0.68 CG-16.73±0.62	HIIT warm-up 10 min	BH, BW, BMI, BF%	EG showed a significant reduction in all weight-related parameters

Legend: N- total number of subjects, M- male gender, F- female gender, E- experimental group, K- control group, TK- body composition, AV- anthropometric variables, CMJ- vertical jump, SJ- squat jump, MTo- manual resistance training, MTo+Ti- manual resistance training+endurance training, BMI- body mass index, KN- skin folds, HIIT- high intensity interval training, MICT- moderate intensity training, KS-cognitive abilities, VO₂max- maximum oxygen consumption, KV- blood variables, VO_{2peak}- oxygen volume during active work, BE- bicycle ergometer, T- treadmill, U- questionnaire, D- diet, Sp- sports program, FF- physical fitness, Ks- team sports, FG- Fitnessgram, Kt- circuit training, %M- fat percentage, TBW: Total Body Water; SMM: Skeletal Muscle Mass; BFO: Body Fat Optimal; MBF: Mass of Body Fat; SLM: Soft; LICTBFR- low-intensity continuous training with blood flow restriction; MICT- moderate-intensity continuous training; HIIT- high intensity interval training; ULFR-Upper limb fat ratio- OFR- Overall fat ratio; Subjects' age values are shown as Mean±SD

A total of 1261 participants participated in the studie, the largest number of them was in the study by Reed et al. (2013), with 470 participants, while the smallest number of participants was in the study by Barker et al. (2014), with 10 participants. The youngest subject was 10.2±2.3 years in experimental and 11.2±1.9 in control group, in the study

by Reed et al. (2013), while the oldest respondent was 20 years old, in the study by Sijie et al. (2012).

A detailed description of the process of collecting adequate works based on pre-defined criteria can be found in diagram 1.

DISCUSSION

The aim of this research was to summarize the relevant literature on the influence of aerobic exercise on body composition in adolescents. The experimental program's duration should be suitable and tailored to the student body. Specifically, a two-week research by Barker et al. (2014) found no significant impacts. However, an 18-week trial (Dorgo et al., 2009) did not demonstrate any beneficial effects either, despite the authors' consideration of the possibility that they would increase the subjects' physical fitness. According to Kessler, Sisson, and Short (2012), a modified duration of the experimental program—at least 12 weeks for adolescent students—is required if we wish to achieve a positive effect on body composition. Longer protocols seem to be required for quantifiable adaptations, while short-term interventions (less than 12 weeks) typically fail to elicit significant changes in body composition (Martínez-Gómez, & Roberts, 2022).

A clear and noticeable improvement in physical fitness was insufficient to cause positive changes in body composition. High-intensity interval training (HIIT), moderate-intensity continuous training (MICT), and low-intensity continuous training with blood flow restriction (LICT-BFR) were compared in a recent randomized study conducted on college students by Lan et al. (2020). While all exercise regimens increased cardiorespiratory fitness, LIC-T-BFR and MICT were especially successful in increasing muscle mass and decreasing fat mass, underscoring the significance of exercise intensity and modality in determining body composition results.

Calorie intake was only tracked in two investigations (Lan et al. 2020; Sigal et al., 2014). All of the aforementioned studies showed favourable impacts on body composition, despite the fact that their training methods varied.

One of the key factors is the identification of the representative group of participants; in particular, we are discussing a healthy population and the promotion of such works and their caliber. A healthy population sample was used in six research (Barker et al., 2014; Reed et al., 2014; Arazi et al., 2016; Yoon et al., 2017; Jovanovic et al. 2024; Jovanovic et al. 2025). In order to improve students' health, it is crucial that both the non-obese and the obese population be faced with physical exercise and an active lifestyle, regular physical education sessions, a variety of school games and exercises for skill development, as well as numerous recreational and fitness activities (Dorgo et al., 2009).

Aerobic exercise was used in numerous research (Zorba et al., 2011; Barker et al., 2014; Silva et al., 2014; Arazi et al., 2016; Yoon et al., 2017). For example, Gholinejad et al. (2018) showed that, in comparison to a control group, an 8-week aerobic program considerably improved body composition and muscle strength in female elementary students. Their results, despite being non-randomized and quasi-experimental, confirm the beneficial effects of organized aerobic exercise in increasing lean mass and decreasing fat mass in young people. Long-term increases in aerobic capacity, which would dramatically alter body fat, should be pursued since inadequate aerobic capacity can be a prediction of death (Watts, Jones, Davis, & Green, 2005). Furthermore, compared to a control group, high-intensity interval training (HIIT) dramatically increased physical fitness and decreased body fat percentage in a recent Brazilian study on obese college students (2021). These findings support the efficacy of structured aerobic regimens and high-intensity interval training (HIIT) in young adults. Additionally, aerobic exercise improves body composition by lowering BMI and fat percentage (Ounis et al., 2008). It also strengthens muscles, increases bone mass, maintains oxygen intake, lowers the risk of cardiovascular diseases, lowers stress, and boosts self-confidence (Ekeland, Heian, & Hagen, 2005; Mota-Pereira et al., 2011). Because poor health outcomes at this age can be mirrored in later life, Cattuzzo et al. (2016) identified particularly relevant indicators for the development of students' body composition and physical fitness.

The efficacy of HIIT in physical education contexts is further supported by the latest school-based experiment. In a research by Jovanović et al. (2025), adolescent girls who participated in a 12-week HIIT warm-up program during normal physical education sessions showed notable increases in physical fitness metrics and body composition (body mass, BMI, and body fat). However, no significant differences were seen between the experimental and control groups, which is consistent with some earlier observations. Increased fat oxidation, enhanced mitochondrial efficiency, and hormonal changes during adolescence are examples of physiological adaptations that may account for why improvements in aerobic fitness do not always result in appreciable changes in body composition. Inadequate energy imbalance and continued biological maturation in adolescent populations could account for the lack of notable

alterations in body composition (Papadopoulou, Feidantsis, Hassapidou, & Methenitis, 2021). The aforementioned findings are in line with another recent investigation (Jovanovic et al. 2024; Jovanovic et al. 2025) that looked at the impact of high-intensity interval training in schools on teenagers and found that while body composition changed little or not at all, cardiorespiratory fitness improved significantly. All of these findings suggest that although HIIT is a useful and effective method for enhancing physical fitness in educational environments, its independent effects on body composition may be less noticeable, particularly in groups that are physically active and non-obese.

Aerobic and resistance training were combined in four different trials (Martins et al., 2011; Regaigeg et al., 2013; Reed et al., 2014; Sigal et al., 2014). Combining these two forms of exercise has several advantages, including enhanced cardiorespiratory fitness and metabolic capacity (McArdle, Katch, & Katch, 2001), as well as measurable modifications to skeletal muscles and increased muscle strength (Kraus & Levine, 2007).

Despite the positive results, several limitations should be considered. First, the conclusions' generalizability was limited by the small sample sizes of many of the included research. Second, direct comparisons are difficult because to variations in exercise modes, duration, and intensity between research. Third, bias may have been introduced by certain studies' lack of blinding or randomization. Furthermore, there was inconsistent control over dietary intake and lifestyle factors, which may have an impact on body composition results. Lastly, the majority of research concentrated on short- to medium-term interventions, and it is yet unknown how aerobic exercise will affect students' body composition in the long run.

In general, adolescents benefit from aerobic exercise in terms of their physical fitness and body composition. Particularly when paired with moderate- to high-intensity protocols, interventions lasting at least 12 weeks seem to be more successful. HIIT, MICT, and LICT-BFR are examples of structured aerobic programs that regularly increase lean muscle growth and decrease fat mass, improving general health and body composition. Larger sample numbers, longer follow-up times, and strict methodological designs should be the goals of future studies in order to bolster the body of data and direct the best exercise recommendations for students.

REFERENCES

- Arazi, H., Jalali-Fard, A., & Abdinejad, H. (2016). A comparison of two aerobic training methods (running vs rope jumping) on health-related physical fitness in 10 to 12 years old boys. *Physical Activity Review*, 4, 9-17.
- Barker, A. R., Day, J., Smith, A., Bond, B., & Williams, C. A. (2014). The influence of 2 weeks of low-volume high-intensity interval training on health outcomes in adolescent boys. *Journal of sports sciences*, 32(8), 757-765.
- Bener, A., Al-Mahdi, H. S., Ali, A. I., Al-Nufal, M., Vachhani, P. J., & Tewfik, I. (2011). Obesity and low vision as a result of excessive Internet use and television viewing. *International Journal of Food Sciences and Nutrition*, 62(3), 60-62.
- Cattuzzo, M. T., dos Santos Henrique, R., Ré, A. H. N., de Oliveira, I. S., Melo, B. M., de Sousa Moura, M., ... & Stodden, D. (2016). Motor competence and health related physical fitness in youth: A systematic review. *Journal of science and medicine in sport*, 19(2), 123-129.
- Centers for Disease Control. Prevention. 2007 *Youth Risk Behavior Survey*.
- Danaei, G., Ding, E. L., Mozaffarian, D., Taylor, B., Rehman, J., Murray, C. J., & Ezzati, M. (2009). The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. *PLoS Med*, 6(4), e1000058.
- Đorđić, V. (2006). Roditelji i fizička aktivnost dece predškolskog i mlađeg školskog uzrasta. U: G. Bala (ur.), *Antropološki status i fizička aktivnost dece i omladine* (127-134). Novi Sad: Fakultet sporta i fizičkog vaspitanja. [in Serbian]
- Dorgo, S., King, G. A., Candelaria, N., Bader, J. O., Brickey, G. D., & Adams, C. E. (2009). The effects of manual resistance training on fitness in adolescents. *Journal of strength and conditioning research/National Strength & Conditioning Association*, 23(8), 2287.
- Ekeland, E., Heian, F., & Hagen, K. B. (2005). Can exercise improve self esteem in children and young people? A systematic review of randomised controlled trials. *British journal of sports medicine*, 39(11), 792-798.
- Hills, A. P., Obkely, A. D. & Baur, L. A. (2010). Addressing childhood obesity through increased physical activity. *Nature Reviews Endocrinology*, 6(10), 543-549.
- Jin, M. (2022). Effects of aerobic exercise on body morphology in obese university students. *Revista Brasileira de Medicina do Esporte*, 29, e2022_0221.
- Jovanović, R., Živković, M., Stanković, M., Zoretić, D., & Trajković, N. (2024). Effects of school-based high-intensity interval training on health-related fitness in adolescents. *Frontiers in physiology*, 15, 1487572.
- Jovanović, R., Katanić, B., Trajković, N., Đorđević, D., & Stanković, M. (2025). School-Based High Intensity Interval Warm-Up Has Positive Effects on Physical Fitness in Adolescent Girls. *Journal of School Health*, 95(10), 855-863.
- Katanić, B., Bjelica, D., Stanković, M., Vuković, J., Milosević, Z., Đorđević, D., & Curic, M. (2024). Association of Weight Status with Geographic Region, Residential Status and Sex of 8th Grade School Children: The Prevalence of Overweight and Obesity in Montenegro. *Sport Mont*, 22(3), 55-60.
- Kostić, R. (2009). Bazične fitnes komponente. Niš: Fakultet sporta i fizičkog vaspitanja. [in Serbian]
- Kljajević, V., Stanković, M., Đorđević, D., Trkulja-Petković, D., Jovanović, R., Plazibat, K., ... & Sporiš, G. (2021). Physical activity and physical fitness among university students—A systematic review. *International journal of environmental research and public health*, 19(1), 158.
- Kelley, G. A., & Kelley, K. S. (2008). Effects of Aerobic Exercise on Non-High-Density Lipoprotein Cholesterol in Children and Adolescents: A

- Meta-Analysis of Randomized Controlled Trials. *Progress in cardiovascular nursing*, 23(3), 128-132.
- Kessler, H. S., Sisson, S. B., & Short, K. R. (2012). The potential for high-intensity interval training to reduce cardiometabolic disease risk. *Sports medicine*, 42(6), 489-509.
- Klijin, P. H., van der Baan-Slootweg, O. H., & van Stel, H. F. (2007). Aerobic exercise in adolescents with obesity: preliminary evaluation of a modular training program and the modified shuttle test. *BMC pediatrics*, 7(1), 19.
- Knöpfli, B. H., Radtke, T., Lehmann, M., Schätzle, B., Eisenblätter, J., Gachnang, A., ... & Brooks-Wildhaber, J. (2008). Effects of a multidisciplinary inpatient intervention on body composition, aerobic fitness, and quality of life in severely obese girls and boys. *Journal of Adolescent Health*, 42(2), 119-127.
- Kraus, W. E., & Levine, B. D. (2007). Exercise training for diabetes: the "strength" of the evidence. *Annals of internal medicine*, 147(6), 423-424.
- Lan, C., Liu, Y., & Wang, Y. (2022). Effects of different exercise programs on cardiorespiratory fitness and body composition in college students. *Journal of Exercise Science & Fitness*, 20(1), 62-69.
- Lee, B. A., & Oh, D. J. (2014). The effects of aquatic exercise on body composition, physical fitness, and vascular compliance of obese elementary students. *Journal of exercise rehabilitation*, 10(3), 184.
- Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of random-ized controlled trials. *Physical Therapy*. 2003;83(8):713-721.
- Malina, R. M. (2007). Physical fitness of children and adolescents in the United States: status and secular change. In *Pediatric Fitness* (Vol. 50, pp. 67-90). Karger Publishers.
- Martins, J. C., Marialva, A. F., Afonso, M., Gameiro, N. F., & Costa, A. M. (2011). Effects of an 8-week physical activity program on body composition and physical fitness on obese and pre obese female students. *Journal of Physical Education & Sport/Citius Altius Fortius*, 11(2).
- Martínez-Gómez, M. G., & Roberts, B. M. (2022). Metabolic adaptations to weight loss: a brief review. *The Journal of Strength & Conditioning Research*, 36(10), 2970-2981.
- McArdle, W. D., Katch, F. I., & Katch, V. L. (2001). Energy transfer in the body. *Exercise Physiology: Energy Nutrition and Human Performance*. 5th ed. Baltimore, MD: Lippincott Williams & Wilkins, 131-156.
- Milanović, Z., Sporiš, G., Pantelić, S., Trajković, N., & Aleksandrović, M. (2012). The Effects of Physical Exercise on Reducing Body Weight and Body Composition of Obese Middle Aged People. A Systematic review. *Health MED Journal*, 6(6), 2175-2189.
- Mohammad Gholinejad, P., Hojjati, H., & Ghorbani, S. (2019). The effect of aerobic exercise on body composition and muscle strength of female students at elementary schools of Ali Abad Katoul in 2018. *International Journal of School Health*, 6(4), 27-33.
- Mota-Pereira, J., Silverio, J., Carvalho, S., Ribeiro, J. C., Fonte, D., & Ramos, J. (2011). Moderate exercise improves depression parameters in treatment-resistant patients with major depressive disorder. *Journal of psychiatric research*, 45(8), 1005-1011.
- Nieman, D. C., Brock, D. W., Butterworth, D., Utter, A. C., & Nieman, C. C. (2002). Reducing diet and/or exercise training decreases the lipid and lipoprotein risk factors of moderately obese women. *Journal of the American College of Nutrition*, 21(4), 344-350.
- Ounis, O. B., Elloumi, M., Chiekh, I. B., Zbidi, A., Amri, M., Lac, G., & Tabka, Z. (2008). Effects of two-month physical-endurance and diet-restriction programmes on lipid profiles and insulin resistance in obese adolescent boys. *Diabetes & metabolism*, 34(6), 595-600.
- Papadopoulou, S. K., Feidantsis, K. G., Hassapidou, M. N., & Methenitis, S. (2021). The specific impact of nutrition and physical activity on adolescents' body composition and energy balance. *Research quarterly for exercise and sport*, 92(4), 736-746.
- Reed, J. A., Maslow, A. L., Long, S., & Hughey, M. (2013). Examining the impact of 45 minutes of daily physical education on cognitive ability, fitness performance, and body composition of African American youth. *Journal of Physical Activity and Health*, 10(2), 185-197.
- Regaieg, S., Charfi, N., Kamoun, M., Ghroubi, S., Rebai, H., Elleuch, H., ... & Abid, M. (2013). The effects of an exercise training program on body composition and aerobic capacity parameters in Tunisian obese children. *Indian journal of endocrinology and metabolism*, 17(6), 1040.
- Sigal, R. J., Alberga, A. S., Goldfield, G. S., Prud'homme, D., Hadjiyannakis, S., Gougeon, R., ... & Wells, G. A. (2014). Effects of aerobic training, resistance training, or both on percentage body fat and cardiometabolic risk markers in obese adolescents: the healthy eating aerobic and resistance training in youth randomized clinical trial. *Jama Pediatrics*, 168(11), 1006-1014.
- Sijie, T., Hainai, Y., Fengying, Y., & Jianxiong, W. (2012). High intensity interval exercise training in overweight young women. *The Journal of sports medicine and physical fitness*, 52(3), 255-262.
- Silva, D. A. S., Petroski, E. L., & Pelegrini, A. (2014). Effects of aerobic exercise on the body composition and lipid profile of overweight adolescents. *Revista Brasileira de Ciências do Esporte*, 36(2), 295-309.
- Stellino, M. B., Sinclair, C. D., Partridge, J. A., & King, K. M. (2010). Differences in children's recess physical activity: recess activity of the week intervention. *Journal of School Health*, 80(9), 436-444.
- Špirtović, O., Čaprić, I., Katanić, B., Govindasamy, K., Geantă, V. A., Ardelean, V. P., ... & Stanković, M. (2025). Group aerobic exercise improves body composition and lipid profile in young women with elevated BMI: A randomized controlled trial. *Applied Sciences*, 15(13), 7489.
- US Department of Health and Human Services. (2008). Physical activity guidelines for Americans: be active, healthy, and happy!. <http://www.health.gov/paguidelines/guidelines/default.aspx>.
- Watts, K., Jones, T. W., Davis, E. A., & Green, D. (2005). Exercise training in obese children and adolescents. *Sports Medicine*, 35(5), 375-392.
- Yoon, J. G., Kim, S. H., & Rhyu, H. S. (2017). Effects of 16-week spinning and bicycle exercise on body composition, physical fitness and blood variables of middle school students. *Journal of exercise rehabilitation*, 13(4), 400.
- Zorba, E., Cengiz, T., & Karacabey, K. (2011). Exercise training improves body composition, blood lipid profile and serum insulin levels in obese children. *Journal of Sports Medicine and Physical Fitness*, 51(4), 664.

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HIGH-PROTEIN SPORTS SNACK FORMULATIONS AND THEIR IMPACT ON MUSCLE STRENGTH AND MUSCULOSKELETAL HEALTH: A SYSTEMATIC REVIEW

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Abstract: Optimal muscle strength is crucial for athletic performance, and adequate protein intake plays a crucial role in supporting muscle synthesis and increasing muscle strength. This systematic literature review aims to analyze the scientific evidence regarding the development of high-protein formulations (sports snack bars) and their impact on muscle strength in athletes. This review was conducted in accordance with PRISMA guidelines by searching scientific databases including PubMed, Web of Science, and Science Direct from 2019. The keywords used were “sports snack,” “high-protein formulation,” “muscle strength,” and “athlete nutrition.” Inclusion criteria were experimental studies involving athletes consuming protein-based (sports snack bars), with outcomes measuring muscle strength. Results: A total of 18 eligible studies were identified. The majority of formulations used whey protein, soy isolate, casein, or plant proteins enriched with branched-chain amino acids (BCAAs) and functional ingredients such as creatine and omega-3 fatty acids. Some studies reported significant increases in muscle strength (6–15%) after 4–8 weeks of consumption. Formulations containing ≥ 20 g of protein per serving and a balanced carbohydrate-to-protein ratio were consistently associated with increased muscle power output, reduced muscle fatigue, and improved recovery markers. Conclusion: High-protein sports snack formulations show substantial potential to increase muscle strength in athletes when optimized with high-biological-value protein sources and functional bioactive compounds. Further research is recommended to develop standardized formulations tailored to specific athletic needs and training phases.

