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Dragi čitaoci,

Predstavljamo vam novo izdanje Časopisa ''Sportske nauke i zdravlje'', gdje možete pronaći 15 radova, autora iz Bosne i Hercegovine, Srbije, Hrvatske, Sjeverne Makedonije, Indonezije Rusije i Turske. U jako izazovnom vremenu po našu struku, sa sigurnošću možemo reći da iza sebe imamo veoma uspješnu godinu.

U ovom broju možete pročitati o aerobnom fizičkom vježbanju i vrijednosti BMI kod učenika sa viškom kilograma, kardiorespiratirnim indikatorima kondicije kod mladih sportista, strukturiranom treningu motoričkih vještina i nestrukturiranom treningu motoričkih vještina u poboljšanju dječjih motoričkih sposobnosti, razvoju modela treninga sa spoljašnjim opterećenjem za povećanje snage u šotokan karateu, razlikama u interkorelacijama psiholoških karakteristika kod karate takmičara i reprezentativaca, faktorska struktura motoričkih sposobnosti kod džudista, poboljšanju brzine plivanja na 50 metara slobodnim stilom, nakom 6 sedmica pliometrijskog treninga kod djece uzrasta 12 – 13 godina, komparativnoj analizi imunuloškog statusa fudbalera različitog nivoa takmičenja, prevelaciji gojaznosti učenika mlađeg školskog uzrasta, razlikama u morfološkim karakteristikama i motoričkim sposobnostima dječaka i djevojčika od 2. do 7. razreda, razlikama zastupljenosti posturalnih poremećaja kučmenog stuba kod učenika nižih razreda osnovne škole, relacija svjetskog rekorda u trčanju na 100 metara sa nadmorskom visinom i brzinom vjetra, uticajima pandemije COVID 19 na fizičku aktivnost i ishranu studenata, korištenju AI tehnologije za obuku o parametrima motoričkih sposobnosti i analizi kvantitativnih promjena morfoloških karakteristika mladih odbojkaša pod uticajem eksperimentalnog programa.

Iskreno se nadamo da smo ovim brojem zadovoljili interesovanja i onih najzahtjevnijih čitalaca. Ono što nas raduje u ovom broju jeste veliki broj domaćih autora. Zahvaljujemo se svim autorima i recenzentima koji su dali svoj doprinos u poboljšanju kvaliteta Časopisa.

UREDNIŠTVO ČASOPISA

Dear readers,

We present to you the new ISSUE of the Journal Sports Science and Health, where you can find 15 articles by authors from Bosnia and Herzegovina, Serbia, Croatia, North Macedonia, Indonesia, Russia and Turkey. In a very challenging time for our profession, we can say with certainty that we have a very successful year behind us..

In this issue you can read about aerobic physical exercise and BMI value in overweight students, cardiorespiratory fitness indicators in young athletes, structured motor skills training and unstructured motor skills training in improving children's motor skills, development of a training model with external load to increase strength in Shotokan karate, differences in the intercorrelations of psychological characteristics in karate competitors and national team members, factor structure of motor skills in judokas, improving 50-meter swimming speed freestyle, after 6 weeks of plyometric training in children aged 12-13 years, comparative analysis of the immunological status of football players of different levels of competition, prevalence of obesity in students of younger school age, differences in morphological characteristics and motor skills of boys and girls from 2nd to 7th grade, differences in the prevalence of postural disorders of the spine in students of lower grades of elementary school, relation of the world record in running at 100 meters from altitude and wind speed, the effects of the COVID 19 pandemic on the physical activity and nutrition of students, the use of AI technology for training on the parameters of motor skills and the analysis of quantitative changes in the morphological characteristics of young volleyball players under the influence of the experimental program.

We sincerely hope that this issue has satisfied the interests of even the most demanding readers. What makes us happy in this issue is the large number of domestic authors. Thanks to all the authors and reviewers who contributed to improving the quality of the Journal.

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Comparative Analysis of the Immunological Status of Soccer Players at Different Levels of Competition

Komparativna analiza imunološkog statusa fudbalera različitih nivoa takmičenja

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Abstract: *The aim of this study was to examine the immune status of football players at different competition levels in Bosnia and Herzegovina through the analysis of key hematological biomarkers. The sample included 59 football players from the first, third, and fifth leagues, whose immune parameters were analyzed based on medical records and laboratory findings. The measured parameters included absolute counts of leukocytes, lymphocytes, monocytes, neutrophils, eosinophils, and basophils. The results did not show statistically significant differences between players from different leagues, although certain variations in individual biomarkers were observed. These findings suggest that the competition level itself is not a key factor in determining the immune responses of athletes under stable physiological conditions. It is concluded that further research is needed, covering different phases of the training cycle, to better understand the impact of training load and periodization on the immune status of football players.*

Keywords: *immune status, football, leukocytes, hematological biomarkers, competition level*

Sažetak: *Cilj ovog istraživanja bio je da se ispita imunološki status fudbalera različitih takmičarskih nivoa u Bosni i Hercegovini putem analize ključnih hematoloških biomarkera. Uzorak je obuhvatio 59 fudbalera iz prve, treće i pete lige, čiji su imunološki parametri analizirani na osnovu medicinskih kartona i laboratorijskih nalaza. Mjereni su apsolutni brojevi leukocita, limfocita, monocita, neutrofila, eozinofila i bazofila. Rezultati nisu pokazali statistički značajne razlike između fudbalera različitih liga, iako su uočene određene varijacije u pojedinim biomarkerima. Ovi nalazi sugerišu da nivo takmičenja sam po sebi ne predstavlja ključni faktor u određivanju imunoloških odgovora sportista u stabilnim fiziološkim uslovima. Zaključuje se da je potrebno sprovesti dodatna istraživanja koja bi obuhvatila različite faze trenažnog ciklusa kako bi se bolje razumio uticaj trenažnog opterećenja i periodizacije treninga na imunološki status fudbalera.*

Ključne riječi: *imunološki status, fudbal, leukociti, hematološki biomarkeri, nivo takmičenja*

Introduction

Variations in the immune profiles of football players of different competitive levels can be partly explained by differences in the intensity and volume of training, which affects the differential distribution of leukocyte subpopulations, including lymphocytes, monocytes, neutrophils, eosinophils and basophils. Understanding the impact of