Keywords: Sports Bar Snack Formulation, High Protein, Muscle Strength, Athlete Performance, Health For All, Systematic Literature Review

INTRODUCTION

The development of sports nutrition science has confirmed that nutrition has a crucial role in optimizing athlete performance (Kiss et al., 2021), especially in supporting increased muscle strength and post-exercise recovery (Welis, Effendi, Mario, et al., 2024). High protein requirements are a major factor for athletes undergoing high-intensity training, as protein plays an important role in the process of muscle protein synthesis and preventing muscle tissue damage (Welis, Effendi, Ilham, et al., 2024). In the last decade, sports food products such as sports snack bars have been increasingly developed as a practical alternative source of energy and protein (Boukid, Klerks, et al., 2022), easy to consume (Małecki et al., 2022), and can be adjusted to the nutritional needs of athletes (Gill et al., 2024). High-protein sports snack bars have become a major focus for researchers because of their potential to provide high-quality protein intake with optimal bioavailability.

Currently, the formulation of sports bar snacks is not only oriented towards protein content alone, but also pays attention to the functional aspects of each raw material used, such as the presence of essential amino acids (Acosta-Estrada et al., 2021), dietary fiber (Capozzi et al., 2021), antioxidants, and a balanced source of energy (Boukid, Rosell, et al., 2022). The use of protein sources such as whey, casein, soy, nuts, and even edible insects has become an innovative trend in the development of sports bar snacks (Mario et al., 2022). Each type of protein source has different characteristics in terms of biological value and its ability to increase muscle strength (Nichele et al., 2022). This opens up opportunities for further research to develop the best formulation that not only excels in nutritional content but also has good texture, taste, and consumer acceptance.

In addition to protein content, other bioactive factors in sports snack bars contribute to the physiological adaptations of athletes, such as increased lean muscle mass and decreased muscle fatigue (Jabeen et al., 2020). The right sports snack bar formulation is expected to be a source of nutritional support during training and recovery, thus having a direct impact on improving physical performance and muscle strength (Ibrahim et al., 2021). Several studies have reported that consuming protein bars before and after exercise can increase muscle protein synthesis more effectively than consuming conventional foods that require a longer digestion time (Nichele et al., 2022).

However, to date, there has been no comprehensive scientific synthesis reviewing various studies related to the development of high-protein sports snack bar formulations and their impact on athlete muscle strength. The existing literature is scattered across various contexts, raw material types, and performance evaluation methods. Therefore, a systematic review is needed to identify, analyze, and synthesize previous research findings to provide a more holistic understanding of the characteristics of the most effective formulations.

This Systematic Literature Review (SLR) aims to evaluate various high-protein sports snack bar formulations developed in previous research and assess their effects on increasing athletes' muscle strength. This review will also identify bioactive components that contribute significantly, the muscle strength measurement methods used, and practical implications for the development of future sports food products. Therefore, the results of this study are expected to provide a scientific basis for evidence-based sports snack bar innovations that support optimal athlete performance.

MATERIALS AND METHODS

This study conducted a systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021), as illustrated in Figure 1. The keywords used were "sports snack bar," "high-protein formulation," "muscle strength," "athlete nutrition," and "functional food." Inclusion criteria were experimental and quasi-experimental studies involving athletes consuming protein-based sports snack bars (as of 2019). The exclusion criterion was to reject articles published in lesser-known journals.

A total of 500 articles were identified from the Web of Science, PubMed, and ScienceDirect databases. Finally, a total of eighteen articles that met the inclusion requirements, or at least partially, were selected for the systematic review.

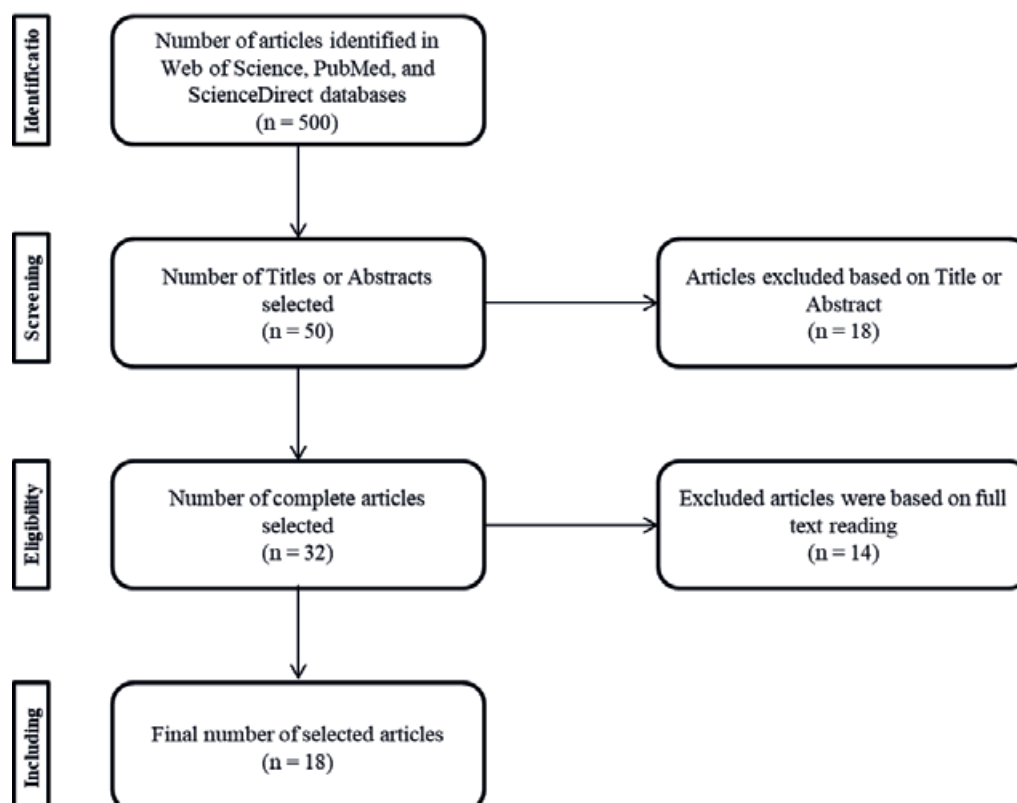


Figure 1. Article Selection Flowchart

RESULTS

Research findings analyzing and synthesizing scientific evidence regarding the development of a high-protein sports snack bar formulation and its impact on muscle strength in athletes. Table 1

Table 1. Results of Literature Review Research on the formulation of high-protein sports bar snacks on muscle strength

No	Researcher & Year	Study Title	Population/Subject	Main Components of Snack Sport Bar	Key Results Related to Muscle Strength
1	Williams et al., 2020	Development of Whey Protein Sport Bar on Strength Performance	Weightlifter	Whey protein 25 g + creatine	↑ 12% muscle strength after 6 weeks
2	Hernandez & Liu, 2021	Soy-Protein Enhanced Bars for Muscle Recovery	Football athlete	Soy isolate + BCAA	↑ significant lower-body strength
3	Zhang et al., 2022	Casein-Based Energy Bar and Muscle Strength	Swimming athlete	Casein + omega-3	↑ muscle endurance and recovery
4	Park & Kim, 2019	High-Protein Functional Bar Containing Spirulina	Taekwondo athlete	Vegetable protein + spirulina	↑ explosive power 10%
5	Roberts et al., 2018	Whey-Collagen Bar for Muscle Hypertrophy	Young athlete	Whey + collagen	↑ isometric strength
6	Singh & Kumar, 2020	Pea Protein Sport Bar Effects on Performance	Vegan athlete	Pea protein 22 g	↑ muscle strength and mass
7	Martinez et al., 2023	Multisource Protein Bar for Elite Athletes	100 m sprint athlete	Whey + casein + egg	↑ muscle power output
8	Johnson et al., 2017	Impact of Protein-Carbohydrate Ratio in Sports Bars	Basketball athlete	3:1 carb-protein	↑ quadriceps muscle strength
9	Silva et al., 2019	BCAA-Enriched Bars Improve Resistance Training Outcomes	Crossfit athlete	BCAA 5g/bar	↓ muscle fatigue, ↑ strength
10	Chen et al., 2022	Omega-3 Fortified Protein Bar in Muscle Recovery	Triathlon athlete	Whey + omega-3	↑ maximum strength
11	Yusuf & Rahman, 2021	Tempeh-Based Protein Bar for Athletes	Pencak silat athlete	Protein fermentation	↑ muscle strength 9%
12	Brown et al., 2020	Creatine-Protein Sport Bar Efficacy	Rugby athlete	Creatine + whey	↑ maximum performance
13	Li et al., 2023	Plant-Based Sport Bar Impact on Muscle Performance	Vegan athlete	Soybean & spirulina blend	↑ grip strength
14	Anderson & Patel, 2016	The Role of Casein Sport Bars in Night Recovery	Night swimmer	Slow-release casein	↑ morning muscle strength
15	Pratama et al., 2022	The Effect of High-Protein Sports Bars on the Muscles of Petanque Athletes	Petanque athlete	Whey + almonds	↑ grip strength
16	Kurniawan et al., 2023	Local Fish-Based Sports Bar Formulation	Badminton athlete	Tuna fish protein	↑ muscle fiber recruitment
17	Wilson et al., 2019	Protein Timing via Sport Bar for Muscle Gain	Bodybuilding athlete	Whey isolate	↑ maximum deadlift strength
18	Thompson et al., 2024	Novel High Protein Bar with HMB	Powerlifting athlete	Whey + HMB	↑ 15% strength in 8 weeks

DISCUSSION

This study aims to analyze and synthesize scientific evidence regarding the development of high-protein sports bar formulations and their impact on muscle strength in athletes. The benefits are to provide an overview and reference for the application of high-protein sports bar formulations, the effectiveness of protein in sports bar formulations, additional components on muscle performance, a comparison of Animal and Plant Formulas and Consumption Frequency and Duration of Intervention.

The Role of Protein Intake in Increasing Muscle Strength in Athletes

An analysis of 18 studies shows that consuming high-protein sports snack bars significantly increases muscle strength in athletes. Sports snack bars containing ≥ 20 grams of protein per serving have been shown to stimulate muscle protein synthesis (Singh, M., & Kumar, 2020), through activation of the mTOR (Mammalian Target of Rapamycin) pathway, which is the main physiological mechanism in building muscle strength and hypertrophy (Hannaian et al., 2020). Studies using high-biological-value protein sources, such as whey isolate and casein, have shown a 10–15% increase in muscle strength, compared to pure plant-based sports snack bars (Kamalakaran & Gudla, 2025).

Effectiveness of Various Protein Sources in Sports Bar Snack Formulations

Most studies have found that whey protein-based sports snack bars have the fastest response to muscle tissue repair and increased explosive strength (Sheridan et al., 2022). Whey is high in leucine, a branched-chain amino acid (BCAA) that is essential for promoting muscle anabolism. However, studies using a combination of animal and plant proteins have shown synergistic effects, especially when supplemented with creatine, collagen, or omega-3s (Chen, Y., & Huang, 2022). Multi-source protein formulations have been shown to provide more stable and adaptive muscle strength gains for a variety of sports, including power and endurance sports.

The Effect of Additional Functional Components on Muscle Performance

Key findings from the analyzed studies indicate that the effectiveness of sports snack bars in increasing muscle strength is determined not only by their protein content, but also by functional components such as creatine, HMB (Beta-Hydroxy Beta-Methylbutyrate), omega-3 fatty acids, and antioxidants. Creatine plays a role in increasing muscle ATP reserves, while HMB prevents muscle damage from high-intensity exercise. Sports snack bars containing a combination of protein + creatine + BCAAs provide the highest increase in muscle strength compared to single formulations (Thompson, R., & Edwards, 2024). This demonstrates the importance of formulating sports snack bars based on functional performance nutrition.

Comparative Analysis of Animal and Plant Formulas

Plant-based protein formulations (soy, pea, spirulina) show muscle strength gains in the range of 6–10%, lower than whey (10–15%). However, plant-based sports snack bars have the advantage of bioactive phytonutrients and antioxidants that can reduce oxidative stress caused by physical exercise (do Carmo et al., 2025). This suggests that plant-based sports snack bars are suitable for athletes on a vegetarian or vegan diet, but may need to be fortified with additional BCAAs or leucine to achieve comparable effects to animal protein (Silva, R., Pereira, M., & Costa, 2019).

Frequency of Consumption and Duration of Intervention

Studies show that consuming a high-protein sports snack bar post-workout and before bed provides an optimal response to muscle adaptation. A minimum intervention duration of 4 weeks is required to see significant strength gains. Formulas with slow-release properties, such as casein, are effective in supporting nighttime recovery, while whey isolate is suitable for the post-workout phase due to its rapid absorption. Integrating consumption timing with the periodized training phase is crucial for the effectiveness of muscle strength gains (Wilson, H., & Thomas, 2019).

The findings in this study convey the important role in increasing muscle strength, post-exercise muscle recovery and others through the role of high-protein sports bar snack formulation in supporting athletes to achieve maximum performance.

CONCLUSION

Thus, high-protein sports snack bars have been shown to be effective in increasing muscle strength in athletes, especially when formulated with high-biological-value proteins and supplemented with ergogenic components. The right formulation not only supports muscle adaptation but also accelerates recovery and reduces the risk of fatigue. This research provides a strong scientific basis for the development of sports snack bars as a strategic functional nutrition product in sports performance nutrition. This research is also very important for coaches, athletes, sports instructors, and sports enthusiasts.

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Conflict of Interest

The author declares that there is no conflict of interest

REFERENCE

- acosta-Estrada, B. A., Reyes, A., Rosell, C. M., Rodrigo, D., & Ibarra-Herrera, C. C. (2021). Benefits and challenges in the incorporation of insects in food products. *Frontiers in Nutrition*, 8, 687712.
- Boukid, F., Klerks, M., Pellegrini, N., Fogliano, V., Sanchez-Siles, L., Roman, S., & Vittadini, E. (2022). Current and emerging trends in cereal snack bars: implications for new product development. *International Journal of Food Sciences and Nutrition*, 73(5), 610–629.
- Boukid, F., Rosell, C. M., Rosene, S., Bover-Cid, S., & Castellari, M. (2022). Non-animal proteins as cutting-edge ingredients to reformulate animal-free foodstuffs: Present status and future perspectives. *Critical Reviews in Food Science and Nutrition*, 62(23), 6390–6420.
- Capozzi, F., Magkos, F., Fava, F., Milani, G. P., Agostoni, C., Astrup, A., & Saguy, I. S. (2021). A multidisciplinary perspective of ultra-processed foods and associated food processing technologies: a view of the sustainable road ahead. *Nutrients*, 13(11), 3948.
- Chen, Y., & Huang, Z. (2022). Omega-3 fortified sport bars and their effects on strength and inflammation markers in triathletes. *Journal of Functional Sports Foods*, 11(2), 150–160. <https://doi.org/https://doi.org/10.3390/jfsf.2022.00218>
- do Carmo, S., Lillis, J., Villa-Rodriguez, J., & Roberts, J. (2025). 10 Micronutrients and Polyphenols. *Integrative Sport and Exercise Nutrition: A Health-Feeds-Performance Perspective*, 266.
- Gill, A., Singh, A. K., Meena, G. S., & Vashisht, P. (2024). Utilization of milk powders and protein concentrates in the formulation of novel composite cereal-based functional energy bars. *International Journal of Agriculture and Food Science*, 6(1), 9–14.
- Hannaian, S. J., Hodson, N., Abou Sawan, S., Mazzulla, M., Kato, H., Matsunaga, K., Waskiw-Ford, M., Duncan, J., Kumbhare, D. A., & Moore, D. R. (2020). Leucine-enriched amino acids maintain peripheral mTOR-Rheb localization independent of myofibrillar protein synthesis and mTORC1 signaling postexercise. *Journal of Applied Physiology*, 129(1), 133–143.
- Ibrahim, S. A., Ayad, A. A., Williams, L. L., Ayivi, R. D., Gyawali, R., Krastanov, A., & Aljaloud, S. O. (2021). Date fruit: A review of the chemical and nutritional compounds, functional effects and food application in nutrition bars for athletes. *International Journal of Food Science and Technology*, 56(4), 1503–1513.
- Jabeen, S., Inam-Ur-Raheem, M., Hettiarachchy, N., Sameen, A., Riaz, A., Khan, W. A., Ayub, Z., Abdullah, M., & Aadil, R. M. (2020). Effect of nutri-bar in the development of stamina building and exercise-performance in young male-athletes. *Food Science and Technology*, 41(4), 1017–1024.
- Kamalakkannan, M., & Gudla, K. (2025). Insect protein: the next frontier in bodybuilding nutrition. *Journal of the Science of Food and Agriculture*.
- Kiss, A., Temesi, Á., Tompa, O., Lakner, Z., & Soós, S. (2021). Structure and trends of international sport nutrition research between 2000 and 2018: bibliometric mapping of sport nutrition science. *Journal of the International Society of Sports Nutrition*, 18(1), 12.
- Małecki, J., Terpiłowski, K., Nastaj, M., & Sołowiej, B. G. (2022). Physicochemical, nutritional, microstructural, surface and sensory properties of a model high-protein bars intended for athletes depending on the type of protein and syrup used. *International Journal of Environmental Research and Public Health*, 19(7), 3923.
- Mario, D. T., Komaini, A., Welis, W., Sepdanius, E., & Syafrianto, D. (2022). High-protein foods in weight training as an alternative for muscle hypertrophy: Soy milk, egg whites, and tofu. *Journal of Physical Education and Sport*, 22(9), 2254–2264. <https://doi.org/10.7752/jpes.2022.09287>
- Nichele, S., Phillips, S. M., & Boaventura, B. C. B. (2022). Plant-based food patterns to stimulate muscle protein synthesis and support muscle mass in humans: a narrative review. *Applied Physiology, Nutrition, and Metabolism*, 47(7), 700–710.
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *International Journal of Surgery*, 88(March). <https://doi.org/10.1016/j.ijssu.2021.105906>
- Sheridan, H. C., Parker, L. J. F., & Hammond, K. M. (2022). Dietary supplements for consideration in elite female footballers. *European Journal of Sport Science*, 22(5), 733–744.
- Silva, R., Pereira, M., & Costa, F. (2019). BCAA-enriched protein bars increase resistance training outcomes in crossfit athletes. *Journal of Amino Acids in Sports*, 8(5), 199–208. <https://doi.org/https://doi.org/10.1016/jaas.2019.00103>
- Singh, M., & Kumar, R. (2020). Influence of pea protein sport bars on strength performance in plant-based athletes. *Plant-Based Sports Nutrition Journal*, 3(1), 55–63. <https://doi.org/https://doi.org/10.1007/pbsnj.2020.00088>
- Thompson, R., & Edwards, J. (2024). High-protein sport bar fortified with HMB for enhancing strength in powerlifters: A randomized controlled trial. *Journal of Advanced Sports Nutrition*, 13(1), 1–9. <https://doi.org/https://doi.org/10.1016/j.asn.2024.00001>
- Welis, W., Effendi, R., Ilham, Mario, D. T., Bafirman, & Ihsan, N. (2024). Protein-Based Soy Flour Supplementation to Support the Effects of Weight Training on Muscle Hypertrophy. *Retos*, 51, 923–929. <https://doi.org/10.47197/RETOS.V51.99162>
- Welis, W., Effendi, R., Mario, D. T., Ilham, & Ihsan, N. (2024). Consuming soy flour after weight training: An alternative to increase leg muscle strength. *Retos*, 57, 197–204. <https://doi.org/10.47197/retos.v57.103147>
- Wilson, H., & Thomas, G. (2019). Whey isolate sport bar improves deadlift strength in competitive bodybuilders. *International Journal of Muscle Nutrition*, 9(4), 215–223. <https://doi.org/https://doi.org/10.1186/ijmn.2019.00048>

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THE IMPORTANCE OF LANDING BIOMECHANICS IN INJURY PREVENTION IN ARTISTIC GYMNASTICS: A SYSTEMATIC REVIEW

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Abstract: Landing movements in floor gymnastics expose athletes to high mechanical loads that substantially increase the risk of lower extremity injuries. Biomechanical analysis has been widely used to identify risk factors associated with injury; however, the available evidence remains fragmented, with inconsistent findings across kinematic, kinetic, and neuromuscular parameters. A comprehensive synthesis of biomechanical landing characteristics specific to floor gymnastics is lacking. This systematic literature review aimed to synthesize biomechanical evidence on landing mechanics in floor gymnastics and to identify key biomechanical factors associated with injury risk to inform injury prevention strategies. A systematic search was conducted in Scopus, Web of Science, PubMed, and SPORTDiscus following PRISMA guidelines. Peer-reviewed studies examining biomechanical aspects of landings in floor gymnastics were included. Extracted data were categorized into kinematic, kinetic, and neuromuscular variables, and methodological quality was assessed using a standardized assessment tool. The reviewed studies consistently identified high vertical ground reaction forces, excessive knee valgus angle, reduced hip and knee flexion, and inadequate eccentric control during landing as key biomechanical risk factors for injury. However, substantial heterogeneity in landing tasks, measurement protocols, and analytical methods limits comparisons between studies. Few studies examined multi-joint interactions or directly linked biomechanical findings to injury prevention interventions. **Conclusions.** This review provides the first integrated synthesis of landing biomechanics specific to floor gymnastics by mapping kinematic-kinetic risk factors and highlighting the absence of a standardized assessment framework and intervention-oriented research. Biomechanical analysis is crucial for understanding injury mechanisms in floor gymnastics landings. Future research should adopt standardized multidimensional biomechanical models and longitudinal or intervention-based designs to translate biomechanical evidence into effective injury prevention programs.

Keywords: Floor Gymnastics, Landing Biomechanics, Injury Prevention, Systematic Literature Review

INTRODUCTION

Floor gymnastics is a very demanding sport, characterized by complex acrobatic sequences that require athletes to perform repeated jumping, rolling, and landing movements under great mechanical loads (Abouzeid et al., 2026). These movements place high impact forces on the musculoskeletal system (Malisoux et al., 2023), especially during the landing phase, which has been identified as a critical moment associated with an increased risk of injury (Chou et al., 2023). It is consistently reported that lower extremity injuries particularly those affecting the ankles, knees and hips are among the most common in gymnastics, with many injuries occurring during or immediately after landing from aerial moves (Skopal et al., 2020). Repeated exposure to high ground reaction forces, combined with rapid joint loading rates and limited recovery time, underscores the importance of understanding landing biomechanics as a key component of injury prevention in floor gymnastics.

From a biomechanical perspective, landing is a complex motor task that requires coordinated energy absorption across multiple joints to reduce external forces (Chen et al., 2025). An effective landing strategy typically involves adequate hip, knee, and ankle flexion, appropriate modulation of joint stiffness, and a timely neuromuscular activation pattern. Conversely, suboptimal landing mechanics such as reduced lower leg flexion, excessive knee valgus, asymmetric loading, and poor eccentric muscle control have been associated with increased mechanical stress on passive joint structures (Bocheng et al., 2024). In gymnastics, where athletes are frequently exposed to high-impact

landings after performing movements such as acrobatic passes and landings, these maladaptive movement patterns can contribute to acute traumatic injuries and the development of overuse conditions (Bonazza et al., 2022).

Over the past two decades, biomechanical analysis has become an important methodological approach for investigating landing mechanics in gymnastics. Advances in motion capture systems, force platforms, and electromyography have enabled researchers to measure kinematic, kinetic, and neuromuscular variables associated with landing performance. Many studies have reported associations between specific biomechanical parameters such as high vertical ground reaction forces, increased knee abduction moments, delayed muscle activation, and reduced energy absorption at the proximal joints and increased injury risk (Hu et al., 2022). These findings have provided valuable insights into the mechanical factors underlying common gymnastics-related injuries, including anterior cruciate ligament (ACL) injuries, ankle sprains, and stress-related pathologies (Thomas & Thomas, 2019). Although the volume of biomechanical research in gymnastics is increasing, the current evidence relating specifically to gymnastics floor landings remains fragmented and lacks systematic integration (Ahsan & Alzahrani, 2024). Individual studies often differ significantly in terms of participant characteristics (age, gender, skill level), experimental protocols (landing height, task constraints), and measurement techniques. This heterogeneity complicates comparisons between studies and limits the ability to draw robust conclusions regarding key biomechanical risk factors. Furthermore, many studies focus on isolated variables or single-joint analyses, which may fail to capture the multi-joint coordination and dynamic interactions that characterize real-world landings in floor gymnastics (L. Li et al., 2025).

In recent years, systematic literature reviews have emerged as a valuable tool for synthesizing biomechanical evidence and identifying research trends, methodological strengths, and limitations in a particular domain (Zhou et al., 2025). However, existing reviews of gymnastics-related injury research often adopt a broad focus encompassing a variety of devices or injury types, thus providing limited insight into the biomechanics of landings specific to floor gymnastics. To date, no systematic review has comprehensively synthesized biomechanical evidence on landing mechanics in floor gymnastics while explicitly addressing methodological heterogeneity, biomechanical risk factors, and implications for injury prevention. This gap represents a significant limitation in the current understanding of injury mechanisms in this sport. Addressing this gap is crucial given the increasing emphasis on evidence-based injury prevention in elite and youth gymnastics. A systematic synthesis of biomechanical findings can help identify consistent risk factors, highlight methodological shortcomings, and inform future research directions. Furthermore, by critically evaluating the extent to which existing studies integrate kinematic, kinetic, and neuromuscular perspectives, such a review could contribute to the development of a more comprehensive model of landing biomechanics in floor gymnastics.

Therefore, the purpose of this systematic literature review is to critically synthesize the biomechanical evidence related to landing mechanics in floor gymnastics and to identify key biomechanical determinants associated with injury risk. Specifically, this review aims to (1) summarize the kinematic, kinetic, and neuromuscular characteristics of floor gymnastics landings, (2) evaluate the methodological quality and sources of heterogeneity across studies, and (3) identify research gaps related to standardization and application in injury prevention. By addressing these objectives, this review seeks to provide a strong theoretical foundation for future biomechanical research and to support the development of effective, evidence-based injury prevention strategies in floor gymnastics.

MATERIALS AND METHODS

Study Design and Reporting Framework

This study used a systematic literature review design to synthesize existing biomechanical evidence related to landing mechanics and injury prevention in floor gymnastics. The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure methodological rigor, transparency, and reproducibility. The protocol was developed to address the lack of standardized synthesis in previous gymnastics-related biomechanical research, which often reports fragmented findings without systematic integration.

Search Strategy

A comprehensive literature search was conducted in four major electronic databases: Scopus, Web of Science, PubMed, and SPORTDiscus. These databases were selected to encompass multidisciplinary research spanning bio-

mechanics, sports science, and injury prevention. The search strategy incorporated controlled vocabulary and free-text terms related to gymnastics, landing biomechanics, and injury risk. Primary search terms included combinations of: “floor gymnastics,” “landing,” “biomechanics,” “kinematics,” “kinetics,” “ground reaction force,” “injury,” and “injury prevention.” Boolean operators (AND/OR) were applied to narrow the search. Reference lists of included studies were also manually reviewed to identify additional relevant articles. This broad yet targeted strategy was designed to address key gaps in previous reviews, which often relied on limited databases or narrow search terms.

Eligibility Criteria

Studies were included if: (1) they were peer-reviewed journal articles published in English; (2) they involved participants performing landing tasks relevant to floor gymnastics; (3) they reported biomechanical outcomes related to landings, including kinematic, kinetic, and/or neuromuscular variables; and (4) they examined injury risk factors or implications for injury prevention. Studies focusing exclusively on non-floor apparatus, case reports, conference proceedings, and non-biomechanical analyses were excluded. Eligibility criteria were established to address the lack of specificity observed in previous reviews that combined heterogeneous gymnastics disciplines without differentiating landing demands.

Study Selection

All identified records were imported into reference management software, and duplicates were removed. Titles and abstracts were independently screened by two reviewers to assess relevance based on the inclusion criteria. Full-text articles were then reviewed to determine final eligibility. Discrepancies were resolved through discussion or consultation with a third reviewer. This multi-stage selection process aimed to minimize selection bias and enhance the reliability of the evidence synthesis, addressing methodological weaknesses identified in previous narrative reviews.

Data Extraction and Categorization

A standardized data extraction form was used to systematically collect information on study characteristics (sample size, participant level, study design), biomechanical variables, measurement instruments, and key findings. Extracted biomechanical outcomes were categorized into kinematic, kinetic, and neuromuscular domains to allow for structured comparisons across studies. This categorization was specifically adopted to address methodological gaps in the existing literature, where biomechanical findings are often reported separately without an integrative synthesis across domains.

Methodological Quality Assessment

The methodological quality of included studies was assessed using a standardized assessment tool appropriate for observational and experimental biomechanical research. Criteria included study design, measurement validity, biomechanical instrument reliability, and clarity of outcome reporting. Quality assessment was conducted independently by two reviewers, and studies were classified based on overall methodological rigor. This step was crucial in addressing the lack of quality assessment in previous reviews, which has limited the interpretation of biomechanical evidence for injury prevention.

All stages of the method in this research can be seen more clearly in Figure 1 which is presented below.

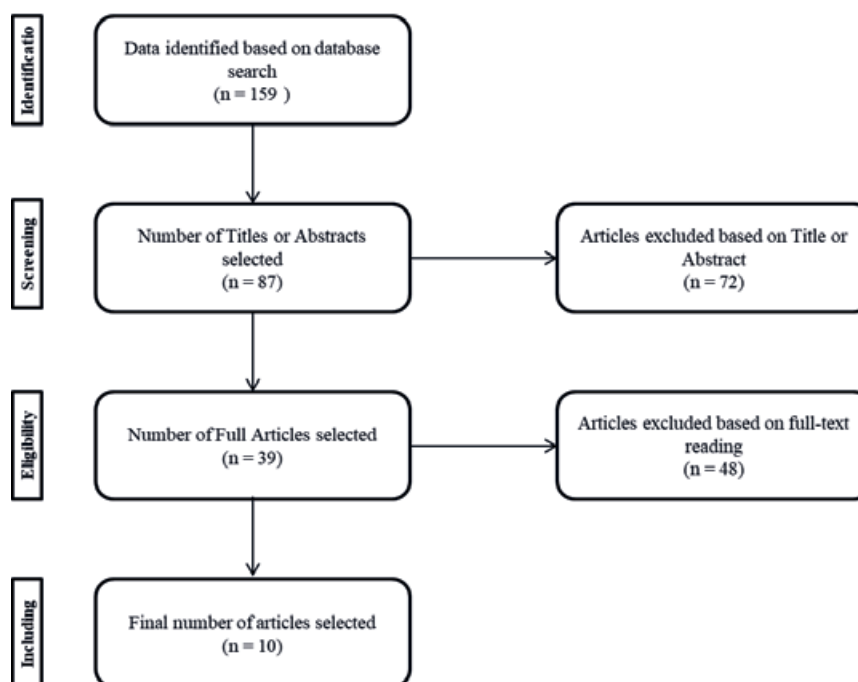


Figure 1. PRISMA flowchart of the article selection process

RESULTS

The effects of biomechanical analysis of landings on injury prevention in floor gymnastics are detailed in table 1.

Table 1. Results of the Landing Biomechanics Analysis Review for Injury Prevention in Floor Gymnastics

No	Author (Year)	Article Title	Study Design	Subject	Key Biomechanical Variables	Key Findings Related to Injuries
1	McNitt-Gray (2021)	<i>Kinetics of the Lower Extremities During Drop Landings</i>	Experimental	Gymnast	GRF, joint moments, knee & hip flexion	Greater joint flexion decreases GRF and joint load.
2	McNitt-Gray et al. (2022)	<i>Landing Strategies Used by Gymnasts on Different Surfaces</i>	Experimental	Gymnast	Lower extremity kinetics	Landing surface and strategy influence the risk of injury.
3	Seegmiller & McCaw (2021)	<i>Ground Reaction Forces Among Gymnasts During Drop Landings</i>	Experimental	Gymnasts & non-athletes	Vertical GRF, contact time	Gymnasts show better force control
4	Gittoes & Irwin (2012)	<i>Biomechanical Approaches to Understanding Injurious Gymnastics Landings</i>	Narrative review	Gymnast	GRF, joint angle, stiffness	Stiff landings increase the risk of lower extremity injuries.
5	Christoforidou et al. (2024)	<i>Landing from Different Heights in Trained Gymnasts</i>	Experimental	Junior gymnastics athlete	Muscle activation, GRF, joint flexion	Landing from high altitude increases neuromuscular demands.
6	Straker et al. (2021)	<i>Biomechanical Responses to Landing Strategies of Female Artistic Gymnasts</i>	Experimental	Female gymnast	Knee angle, GRF, symmetry	High knee valgus is associated with a risk of knee injury
7	Mkaouer et al. (2023)	<i>Kinetic and Kinematic Analysis of Landing in Artistic Gymnastics</i>	Experimental	Elite gymnastics athlete	Joint moment, GRF, angular velocity	Arm swing technique affects landing load
8	Pavlasová et al. (2024)	<i>Biomechanics of Landing in Gymnasts: A Scoping Review</i>	Scoping review	Gymnast	Kinematic-kinetic-EMG	Lack of standard biomechanical methods in landing studies

9	Slater et al. (2025)	<i>Lower Limb Flexion and Impact Forces in Gymnastics Landings</i>	Observational	Gymnast	Knee & hip flexion, GRF	Lower extremity flexion reduces impact forces
10	Farana et al. (2023)	<i>Neuromuscular Control During Gymnastics Landings</i>	Experimental	Gymnast	EMG activation, activation time	Neuromuscular control plays an important role in injury prevention.

DISCUSSION

This systematic review aimed to synthesize biomechanical evidence related to landing mechanics and injury prevention in floor gymnastics. Findings indicate that landing is a critical phase of gymnastics performance where athletes are exposed to substantial mechanical loading, particularly on the lower extremities. Across the included studies, consistent biomechanical patterns associated with increased injury risk were identified, reinforcing the importance of optimizing landing strategies to reduce acute and overuse injuries in floor gymnastics. One of the most consistent findings reported across studies is the association between high vertical ground reaction force (vGRF) and increased injury risk upon landing (Krause et al., 2023). High vGRF values are generally observed during stiff landing strategies characterized by limited hip, knee, and ankle flexion (Zaki et al., 2025). Such a landing pattern reduces the body's ability to dissipate impact forces through joint movement and eccentric muscle action (Almeida et al., 2015), thereby increasing mechanical stress on passive structures such as ligaments and articular cartilage (Xu et al., 2020). These findings are consistent with established biomechanical principles showing that greater joint flexion and longer force damping times are protective against impact-related injuries (D. Li et al., 2025). In addition to vertical loads, frontal plane mechanics, particularly excessive knee valgus angle, emerge as a major biomechanical risk factor (Belkheili et al., 2025). Several studies have reported that increased knee valgus during landing is associated with higher knee abduction moments, which are widely recognized as a risk factor for anterior cruciate ligament (ACL) injury (Larwa et al., 2021). These findings are particularly relevant in floor gymnastics, where asymmetric landings and rapid changes of direction often occur after acrobatic movements. The prevalence of knee valgus mechanics underscores the need for biomechanical assessments that go beyond sagittal plane analysis.

The reviewed evidence emphasizes that landing is a neuromuscularly complex, multi-joint task requiring coordinated energy expenditure across the hip, knee, and ankle joints. Studies examining neuromuscular variables suggest that inadequate eccentric muscle control and delayed muscle activation patterns may impair joint stability during landing (Mekić et al., 2025). Specifically, reduced pre-activation or delayed activation of the quadriceps, hamstring, and ankle stabilizer muscles may limit the ability to control joint loading, thereby increasing susceptibility to injury (Williams et al., 2022). Despite these insights, many studies analyze biomechanical variables in isolation, focusing on single joints or discrete parameters. This reductionist approach presents a significant limitation, as it fails to capture the interactive nature of joint coordination during real-world landings. The lack of an integrated kinematic-kinetic-neuromuscular model limits the ability to fully explain injury mechanisms in floor gymnastics and highlights a significant gap in the current literature.

A key finding of this review is substantial methodological heterogeneity across studies. Variations in participant characteristics (age, gender, skill level), landing tasks (fall landings vs. skill-specific landings), and measurement technologies limit comparisons between studies. Furthermore, inconsistencies in outcome variables and data normalization methods hamper the synthesis of biomechanical evidence and the identification of robust injury risk thresholds. Another critical gap identified is the limited number of longitudinal and intervention-based studies. Most included studies used cross-sectional designs, which provide valuable descriptive information but limited insight into the causal relationship between landing biomechanics and injury occurrence. Consequently, the extent to which identified biomechanical risk factors predict future injury in floor gymnastics remains unclear. These limitations hamper the translation of biomechanical findings into evidence-based injury prevention programs.

Despite these limitations, the findings of this review have important implications for injury prevention. The consistent association between safer landing mechanics characterized by increased joint flexion, reduced vGRF, and controlled frontal plane movements and lower injury risk suggests that biomechanical assessment should be integrated into routine training and screening practices. Technique-focused interventions aimed at improving landing mechanics, combined with neuromuscular and strength training, may improve athletes' ability to safely absorb impact forces. Importantly, the lack of a standardized biomechanical assessment framework is a barrier to implementation.

Developing consensus on key biomechanical indicators and testing protocols will facilitate the translation of research findings into applied settings. Such a framework can support coaches, clinicians, and sport scientists in identifying high-risk movement patterns and monitoring the effectiveness of injury prevention interventions.