Uvod

Varijacije u imunološkim profilima fudbalera različitih takmičarskih nivoa mogu se dijelom objasniti razlikama u intenzitetu i obimu treninga, što utiče na diferencijalnu raspodjelu leukocitnih subpopulacija, uključujući limfocite, monocite, neutrofile, eozinofile i bazofile. Razumijevanje uticaja treninga na imunološke biomar-

training on immune biomarkers is crucial for understanding potential risks to the immune function of athletes at different levels of competition. Hematological parameters, including the number of leukocytes, are important indicators of immune status and response to physical stress. Research shows that elite soccer players often experience acute changes in leukocyte populations after intense training or matches. In particular, an increase in the number of neutrophils after exertion is noted, which suggests an inflammatory response to physical stress (Fernández-Lázaro et al., 2022). Studies on hematological biomarkers indicate that training volume in elite athletes affects variations in leukocyte profiles, whereby increased neutrophilia is often associated with transient immune suppression known as the "open window" effect (Fernández-Lázaro et al., 2022). In contrast, athletes of lower competitive ranks usually show a more stable leukocyte profile with smaller fluctuations (Díaz et al., 2022). For example, studies suggest that amateur soccer players have higher values of lymphocytes and lower values of neutrophils compared to elite players, which may indicate a more preserved immune function despite increased physical effort (Díaz et al., 2022). These findings are consistent with data indicating that elite athletes have a higher prevalence of negative immune responses, including relative lymphopenia, which may increase the risk of post-competition infections (Fernández-Lázaro et al., 2022; Díaz et al., 2022). In addition to neutrophils and lymphocytes, monocytes and eosinophils also play an important role in the immune response of athletes. Monocytes reflect the inflammatory status after exertion, and in elite soccer players they can vary depending on the level of recovery and load, whereby increased values can indicate a state of chronic inflammation due to overtraining (Fernández-Lázaro et al., 2022). Eosinophils, although less investigated in the context of sports performance, are associated with inflammatory processes and may be relevant in athletes exposed to allergic reactions or specific environmental factors (Díaz et al., 2022). The role of basophils in the immune responses of athletes remains insufficiently investigated, but their increase may indicate hypersensitive reactions associated with intense physical exertion (Fernández-Lázaro et al., 2022). In elite soccer players, increased training load can induce stressful conditions that potentially worsen allergic reactions and affect training adaptation. Continuous hematological monitoring, including the analysis of leukocyte subpopulations, is a key strategy for monitoring the immune status and preventing the negative effects of overtraining in athletes. Regular monitoring of changes in biomarkers allows coaches and sports doctors to optimize workload and adkere ključno je za sagledavanje potencijalnih rizika po imunološku funkciju sportista na različitim nivoima takmičenja. Hematološki parametri, uključujući broj leukocita, predstavljaju važne indikatore imunološkog statusa i odgovora na fizičko opterećenje. Istraživanja pokazuju da elitni fudbaleri često doživljavaju akutne promjene u leukocitnim populacijama nakon intenzivnih treninga ili utakmica. Posebno se bilježi povećanje broja neutrofila nakon napora, što sugeriše upalni odgovor na fizički stres (Fernández-Lázaro i sar., 2022). Studije o hematološkim biomarkerima ukazuju da volumen treninga kod elitnih sportista utiče na varijacije u leukocitnim profilima, pri čemu je povećana neutrofilija često povezana sa prolaznom imunološkom supresijom poznatom kao "open window" efekat (Fernández-Lázaro i sar., 2022). Nasuprot tome, sportisti nižih takmičarskih rangova obično pokazuju stabilniji leukocitni profil s manjim fluktuacijama (Díaz i sar., 2022). Na primjer, studije sugerišu da amaterski fudbaleri imaju više vrijednosti limfocita i niže vrijednosti neutrofila u poređenju sa elitnim igračima, što može ukazivati na očuvaniju imunološku funkciju uprkos povećanom fizičkom naporu (Díaz i sar., 2022). Ovi nalazi su u skladu s podacima koji ukazuju da elitni sportisti imaju veću prevalenciju negativnih imunoloških odgovora, uključujući relativnu limfopeniju, što može povećati rizik od infekcija nakon takmičenja (Fernández-Lázaro i sar., 2022; Díaz i sar., 2022). Pored neutrofila i limfocita, monociti i eozinofili takođe igraju važnu ulogu u imunološkom odgovoru sportista. Monociti odražavaju inflamatorni status nakon napora, a kod elitnih fudbalera mogu varirati u zavisnosti od nivoa oporavka i opterećenja, pri čemu povećane vrijednosti mogu ukazivati na stanje hronične upale usljed pretreniranosti (Fernández-Lázaro i sar., 2022). Eozinofili, iako manje istraženi u kontekstu sportskog učinka, povezani su sa inflamatornim procesima i mogu biti relevantni kod sportista izloženih alergijskim reakcijama ili specifičnim ekološkim faktorima (Díaz i sar., 2022). Uloga bazofila u imunološkim odgovorima sportista ostaje nedovoljno istražena, ali njihovo povećanje može ukazivati na hipersenzitivne reakcije povezane sa intenzivnim fizičkim opterećenjem (Fernández-Lázaro i sar., 2022). Kod elitnih fudbalera, povećano trenažno opterećenje može indukovati stresna stanja koja potencijalno pogoršavaju alergijske reakcije i utiču na trenažnu adaptaciju. Kontinuirani hematološki monitoring, uključujući analizu leukocitnih subpopulacija, predstavlja ključnu strategiju za praćenje imunološkog statusa i prevenciju negativnih efekata pretreniranosti kod sportista. Redovno praćenje promjena u biomarkerima omoguća-

just recovery strategies, thereby reducing the risk of immune dysfunctions and overtraining (Soriano et al., 2021). The differences in the immune profiles of football players of different competitive levels emphasize the complexity of immune responses induced by training and competition. Increased intensity of training in elite athletes is associated with more pronounced changes in leukocyte status, which may indicate stress-induced immune suppression, while lower league soccer players show more stable immune profiles.

The goal of this research is to determine the differences in immunological biomarkers of football players from the first, third and fifth leagues in Bosnia and Herzegovina, which will enable a better understanding of the influence of the level of competition on the immune status of athletes.

Methods

Study design

This study used a transference design to examine the immune status of soccer players competing at three different levels in Bosnia and Herzegovina. The data was collected from the medical records of athletes who had a blood analysis performed at the Institute of Sports Medicine of the Republic of Srpska during the competition break in 2024. The study included football players from the first, third and fifth leagues, which enabled a comparative assessment of immune parameters between different levels of competition. The choice of immune biomarkers is based on routine blood tests that were carried out as part of mandatory health examinations of athletes. By using the existing medical records, an objective and standardized assessment of the immune status was ensured without additional testing. Given the transferal nature of the study, the findings allow insight into the immune function of soccer players at one point in time, providing a comparison between levels of competition, but not tracking longitudinal changes or determining causality. The study was conducted in accordance with ethical standards for medical research on humans and in the spirit of the principles of the Declaration of Helsinki. Prior to data collection, institutional consent was obtained, which ensured compliance with the principles of confidentiality and data protection. The measurement of immune parameters was carried out during the winter break, immediately before the start of preparations for the spring season of 2024, in order to ensure stable physiological conditions without acute training stress. Sampling was carried out in January, which corresponds to the period between the two half-seasons (au-

va trenerima i sportskim ljekarima optimizaciju opterećenja i prilagođavanje strategija oporavka, čime se smanjuje rizik od imunoloških disfunkcija i pretreniranosti (Soriano i sar., 2021). Razlike u imunološkim profilima fudbalera različitih takmičarskih nivoa naglašavaju kompleksnost imunoloških odgovora izazvanih treningom i takmičenjem. Povećani intenzitet treninga kod elitnih sportista povezan je s izraženijim promjenama u leukocitnom statusu, što može ukazivati na stresom indukovanu imunološku supresiju, dok fudbaleri nižih liga pokazuju stabilnije imunološke profile.