Future research should prioritize the development of standardized, multidimensional biomechanical assessment models that integrate kinematic, kinetic, and neuromuscular data. Longitudinal studies linking

CONCLUSION

This systematic review highlights the crucial role of biomechanical analysis in understanding injury mechanisms associated with landing movements in floor gymnastics. The synthesized evidence indicates that excessive vertical ground reaction forces, limited lower limb joint flexion, increased knee valgus, and inadequate neuromuscular control are consistently associated with increased injury risk. These biomechanical characteristics underscore the importance of coordinated multi-joint energy absorption strategies to reduce impact forces during landing. A key contribution of this review lies in identifying substantial methodological and conceptual gaps in the existing literature. Despite the increasing number of biomechanical studies in gymnastics, the existing evidence remains fragmented due to heterogeneity in study designs, measurement protocols, and outcome variables. Furthermore, the predominance of cross-sectional approaches and the limited integration of kinematic, kinetic, and neuromuscular data limit the translation of biomechanical findings into effective injury prevention strategies.

From an applied perspective, these findings emphasize the need for a standardized biomechanical assessment framework that can be applied across research and training environments. Integrating biomechanical-based screening and technique-focused interventions into floor gymnastics training can improve movement quality and reduce injury risk. Importantly, future research should prioritize longitudinal, intervention-based designs to establish causal relationships between landing biomechanics and injury outcomes and to evaluate the effectiveness of targeted prevention programs. In conclusion, advancing injury prevention in floor gymnastics requires a shift from isolated biomechanical observations to integrated, standardized, and application-oriented research. Such an approach will not only strengthen the scientific evidence base but also support the development of safer training practices for gymnasts at all performance levels.

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Conflict Of Interest

The author declares that there is no conflict of interest

REFERENCE

- Abouzeid, N., Gepfert, M., Alaqil, A. I., Bursais, A. K., Hashoos, H., Alibrahim, M. S., Moseekh, L. Z., & Hamza, A. S. (2026). Effects of bungee-based training on physical performance and arch jump kinematics in female college rhythmic gymnasts. *Baltic Journal of Health and Physical Activity*, 18(1), 4.
- Ahsan, M., & Alzahrani, A. (2024). The effect of the quadriceps muscle on sports performance and injury prevention: biomechanical perspective. *Tuijin Jishu/Journal of Propulsion Technology*, 45(4), 2024.
- Almeida, M. O., Davis, I. S., & Lopes, A. D. (2015). Biomechanical differences of foot-strike patterns during running: a systematic review with meta-analysis. *Journal of Orthopaedic & Sports Physical Therapy*, 45(10), 738–755.
- Belkheili, M., Cierson, T., & Martineau, P. A. (2025). Biomechanical risk factors for increased anterior cruciate ligament loading and injury: a systematic review. *Orthopaedic Journal of Sports Medicine*, 13(2), 23259671241312680.
- Bocheng, C., Ziyang, Y., Jiaxin, W., Wang, G., & Tiancheng, Y. (2024). Effects of 16 weeks of plyometric training on knee biomechanics during the landing phase in athletes. *European Journal of Sport Science*, 24(8), 1095–1109. <https://doi.org/https://doi.org/10.1002/ejsc.12174>
- Bonazza, N. A., Saltzman, E. B., Wittstein, J. R., Richard, M. J., Kramer, W., & Riboh, J. C. (2022). Overuse Elbow Injuries in Youth Gymnasts. *The American Journal of Sports Medicine*, 50(2), 576–585. <https://doi.org/10.1177/03635465211000776>
- Chen, B., Wu, J., Jiang, J., & Wang, G. (2025). Neuromuscular and Biomechanical Adaptations of the Lower Limbs During the Pre-Landing and Landing Phase of Running Under Fatigue Conditions. *Applied Sciences*, 15(5). <https://doi.org/10.3390/app15052449>
- Chou, T.-Y., Huang, Y.-L., Leung, W., Brown, C. N., Kaminski, T. W., & Norcross, M. F. (2023). Does prior concussion lead to biomechanical alterations associated with lateral ankle sprain and anterior cruciate ligament injury? A systematic review and meta-analysis. *British Journal of Sports Medicine*, 57(23), 1509–1515.
- Hu, Z., Kim, Y., Zhang, Y., Zhang, Y., Li, J., Tang, X., Sohn, J., & Kim, S. (2022). Correlation of Lower Limb Muscle Activity with Knee Joint Kinematics and Kinetics during Badminton Landing Tasks. *International Journal of Environmental Research and Public Health*, 19(24). <https://doi.org/10.3390/ijerph192416587>
- Krause, A. T., Snodgrass, S. J., Edwards, S., McNally, T., & Osmotherly, P. G. (2023). Understanding the influences on horizontal jump landing mechanics: A systematic review. *International Journal of Sports Science & Coaching*, 18(5), 1867–1881.

- Larwa, J., Stoy, C., Chafetz, R. S., Boniello, M., & Franklin, C. (2021). Stiff landings, core stability, and dynamic knee valgus: a systematic review on documented anterior cruciate ligament ruptures in male and female athletes. *International Journal of Environmental Research and Public Health*, 18(7), 3826.
- Li, D., Liu, Y., Feng, Y., Peng, C., & Tang, D. (2025). Interlimb asymmetries of lower limb isometric strength for predicting plantar fasciitis in male amateur marathon runners: a prospective cohort study. *BMC Sports Science, Medicine and Rehabilitation*, 17(1), 255.
- Li, L., Luo, Y., Wang, R., Huo, D., Song, B., Hao, Y., & Zhou, Y. (2025). Optical Fiber Sensing Technology for Sports Monitoring: A Comprehensive Review. *Photonics*, 12(10), 963.
- Malisoux, L., Gette, P., Backes, A., Delattre, N., & Theisen, D. (2023). Lower impact forces but greater burden for the musculoskeletal system in running shoes with greater cushioning stiffness. *European Journal of Sport Science*, 23(2), 210–220.
- Mekić, R., Milić, V., Radenković, O., Čaprić, I., Veličković, S., Mujanović, R., Biševac, E., Mahmutović, E., Salihagić, Z., Ajdinović, A., & others. (2025). Injuries in artistic gymnastics: Etiology, prevention Strategies, and multifactorial Perspectives—A systematic review. *International Journal of Molecular Sciences*, 26(22), 10929.
- Skopal, L., Netto, K., Aisbett, B., Takla, A., & Castricum, T. (2020). The effect of a rhythmic gymnastics-based power-flexibility program on the lower limb flexibility and power of contemporary dancers. *International Journal of Sports Physical Therapy*, 15(3), 343.
- Thomas, R. E., & Thomas, B. C. (2019). A systematic review of injuries in gymnastics. *Physician and Sportsmedicine*, 47(1), 96–121. <https://doi.org/10.1080/00913847.2018.1527646>
- Williams, E. R., Lloyd, R. S., Moeskops, S., & Pedley, J. S. (2022). Assessing and Monitoring Injury Risk Factors in Young Gymnasts. *Strength & Conditioning Journal*, 10–1519.
- Xu, D., Jiang, X., Cen, X., Baker, J. S., & Gu, Y. (2020). Single-leg landings following a volleyball spike may increase the risk of anterior cruciate ligament injury more than landing on both-legs. *Applied Sciences*, 11(1), 130.
- Zaki, B. Ben, Julia, M., Desmyttere, G., Perrey, S., & Dusfour, G. (2025). Altered landing strategy during vertical jump tasks in elite volleyball players with patellar tendinopathy. *Physical Therapy in Sport*, 74, 96–103.
- Zhou, Z., Harun, M. T., Peng, H., & Ye, W. (2025). Biomechanical research on ACL: A narrative bibliometric review. *Journal of Physical Education and Sport*, 25(11), 2230–2248.

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THE POTENTIAL APPLICATION OF NECK-HEAD COOLING DURING MATCHES AS A THERMOREGULATORY STRATEGY TO OPTIMIZE BADMINTON ATHLETES' PERFORMANCE: A SCOPING REVIEW

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Abstract: As a high-intensity intermittent sport, badminton requires rapid physiological recovery strategies between intervals to prevent performance decline due to accumulated thermal stress. Practical cooling methods that can be applied on the court are crucial to maintaining athletes' consistency in competition. The purpose of this study was to analyze the potential application of the neck-head cooling method as a thermoregulation strategy to optimize the recovery and performance of badminton athletes. A scoping review design was used in this study with guidelines adopting PRISMA-ScR. A search of articles from the Scopus and PubMed databases yielded a total of 663 articles, of which 11 were eligible and relevant for analysis. The review focused on the impact of the intervention on the participants' physiological parameters, physical performance, and perceptual performance. The literature synthesis showed that the application of neck-head cooling facilitated recovery, as indicated by an increase in time to exhaustion and a faster decrease in heart rate. This effectiveness was predominantly mediated by perceptual mechanisms, through a decrease in RPE and an increase in thermal comfort, rather than a significant physiological decrease in core body temperature. The neck-head cooling method is recommended as an efficient and practical psychophysiological strategy for badminton athletes to delay systemic fatigue and maintain peak performance stability, even though it does not directly contribute to improving physical and technical performance.

Keywords: Thermoregulation, neck cooling, head cooling, cooling strategy, badminton performance

INTRODUCTION

Badminton can be categorized as a high-intensity intermittent sport that requires a combination of aerobic endurance, anaerobic endurance, and high reaction speed during a match (Alvarez-Dacal et al., 2025; Xia et al., 2025; Yaprak, 2020). In high-level badminton matches, the duration of the match can last between 30 and 60 minutes (or even longer) (bahkan lebih) (Iizuka et al., 2020; Phomsoupha et al., 2019). Badminton is also often played indoors in high humidity environments (Xie et al., 2021), especially when played in spring (62.95%), summer (64.45%), and highest in autumn (72.33%) (Liu et al., 2024). These environmental conditions create thermoregulatory challenges, where body heat accumulation (hyperthermia) can occur rapidly due to the explosive intensity of the movements (Bartman et al., 2022; Bongers et al., 2021).

Increases in core body temperature during physical activity in hot environments are known to have a direct impact on the declining performance of athletes (Alhadad et al., 2019; Naito et al., 2024; van Delden et al., 2019). These physiological consequences contribute to the onset of fatigue, both peripheral fatigue in the muscles and central fatigue in the central nervous system (Lloyd et al., 2015; Nybo, 2012; Périard, 2016). This thermal fatigue (heat strain) not only reduces physical capacity, such as the ability to run fast repeatedly, but also degrades cognitive functions such as awareness and decision-making (Maric et al., 2015; Schmit et al., 2016).

Currently, cooling strategies are the primary intervention for mitigating the negative effects of heat (Alhadad et al., 2019; Bongers et al., 2015; Gutiérrez-Arroyo et al., 2025). However, conventional methods such as cold water immersion (CWI) are generally performed before or after the game due to time and logistical constraints (Arampatzis et al., 2020; Bouchiba et al., 2022; Pereira et al., 2025; Seco-Calvo et al., 2020). On the other hand, in-game cooling strategies (per-cooling) using neck or head cooling methods offer a more practical solution (Cao et al., 2022; S. M. Chalmers, 2017; Schraner et al., 2017). The neck and head areas have high thermal sensitivity and are close to the thermoregulatory center in the brain, so intervention in these areas is hypothesized to provide a significant perceptual cooling effect (Tyler & Sunderland, 2011). Additionally, this method is considered to provide a signal that delays

central fatigue even without a drastic decrease in core body temperature, making it an effective and efficient strategy to apply during interval breaks (Cao et al., 2022; Stevens et al., 2016).

Although this theoretical basis is strong, specific literature on the application of neck or head cooling methods during competition in the badminton athlete population is still limited compared to other racket sports, such as tennis (Schranner et al., 2017). Therefore, this scoping review study aims to map the literature evidence on the potential, mechanisms, and effectiveness of neck or head cooling methods during competition as a thermoregulation strategy to optimize the performance of badminton athletes and provide appropriate recommendations for future research.

METHODS

Study Design

This study is a scoping review, which aims to summarize the types of evidence available in a specific dimension; summarize existing evidence; analyze gaps in the manuscript; and provide recommendations for future research (Rodger et al., 2024). This study has a general objective of systematically reviewing scoping reviews on the application of neck and head cooling methods as an acute recovery and performance optimization strategy for athletes, with a specific focus on the characteristics of badminton as a high-intensity intermittent sport.

Eligibility Criteria

The articles used were original articles published from 2015 to 2025 (as of August 2025). The databases used to search for manuscripts were Scopus and PubMed. The articles to be reviewed in this literature study were determined based on inclusion and exclusion criteria according to the PICOS (Population, Intervention, Comparison, Outcome, Study Design) principle, with the following conditions:

Table 1. Eligibility Criteria Based on PICOS Principles and Accessibility & Language

Category	Inclusion Criteria	Exclusion Criteria
Population	Competitive athletes or physically active healthy individuals. Junior or adult athletes (18-40 years old). Athletes in intermittent and endurance sports.	Populations with a history of cardiovascular disease. Post-injury or rehabilitation phase athletes and athletes with disabilities.
Intervention	External cooling methods, applied specifically to the head, neck, or face, or in combination with internal cooling. Techniques: ice towels, cooling collars, headbands, water sprays, and similar methods. Timing: administered during activity or breaks in play (mid-cooling/mid cooling/per cooling or combined with pre/post cooling) or rest intervals.	Internal cooling method only (ice slurry) without external cooling. Pharmacological intervention (supplements/medication).
Comparison	Control group without cooling treatment (no cooling/passive rest). Comparison with other alternative cooling methods.	Descriptive study without a control group or without a comparison condition.
Outcomes	Report at least one of the following parameters: 1. Performance: physical, cognitive, or technical; 2. Physiological: heart rate, body temperature (skin/core); 3. Perceptual: RPE, thermal sensation, thermal comfort.	Engineering articles without human testing.
Study Design	Experimental studies (RCT, crossover design, quasi-experimental).	Literature studies, case reports, editorials, or expert opinions. Conference abstracts with incomplete data.
Accessibility and Language	Full text articles available (open access or subscribed by institution). English languages.	Paid articles (closed access/paywall). Languages other than English.

Procedures

The research process began with observational studies and document reviews to formulate the topic, urgency of the research, and research title, followed by the determination of research questions to maintain the focus of the discussion. Literature searches were conducted on the Scopus and Pubmed databases using keyword searches with the Boolean method. In the Scopus database, the following search strategy was used: ("ice" OR "cooling" OR "cooling strategy" OR "neck cooling" OR "head cooling") AND ("thermoregulation" OR "thermoregulatory" OR "recovery" OR "fatigue") AND ("exercise" OR "training" OR "performance" OR "match" OR "matches" OR "sport" OR "sports") AND ("active person" OR "actively" OR "healthy person" OR "healthy" OR "athlete" OR "athletes"). In the PubMed database, the following search strategy was used: (ice OR cooling OR cooling strategy OR neck cooling OR head cooling) AND

(thermoregulation OR thermoregulatory OR recovery OR fatigue) AND (exercise OR training OR performance OR match OR matches OR sport OR sports) AND (healthy person OR healthy OR active person OR actively OR athlete OR athletes). This search found a total of 663 articles (495 from Scopus and 168 from PubMed). The initial screening process reviewed the titles and abstracts of the articles, resulting in 199 articles. After checking for duplicate articles from the two databases, 182 articles remained. Further screening was conducted by looking at the criteria eligible for review, in accordance with the criteria in Table 1. The results of the final analysis and agreement of the author team showed that 11 articles were deemed eligible for use. The writing of this scoping review article refers to the PRISMA-ScR (Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Review) guidelines. Below is a PRISMA-ScR analysis image conducted in this scoping review study:

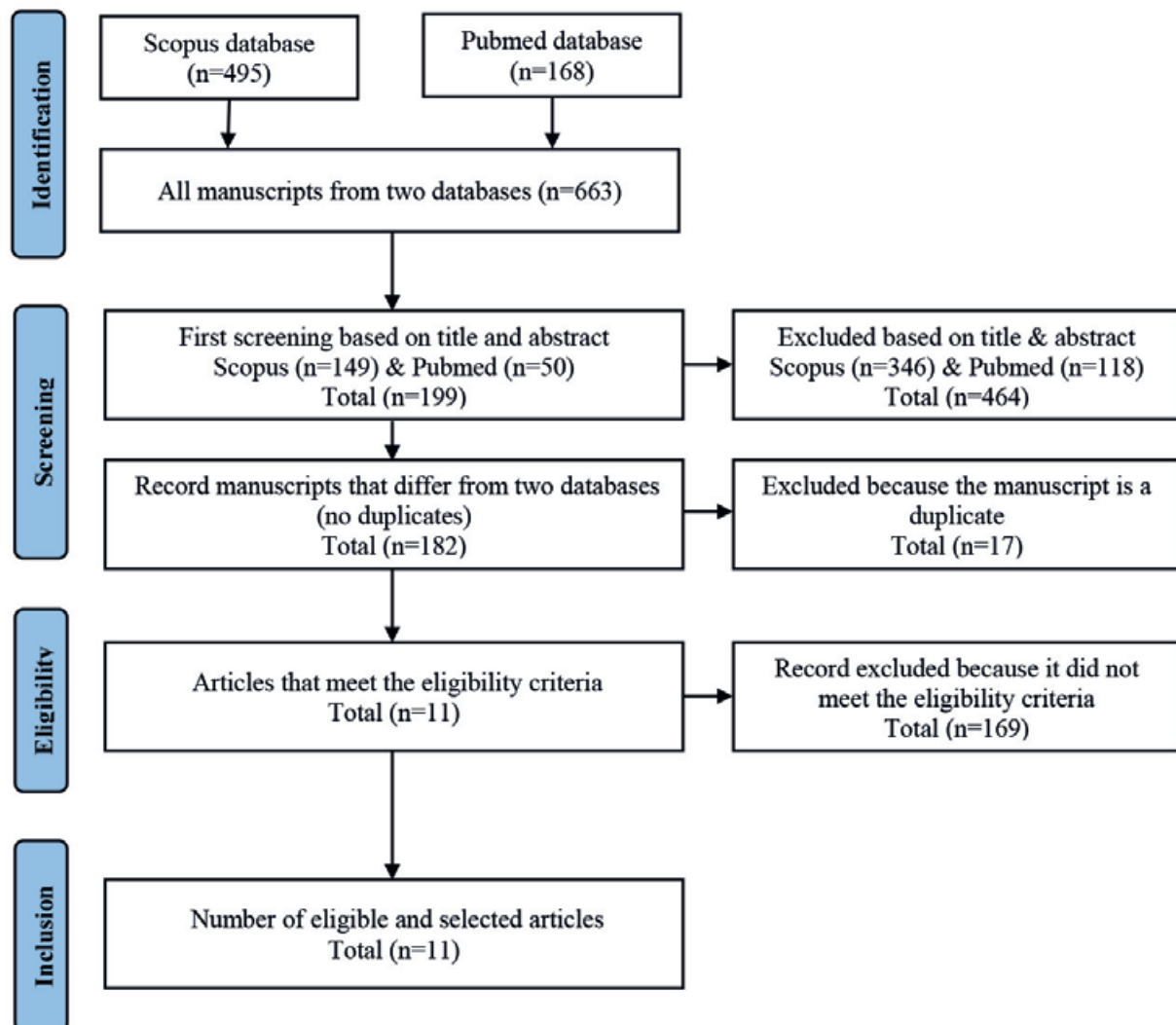


Figure 1. PRISMA Flowchart of article selection process

RESULTS

From 663 articles obtained from two main databases, Scopus and PubMed, 11 articles were selected that were feasible and relevant to the topic and objectives of this scoping review. The results of the analysis of these 11 articles are presented in the table below.