Cilj ovog istraživanja je da se utvrde razlike u imunološkim biomarkerima fudbalera iz prve, treće i pete lige u Bosni i Hercegovini, čime će se omogućiti bolje razumijevanje uticaja nivoa takmičenja na imunološki status sportista.

Metode

Dizajn studije

Ova studija koristila je transferzalni dizajn kako bi ispitala imunološki status fudbalera koji se takmiče na tri različita nivoa u Bosni i Hercegovini. Podaci su prikupljeni iz medicinskih kartona sportista koji su tokom takmičarske pauze 2024. godine obavili analizu krvi u Zavodu za medicinu sporta Republike Srpske. Studijom su obuhvaćeni fudbaleri iz prve, treće i pete lige, što je omogućilo komparativnu procjenu imunoloških parametara između različitih nivoa takmičenja. Izbor imunoloških biomarkera zasnovan je na rutinskim analizama krvi koje su sprovedene u sklopu obaveznih zdravstvenih pregleda sportista. Korištenjem postojećih medicinskih kartona osigurana je objektivna i standardizovana procjena imunološkog statusa bez dodatnih testiranja. S obzirom na transferzalni karakter studije, nalazi omogućavaju uvid u imunološku funkciju fudbalera u jednoj vremenskoj tački, pružajući poređenje između nivoa takmičenja, ali ne i praćenje longitudinalnih promjena ili utvrđivanje uzročnosti. Studija je sprovedena u skladu s etičkim standardima za medicinska istraživanja na ljudima i u duhu principa Helsinške deklaracije. Prije prikupljanja podataka pribavljena je institucionalna saglasnost, čime je osigurano poštovanje principa povjerljivosti i zaštite podataka. Mjerenje imunoloških parametara sprovedeno je tokom zimske pauze, neposredno prije početka priprema za proljetni dio sezone 2024. godine, u cilju osiguravanja stabilnih fizioloških uslova bez akutnog trenažnog stresa. Uzorkovanje je realizovano u januaru, što vremenski odgovara periodu između dvije polusezone (jesenje i proljet-

tumn and spring). In this way, the potential impact of the acute load characteristic of the competition period or the early stages of preparation was avoided.

Respondents

A total of 59 male soccer players who compete at different levels in Bosnia and Herzegovina participated in the research. The sample is approximately evenly distributed between the three competitive leagues, with 20 players each from the first and third leagues, and 19 players from the fifth leagues. The respondents came from three different football clubs and competition ranks: FK Borac Banja Luka (Premier League of BiH), FK Naprijed Banja Luka (Second League of Republika Srpska), and FK Krupa from Krupa na Vrbas (Fourth League of Republika Srpska). All subjects were active competitors during the 2024 season and underwent routine medical examinations, including blood analysis, at the Institute of Sports Medicine of the Republic of Srpska. The criteria for inclusion in the research were active playing in one of the three selected leagues, possession of complete medical documentation with relevant immunological parameters and the absence of acute infections or chronic diseases at the time of testing. Players who had a recent illness, injury or used immunomodulatory drugs were excluded from the study in order to reduce the influence of possible factors that could impair the reliability of the results. Prior to data collection, institutional consent was obtained, and the study was conducted in accordance with the ethical guidelines and principles of the Declaration of Helsinki.

Variables

The immune status of the subjects was assessed using blood biomarkers obtained from a routine hematological analysis. The measured variables included absolute values of key immune cell populations: leukocytes (WBC), lymphocytes (LYM), monocytes (MON), neutrophils (NEU), eosinophils (EOS) and basophils (BAS). These biomarkers were chosen because they provide insight into the function of the immune system and possible variations in the immune response between different levels of competition. Blood samples were collected by standardized venipuncture, performed by an accredited laboratory technician. All samples were taken in the morning, on an empty stomach, in order to reduce variations caused by the circadian rhythm and external factors that can affect the number of immune cells. The analysis was carried out using a Sysmex XN-330 automatic hematology analyzer, a validated and widely used system for precise measurement of the differential blood count. Throughout the process, estab-

ne). Na taj način je izbjegnut potencijalni uticaj akutnog opterećenja karakterističnog za takmičarski period ili rane faze priprema.

Ispitanici

U istraživanju je učestvovalo ukupno 59 fudbalera muškog pola koji se takmiče na različitim nivoima u Bosni i Hercegovini. Uzorak je približno ravnomjerno raspoređen između tri takmičarske lige, sa po 20 igrača iz prve i treće lige, i sa 19 igrača iz pete lige. Ispitanici su dolazili iz tri različita fudbalska kluba i takmičarska ranga: FK Borac Banja Luka (Premijer liga BiH), FK Naprijed Banja Luka (Druga liga Republike Srpske), i FK Krupa iz Krupe na Vrbasu (Četvrta liga Republike Srpske). Svi ispitanici su bili aktivni takmičari tokom sezone 2024. godine i prošli su rutinske medicinske preglede, uključujući analizu krvi, u Zavodu za medicinu sporta Republike Srpske. Kriterijumi za uključivanje u istraživanje bili su aktivno igranje u jednoj od tri odabrane lige, posjedovanje kompletne medicinske dokumentacije sa relevantnim imunološkim parametrima i odsustvo akutnih infekcija ili hroničnih oboljenja u trenutku testiranja. Igrači koji su u nedavnom periodu imali bolest, povredu ili koristili imunomodulatorne lijekove bili su isključeni iz studije kako bi se smanjio uticaj mogućih faktora koji bi mogli narušiti pouzdanost rezultata. Prije prikupljanja podataka, pribavljena je institucionalna saglasnost, a studija je sprovedena u skladu s etičkim smjernicama i principima Helsinške deklaracije.

Varijable

Imunološki status ispitanika procijenjen je putem biomarkera iz krvi dobijenih iz rutinske hematološke analize. Mjerene varijable obuhvatale su apsolutne vrijednosti ključnih imunoloških ćelijskih populacija: leukocita (WBC), limfocita (LYM), monocita (MON), neutrofila (NEU), eozinofila (EOS) i bazofila (BAS). Ovi biomarkeri su odabrani jer pružaju uvid u funkciju imunološkog sistema i moguće varijacije imunološkog odgovora između različitih nivoa takmičenja. Uzorci krvi prikupljeni su standardizovanom venepunkcijom, koju je izvodio akreditovani laboratorijski tehničar. Svi uzorci uzeti su u jutarnjim satima, natašte, kako bi se smanjile varijacije uzrokovane cirkadijalnim ritmom i spoljnim faktorima koji mogu uticati na broj imunoloških ćelija. Analiza je sprovedena pomoću Sysmex XN-330 automatskog hematološkog analizatora, validiranog i široko korištenog sistema za precizno mjerenje diferencijalne krvne slike. Tokom cijelog procesa poštovani su uspostavljeni protokoli kontrole kvaliteta kako bi se osigurala

lished quality control protocols were followed to ensure the reliability and accuracy of the results. All blood analyses were performed in an accredited laboratory, strictly adhering to standardized sampling, processing, and storage procedures. The analysis methodology was aligned with international hematology guidelines, ensuring that the measured immunological parameters accurately reflected the physiological status of the subjects.

Statistical analyses

All statistical analyzes were performed using the IBM SPSS Statistics 20 for Windows software (IBM Corp., Armonk, NY, USA). Descriptive statistical indicators, including mean value, standard deviation, minimum and maximum values, were calculated for all investigated variables, in order to summarize the immune status of football players of different competitive levels. The normality of data distribution was tested using the Shapiro-Wilk test. Homogeneity of variances was assessed using Levene's test. One-way analysis of variance (ANOVA) was used to determine differences in immune parameters between the three competitive leagues. The threshold of statistical significance was set at $p < 0.05$. All analysis were conducted in accordance with standard statistical guidelines for biomedical research, which ensured the reliability and reproducibility of the findings.

The results

The analysis of immune biomarkers of soccer players of different competitive levels showed certain variations in leukocyte subpopulations, but without statistically significant differences between groups. Descriptive data (Table 1) indicate that football players from the third and fifth leagues had slightly higher average values of total leukocytes compared to players from the first league (6,243 ± 1,269 and 6,233 ± 1,243 compared to 5,999 ± 1,221, respectively).

However, the analysis of variance (ANOVA) did not show a statistically significant difference between the groups ($F = 0.243$, $p = 0.785$). A similar trend was recorded in lymphocytes, where football players of the third league had the highest average values (2.476 ± 0.638), while players of the first league had the lowest (2.166 ± 0.443). Despite these differences, statistical analysis did not confirm a significant effect of the level of competition on the number of lymphocytes ($F = 1.734$, $p = 0.186$). In terms of monocytes, football players of the first league had slightly higher values (0.640 ± 0.201) compared to the third (0.535 ± 0.130) and fifth league (0.526 ± 0.162).

Although the differences were more pronounced compared to other biomarkers, the analysis of variance did not

pouzdanost i tačnost rezultata. Sve analize krvi obavljene su u akreditovanoj laboratoriji, uz strogo pridržavanje standardizovanih procedura za uzorkovanje, obradu i skladištenje. Metodologija analize usklađena je s međunarodnim hematološkim smjernicama, čime je osigurano da izmjereni imunološki parametri precizno odražavaju fiziološki status ispitanika.

Statističke analize

Sve statističke analize sprovedene su korištenjem softvera IBM SPSS Statistics 20 for Windows (IBM Corp., Armonk, NY, USA). Za sve ispitivane varijable izračunati su deskriptivni statistički pokazatelji, uključujući srednju vrijednost, standardnu devijaciju, minimalne i maksimalne vrijednosti, kako bi se sažeto prikazao imunološki status fudbalera različitih takmičarskih nivoa. Normalnost distribucije podataka testirana je pomoću Shapiro-Wilk testa. Homogenost varijansi procijenjena je korištenjem Leveneovog testa. Za utvrđivanje razlika u imunološkim parametrima između tri takmičarske lige korištena je jednosmjerna analiza varijanse (ANOVA). Prag statističke značajnosti postavljen je na $p < 0.05$. Sve analize sprovedene su u skladu sa standardnim statističkim smjernicama za biomedicinska istraživanja, čime je osigurana pouzdanost i ponovljivost nalaza.

Rezultati

Analiza imunoloških biomarkera fudbalera različitih takmičarskih nivoa pokazala je određene varijacije u leukocitnim subpopulacijama, ali bez statistički značajnih razlika između grupa. Deskriptivni podaci (Tabela 1) ukazuju na to da su fudbaleri iz treće i pete lige imali nešto veće prosječne vrijednosti ukupnih leukocita u odnosu na igrače prve lige (6.243 ± 1.269 i 6.233 ± 1.243 u odnosu na 5.999 ± 1.221, respektivno).

Međutim, analiza varijanse (ANOVA) nije pokazala statistički značajnu razliku među grupama ($F = 0.243$, $p = 0.785$). Sličan trend zabilježen je i kod limfocita, gdje su fudbaleri treće lige imali najviše prosječne vrijednosti (2.476 ± 0.638), dok su igrači prve lige imali najniže (2.166 ± 0.443). Uprkos ovim razlikama, statistička analiza nije potvrdila značajan efekat nivoa takmičenja na broj limfocita ($F = 1.734$, $p = 0.186$). Kod monocita, fudbaleri prve lige su imali nešto više vrijednosti (0.640 ± 0.201) u poređenju sa trećom (0.535 ± 0.130) i petom ligom (0.526 ± 0.162).

Iako su razlike bile izraženije u odnosu na druge biomarkere, analiza varijanse nije pokazala statistički značajan efekat ($F = 2.841$, $p = 0.067$). Vrijednosti neutrofila bile su relativno ujednačene između grupa, sa

Table 1. *Descriptive statistics of immune parameters in football players of different competitive levels*

Tabela 1. *Deskriptivna statistika imunoloških parametara kod fudbalera različitih takmičarskih nivoa*

Parameter / **Parametar**	***Competitive rank /*** **Takmičarski rang**	***N***	***M (SD)***	***Min***	***Max***
Leukociti (10^9/L)	*First league /* Prva liga	20	5.999 (1.221)	4.2	8.8
	Third league / Treća liga	20	6.243 (1.269)	4.39	8.84
	Fifth league / Peta liga	19	6.233 (1.242)	4.15	9.27
Limfociti (10^9/L)	*First league /* Prva liga	20	2.166 (0.444)	1.50	3.10
	Third league / Treća liga	20	2.476 (0.638)	1.55	3.79
	Fifth league / Peta liga	19	2.405 (0.552)	1.41	3.61
Monociti (10^9/L)	*First league /* Prva liga	20	0.640 (0.201)	0.36	1.00
	Third league / Treća liga	20	0.535 (0.130)	0.32	0.84
	Fifth league / Peta liga	19	0.526 (0.163)	0.35	0.86
Neutrofili (10^9/L)	*First league /* Prva liga	20	3.036 (1.145)	1.03	6.00
	Third league / Treća liga	20	3.006 (0.790)	1.99	4.78
	Fifth league / Peta liga	19	3.091 (0.962)	1.84	5.81
Eozinofili (10^9/L)	*First league /* Prva liga	20	0.439 (0.720)	0.08	2.05
	Third league / Treća liga	20	0.206 (0.186)	0.05	0.89
	Fifth league / Peta liga	19	0.183 (0.075)	0.06	0.33
Bazofili (10^9/L)	*First league /* Prva liga	20	0.009 (0.007)	0.00	0.02
	Third league / Treća liga	20	0.018 (0.011)	0.00	0.05
	Fifth league / Peta liga	19	0.045 (0.089)	0.01	0.41

N-number of respondents, M-arithmetic mean, SD-standard deviation, Min- the lowest score, Max-the highest score

N-broj ispitanika, M-aritmetička sredina, SD-standardna devijacija, Min- najmanji rezultat, Max-najveći rezultat

Table 2. *Results of ANOVA analysis of immune parameters in football players of different competitive levels*

Tabela 2. *Rezultati ANOVA analize imunoloških parametara kod fudbalera različitih takmičarskih nivoa*