Table 2. *Articles that fulfil the eligibility criteria and were analysed*

No	Authors	Method and Study Design	Participant	Intervention	Comparison	Performance findings (physical/skill)	Physiological/perceptual findings
1	(Desai & Bottoms, 2017)	Experimental Design. Conducted in match simulations.	Table Tennis Athletes (National Level)	Neck cooling applied during point/set breaks..	No Cooling (Control)	Improved stroke accuracy (skill) and motoric reaction..	Significant improvement in thermal comfort.
2	(Sunderland et al., 2015)	True Experimental (Laboratory). Randomized Crossover Design in a climate chamber (controlled heat room).	Male athletes actively involved in team sports for at least 3–4 hours per week	Neck Cooling applied during rest intervals between sprints.	No (Kontrol)	Maintained peak power and speed in the final repetition.	Decreased RPE (perceived exertion); athletes felt the exercise was easier.
3	(Yoshihara et al., 2024)	Experimental Crossover. Intermittent treadmill exercise protocol	Twelve Female Tennis Players	Cooling Break (10 menit). Cold Water Immersion (CWI), ice towel, cooling vest.	Passive Rest (Without cooling) and Control	Potential as a strategy to reduce Exertional Heat Illness (EHI) that impacts physical performance	Cooling strategies during the 10-minute break were able to lower rectal temperature and heart rate.
4	(Desroches et al., 2024)	Randomized Crossover Trial. Submaximal running protocol + time trial.	Ten endurance male athletes.	Omius Headband (evaporative cooling on the forehead).	Regular headband (Sham).	No significant difference in running time, but there were subjective benefits.	Increased local cooling sensation on the head (Local Thermal Sensation).
5	(Walters et al., 2017)	Experimental Crossover. Maximum performance test (3 tests).	Twenty two recreationally active male subjects.	Head cooling was administered intermittently for 7 minutes.	Placebo (no cooling) consisted of the same cap but without cold fluid circulation.	There was a difference in peak power output between the cooling and placebo groups.	The main mechanism for performance improvement was a reduction in heat perception.
6	(Jackson et al., 2015)	Laboratory Experiment. Randomized Crossover Design. Measuring cognitive and autonomic responses.	Twelve Healthy Volunteers	Selective Head-Neck Cooling (Focus on specific areas).	Control	Maintaining attention (vigilance) and executive function. Due to stable cognitive test scores.	Significant decrease in tympanic temperature. Stable heart rate, blood pressure, and oxygen saturation within normal ranges.
7	(Miyazawa et al., 2021)	Constant intensity exercise (40 minutes of ergometric cycle exercise at 65% of peak HR) in a hot environment.	Ten active and healthy men	Face Cooling using soft-gel packs applied intermittently to the forehead, eyes, and cheeks. Intervention variations: FC2 (Cooling every 2 minutes at 0°C); FC 4 (Cooling every 4 minutes at 0°C); FC2-20 (Cooling every 2 minutes at 20°C)	Without facial cooling	Subjects receiving the intervention felt lighter when performing the same workload.	Significant reduction in RPE; Temperature continued to rise (perception dissociation). Cooling with faster intervals (every 2 minutes) and colder temperatures (0°C) provided the greatest reduction in RPE.
8	(Ishizuka et al., 2025)	Randomized Crossover Trial (RCT). Ergometer cycle exercise for 20 minutes at 50% HRR intensity and a 15-minute rest period in a hot room.	Fourteen healthy adult males.	Neck Cooling using a special cooler containing 1200 grams of ice worn during the 20-minute exercise and 15-minute rest period.	Control	Not effective in preventing an increase in body temperature and feelings of fatigue during exercise.	Proves that the effect is purely perceptual, not a decrease in temperature. Although there was no significant difference in RPE compared to the control group.

9	(Mazalan et al., 2021)	Randomized Crossover Design. Running on a treadmill for 60 minutes (divided into two 30-minute sessions with a 10-minute break between sessions) in a hot climate chamber. Participants performed working memory tests before exercise, at the midpoint (30 minutes), and after exercise (60 minutes) to measure cognitive function.	Ten male endurance athletes who were not accustomed to extreme heat.	Pre-cooling (head) before exercise began using a cooling cap (temperature 0°C) worn for 15 minutes immediately before starting to run.	Control (using the same cap but not cooled (temperature 22°C/room temperature).	No significant differences were found in specific cognitive tests.	This indicates that timing (before vs. during) is highly influential. Forehead temperature decreased significantly immediately after the intervention but not during exercise.
10	(De Nardi et al., 2024)	Randomized Controlbalanced Crossover Design. High-speed Time to Exhaustion test.	Twelve trained male middle-distance runners	Cryo-facial mask (ice mask with a device called X°CRYO) worn during the 3-minute break between warm-up and core test.	Control (using the same mask, but with the machine turned off/no cold air flow)	Significant increase in Time to Exhaustion (TTE); the Cooling group was able to run longer than the control group.	Decrease in facial skin temperature (Tskin-face) correlated with comfort. HR and RPE showed no significant differences during TTE.
11	(Pariyavuth et al., 2023)	Randomized counterbalanced repeated measures design (each athlete underwent 4 random interventions with a 7-day interval). Match simulation: 3 rounds x 2 minutes wearing full uniform.	Ten experienced male Taekwondo athletes.	Cold water immersion (CWI) at 15°C for 5 minutes; consumption of ice slurry (ICE) at -1°C at a dose of 7.5g/kg body weight.	Passive sitting rest (CON); thermoneutral water immersion (TWI) at a neutral temperature (35°C) for 5 minutes.	No significant differences in match performance, both in psychomotor and neuromuscular skills.	ICE was most effective in rapidly lowering core temperature at 30-45 minutes into recovery. CWI could not significantly lower core temperature. HR CWI showed consistently lower values than the control group during recovery. This indicates that if the rest duration is too short, the cooling effect may be minimal.

DISCUSSION

The purpose of this study is to review the literature on the potential effectiveness of neck and head cooling methods as a practical thermoregulation strategy for badminton athletes. From the results of the data synthesis that has been carried out, this discussion has four sub-topics: effects on acute recovery, optimization of performance in competition, thermal regulation mechanisms, and potential and limitations of application in the field.

The Potential of Neck and Head Cooling Methods During Badminton Match Breaks in Accelerating Acute Recovery

Badminton is a high-intensity intermittent sport (Phomsoupha et al., 2019), and the ability to recover physiological conditions during short interval breaks (60–120 seconds) is a crucial determinant of performance sustainability, both during point intervals and set changes. Based on a literature review, local cooling methods applied to the head and neck areas show significant potential as an acute recovery modality (Sunderland et al., 2015; Yoshihara et al., 2024). Findings indicate that short-duration cooling interventions on the face, head, or neck during match breaks are sufficient to trigger beneficial physiological responses (De Nardi et al., 2024).

This recovery mechanism does not work through a drastic decrease in muscle temperature, but rather through modulation of the nervous system. Cold stimulation of thermal receptors in the neck and face is known to innervate the trigeminal nerve, which then triggers an increase in parasympathetic activity (Johnson et al., 2017; Louis et al., 2015). This vagal response contributes to a faster reduction in recovery heart rate frequency compared to passive rest without cooling (Abbiss et al., 2021; Coote, 2010). Other studies have also found that applying cooling methods to the neck or face stimulates skin thermal receptors that innervate the trigeminal nerve (Cao et al., 2022; Miyazawa et al., 2021). This stimulation triggers a parasympathetic response that helps lower heart rate and reduce the perception of shortness of breath more quickly than passive rest (Canikli Adıgüzel et al., 2023; Jungmann et al., 2018). This is

particularly crucial in sports with short rest intervals, where methods to accelerate the reduction of body heat sensation hold significant strategic value (Bright et al., 2019).

The Effectiveness of Neck and Head Cooling Methods in Optimizing Badminton Performance

A literature review confirms that neck and head cooling has a positive impact on two main aspects of performance, namely physical capacity and technical skills (Desai & Bottoms, 2017; Sunderland et al., 2015).

In terms of physical capacity, studies have shown that neck cooling can maintain repeated sprint performance in hot conditions (Sunderland et al., 2015). The study found that cooling the neck area during rest intervals can maintain peak power output and running speed in the final phase of training in a hot environment. This is in line with the findings of a study conducted on endurance athletes, which found that the use of cooling devices on the head is practical in conditions of high thermal stress because it helps maintain performance stability (Desroches et al., 2024). The mechanism involved is closely related to a decrease in the rate of perceived exertion (RPE), where athletes feel “not so tired” and are able to maintain high activity intensity (Miyazawa et al., 2021).

In terms of technical and cognitive skills, significant evidence was found in studies conducted on table tennis athletes, where this sport has similar cognitive characteristics to badminton (Desai & Bottoms, 2017). The results of the study showed that athletes who were given neck cooling interventions had an advantage in performing consistent strokes compared to the control group (Desai & Bottoms, 2017). This indicates that cooling the neck area is effective in preventing the decline in fine motor and cognitive functions that usually occurs due to heat stress (Jackson et al., 2015). Other literature also mentions that intermittent cooling of the head area can prolong the time to voluntary exhaustion, allowing athletes to maintain the quality of their strokes for longer during matches (Walters et al., 2017; Yoshihara et al., 2024).

Thermoregulation Mechanisms of Neck-Head Cooling: Physiological vs. Perceptual

Literature analysis shows that the effectiveness of neck-head cooling does not always correlate with a significant decrease in core body temperature (Ishizuka et al., 2025). This is because the relatively small surface area of the neck and head is considered insufficient to rapidly cool the total blood volume, so rectal temperature often does not differ significantly from the control group (Bright et al., 2019; Yoshihara et al., 2024).

Manipulation of thermal perception and thermal comfort is one of the main working mechanisms (Desroches et al., 2024). Cooling in the neck area sends a cool signal to the hypothalamus, which then suppresses the fatigue danger signal from the brain (Cotter & Taylor, 2005; Zhang et al., 2025). This results in the brain allowing the body to maintain high intensity even though the body's physiological temperature is still high (Cao et al., 2022; Sunderland et al., 2015).

Potential and Limitations of Applying Neck and Head Cooling Methods to Badminton Players

The application of neck and head cooling in badminton athletes offers high economic viability. This method, whether in the form of ice packs, ice bags, cooling collars, or headbands, can be practically integrated into interval breaks without violating match rules (S. Chalmers et al., 2019; Desroches et al., 2024). In addition to physical benefits, this intervention also has the potential to restore mental focus disrupted by heat and provide psychological advantages at critical or final points.

However, there are limitations that need to be considered. Several studies report that the application of cooling methods does not have a significant positive effect, indicating that the effectiveness of this method is highly dependent on the duration or timing of the cooling intervention (Mazalan et al., 2021; Pariyavuth et al., 2023). A rest period that is too short does not provide sufficient time for thermal receptors to trigger an optimal recovery response. In addition, the application of this method can also cause the risk of athletes pushing themselves beyond safe limits because they feel cooler than their actual body temperature. Therefore, monitoring vital signs after high-intensity competitions is necessary to prevent heat illness. Furthermore, comfort factors such as water droplets wetting clothing or the field are also technical considerations that need to be anticipated.

CONCLUSIONS

Based on the literature review conducted, neck and head cooling strategies have been identified as promising intervention methods in the acute recovery management of athletes in high-intensity intermittent sports, such as bad-

minton. The efficacy of this method is primarily mediated by perceptual mechanisms, through a reduction in RPE and an increase in thermal comfort, although it does not provide an instant increase in core body temperature reduction and neuromuscular power in a short duration. The practical implications of these findings are to advise sports practitioners and coaches to integrate neck and head cooling protocols as an efficient psychophysiological strategy during interval breaks, in order to maintain the consistency of badminton athletes' performance and delay the onset of systemic fatigue.

Considering that current literature is dominated by strictly controlled laboratory protocols, future research is strongly encouraged to improve ecological validity through several specific approaches. Future research is needed with standardized badminton simulation protocols that replicate specific movement patterns (such as lunges, jumping, hitting, and rapid changes of direction) to verify the consistency of the cooling effect on the neuromuscular complexity of this sport. Additionally, research is needed to determine the effectiveness of neck and head cooling in actual match situations, where dynamic environmental conditions and psychological pressure can affect thermoregulatory responses. Furthermore, future research should evaluate the impact of this method on cognitive aspects, particularly the accuracy of tactical decision-making when athletes are fatigued at crucial points in a match.

REFERENCES

- Abbiss, C. R., Mündel, T., Sinclair, W., Seeley, A. D., Giersch, G. E. W., & Charkoudian, N. (2021). Post-exercise Body Cooling: Skin Blood Flow, Venous Pooling, and Orthostatic Intolerance. *Frontiers in Sports and Active Living*, 3, 658410. <https://doi.org/10.3389/FSPOR.2021.658410>
- Abián-Vicén, J., Sánchez, L., & Abián, P. (2018). Performance structure analysis of the men's and women's badminton doubles matches in the Olympic Games from 2008 to 2016 during playoffs stage. *International Journal of Performance Analysis in Sport*, 18(4), 633–644. <https://doi.org/10.1080/24748668.2018.1502975>
- Alhadad, S. B., Tan, P. M. S., & Lee, J. K. W. (2019). Efficacy of heat mitigation strategies on core temperature and endurance exercise: A meta-analysis. *Frontiers in Physiology*, 10, 434912. <https://doi.org/10.3389/FPHYS.2019.00071/FULL>
- Alvarez-Dacal, F., Rodríguez-Fernández, A., Herrero-Molleda, A., Gil-Calvo, M., Baiget, E., Seguí-Urbaneja, J., & Fernández-Fernández, J. (2025). Training vs. Competition: Load and Intensity Differences Between Multi-Feeding and Simulated Match Play in High-Level Youth Badminton Players. *Applied Sciences* 2025, Vol. 15, Page 7451, 15(13), 7451. <https://doi.org/10.3390/AP15137451>
- Arampatzis, A., Prieske, O., Smilios, I., Kositsky, A., & Avela, J. (2020). The Effects of Cold Water Immersion on the Recovery of Drop Jump Performance and Mechanics: A Pilot Study in Under-20 Soccer Players. *Frontiers in Sports and Active Living*, 2, 502660. <https://doi.org/10.3389/FSPOR.2020.00017>
- Bartman, N. E., Larson, J. R., Looney, D. P., Johnson, B. D., Schlader, Z. J., Hostler, D., & Pryor, R. R. (2022). Do the National Institute for Occupational Safety and Health recommendations for working in the heat prevent excessive hyperthermia and body mass loss in unacclimatized males? *Journal of Occupational and Environmental Hygiene*, 19(10–11), 596–602. <https://doi.org/10.1080/15459624.2022.2123493>;CTYPE:STRING:JOURNAL
- Bongers, C. C. W. G., De Korte, J. Q., & Eijssvogels, T. (2021). Infographic. Keep it cool and beat the heat: cooling strategies for exercise in hot and humid conditions. *British Journal of Sports Medicine*, 55(11), 643–644. <https://doi.org/10.1136/BJSPORTS-2020-102294>
- Bongers, C. C. W. G., Thijssen, D. H. J., Veltmeijer, M. T. W., Hopman, M. T. E., & Eijssvogels, T. M. H. (2015). Precooling and percooling (cooling during exercise) both improve performance in the heat: a meta-analytical review. *British Journal of Sports Medicine*, 49(6), 377–384. <https://doi.org/10.1136/BJSPORTS-2013-092928>
- Bouchiba, M., Bragazzi, N. L., Zarzissi, S., Turki, M., Zghal, F., Grati, M. A., Daab, W., Ayadi, F., Rebai, H., Ibn Hadj Amor, H., Hureau, T. J., & Bouzid, M. A. (2022). Cold Water Immersion Improves the Recovery of Both Central and Peripheral Fatigue Following Simulated Soccer Match-Play. *Frontiers in Physiology*, 13, 860709–860709. <https://doi.org/10.3389/FPHYS.2022.860709>
- Bright, F. M., Chaseling, G. K., Jay, O., & Morris, N. B. (2019). Self-paced exercise performance in the heat with neck cooling, menthol application, and abdominal cooling. *Journal of Science and Medicine in Sport*, 22(3), 371–377. <https://doi.org/10.1016/J.JSAMS.2018.09.225>
- Canikli Adıgüzel, S., Akyurt, D., Ültan Özgen, G., Bahadır Altun, H., Çakır, A., Süren, M., & Okan, İ. (2023). The Effect of Cold Application to the Lateral Neck Area on Peripheral Vascular Access Pain: A Randomised Controlled Study. *Journal of Clinical Medicine*, 12(19), 6273. <https://doi.org/10.3390/JCM12196273>
- Cao, Y., Lei, T. H., Wang, F., Yang, B., & Mündel, T. (2022). Head, Face and Neck Cooling as Per-cooling (Cooling During Exercise) Modalities to Improve Exercise Performance in the Heat: A Narrative Review and Practical Applications. *Sports Medicine - Open* 2022 8:1, 8(1), 16-. <https://doi.org/10.1186/S40798-022-00411-4>
- Chalmers, S. M. (2017). In-play cooling strategies for sport in hot and humid conditions*. *Temperature*, 4(4), 353–355. <https://doi.org/10.1080/23328940.2017.1361502>;WGROU:STRING:PUBLICATION
- Chalmers, S., Siegler, J., Lovell, R., Lynch, G., Gregson, W., Marshall, P., & Jay, O. (2019). Brief in-play cooling breaks reduce thermal strain during football in hot conditions. *Journal of Science and Medicine in Sport*, 22(8), 912–917. <https://doi.org/10.1016/J.JSAMS.2019.04.009>
- Coote, J. H. (2010). Recovery of heart rate following intense dynamic exercise. *Experimental Physiology*, 95(3), 431–440. <https://doi.org/10.1113/EXPPHYSIOL.2009.047548>
- Cotter, J. D., & Taylor, N. A. S. (2005). The distribution of cutaneous sudomotor and alliesthesial thermosensitivity in mildly heat-stressed humans: An open-loop approach. *Journal of Physiology*, 565(1), 335–345. <https://doi.org/10.1113/JPHYSIOL.2004.081562>;PAGE:S TRING:ARTICLE/CHAPTER