Parameter / **Parametar**	***F***	***p***
Leukociti (10^9/L)	0.243	0.785
Limfociti (10^9/L)	1.734	0.186
Monociti (10^9/L)	2.841	0.067
Neutrofili (10^9/L)	0.038	0.962
Eozinofili (10^9/L)	1.995	0.148
Bazofili (10^9/L)	1.527	0.229

F-F statistic, p-significance level

F-F statistik, p-nivo značajnosti

show a significant effect (F = 2.841, p = 0.067). Neutrophil values were relatively uniform between groups, with the lowest value in the third league (3.006 ± 0.790) and slightly higher averages in the first (3.036 ± 1.144) and fifth league (3.091 ± 0.961). However, ANOVA did not indicate significant differences (F = 0.038, p = 0.962). In the case of eosinophils, a slightly higher value was observed in the first division (0.438 ± 0.719) compared to the third (0.206 ± 0.185) and fifth division (0.182 ± 0.074). However, statistical analysis did not confirm a significant difference between the groups (F = 1.995, p = 0.148). Basophils showed certain variations between the groups, with the fifth league soccer players having the highest values (0.045 ± 0.089), while the first league players had the lowest (0.0086 ± 0.0069).

najmanjom vrijednošću u trećoj ligi (3.006 ± 0.790) i nešto višim prosjecima u prvoj (3.036 ± 1.144) i petoj ligi (3.091 ± 0.961). Međutim, ANOVA nije ukazala na značajne razlike (F = 0.038, p = 0.962). Kod eozinofila je primijećena nešto viša vrijednost u prvoj ligi (0.438 ± 0.719) u poređenju sa trećom (0.206 ± 0.185) i petom ligom (0.182 ± 0.074). Ipak, statistička analiza nije potvrdila značajnu razliku između grupa (F = 1.995, p = 0.148). Bazofili su pokazali određene varijacije među grupama, pri čemu su fudbaleri pete lige imali najviše vrijednosti (0.045 ± 0.089), dok su igrači prve lige imali najniže (0.0086 ± 0.0069). Uprkos ovim razlikama, ANOVA nije pokazala statistički značajan efekat (F = 1.527, p = 0.229). Ukupno gledano, analiza leukocit-

Despite these differences, ANOVA did not show a statistically significant effect ($F = 1.527$, $p = 0.229$). Overall, the analysis of leukocyte subpopulations did not reveal significant differences between first, third and fifth league football players. Although certain variations in certain biomarkers were observed, they did not reach the threshold of statistical significance. These findings suggest that the level of competition does not significantly affect immune biomarkers in stable conditions, but additional research is needed to examine the longer-term effects of different training regimens and loads on the immune system of soccer players.

Discussion

The results of this study did not show statistically significant differences in immune biomarkers between football players of the first, third and fifth leagues, although certain variations were observed between the groups. To some extent, these findings contradict previous research that indicated more pronounced changes in leukocyte subpopulations in athletes of a higher competitive level due to greater training stress and load (Fernández-Lázaro et al., 2022; Díaz et al., 2022). In the context of the total number of leukocytes, football players of the third and fifth league had slightly higher values compared to the players of the first league, but these differences were not significant. Previous research suggests that training intensity can cause acute changes in leukocyte counts, especially after strenuous matches and training, but that values usually return to reference limits after adequate recovery (Díaz et al., 2022). The absence of significant differences in this study can be attributed to the fact that the blood samples were taken during the period between seasons, when football players are in a phase of reduced load, which could explain the relatively stable immune parameters between the groups. Comparing lymphocytes, football players of the third league had slightly higher average values compared to football players of the first and fifth leagues, but without a statistically significant effect. Previous research has shown that elite athletes often have reduced lymphocyte values after intense efforts, which may indicate transient immune suppression ("open window" effect) and increased susceptibility to infections (Fernández-Lázaro et al., 2022). In this study, the absence of a significant difference can be explained by the stable physiological conditions during the data collection period. The values of monocytes were slightly higher in football players of the first league compared to other groups, which could indicate a slight increase in the inflammatory response in players who are exposed to a higher intensity of training during the season. Previous studies suggest that monocytes may reflect a state of chronic inflammation in athletes exposed

nih subpopulacija nije otkrila značajne razlike između fudbalera prve, treće i pete lige. Iako su primijećene određene varijacije u pojedinim biomarkerima, one nisu dostigle prag statističke značajnosti. Ovi nalazi sugerišu da nivo takmičenja ne utiče značajno na imunološke biomarkere u stabilnim uslovima, ali je potrebno dodatno istraživanje kako bi se ispitali dugoročniji efekti različitih trenažnih režima i opterećenja na imunološki sistem fudbalera.

Diskusija

Rezultati ovog istraživanja nisu pokazali statistički značajne razlike u imunološkim biomarkerima između fudbalera prve, treće i pete lige, iako su primijećene određene varijacije među grupama. Ovi nalazi su u određenoj mjeri u suprotnosti s prethodnim istraživanjima koja su ukazivala na izraženije promjene u leukocitnim subpopulacijama kod sportista višeg takmičarskog nivoa usljed većeg trenažnog stresa i opterećenja (Fernández-Lázaro i sar., 2022; Díaz i sar., 2022). U kontekstu ukupnog broja leukocita, fudbaleri treće i pete lige imali su nešto više vrijednosti u odnosu na igrače prve lige, ali ove razlike nisu bile značajne. Prethodna istraživanja sugerišu da intenzitet treninga može izazvati akutne promjene u broju leukocita, posebno nakon napornih utakmica i treninga, ali da se vrijednosti obično vraćaju u referentne granice nakon adekvatnog oporavka (Díaz i sar., 2022). Odsustvo značajnih razlika u ovom istraživanju može se pripisati činjenici da su uzorci krvi uzeti tokom perioda između sezona, kada su fudbaleri u fazi smanjenog opterećenja, što bi moglo objasniti relativno stabilne imunološke parametre među grupama. Poredeći limfocite, fudbaleri treće lige imali su nešto više prosječne vrijednosti u odnosu na fudbalere prve i pete lige, ali bez statistički značajnog efekta. Prethodna istraživanja su pokazala da elitni sportisti često imaju smanjene limfocitne vrijednosti nakon intenzivnih napora, što može ukazivati na prolaznu imunološku supresiju ("open window" efekat) i povećanu podložnost infekcijama (Fernández-Lázaro i sar., 2022). U ovom istraživanju, odsustvo značajne razlike može se objasniti stabilnim fiziološkim uslovima tokom perioda prikupljanja podataka. Vrijednosti monocita bile su nešto više kod fudbalera prve lige u poređenju sa ostalim grupama, što bi moglo ukazivati na blag porast inflamatornog odgovora kod igrača koji su izloženi većem intenzitetu treninga tokom sezone. Prethodne studije sugerišu da monociti mogu odražavati stanje hronične upale kod sportista izloženih dugotrajnim naporima i neadekvatnom oporavku (Fernández-Lázaro i sar., 2022). Ipak, razlike nisu bile statistički značajne, što ukazuje

to prolonged exertion and inadequate recovery (Fernández-Lázaro et al., 2022). Nevertheless, the differences were not statistically significant, which indicates the need for further research of this biomarker in different phases of the training cycle. Neutrophils, which are often associated with an acute inflammatory response to physical stress, did not show significant differences between football players of different leagues. This contrasts with some previous studies that have shown an increase in neutrophils after intense training in elite athletes (Díaz et al., 2022). Again, the period of data collection in this study, which took place between seasons, may have played a role in the relatively stable values of this biomarker. Eosinophils showed some differences between groups, with the highest values in the first league, but these differences were not statistically significant either. Eosinophils are associated with allergic reactions and can be influenced by environmental factors and stress conditions, which may be more pronounced in athletes exposed to long-term training and different living conditions (Díaz et al., 2022). Basophils had the highest values in fifth-league footballers, while the lowest values were recorded in first-league footballers. Although their function in the sporting context is less well studied, basophils are involved in hypersensitivity reactions and may potentially be indicators of immunological changes induced by physical stress. Overall, the results of this research do not confirm significant differences in the immune status of football players of different levels of competition, which may indicate that the level of competition in itself is not a key factor that determines immune responses in stable physiological conditions. One of the possible reasons for the absence of statistically significant differences is the fact that the sampling was done during the competition break, in a period when there was no training process or matches. In such a period of rest, the athlete's immune system is in a more stable homeostatic state, without pronounced acute physiological stresses, which can lead to the normalization of hematological biomarkers. Given that immune parameters show high variability depending on training load and cycle phase, future research should be conducted in periods of active training and competition, in order to more precisely see the dynamics of the immune response of athletes of different competitive levels. These findings further emphasize the importance of contextual factors such as training period, load and recovery strategies in understanding immune responses in athletes. Although the results do not indicate significant differences between the groups, it is necessary to conduct further research in different phases of the season, in order to better understand the impact of training and competition on immune biomarkers in football players of different competitive levels.

na potrebu za daljim istraživanjem ovog biomarkera u različitim fazama trenažnog ciklusa. Neutrofili, koji su često povezani s akutnim inflamatornim odgovorom na fizičko opterećenje, nisu pokazali značajne razlike između fudbalera različitih liga. Ovo je u kontrastu s nekim ranijim istraživanjima koja su pokazala povećanje broja neutrofila nakon intenzivnog treninga kod elitnih sportista (Díaz i sar., 2022). Ponovo, period prikupljanja podataka u ovoj studiji, koji se odvijao između sezona, mogao je igrati ulogu u relativno stabilnim vrijednostima ovog biomarkera. Eozinofili su pokazali određene razlike među grupama, s najvišim vrijednostima u prvoj ligi, ali ni ove razlike nisu bile statistički značajne. Eozinofili su povezani s alergijskim reakcijama i mogu biti pod uticajem ekoloških faktora i stanja stresa, što može biti izraženije kod sportista koji su izloženi dugotrajnim treninzima i različitim životnim uslovima (Díaz i sar., 2022). Bazofili su imali najviše vrijednosti kod fudbalera pete lige, dok su najniže vrijednosti zabilježene kod fudbalera prve lige. Iako je njihova funkcija u sportskom kontekstu manje istražena, bazofili su uključeni u reakcije preosjetljivosti i potencijalno mogu biti indikatori imunoloških promjena izazvanih fizičkim stresom. Sveukupno, rezultati ovog istraživanja ne potvrđuju značajne razlike u imunološkom statusu fudbalera različitih nivoa takmičenja, što može ukazivati na to da nivo takmičenja sam po sebi ne predstavlja ključni faktor koji određuje imunološke odgovore u stabilnim fiziološkim uslovima. Jedan od mogućih razloga za odsustvo statistički značajnih razlika jeste činjenica da su uzorkovanja obavljena tokom takmičarske pauze, u fazi kada nije bilo trenažnog procesa niti utakmica. U takvom periodu mirovanja, imunološki sistem sportista se nalazi u stabilnijem homeostatskom stanju, bez izraženih akutnih fizioloških stresova, što može dovesti do normalizacije hematoloških biomarkera. S obzirom na to da imunološki parametri pokazuju visoku varijabilnost u zavisnosti od trenažnog opterećenja i faze ciklusa, buduća istraživanja bi trebalo sprovesti u periodima aktivnog treninga i takmičenja, kako bi se preciznije sagledala dinamika imunološkog odgovora sportista različitih takmičarskih nivoa.Ovi nalazi dodatno naglašavaju važnost kontekstualnih faktora kao što su trenažni period, opterećenje i strategije oporavka u razumijevanju imunoloških odgovora kod sportista. Iako rezultati ne ukazuju na značajne razlike između grupa, neophodno je sprovesti dalja istraživanja u različitim fazama sezone, kako bi se bolje razumio uticaj treninga i takmičenja na imunološke biomarkere kod fudbalera različitih takmičarskih nivoa.

Conclusion

This research examined the immune status of football players of different competitive levels in Bosnia and Herzegovina through the analysis of key hematological biomarkers. Although certain variations were observed in the values of leukocytes, lymphocytes, monocytes, neutrophils, eosinophils and basophils between first, third and fifth league football players, statistically significant differences were not identified. These findings suggest that the level of competition is not a decisive factor in determining the immune response of athletes in stable physiological conditions. The results are to a certain extent contrary to previous research that indicated significant differences in immune biomarkers between elite and amateur athletes, which indicates the need for further research in different phases of the training cycle. It is especially important to consider the impact of acute and chronic training load, periodization of training and recovery strategies on the immune status of soccer players. The practical implications of this research emphasize the importance of regular hematological monitoring of football players of all competition levels, in order to timely identify potential changes in immune function and reduce the risk of infections and overtraining. Future studies should include a longitudinal design that would allow a more precise analysis of immune responses during different phases of the season and under different training conditions.

Zaključak

Ovo istraživanje ispitalo je imunološki status fudbalera različitih takmičarskih nivoa u Bosni i Hercegovini kroz analizu ključnih hematoloških biomarkera. Iako su uočene određene varijacije u vrijednostima leukocita, limfocita, monocita, neutrofila, eozinofila i bazofila između fudbalera prve, treće i pete lige, statistički značajne razlike nisu identifikovane. Ovi nalazi sugerišu da nivo takmičenja sam po sebi ne predstavlja odlučujući faktor u određivanju imunološkog odgovora sportista u stabilnim fiziološkim uslovima. Rezultati su u određenoj mjeri u suprotnosti s prethodnim istraživanjima koja su ukazivala na značajne razlike u imunološkim biomarkerima između elitnih i amaterskih sportista, što ukazuje na potrebu za daljim istraživanjem u različitim fazama trenažnog ciklusa. Posebno je važno razmotriti uticaj akutnog i hroničnog trenažnog opterećenja, periodizacije treninga i strategija oporavka na imunološki status fudbalera. Praktične implikacije ovog istraživanja naglašavaju značaj redovnog hematološkog praćenja fudbalera svih nivoa takmičenja, kako bi se pravovremeno identifikovale potencijalne promjene u imunološkoj funkciji i smanjio rizik od infekcija i pretreniranosti. Buduće studije trebale bi uključiti longitudinalni dizajn koji bi omogućio precizniju analizu imunoloških odgovora tokom različitih faza sezone i u različitim trenažnim uslovima.