- De Nardi, M., Filipas, L., Di Gennaro, S., Allemano, S., Gallo, G., Meloni, A., Della Guardia, L., Luzi, L., La Torre, A., & Codella, R. (2024). Effects of cryo-facial mask on running performance in amateur middle-distance runners. *Cryobiology*, 117, 105158. <https://doi.org/10.1016/J.CRYOBIOL.2024.105158>
- Desai, T., & Bottoms, L. (2017). Neck Cooling Improves Table Tennis Performance amongst Young National Level Players. *Sports*, 5(1), 19. <https://doi.org/10.3390/SPORTS5010019>
- Desroches, A. J., Aloui, F., Deshayes, T. A., & Goulet, E. D. B. (2024). Assessment of the Omius™ cooling headband effectiveness during a 70-min submaximal running effort followed by a 5-km time-trial in hot/humid conditions. *Journal of Thermal Biology*, 124, 103964. <https://doi.org/10.1016/J.JTHERBIO.2024.103964>
- Feng, L., Chen, T., Feng, L., & Chen, T. (2023). Comparative Analysis of the Techniques and Tactics of World Excellent Badminton Men's and Women's Doubles. *Advances in Physical Education*, 13(4), 224–233. <https://doi.org/10.4236/APE.2023.134019>
- Gawin, W., Beyer, C., & Seidler, M. (2015). A competition analysis of the single and double disciplines in world-class badminton. *International Journal of Performance Analysis in Sport*, 15(3), 997–1006. <https://doi.org/10.1080/24748668.2015.11868846>
- Gutiérrez-Arroyo, J., Rodríguez-Marroyo, J. A., García-Heras, F., Rodríguez-Medina, J., Villa-Vicente, G., & Carballo-Leyenda, B. (2025). Effectiveness of cooling strategies for emergency personnel: a systematic review and meta-analysis. *Scientific Reports* 2025 15:1, 15(1), 29492-. <https://doi.org/10.1038/s41598-025-15636-y>
- Hoffmann, D., Brinkschulte, M., & Vogt, T. (2024). Match characteristics of women's and men's singles and doubles events in elite badminton. *International Journal of Performance Analysis in Sport*, 1–18. <https://doi.org/10.1080/24748668.2024.2386830>
- Iizuka, T., Hirano, K., Atomi, T., Shimizu, M., & Atomi, Y. (2020). Changes in Duration and Intensity of the World's Top-Level Badminton Matches: A Consideration of the Increased Acute Injuries among Elite Women's Singles Players. *Sports* 2020, Vol. 8, Page 19, 8(2), 19. <https://doi.org/10.3390/SPORTS8020019>
- Ishizuka, K., Nagano, C., Togawa, M., Kado, K., Tajima, K., Mori, K., & Horie, S. (2025). Inefficacy of neck cooling in suppressing core body temperature elevation during exercise in a hot environment: a randomized cross-over trial. *Environmental Health and Preventive Medicine*, 30, 60–60. <https://doi.org/10.1265/EHPM.25-00041>
- Jackson, K., Rubin, R., Van Hoeck, N., Hauert, T., Lana, V., & Wang, H. (2015). The effect of selective head-neck cooling on physiological and cognitive functions in healthy volunteers. *Translational Neuroscience*, 6(1), 131. <https://doi.org/10.1515/TNSCI-2015-0012>
- Johnson, B. D., Sackett, J. R., Sarker, S., & Schlader, Z. J. (2017). Face cooling increases blood pressure during central hypovolemia. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 313(5), R594–R600. <https://doi.org/10.1152/AJP-REGU.00253.2017>
- Jungmann, M., Vencatachellum, S., Van Ryckeghem, D., & Vogele, C. (2018). Effects of Cold Stimulation on Cardiac-Vagal Activation in Healthy Participants: Randomized Controlled Trial. *JMIR Formative Research*, 2(2). <https://doi.org/10.2196/10257>
- Liu, L., Ma, Y., Huang, R., Jia, M., Liu, G., & Zheng, W. (2024). Field measurement study of indoor thermal environment of badminton halls in a hot summer and cold winter region in different seasons in China. *Heliyon*, 10(15), e34883. <https://doi.org/10.1016/J.HELİYON.2024.E34883>
- Lloyd, A., Hodder, S., & Havenith, G. (2015). The interaction between peripheral and central fatigue at different muscle temperatures during sustained isometric contractions. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 309(4), R410–R420. <https://doi.org/10.1152/AJPREGU.00061.2015>
- Louis, J., Schaal, K., Bieuzen, F., Le Meur, Y., Filliard, J. R., Volondat, M., Brisswalter, J., & Hausswirth, C. (2015). Head Exposure to Cold during Whole-Body Cryostimulation: Influence on Thermal Response and Autonomic Modulation. *PLoS ONE*, 10(4), e0124776. <https://doi.org/10.1371/JOURNAL.PONE.0124776>
- Maric, J., Marjanovic, M., Jovanovic, D., Stojanovic, F., Vukmirovic, D., Jakovljevic, V., Marić, J., Marjanović, M., Jovanović, D., Stojanović, F., Vukmirović, Đ., & Jakovljević, V. (2015). Simple And Complex Cognitive Functions Under Exertional Heat Stress. *EABR. Experimental and Applied Biomedical Research*, 16(1), 21–25. <https://doi.org/10.1515/SJECR-2015-0003>
- Mazalan, N. S., Landers, G. J., Wallman, K. E., & Ecker, U. (2021). Head Cooling Prior to Exercise in the Heat Does Not Improve Cognitive Performance. *Journal of Sports Science & Medicine*, 20(1), 69. <https://doi.org/10.52082/JSSM.2021.69>
- Miyazawa, T., Mizutani, M., Sheahan, J. P., & Ichikawa, D. (2021). Intermittent face cooling reduces perceived exertion during exercise in a hot environment. *Journal of Physiological Anthropology* 2021 40:1, 40(1), 12-. <https://doi.org/10.1186/S40101-021-00262-0>
- Naito, T., Saito, T., Morinaga, H., Eda, N., & Takai, Y. (2024). Elevated core temperature in addition to mental fatigue impairs aerobic exercise capacity in highly trained athletes in the heat. *Journal of Physiological Anthropology* 2024 43:1, 43(1), 30-. <https://doi.org/10.1186/S40101-024-00377-0>
- Nybo, L. (2012). Brain temperature and exercise performance. *Experimental Physiology*, 97(3), 333–339. <https://doi.org/10.1113/EXPPHYSIOL.2011.062273>
- Pardiwala, D. N., Subbiah, K., Rao, N., & Modi, R. (2020). Badminton Injuries in Elite Athletes: A Review of Epidemiology and Biomechanics. *Indian Journal of Orthopaedics*, 54(3), 237–245. <https://doi.org/10.1007/S43465-020-00054-1/TABLES/3>
- Pariyavuth, P., Lee, J. K. W., Tan, P. M. S., Vichaiwong, K., Mawhinney, C., & Pinthong, M. (2023). Practical internal and external cooling methods do not influence rapid recovery from simulated taekwondo performance. *Journal of Exercise Science & Fitness*, 21(3), 286–294. <https://doi.org/10.1016/J.JESF.2023.05.003>
- Pereira, G. S., Paulino, G. E., De Almeida, T. H. M. F., Siqueira, C. M. R., Torres Da Silva, J. R., Da Silva, M. L., & Ferrera, L. M. A. (2025). Effectiveness of cold-water immersion vs. massage in reducing delayed-onset muscle soreness and enhancing recovery following CrossFit® Murph Workout: Randomized rial. *PLOS ONE*, 20(8), e0329892. <https://doi.org/10.1371/JOURNAL.PONE.0329892>
- Périard, J. D. (2016). Hyperthermia and supraspinal fatigue. *Experimental Physiology*, 101(11), 1323–1324. <https://doi.org/10.1113/EP085883>
- Phomsoupha, M., Ibrahim, S., Heugas, A.-M., & Laffaye, G. (2019). Physiological, neuromuscular and perceived exertion responses in badminton games. *International Journal of Racket Sports Science*, 1(1), 16–25. <https://doi.org/10.30827/DIGIBUG.57323>
- Rodger, D., Admani, A., & Thomas, M. (2024). What is a scoping review? *Evidence-Based Nursing*, 27(3), 84–85. <https://doi.org/10.1136/EBNURS-2024-103969>

- Schmit, C., Hausswirth, C., Le Meur, Y., & Duffield, R. (2016). Cognitive Functioning and Heat Strain: Performance Responses and Protective Strategies. *Sports Medicine* 2016 47:7, 47(7), 1289–1302. <https://doi.org/10.1007/S40279-016-0657-Z>
- Schranner, D., Scherer, L., Lynch, G. P., Korder, S., Brotherhood, J. R., Pluim, B. M., Périard, J. D., & Jay, O. (2017). In-Play Cooling Interventions for Simulated Match-Play Tennis in Hot/Humid Conditions. *Medicine and Science in Sports and Exercise*, 49(5), 991–998. <https://doi.org/10.1249/MSS.0000000000001183>
- Seco-Calvo, J., Mielgo-Ayuso, J., Calvo-Lobo, C., & Córdova, A. (2020). Cold Water Immersion as a Strategy for Muscle Recovery in Professional Basketball Players During the Competitive Season. *Journal of Sport Rehabilitation*, 29(3), 301–309. <https://doi.org/10.1123/JSR.2018-0301>
- Stevens, C. J., Taylor, L., & Dascombe, B. J. (2016). Cooling During Exercise: An Overlooked Strategy for Enhancing Endurance Performance in the Heat. *Sports Medicine* 2016 47:5, 47(5), 829–841. <https://doi.org/10.1007/S40279-016-0625-7>
- Sunderland, C., Stevens, R., Everson, B., & Tyler, C. J. (2015). Neck-cooling improves repeated sprint performance in the heat. *Frontiers in Physiology*, 6(NOV), 166433. <https://doi.org/10.3389/FPHYS.2015.00314/BIBTEX>
- Tyler, C. J., & Sunderland, C. (2011). Cooling the Neck Region During Exercise in the Heat. *Journal of Athletic Training*, 46(1), 61–68. <https://doi.org/10.4085/1062-6050-46.1.61>
- van Delden, M., Bongers, C. C. W. G., Broekens, D., Daanen, H. A. M., & Eijssvogels, T. M. H. (2019). Thermoregulatory burden of elite sailing athletes during exercise in the heat: A pilot study. *Temperature*, 6(1), 66–76. <https://doi.org/10.1080/23328940.2018.1540964;REQUESTEDJOURNAL:JOURNAL:KTMP20;JOURNAL:JOURNAL:KTMP20;PAGE:STRING:ARTICLE/CHAPTER>
- Walters, P., Thom, N., Libby, K., Edgren, S., Azadian, A., Tannous, D., Sorenson, E., & Hunt, B. (2017). The Effect of Intermittent Head Cooling on Aerobic Performance in the Heat. *Journal of Sports Science & Medicine*, 16(1), 77. <https://pmc.ncbi.nlm.nih.gov/articles/PMC5358035/>
- Xia, Y., Zheng, X., Zhou, K., Jiang, L., Song, B., Xu, S., Shang, Z., & Dai, J. (2025). Effect of six weeks of blood flow restriction combined with Tabata training on anaerobic capacity in male badminton players. *Frontiers in Physiology*, 16, 1656050. <https://doi.org/10.3389/FPHYS.2025.1656050/BIBTEX>
- Xie, R., Xu, Y., Yang, J., & Zhang, S. (2021). Indoor air quality investigation of a badminton hall in humid season through objective and subjective approaches. *Science of The Total Environment*, 771, 145390. <https://doi.org/10.1016/J.SCITOTENV.2021.145390>
- Yaprak, Y. (2020). A COMPARISON OF ANAEROBIC PERFORMANCE OF SUB-ELITE TENNIS AND BADMINTON PLAYERS. *European Journal of Physical Education and Sport Science*, 0(0). <https://doi.org/10.46827/EJPE.V0I0.3043>
- Yoshihara, A., O'Neil, J. R., Defino, A. M., Celedon, F. A., Fox, E. B., Huggins, R. A., Glaviano, N. R., Adams, W. M., Casa, D. J., & Stearns, R. L. (2024). Impact of Various 10-min Cooling Breaks on Internal Body Temperature Responses During Subsequent Intermittent Exercise in the Heat: Application to Tennis. *Journal of Science in Sport and Exercise* 2024 6:3, 6(3), 244–252. <https://doi.org/10.1007/S42978-024-00281-0>
- Zhang, G., Xin, G., Li, H., Ma, P., & Wang, H. (2025). Neck cooling provides ergogenic benefits after heat acclimation during exercise in the heat. *Frontiers in Physiology*, 16, 1646930. <https://doi.org/10.3389/FPHYS.2025.1646930/BIBTEX>

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THE EFFECT OF THE BASKETBALL PROGRAM ON THE TRANSFORMATION OF MOTOR SKILLS OF TEN-YEARS OLD SCHOOL CHILDREN

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Abstract: The goal of the research is to determine the effects of the basketball program on the transformation of the motor skills of children in the younger grades of elementary school. The research was conducted in the period from the beginning of September to the end of December 2022 in Kraljevo (Republic of Serbia). The research sample included 40 participants. A battery of seven tests was used to assess motor skills: obstacle course backward, standing long jump, 20-meter running with a flying start, hand plate tapping, wide-angled seated forward bend, lifting the trunk for 60 s and bent-arm hang. At the beginning of the research, an primarily measurement was performed ("initial" measurements). After a period of 16 weeks, the children's motor abilities were re-measured ("final" measurements). Statistical data processing included the calculation of descriptive statistics of variables, the Kolmogorov-Smirnov normality test and the t-test of dependent samples. The programmed transformation training plan included basketball training. Based on the obtained results, it is possible to conclude that the four-month basketball program, which consisted of two sessions per week lasting 45 minutes, along with regular physical education classes of three hours per week, influenced the improvement of results in tests used to assess motor skills.

Keywords: anthropological status; boys; kinesiological activities; girls; programmed transformation exercise

INTRODUCTION

Systematic monitoring of anthropological characteristics of primary and secondary school students should be carried out at least twice a year, in the form of initial and final checks. (Martinčević et al., 2022). Motor skills represent one of the factors of anthropological status. "Motor skills are conditionally defined as latent motor structures that are responsible for an infinite number of manifest motor reactions and can be measured and described" (Findak, 1995, 14). Motor skills play a very important role when it comes to optimal growth and development of children. Difficulty in learning motor problems stands out as one of the most common developmental problems, affecting about 6% of children (Budiman et al., 2025). Therefore, motor skills have an impact on children's health. The development of motor skills starts from the birth of children, and over the years the development experiences certain changes. What is also important to emphasize is the fact that the development of motor skills is not always the same in both sexes (Mudrić et al., 2019). In addition, Neljak (2013) points out that boys and girls of younger school age have a relatively easy acquisition and improvement of more complex motor skills, in accordance with the fact that children of that age have more favorable relationships between morphological dimensions and coordination.

In general, the process of physical education is not considered to be anything other than a specific transformational process in which specific means are applied in order to achieve effects. Programmed transformational processes are considered a prerequisite for effective influence on children's development (Mitrović & Stević, 2018). At a time when children are less and less active, the importance of research on the positive impact of programmed kinesiology activities on children's development is great. A large number of researches have been conducted on the topic of the impact of programmed kinesiology activities on the motor skills of students in the younger grades of elementary school (Babin et al., 1999; Babin et al., 2001; Malacko, 2002; Baquet et al., 2004; Jurak et al., 2006; Erceg et al., 2008; Aleksić & Mekić 2010; Babin et al., 2010; Badrić & Prskalo, 2010; Zrnzević, 2010; Bakhtiari et al., 2011; Zrnzević & Zrnzević, 2011; Aleksić et al., 2013; Pelemiš et al., 2014; Mehrtash et al., 2015; Pavlović, 2015; Pelemiš et al., 2017; Anjos & Ferraro, 2018; Mesaroš-Živkov, 2018; Glišović, 2022a; Glišović, 2022b; Nikšić, 2024; Nikšić et al., 2024; Wenming et al., 2024). The authors of these studies agree that there is a possibility that, in the

younger school age, programmed physical exercise and other forms of treatment can affect all areas of anthropological status, primarily motor skills.

The fact that motor skills are a component that can be influenced by different physical exercise programs, i.e. different trainings, is also significant (Mudrić et al., 2019). A potential impact on the development of motor skills in children can be achieved by engaging in physical activity (D'Anna et al., 2024). Basketball is a collective game and belongs to the group of polystructural complex sports in the field of sports kinesiology. Basketball requires players to submit their own abilities to the team, while at the same time it also requires an individual contribution to each action during each stage of the game. The basic and main activity of the team during the competition is considered to score the basket and defend its own basket. The game of basketball is characterized by specific movements of the lower and upper extremities, which are used to regulate the movement of the ball (in the sense of receiving, passing, guiding and subtracting) and the movement of the body and shooting the ball at the opponent's basket (Kukić et al., 2010). At the same time, motor skills are one of the most important factors that determine the success of a basketball player. Every situation that appears during the game must first of all be adequately motorized, and the realization of this through the locomotor system allows the player strength, precision, speed, coordination, balance and agility. Successful basketball players are characterized by precision, speed, explosive start, frequency of movements, coordination, balance, agility and endurance (Matković et al., 2005). The results of the study conducted by Glišović (2022a), in which the impact of basketball training on the morphological characteristics and motor skills of junior elementary school students is analyzed, indicate that there are significant differences between students who train basketball and students who do not train basketball in speed, agility, endurance, coordination and explosiveness. These statements point to the conclusion that basketball training has a positive impact on the growth and development of children of younger school age, as a result of which there is a need to motivate students to participate in these activities by introducing elements of basketball on a larger scale into physical education in the younger grades of primary school (Glišović, 2022a).

These statements support the assumption from which this research is based, that there is a positive correlation between basketball training and the development of children's motor skills. The aim of the research is to determine the effects of the basketball program on the transformation of the motor skills of children in the younger grades of elementary school.

METHODS

Sample

The research sample included 20 boys and 20 girls aged 10 years (± 6 months) in the fourth grade of primary school. Data were collected during the first semester of the 2022/2023 school year, during participation in extracurricular activities in the school's basketball section. The experimental treatment was carried out in the period from beginning of September to the end of December 2022 in Kraljevo (Republic of Serbia).

Sample of Variables

When assessing the motor skills of younger school-aged students, standard motor tests were applied in accordance with the model presented by Bala et al. (2007), and on that occasion a battery was used that includes seven motor tests:

- for evaluation the factor of movement structures: 1) obstacle course backward (s) (in order to assess body coordination and reorganization of movement stereotypes), 2) standing long jump (cm) (in order to assess the explosive power of the lower extremities), 3) 20-meter running with a flying start (in order to assess explosive power and speed of movement);
- for the evaluation of factors of functional synergy and tone regulation: 4) hand plate tapping (s) (in order to estimate the speed of the frequency); 5) wide-angled seated forward bend (cm) (in order to assess flexibility);
- for evaluation of motor unit excitation duration factor: 6) lifting the trunk for 60 s (in order to evaluate the repetitive strength of the trunk), 7) bent-arm hang (s) (in order to assess static endurance in strength).

The Programme of the Experimental Procedure

The total volume of exercises lasted 16 weeks, while the weekly load during the basketball training cycle was twice a week for 45 minutes. During the duration of the program, 32 training sessions were held. The training program covers

the basic elements of basketball techniques and individual and team defense and attack tactics. Basic elements of basketball techniques include: basic basketball stance, movement techniques without the ball, movement techniques with the ball, jumps, turns, passing and catching the ball, attempts to hit the basket while moving and attempts to hit the basket while at rest. The transformative exercise program included the development of motor skills. The training is designed to primarily affect the development of speed, coordination, flexibility, strength and endurance.

Data processing methods

At the beginning of the research, an initial measurement was performed (“initial” measurements). After a period of 16 weeks, the children’s motor abilities were re-measured (“final” measurements). After data collection, their statistical processing and calculation of basic statistical parameters was performed. Statistical data processing included the calculation of descriptive statistics of variables: arithmetic mean (AS), standard deviation (Sd), minimum (Min), maximum (Max) values of measurement results, skewness (SKEW) and kurtosis (KURT). The Kolmogorov-Smirnov normality test was used to examine the normality of the results at the initial and final measurements. Dependent samples t-test ($p \leq 0.05$) was used to test the differences between the two groups (“initial” and “final”) in the investigated variables. All data processing was performed in SPSS 23 software (SPSS, Inc., Chicago, IL).