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Cardiorespiratory Fitness Indicators in Young Athletes: Analysis for Personalized Training Programs

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Abstract: *This study investigates the cardiorespiratory indicators of junior athletes (16–18 years old) with a focus on aerobic (AT) and anaerobic (AnT) thresholds, maximal oxygen uptake (VO_2max), power output, and their relationship with anthropometric parameters. Testing was conducted on 26 triathletes who are candidates for Master of Sport (13 males and 13 females) using a Wattbike ergometer, a Cosmed gas analyzer, and a Polar heart rate monitor. Significant individual and gender differences in functional capabilities were observed. The mean VO_2max values were 68.7±7.2 ml/min/kg for males and 55.1±8.4 ml/min/kg for females ($p < 0.001$), indicating differences in oxygen potential and aerobic power between the groups. The anaerobic threshold was reached at 84.3±6.1% of VO_2max on average, demonstrating high lactate tolerance and efficient use of aerobic and anaerobic energy systems. The power-to-weight ratio (W/kg) was higher in athletes with lower BMI, with values such as 6.0 W/kg at a BMI of 20.8 and 4.9 W/kg at a BMI of 15.9.*

The results highlight the necessity of personalized training programs based on threshold values and anthropometric characteristics. Athletes with low AT/MAX% (<70%) should focus on aerobic endurance development, while those with critically low BMI (<18.5) require adjustments in nutrition and workload to prevent metabolic disorders. This study also proposes a methodology for integrating objective testing data into training programs to optimize young triathletes' preparation. The findings have practical implications for coaches and sports physiologists working in endurance sports.

Keywords: *cardiorespiratory testing, aerobic threshold, anaerobic threshold, VO_2max, personalized training.*

Introduction

Modern sports science places significant emphasis on studying cardiorespiratory indicators as key markers of athletes' physical fitness, particularly in endurance sports like triathlon (Joyner & Coyle, 2008). The individualization of training programs based on objective physiological data has become a primary trend in junior athlete preparation, supported by an increasing number of studies focused on optimizing aerobic and anaerobic thresholds (Buchheit & Laursen, 2013). Maximal oxygen uptake (VO_2max) remains the "gold standard" for assessing aerobic capacity, yet its interpretation requires consideration of age, sex, and anthropometric factors (Bassett & Howley, 2000).

In young athletes, the development of cardiorespiratory endurance involves unique physiological and metabolic adaptations driven by pubertal changes (Armstrong & McManus, 2011). Recent research indicates that the anaerobic threshold (AnT) in juniors occurs at higher VO_2max levels compared to adults, underscoring the need for age-specific training adaptations (Wernhart et al., 2021). However, the relationship between body mass, BMI, and relative power output (W/kg) remains insufficiently studied, especially concerning gender differences (Stöggl & Sperlich, 2015). For instance, female triathletes exhibit lower VO_2max compared to males, partly due to differences in body composition and hormonal profile (Heiestad et al., 2022).

Advanced technologies, such as gas analysis and cycle ergometry, allow precise determination of threshold values, yet their integration into training programs requires methodological standardization (Burnley & Jones, 2022). The use of the respiratory exchange ratio (RER) to identify AnT demonstrates high correlation with lactate measurements but has limited applicability in field settings (Meyer & Timmons, 2021). Additionally, the impact of low BMI on aerobic performance remains debated: some researchers highlight its advantages for relative power output (Singh et al., 2023), while others emphasize the risk of reduced absolute VO_2max (Zhou et al., 2022). For example, female athletes with BMI <18.5 are at increased risk of overtraining and metabolic imbalances (Mountjoy et al., 2023).

Despite progress in sports physiology, there is a lack of studies comprehensively analyzing the relationship between cardiorespiratory indicators, anthropometric data, and training adaptations in juniors (Lucia et al., 2023). Most research focuses on adult athletes, neglecting the characteristics of developing bodies (Biddle & Asare, 2011).

Moreover, standardized protocols for personalizing training loads based on threshold values are missing, limiting their practical application (Laursen & Buchheit, 2013). For example, recommendations on training intensity for improving AnT are often derived from adult data, which may be irrelevant for juniors (Esteve-Lanao et al., 2022).

Another challenge is the integration of recovery and nutrition data into training programs. Nutritional strategies, such as carbohydrate periodization, can influence energy efficiency (Burke et al., 2023), yet their role in junior triathlon remains understudied (Baker & Francis, 2004). Additionally, psychological factors, including motivation and stress resilience, play a crucial role in training adaptation but are rarely incorporated into physiological models (Saw et al., 2022).

The aim of this study is to analyze the cardiorespiratory thresholds (AT, AnT), VO_2max, power output, and their relationship with BMI in junior triathletes aged 16–18. Testing was conducted on 26 athletes using a Wattbike ergometer and Cosmed gas analyzer. Special attention is given to developing recommendations for individualized training programs based on physiological and anthropometric findings. The study aims to fill gaps in existing knowledge and provide practical tools for coaches and sports physiologists working with juniors in endurance sports.

Materials and Methods

This study involved 26 junior triathletes (13 males and 13 females) aged 16–18, all candidates for Master of Sport and actively competing. Inclusion criteria included the absence of injuries or chronic diseases and signed informed consent from athletes and legal representatives. The study was approved by the Ethics Committee of Moscow City University (Protocol No. 01/2025) and conducted following the Helsinki Declaration.

Cardiorespiratory indicators were assessed using a Wattbike Pro ergometer (Wattbike Ltd, UK), with stepwise load increments of 30 W for males and 25 W for females. Each stage lasted 2 minutes until reaching test termination criteria: voluntary exhaustion, a 10% drop in power for 30 seconds, or heart rate ≥95% of age-predicted maximum (calculated as $208 - 0.7 \times$ age). Gas exchange parameters, including oxygen uptake (VO_2), carbon dioxide output (VCO_2), and respiratory exchange ratio (RER), were recorded using a Cosmed K5 gas analyzer (Cosmed, Italy) at a sampling rate of 1 Hz. Equipment calibration was performed before each test using standard gas mixtures (16% O_2, 5% CO_2) and ambient air. Heart rate was monitored with a Polar H10 sensor (Polar Electro Oy, Finland) synchronized with Wattbike and Cosmed software.

Aerobic threshold (AT) was identified by the onset of a sustained increase in ventilation (VE/VO_2) without a concurrent rise in VE/VCO_2, blood lactate concentration ≥2 mmol/L, and an RER of ~0.85, measured with a Lactate Scout+ analyzer (EKF Diagnostics, Germany). Anaerobic threshold (AnT) was determined by an RER ≥1.0 and a sharp lactate rise (>4 mmol/L). VO_2max was calculated as the average VO_2 over the last 30 seconds of the test, while relative power output (W/kg) was defined as the ratio of peak power to body mass.

Data analysis was conducted in SPSS 29.0 (IBM, USA). Group comparisons were performed using Student's t-test, and correlation analysis was carried out using Pearson's method with a significance level of $p < 0.05$. All tests were conducted under standardized conditions: temperature 21±1°C, humidity 50±5%. A medical professional supervised all testing sessions.