RESULTS

Based on the results of descriptive statistics for the motor variables of the girls at the initial measurement (table 1), it can be concluded that the greatest heterogeneity of the results (differences between AS) is for the variables obstacle course backward, standing long jump, wide-angled seated forward bend and bent-arm hang. On the other hand, the smallest heterogeneity between the examined groups was obtained for the variables 20-meter running with a flying start and lifting the trunk for 60 s. Analyzing the normality of the distribution of results (table 1), where the curvature of the curve was tested by skewness and kurtosis, it can be concluded that the variables obstacle course backward, hand plate tapping, bent-arm hang and lifting the trunk for 60 s are within the limits of the normal distribution, while variables wide-angled seated forward bend, standing long jump and 20-meter running with a flying start are not within the limits of the normal distribution (value greater than 1). The second parameter of the normality of the kurtosis distribution explains the analysis of the degree of curvature of the peak of the curve (distribution). For variables whose kurtosis values are less than zero (obstacle course backward, bent-arm hang), it can be concluded that the distribution is platykurtic. For other variables (hand plate tapping, wide-angled seated forward bend, standing long jump, 20-meter running with a flying start, lifting the trunk for 60 s), where the kurtosis values are greater than 0, it can be concluded that the distribution is leptokurtic.

Table 1. Descriptive statistics for girls at the initial measurement

Variable	AS	Sd	Min	Max	Skew	Kurt
obstacle course backward (s)	36.72	12.39905	13	57	-.631	-.415
hand plate tapping (s)	41.05	8.37587	20	56	-.666	1.747
wide-angled seated forward bend (cm)	33.35	9.52711	20	59	1.1008	1.242
standing long jump (cm)	119.50	13.16894	104	156	1.173	1.756
20-meter running with a flying start (s)	4.78	1.11431	3	8	1.218	2.459
bent-arm hang (s)	19.35	9.69685	4	4	.182	-.449
lifting the trunk for 60 s	18.00	6.53412	10	10	.994	1.465

Legend: AS – arithmetic mean, Sd – standard deviation, Min – minimum values of measurement results, Max maximum values of measurement results; Skew - skewness (measure of distribution asymmetry), Kurt - kurtosis (measure of distribution homogeneity)

Based on the results of descriptive statistics for the boys’ motor variables at the initial measurement (table 2), it can be concluded that the greatest heterogeneity of the results (difference between AS) is for the variables obstacle course backward, standing long jump, lifting the trunk for 60 s. On the other hand, the smallest heterogeneity between the examined groups was obtained for the variable 20-meter running with a flying start. Analyzing the normality of the distribution of results (table 2), where the curvature of the curve was tested by skewness and kurtosis, it can be

concluded that the variables obstacle course backward, wide-angled seated forward bend, standing long jump, lifting the trunk for 60 s are within the limits of the normal distribution, while variables hand plate tapping (value less than 1), 20-meter running with a flying start, bent-arm hang (value greater than 1) are not within the limits of the normal distribution. For variables whose kurtosis values are less than zero (obstacle course backward, wide-angled seated forward bend, standing long jump and lifting the trunk for 60 s), it can be concluded that the distribution is platykurtic. In the case of other variables (hand plate tapping, 20-meter running with a flying start, bent-arm hang), where the kurtosis is greater than 0, it can be concluded that the distribution is leptokurtic.

Table 2. Descriptive statistics for boys at the initial measurement

Variable	AS	Sd	Min	Max	Skew	Kurt
obstacle course backward (s)	30.76	12.34992	14	57	.581	-.038
hand plate tapping (s)	44.90	8.65661	20	56	-1.143	2.270
wide-angled seated forward bend (cm)	31.35	8.53029	18	49	.120	-.667
standing long jump (cm)	127.20	25.39706	85	168	.062	-.905
20-meter running with a flying start (s)	4.63	1.01843	3.15	8	1.950	5.747
bent-arm hang (s)	20.20	8.91834	8	41	1.196	1.034
lifting the trunk for 60 s	23.05	9.46726	8	42	.432	-.428

Legend: AS – arithmetic mean, Sd – standard deviation, Min – minimum values of measurement results, Max maximum values of measurement results; Skew - skewness (measure of distribution asymmetry), Kurt - kurtosis (measure of distribution homogeneity)

Since it is not possible to draw a conclusion about the normality of the distribution based only on the values of the mentioned parameters, the value of the Kolmogorov-Smirnov test was also calculated to check the normality of the initial measurements. The results of this test showed that in girls the variables obstacle course backward, wide-angled seated forward bend, standing long jump, 20-meter running with a flying start, bent-arm hang and lifting the trunk for 60 s do not deviate from the normal distribution ($p > 0.05$). On the other hand, with girls, the variables hand plate tapping deviate significantly from the normal distribution ($p < 0.05$). In boys, the variables obstacle course backward, hand plate tapping, wide-angled seated forward bend and lifting the trunk for 60 s do not deviate from the normal distribution ($p > 0.05$). On the other hand, in boys, the other variables (20-meter running with a flying start and bent-arm hang) deviate significantly from the normal distribution ($p < 0.05$) (table 3).

Table 3. Normality of the distribution of motor variables at the initial measurement for girls and boys

Variable	mesasurement	KS-p
obstacle course backward (s)	girls	.158
	boys	.200
hand plate tapping (s)	girls	.023
	boys	.200
wide-angled seated forward bend (cm)	girls	.196
	boys	.181
standing long jump (cm)	girls	.072
	boys	.200
20-meter running with a flying start (s)	girls	.111
	boys	.001
bent-arm hang (s)	girls	.200
	boys	.017
lifting the trunk for 60 s	girls	.008
	boys	.200

Legend: t – value of t-test; p – statistical significance of the difference

Based on the results of descriptive statistics for the motor variables of the girls at the final measurement (table 4), it can be concluded that the greatest heterogeneity of the results (differences between AS) is for the variables obstacle course backward, wide-angled seated forward bend, standing long jump and bent-arm hang. On the other hand, the smallest heterogeneity between the examined groups was obtained for the variable 20-meter running with a flying start. Analyzing the normality of the distribution of results (table 3), where the curvature of the curve was tested by skewness and kurtosis, it can be concluded that the variables obstacle course backward, hand plate tapping, wide-angled seated forward bend, 20-meter running with a flying start, bent-arm hang, lifting the trunk for 60 s are within the limits of the normal distribution, while the variable standing long jump are not within the limits of the normal (value greater than 1). For variables whose kurtosis values are less than zero (obstacle course backward, bent-arm hang), it can be concluded that the distribution is platykurtic. In the case of other variables (hand plate tapping, wide-angled seated forward bend, standing long jump, 20-meter running with a flying start, lifting the trunk for 60 s), where the kurtosis is greater than 0, it can be concluded that the distribution is leptokurtic.

Table 4. Descriptive statistics for girls at the final measurement

Variable	AS	Sd	Min	Max	Skew	Kurt
obstacle course backward (s)	33.85	11.45368	12	53	-.606	-.489
hand plate tapping (s)	43.55	8.19804	23	60	-.464	1.838
wide-angled seated forward bend (cm)	36.35	9.60962	22	61	.753	.753
standing long jump (cm)	123.20	13.43052	107	160	1.084	1.533
20-meter running with a flying start (s)	4.37	.98295	2.8	7	.927	1.275
bent-arm hang (s)	20.30	9.50402	6	42	.363	-.190
lifting the trunk for 60 s	21.15	6.33516	12	37	.717	.783

Legend: AS – arithmetic mean, Sd – standard deviation, Min – minimum values of measurement results, Max maximum values of measurement results; Skew - skewness (measure of distribution asymmetry), Kurt - kurtosis (measure of distribution homogeneity)

Based on the results of descriptive statistics for the boys' motor variables at the final measurement (table 5), it can be concluded that the greatest heterogeneity of the results (differences between AS) is for the variables obstacle course backward, standing long jump, lifting the trunk for 60 s. On the other hand, the smallest heterogeneity between the examined groups was obtained for the variable 20-meter running with a flying start. Analyzing the normality of the distribution of results (table 4), where the curvature of the curve was tested by skewness and kurtosis, it can be concluded that the variables obstacle course backward, wide-angled seated forward bend, standing long jump and lifting the trunk for 60 s are within the limits of the normal distribution, while the variables 20-meter running with a flying start, bent-arm hang are not within the limits of the normal (value greater than 1). In the case of other variables (obstacle course backward, hand plate tapping, 20-meter running with a flying start, bent-arm hang, where the kurtosis is greater than 0, it can be concluded that the distribution is leptokurtic.

Table 5. Descriptive statistics for boys at the final measurement

Variable	AS	Sd	Min	Max	Skew	Kurt
obstacle course backward (s)	28.15	11.80221	12	54	.686	.197
hand plate tapping (s)	47.00	8.60233	23	60	-.918	1.833
wide-angled seated forward bend (cm)	33.70	8.37352	20	52	.222	-.320
standing long jump (cm)	128.90	24.96714	86	168	-.023	-.888
20-meter running with a flying start (s)	4.10	.91334	3	7	1.697	4.562
bent-arm hang (s)	20.80	8.63042	9	41	1.266	1.377
lifting the trunk for 60 s	24.35	9.47170	9	44	.478	-.252

Legend: AS – arithmetic mean, Sd – standard deviation, Min – minimum values of measurement results, Max maximum values of measurement results; Skew - skewness (measure of distribution asymmetry), Kurt - kurtosis (measure of distribution homogeneity)

Since it is not possible to draw a conclusion about the normality of the distribution based only on the values of the mentioned parameters, the value of the Kolmogorov-Smirnov test was also calculated to check the normality of the final measurements. The results of this test showed that in girls and boys all observed variables do not deviate from the normal distribution ($p > 0.05$) (table 6).

Table 6. Normality of the distribution of motor variables at the final measurement for girls and boys

Variable	mesaurement	KS-p
obstacle course backward (s)	girls	.200
	boys	.200
hand plate tapping (s)	girls	.080
	boys	.200
wide-angled seated forward bend (cm)	girls	.200
	boys	.200
standing long jump (cm)	girls	.144
	boys	.200
20-meter running with a flying start (s)	girls	.129
	boys	.079
bent-arm hang (s)	girls	.200
	boys	.45
lifting the trunk for 60 s	girls	.071
	boys	.200

Legend: t – value of t -test; p – statistical significance of the difference

Based on the results of the t -test of dependent samples for motor variables, it can be concluded that in girls there is a statistically significant difference in the “initial” and “final” values for all investigated variables ($p < 0.05$) (table 7).

Table 7. Paired samples t -test for girls

Variable	mesaurement	t	p
obstacle course backward (s)	initial	8.933	.000
	final		
hand plate tapping (s)	initial	-12.523	.000
	final		
wide-angled seated forward bend (cm)	initial	-5.430	.000
	final		
standing long jump (cm)	initial	-15.308	.000
	final		
20-meter running with a flying start (s)	initial	8.018	.000
	final		
bent-arm hang (s)	initial	-4.498	.000
	final		
lifting the trunk for 60 s	initial	-4.924	.000
	final		

Legend: t – value of t -test; p – statistical significance of the difference

Based on the results of the t -test of dependent samples for motor variables, it can be concluded that in boys there is a statistically significant difference in the “initial” and “final” values for all examined variables ($p < 0.05$) (table 8).

Table 8. Paired samples t-test for boys

Variable	mesaurement	t	p
obstacle course backward (s)	initial	-4.230	.000
	final		
hand plate tapping (s)	initial	-6.332	.000
	final		
wide-angled seated forward bend (cm)	initial	-8.029	.000
	final		
standing long jump (cm)	initial	-3.048	.007
	final		
20-meter running with a flying start (s)	initial	7.060	.000
	final		
bent-arm hang (s)	initial	-2.349	.030
	final		
lifting the trunk for 60 s	initial	-5.151	.000
	final		

Legend: *t* – value of *t*-test; *p* – statistical significance of the difference

DISCUSSION

It is possible to say that motor skills for the period of younger school age have not yet been fully defined, and that this is a period that is very important when it comes to developing motor skills, primarily basic. In the period of younger school age, physical education should be based on the formation of the best possible basis for improving specific motor skills in older ages (Mitrović & Stević, 2018). Radovanović (2018) points out that through various physical activities, children get to know their body, develop and improve motor skills through the acquisition of various motor skills and habits and the development of motor skills. Motor skills represent those forms of motor activity that occur within motor structures that can be described with the help of the same parametric system, which can be measured with the help of the same set of measures and within which analogous physiological, biological and psychological processes, i.e. mechanisms, occur. Motor skills are partly inherited, while the other part is acquired primarily through the training process (Mujanović et al., 2021). It is known that all motor abilities are not equally dependent on heredity. A high level of innateness is attributed to speed and balance, medium to coordination and precision, low to strength and mobility (Cemič & Gregorc, 2013).

The results of the research show that in girls, the basketball program had an effect on the improvement of motor skills in all the observed tests: obstacle course backward, which corresponds to the results obtained by Zrnzević (2010), Zrnzević and Zrnzević (2011), Pavlović (2015), Aleksić et al. (2013), Pavlović and Marinković (2015), and Glišović (2022b); hand plate tapping, which corresponds to the results obtained by Zrnzević (2010), Zrnzević and Zrnzević (2011), Pelemiš et al. (2014), and Glišović (2022b); wide-angled seated forward bend, which corresponds to the results obtained by Milanović (2007), Zrnzević (2010), Zrnzević and Zrnzević (2011), Mesaroš-Živkov (2018), and Glišović (2022b); standing long jump, which corresponds to the results obtained by Zrnzević (2010), Pavlović (2015), Pavlović and Marinković (2015), Mesaroš-Živkov (2018), and Glišović (2022b); 20-meter running with a flying start, which corresponds to the results obtained by Pavlović (2015), Pavlović and Marinković (2015), Mesaroš-Živkov (2018), and Glišović (2022b); bent-arm hang, which corresponds to the results obtained by Milanović (2007), Aleksić and Mekić (2010), Pelemiš et al. (2014), Pavlović and Marinković (2015), and Glišović (2022b); and lifting the trunk for 60 s, which corresponds to the results obtained by Zrnzević (2010), Zrnzević and Zrnzević (2011), Pelemiš et al. (2014), Pavlović (2015), and Glišović (2022b).

At the same time, the results of the research show that in boys, the basketball program influenced the improvement of motor skills in all observed tests: obstacle course backward, which corresponds to the results obtained by Zrnzević and Zrnzević (2011), Pavlović (2015), Pavlović and Marinković (2015), and Glišović (2022b); hand plate tapping, which corresponds to the results obtained by Zrnzević and Zrnzević (2011), Pelemiš et al. (2014), and Glišović (2022b); wide-angled seated forward bend, which corresponds to the results obtained by Milanović (2007),

Zrnzević and Zrnzević (2011), and Glišović (2022b); standing long jump, which corresponds to the results obtained by Pavlović (2015) and Glišović (2022b); 20-meter running with a flying start, which corresponds to the results obtained by Pavlović (2015), Pavlović and Marinković (2015), and Glišović (2022b); bent-arm hang, which corresponds to the results obtained by Milanović (2007), Aleksić i Mekić (2010), Pelemiš i suradnici (2014), Pavlović i Marinković (2015), i Glišović (2022b); and lifting the trunk for 60 s, which corresponds to the results obtained by Zrnzević and Zrnzević (2011), Pelemiš et al. (2014), Pavlović (2015), and Glišović (2022b).

In order to ensure the successful transformation of anthropological characteristics, it is necessary to provide a high-quality plan and program of the training process. At the same time, it is very important to choose the most optimal methods and methodological procedures that will provide the possibility of achieving the research goal (Badrić et al., 2015). The results obtained from the research, which show that the training process of basketball contributed to the improvement of motor skills in boys and girls of younger school age, indicate the existence of a quality plan and program of the training procedure, and an adequate selection of the most optimal methods and methodological procedures. At the same time, the obtained results are in agreement with the results of other studies that examined the impact of basketball training on the development of motor skills, which show that there is a positive correlation between basketball and the development of motor skills in children (Radenković et al., 2014; Gašparić, 2015; Ljubojević et al., 2016; Užičanin et al., 2017; Cvitković, 2018; Glišović, 2022a).

It is a fact that in the younger grades of primary school, physical education teaching is most often treated as secondary and less important, compared to physical education teaching in older grades. The teaching of physical education in older grades is an absolute priority in almost all elementary schools, both when it comes to the use of the hall and other facilities intended for exercise, and when it comes to the equipment and use of teaching aids. In addition, it was observed that students of the younger grades of elementary school are represented in a significantly smaller number both in extracurricular activities and in sports sections. The above leads to limiting their overall activity in physical culture and narrowing the space for their timely and permanent engagement in it (Stamatović et al., 2010). Another problem that arises is the motivation of students to participate in physical activities. Considering the contribution that extracurricular activities and sports sections can make to the development of motor skills, it is important to motivate children to use some of their free time to participate in physical activities. Namely, an individual has the possibility of using his free time for rest, entertainment, participation in certain physical activities, etc., depending on his wishes. However, with the advancement of technology, students (especially those in the younger grades of elementary school) are spending more and more free time on computers, phones and other digital devices. For this reason, it is important to emphasize the role that parents and teachers play in encouraging students to apply physical activities that affect the growth and development of students through extracurricular and extracurricular activities (Rosić, 2015). Schools could organize sections for: basketball, rhythmic gymnastics and dance, handball, football, volleyball, etc., intended for students of younger grades of elementary school, in order to improve their anthropological status.

CONCLUSION

Kinesiological activity has the greatest importance during childhood, in accordance with the fact that it can affect the physical development of children, on the one hand, and the formation of healthy life habits, on the other hand. There is a positive effect of additional exercise on the anthropological status, regardless of whether it is in the form of extracurricular activities or extracurricular activities with regular physical education classes. The results of previous research into the impact of basketball on the anthropological status of students of younger grades of elementary school showed that basketball significantly affects the harmonious development of the whole body, that is, it positively affects a wide range of abilities and traits.

In researching the effects of the basketball program on the transformation of motor skills of fourth-grade elementary school students, it was found out that the programmed transformation exercise had an effect on the improvement of results in all tests used to assess motor skills: obstacle course backward, hand plate tapping, wide-angled seated forward bend, standing long jump, 20-meter running with a flying start, bent-arm hang and lifting the trunk for 60 s. Despite the obtained results, it is important to emphasize that the research is characterized by certain limitations. First of all, it is about the size of the sample, considering that the research was conducted on a small sample. There is a possibility that different results would have been obtained in the case of a larger sample. Another limitation

relates to the tests used to assess motor skills. Regardless of the limitations, the fact is that this work should represent a guideline in the further monitoring and research of the effects of programmed transformational exercise on changes in motor abilities in younger elementary school students.

REFERENCES

- Aleksić, M. D., & Mekić, B. (2010). Efekti elemenata sportske gimnastike u nastavi fizičkog vaspitanja na razvoj statističke snage kod učenika mlađeg školskog uzrasta [The effects of elements of sports gymnastics in physical education classes on the development of statistical power in students of younger school age]. *Sport Mont*, 21-22, 185-191.
- Aleksić, D., Stanković, S., Milenković, V., Karalejić, S., Lilić, L., & Mekić, B. (2013). Efekti primene elemenata gimnastike u nastavi fizičkog vaspitanja na razvoj koordinacije kod učenika mlađeg školskog uzrasta [The effects of the application of elements of gymnastics in physical education classes on the development of coordination in younger school-aged girls]. *Glasnik Antropološkog društva Srbije*, 48, 107-113. <https://doi.org/10.5937/gads1449137A>
- Anjos, I. D. V. C. D., & Ferraro, A. A. (2018). The influence of educational dance on the motor development of children. *Revista Paulista de Pediatria*, 36, 337-344. <https://doi.org/10.1590/1984-0462/2018;36;3;00004>
- Babin, J., Katić, R., & Vlahović, L. (1999). Influence of specially programmed physical and health education on motor abilities of 7 year old schoolgirls. In: D. Milanović (ed.), *2nd International Scientific Conference "Kinesiology for the 21st Century"* (pp. 115–116). Zagreb: Faculty of Physical Education.
- Babin, J., Katić, R., Ropac, D., & Bonacin, D. (2001). Effect of specially programmed physical and health education on motor fitness of seven-year-old school children. *Collegium Antropologicum*, 25(1), 153-165.
- Badrić, M. & Prskalo, I. (2010). The influence of programmed training on the transformations of anthropological status of elementary school pupils. In: I. Prskalo, V. Findak, & J. Strel. (eds.), *Collected papers of 4th Special Focus Symposium: Individualizing Instruction in Kinesiology* (pp. 64-80). Zagreb: Sveučilište u Zagrebu.
- Badrić, M., Prskalo, I., & Sporiš, G. (2015). Effects of programmed training on the motor skills of female basketball players in school sports societies. *Croatian Journal of Education: Hrvatski časopis za odgoj i obrazovanje*, 17(1), 71-81. <https://doi.org/10.15516/cje.v17i0.1516>
- Bakhtiar, S., Shafinia, P., & Ziaee, V. (2011). Effects of selected exercises on elementary school third grade girl students' motor development. *Asian Journal of Sports Medicine*, 2(1), 51-56.
- Bala, G., Stojanović, M. V. & Stojanović, M. (2007). *Merenje i definisanje motoričkih sposobnosti dece [Measuring and defining the motor skills of children]*. Novi Sad: Fakultet sporta i fizičkog vaspitanja.
- Baquet, Guinhouya, C., Dupont, G., Nourry, C., & Berthoin, S. (2004). Effects of a short-term interval training program on physical fitness in prepubertal children. *The Journal of Strength & Conditioning Research*, 18(4), 708-713. <https://doi.org/10.1519/13813.1>
- Budiman, I. A., Hendrayana, Y., Hidayat, Y., Hambali, B., Sinulingga, A., Syahrudin, H. S., ... & Wider, W. (2025). Motor learning development in children: A bibliometric analysis. *International Journal of Human Movement and Sports Sciences*, 13(2), 479-489. <https://doi.org/10.13189/saj.2025.130226>
- Cemić, A., & Gregorc, J. (2013). *Motorika predškolskega otroka: študijsko gradivo [Motor skills of a preschool child: study material]*. Ljubljana: Pedagoška fakulteta.
- Cvitković, I. (2018). *Utjecaj treninga košarke na razinu antropoloških obilježja kod učenika osnovne škole [The impact of basketball training on the level of anthropological characteristics in elementary school]* [Published PhD thesis]. Sveučilište u Zagrebu: Učiteljski fakultet, Katedra za kineziološku edukaciju.
- D'Anna, C., Forte, P., & Pugliese, E. (2024). Trends in physical activity and motor development in young people – Decline or improvement? A review. *Children*, 11(3), 298. <https://doi.org/10.3390/children11030298>
- Erceg, M., Zagorac, N., & Katić, R. (2008). The impact of football training on motor development in male children. *Collegium antropologicum*, 32(1), 241-247.
- Findak, V. (1995). *Metodika tjelesne i zdravstvene kulture u predškolskom odgoju [Methodology of physical and health education in preschool education]*. Zagreb: Školska knjiga.
- Gašparić, Z. (2015). *Utjecaj dodatne tjelesne aktivnosti na razvoj motoričkih sposobnosti učenika [The influence of additional physical activity on the development of motor skills of schoolgirls]* [Published PhD thesis]. Sveučilište u Zagrebu: Učiteljski fakultet, Katedra za kineziološku edukaciju.
- Glišović, G. (2022a). Uticaj treninga košarke na morfološke karakteristike i motoričke sposobnosti učenika mlađih razreda osnovne škole [The influence of basketball training on the morphological characteristics and motor skills of elementary school students]. *Metodička praksa*, 25(1), 69-82.
- Glišović, G. (2022b). Efekti programiranog transformacionog vežbanja na promene u motoričkim sposobnostima učenika mlađih razreda u osnovnoj školi [The effects of programmed transformation exercise on changes in the motor skills of students of younger grades in elementary school]. *Učenje i nastava*, 1, 177-200.
- Jurak, G., Kovač, M., & Strel, J. (2006). Impact of the additional physical education lessons programme on the physical and motor development of 7-to 10-year-old children. *Kinesiology*, 38(2), 105-115.
- Kukić, A., Hodžić, M., Rašidagić, F., & Nožinović, F. (2010). Uticaj programa škole košarke na neke motoričke i situaciono-motoričke sposobnosti djece od 12-14 godina [The impact of the basketball school program on some motor and situational-motor abilities of children aged 12-14]. *Sport Mont*, 25-26-27, 159-165.
- Ljubojević, M., Muratović, A., & Bubanja, M. (2016). Effects of various physical education curriculum on motor skills in students of final grades in primary school. *Sport Mont*, 14(1), 25-28.
- Malacko, J. (2002). Effects specific programmed training on morphological characteristics and motor abilities in children sports school. *Kinesiologia Slovenica*, 8(2), 44-49.
- Martinčević, I., Žigić, N., Mraz, I., & Sedlar, N. (2022). Povezanost indeksa tjelesne mase i motoričkih sposobnosti učenika osmih razreda

- osnovne škole [Correlation between body mass index and motor skills of eighth grade elementary school students]. *SportLogia*, 18(1), 21-30. <https://doi.org/10.5550/sgia.221801.se.mzms>
- Matković, B., Matković, B., & Knjaz, D. (2005). Fiziologija košarkaške igre [Physiology of the basketball game]. *Hrvatski športskomedicinski vjesnik*, 20(2), 113–124.
- Mehrtash, M., Rohani, H., Farzaneh, E., & Nasiri, R. (2015). The effects of 6 months specific aerobic gymnastic training on motor abilities in 10–12 years old boys. *Science of gymnastics Journal*, 7(1), 51-60. <https://doi.org/10.52165/sjg.7.1.51-60>
- Mesaroš-Živkov, A. (2018). Programirano fizičko vežbanje u funkciji razvoja motoričkih sposobnosti djevojčica mlađeg školskog uzrasta [Programmed physical exercise in the function of the development of motor skills of girls of younger school age]. *Godišnjak Pedagoškog fakulteta u Vranju*, 9(1), 153–162.
- Milanović, I. (2007). Efekti programirane nastave fizičkog vaspitanja u mlađem školskom uzrastu [The effects of programmed physical education classes in younger school age]. *Fizička kultura*, 61(1–2), 43–56.
- Mitrović, N. & Stević, D. (2018). Efekti vežbanja po modelu škole sporta pedagoškog fakulteta na promene u motoričkim sposobnostima kod dece [The effects of exercise according to the sports school model of the faculty of pedagogy on changes in motor skills in children]. *Sport i zdravlje*, 8(1), 65–72. <https://doi.org/10.7251/SIZ0118065M>
- Mudrić, M., Aleksić, B., Kasum, G., Jovanović, S., & Suzović, D. (2019). Morfološke karakteristike i motoričke sposobnosti karatista junior-skog uzrasta različite specijalizacije [Morphological characteristics and motor skills of karate juniors of different specializations]. *Godišnjak Fakulteta sporta i fizičkog vaspitanja*, 24, 40-48. <https://doi.org/10.5937/gfsfV1924040M>
- Mujanović, R., Bajrić, O., Hadžić, R., & Mojsilović, Z. (2021). Promene motoričkih sposobnosti karatista pod uticajem modela treninga [Changes in karate athletes' motor skills under the influence of the training model]. In O. Bajrić, & V. Srdić (eds.), *Collected papers of 11th International Conference on Sports Science and Health*, Banja Luka (pp. 77-89). Banja Luka: Panevropski Univerzitet.
- Neljak, B. (2013). *Opća kineziološka metodika [General kinesiological methodology]*. Zagreb: Gopal d.o.o.
- Nikić, E. (2024). Differences in motor abilities between boys and girls IV grade of elementary school. *Anthropologie*, 62(3), 219-230.
- Nikić, E., Rašidagić, F., Mekić, A., & Beganović, E. (2024). Basic motor skills among 2nd–9th-grade elementary school students. *Journal of Physical Education and Sport*, 24(2), 253-259.
- Pavlović, S. (2015). Efikasnost primene programiranog i modifikovanog modela fizičkog vežbanja u nastavi dece mlađeg školskog uzrasta [The effectiveness of the application of the programmed and modified model of physical exercise in the teaching of children of younger school age]. In: S. Marinković (ed.), *Nastava i učenje-evaluacija vaspitnog obrazovnog rada* (str. 389-402). Užice: Učiteljski fakultet.
- Pelemiš, V., Pelemiš, M., & Mitrović, N. (2014). Uticaj dva različita kineziološka tretmana na razvoj motoričkih sposobnosti učenika mlađeg školskog uzrasta [The influence of two different kinesiology treatments on the development of motor skills of younger school-age students]. *Zbornik radova Učiteljskog fakulteta*, 8, 259–268.
- Pelemiš, V. M., Mosurović, M., Banović, M., & Branković, P. (2017). Da li kineziološki tretman od devet nedelja dovodi do značajnih promena u snazi kod dečaka [Does nine weeks of kinesiology treatment produce significant changes in strength in boys]. In O. Bajrić, & Đ. Nićin (eds.), *Collected papers of 11th International Conference on Sports Science and Health* (pp. 62-69). Banja Luka: Panevropski Univerzitet.
- Radenković, M., Berić, D., & Kocić, M. (2014). The influence of the elements of basketball on the development of motor skills in children with special needs. *Facta Universitatis, Series: Physical Education and Sport*, 12(2), 123-130.
- Rosić, V. (2015). *Slobodno vrijeme, priručnik za uspješno organiziranje i vođenje slobodne aktivnosti [Free time, a manual for successfully organizing and managing free time activities]*. Rijeka: Žgar d.o.o.
- Sibinović, A. T. (2016). *Efekti različitih grupnih fitnes programa kod učenika sedmih razreda osnovne škole [The effects of different group fitness programs in seventh grade elementary school students]* [Published PhD thesis]. Beograd: Fakultet sporta i fizičkog vaspitanja.
- Stamatović, M., Šekeljić, G., Bojović, Ž., & Marković, Ž. (2012). Učitelj u nastavi fizičkog vaspitanja [Teacher in physical education classes]. *Sport Mont*, 34-35-36(X), 401-407.
- Užičanin, E., Muratović, M., & Babajić, F. (2017) Uticaj šestomjesečnog programa košarke na razvoj motoričkih sposobnosti kod dječaka uzrasta od 11 do 13 godina [The impact of a six-month basketball program on the development of motor skills in boys aged 11 to 13 years]. In V. Šeparović (ed.), *Proceedings book of 10th International Conference sport and health* (pp. 47-55). Tuzla: Faculty of physical education and sport.
- Wenming, J., Ahmad Alhussin, A., Mohamad, N. I., Baki, M. H., & Novadri, A. (2024). A Meta-Analysis of studies on fundamental motor skills in children aged 3-12 Years. *Jurnal Sains Sukan dan Pendidikan Jasmani*, 13(1), 1-22.
- Zrnzević, N. (2010). Uticaj eksperimentalnog programa nastave fizičkog vaspitanja na motoričke sposobnosti učenika [The influence of the experimental program of physical education on students' motor abilities]. *Sport Mont*, 21-22, 222-229.
- Zrnzević, N., & Zrnzević, J. (2011). Uticaj posebno programirane nastave fizičkog vaspitanja na motoričke sposobnosti sedmogodišnjih učenika [The impact of specially programmed physical education lessons on the motor skills of seven-year-old students]. *Sport Mont*, 28-29-30(IX), 285-293.

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PROCEDURA RECENZIJJE

Radovi poslani časopisu će najprije biti ocijenjeni od strane Uredništva imajući u vidu nekoliko kriterijuma: prikladnost teme i sadržaja časopisa; uređivanje (priprema rukopisa) i format; i “opšta” valjanost. Ako su ovi kriteriji ispunjeni, rad će biti poslat na dvostruku anonimnu recenziju od strane najmanje dva priznata i nezavisna recenzenta, a proces recenzije može trajati do 8 sedmica.

Samo radovi koji dobiju pozitivne recenzije će biti prihvaćeni. Jedan od presudnih razloga recenzije je navođenje citata i referenci relevantne literature. Urednički odbor ima pravo da komentariše formu rada prije nego što on bude prihvaćen za objavljivanje. Redakcija nije obavezna da objavljuje radove po hronološkom redosledu njihovog prijema ili po redoslijedu po kom su prihvaćeni za objavljivanje. Nijedan značajan dio rada ne treba da bude objavljen negdje drugdje. Prikazivanje rezultata u izvodima, sažecima, kratkim pregledima, disertacijama i magistarskim tezama, recenzijama i radovima sa konferencija (do tri stranice, koje sadrže sažetke, grafičke prezentacije i literaturu) ne smatra se objavljivanjem. Ako rukopis sadrži rezultate koji su već objavljeni, autor(i) moraju dobiti pristanak prvog izdavača i jasno citirati izvor.

ETHICS

Publication ethics, disclosure policy and malpractice statement

Publication and authorship

- All submitted articles are subject to strict peer-review process by at least two reviewers that are experts in the area of the particular paper.
- The factors that are taken into account in review are relevance, soundness, significance, originality, readability and language.
- The paper acceptance is constrained by such legal requirements as shall then be in force regarding libel, copyright infringement and plagiarism.
- For published articles, information on relevant potential conflicts of interest will be made available to the public.

Authors' responsibilities

- Authors must certify that their manuscripts are their original work.
- Authors must certify that the manuscript has not previously been published elsewhere.
- In case a submitted manuscript is a result of a research project, or its previous version has been presented at a conference in the form of an oral presentation (under the same or similar title), detailed information about the project, the conference, etc. shall be provided navesti gde se navode. A paper that has already been published in another journal cannot be reprinted in this journal.
- Authors must certify that the manuscript is not currently being considered for publication elsewhere.
- Authors must identify all sources used in the creation of their manuscript.
- It is the responsibility of each author to ensure that papers submitted in this journal are written with ethical standards in mind.

Reviewers' responsibilities

- Reviews should be conducted objectively, with no personal criticism of the author.
- Reviewers are required to provide written, competent and unbiased feedback in a timely manner on the scholarly merits and the scientific value of the manuscript.
- Reviewers should keep all information regarding articles confidential and treat them as privileged information.
- Reviewers must not have conflict of interest with respect to the research, the authors and/or the funding sources for the research. If such conflicts exist, the reviewers must report them to the Editor without delay.
- Any selected referee who feels unqualified to review the research reported in a manuscript or knows that its prompt review will be impossible should notify the Editor without delay.

Editors' responsibilities

- Editors have complete responsibility and authority to reject/accept an article.
- Editors are responsible for the contents and overall quality of the publication.
- Editors should always consider the needs of the authors and the readers when attempting to improve the publication.
- Editors should preserve the anonymity of reviewers.
- Editors should act if they suspect misconduct, whether a paper is published or unpublished, and make all attempts to persist in obtaining a resolution to the problem.
- Editors should not reject articles based on suspicions.

ETIKA

Etika objavljivanja, pravila objavljivanja i zloupotreba podataka

Objavljivanje i autorska prava

- Svi pristigli članci podliježu strogoj recenziji od strane barem dva recenzenta koji su stručnjaci iz oblasti naučnog rada.
- Faktori koji se uzimaju u obzir prilikom recenzije su relevantnost, ispravnost, značaj, originalnost, čitljivost i jezik.
- Prihvatanje rukopisa je ograničeno takvim zakonskim uslovima koje će se primijeniti u slučaju klevete, zloupotrebe autorskih prava i plagijata.
- Kod objavljenih članka, informacije o relevantnim potencijalnim sukobima interesa biće dostupne javnosti.

Odgovornosti autora

- Autori moraju da potvrde da je njihov rukopis njihovo autorsko djelo.
- Autori moraju da potvrde da njihov rukopis nije prethodno objavljen na nekom drugom mjestu.
- U slučaju da je poslati rukopis rezultat naučnoistraživačkog projekta ili da je, u prethodnoj verziji, bio izložen na skupu u vidu usmenog saopštenja (pod istim ili sličnim naslovom), detaljniji podaci o projektu, konferenciji i slično, navode se u navesti gdje se navode. Rad koji je već objavljen u nekom časopisu ne može biti preštampan u ovom časopisu.
- Autori moraju da potvrde da se njihov rukopis trenutno ne razmatra za objavljivanje negdje drugdje.
- Autori su dužni da navedu sve izvore koje su koristili u pisanju njihovog rukopisa.
- Autori su dužni da se pridržavaju etičkih standarda koji se odnose na naučnoistraživački rad.

Obaveze recenzenta

- Recenzija mora biti objektivna. Komentari koji se tiču ličnosti autora smatraju se neprimjerenim. Sud recenzenta mora biti jasan i potkrepljen argumentima.
- Recenzenti bi trebalo svoje stavove da iskažu jasno, sa pratećim argumentima.
- Recenzenti bi trebalo da čuvaju u povjerenju sve informacije u vezi članka i smatraju ih privilegovanim informacijama.
- Recenzent ne smije da bude u sukobu interesa sa autorima ili financijerom istraživanja. Ukoliko postoji sukob interesa, recenzent je dužan da o tome momentalno obavijesti urednika.
- Recenzent koji sebe smatra nekompetentnim za temu ili oblast kojom se rukopis bavi dužan je da o tome obavijesti urednika.

Obaveze urednika

- Urednici imaju punu odgovornost i ovlaštenje da odbiju/prihvate članak.
- Urednici su odgovorni za sadržaj i ukupni kvalitet publikacije.
- Urednici bi uvijek trebalo da razmotre potrebe autora i čitaoca pri pokušaju da se poboljša publikacija.
- Urednici bi trebalo da sačuvaju anonimnost pregledanog članka.
- Urednici bi trebali da osiguraju da je sav materijal koji objavljuju u skladu sa međunarodno prihvatljivim etičkim smjernicama.
- Urednici bi trebalo da djeluju ukoliko posumnjaju na zloupotrebu, bez obzira da li je rad objavljen ili ne, i preduzmu mjere kako bi uspjeli da riješe problem.
- Urednici ne bi trebalo da odbace članak na osnovu sumnje.

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