Results

Analysis of Cardiorespiratory Indicators. The study analyzed the cardiorespiratory parameters of young triathletes, including maximal oxygen uptake (VO_2max), aerobic threshold (AT), anaerobic threshold (AnT), and power output expressed in watts per kilogram of body mass (W/kg).

Sample Characteristics. The study included 26 athletes (13 males and 13 females) aged 16–18 years. The mean anthropometric characteristics differed between the groups: males exhibited significantly greater body mass and height ($p<0.001$), while BMI differences were not statistically significant ($p=0.12$).

Table 1. *Anthropometric Characteristics of Participants (M±SD)*

Parameter	Males (n=13)	Females (n=13)	p-value
Age (years)	17.1 ± 0.7	16.9 ± 0.6	0.58
Body mass (kg)	64.8 ± 5.9	55.4 ± 4.8	<0.001
Height (cm)	175.2 ± 6.1	165.5 ± 5.7	<0.001
BMI (kg/m²)	21.1 ± 1.4	20.2 ± 1.6	0.12

Cardiorespiratory Parameters. Maximal oxygen uptake (VO_2max) was significantly higher in males (68.7 ± 7.2 ml/min/kg) compared to females (55.1 ± 8.4 ml/min/kg, $p<0.001$). This difference reflects higher aerobic endurance in males, likely due to a combination of factors, including greater skeletal muscle mass, higher hemoglobin levels, and other physiological characteristics.

Aerobic threshold (AT), expressed as a percentage of VO_2max, was similar between the groups (62.5 ± 5.3% in males vs. 65.2 ± 4.7% in females, $p=0.15$), indicating comparable initial metabolic transition mechanisms. However, the anaerobic threshold (AnT) was significantly higher in males (84.3 ± 6.1% of VO_2max) than in females (79.5 ± 5.8% of VO_2max, $p=0.03$), suggesting greater lactate tolerance in males.

Table 2. *Cardiorespiratory Parameters (M±SD)*

Parameter	Males (n=13)	Females (n=13)	p-value
VO_2max (ml/min/kg)	68.7 ± 7.2	55.1 ± 8.4	<0.001
Aerobic threshold (AT) %VO_2max	62.5 ± 5.3	65.2 ± 4.7	0.15
Anaerobic threshold (AnT) %VO_2max	84.3 ± 6.1	79.5 ± 5.8	0.03

Power Output. The average relative power output (W/kg) recorded in the cycle ergometer test showed significant individual differences associated with BMI. For example, an athlete with a BMI of 20.8 kg/m² achieved 6.0 W/kg, whereas a triathlete with a BMI of 15.9 kg/m² recorded a power output of 4.9 W/kg. The analysis indicates a trend where lower BMI correlates with higher relative power output; however, critically low BMI values (<18.5) may pose risks of impaired aerobic performance.

Discussion

The obtained results demonstrate significant gender differences in the cardiorespiratory characteristics of young triathletes, aligning with previous research in sports physiology (Bassett & Howley, 2000; Lucia et al., 2023). Specifically, it was confirmed that VO_2max is significantly higher in males compared to females, which can be explained by greater skeletal muscle mass, higher hemoglobin concentration, and improved oxygen transport capacity (Heiestad et al., 2022).

Aerobic threshold (AT) as a percentage of VO_2max did not show significant differences between groups, indicating similar aerobic energy supply mechanisms. However, the anaerobic threshold (AnT) was significantly higher in males (84.3 ± 6.1% vs. 79.5 ± 5.8%, $p=0.03$), which is consistent with studies by Hawley & Leckey (2015), confirming greater lactate tolerance and the ability to process lactate more efficiently in males.

Athletes with lower BMI demonstrated relatively high power output (W/kg); however, critically low BMI values (<18.5) associated with insufficient muscle mass may lead to reduced absolute aerobic performance and an increased risk of catabolic states. This is supported by studies (Mountjoy et al., 2014) indicating a high risk of metabolic disorders in female athletes with low BMI. This aspect requires particular attention in training and nutritional planning.

Gender differences in physiological adaptations should also be considered when designing training programs. Males exhibit greater mitochondrial density, a more developed capillary network, and higher levels of aerobic enzymes, whereas females rely more on lipid oxidation for energy metabolism. For example, studies (Seiler & Tønnessen, 2022) indicate that males demonstrate greater resilience to high-intensity training, whereas in females, endocrine regulation of metabolism, including estrogen levels, plays a crucial role in substrate utilization and lactate clearance capacity.

Furthermore, differentiation in training approaches in triathlon remains an essential aspect, given the specificity

of each discipline. For instance, aerobic mechanisms dominate in swimming for both groups, whereas in cycling and running, males show greater resistance to lactate accumulation (Morrison & Newell, 2023).

Thus, the results of this study confirm the necessity of individualizing training programs based on sex, cardiorespiratory thresholds, and anthropometric characteristics. Future research should focus on longitudinal studies of adaptations, including the assessment of physiological parameter dynamics throughout long-term athletic training.

Conclusion

This study identified significant gender differences in the cardiorespiratory parameters of young triathletes. Males demonstrated significantly higher VO_2max and anaerobic threshold (AnT), whereas the aerobic threshold (AT) was similar between groups. Analysis of the relationship between BMI and power output showed that athletes with lower BMI exhibited higher relative power, yet critically low values (<18.5) may lead to reduced absolute aerobic performance and an increased risk of metabolic disorders.

The findings emphasize the necessity of individualizing training programs based on sex, cardiorespiratory thresholds, and anthropometric characteristics. Specifically:

- Males with low AnT (<80% VO_2max) are recommended to increase moderate-intensity training to enhance lactate tolerance.
- Females with low BMI (<18.5) require nutritional adjustments and recovery strategies to prevent declines in aerobic performance.
- Optimization of training loads based on objective physiological data enhances the effectiveness of young triathlete preparation.

The main limitations of this study include the relatively small sample size and the lack of longitudinal monitoring. Future research should focus on tracking physiological adaptations over time, including changes in aerobic and anaerobic thresholds, mitochondrial biogenesis, and the impact of training periodization on young athletes' cardiorespiratory parameters.

Conflict of interest

The authors state no conflict of interest.

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Comparative Study : Structured Motor Skill Training and Unstructured Motor Skill Training in Improving Children's Movement Ability

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Abstract: *This study aims to compare the effectiveness of structured motor skill training and unstructured motor skill training in improving movement skills in children. The movement skills in question include coordination, balance, strength, and agility. This study used an experimental design with a control group and a treatment group. The group of children was divided into two groups: one group did structured motor skill training and the other group did unstructured motor skill training. The population of this study was children aged 6-8 years. The sample was randomly drawn and consisted of 40 children divided into two groups, each group consisting of 20 children. The exercises were conducted for 6 weeks with a frequency of 2 times per week. Each training session lasted for 40 minutes. Based on the results of data analysis, there is a significant difference between structured motor skill training and unstructured motor skill training in improving motor skills. The group that followed structured motor skill training had an average improvement of 19.75, while the group that followed unstructured motor skill training had an average improvement of 12.85. The mean difference between the two groups was 6.90, indicating that structured motor skill training provided better results. A t-value of 7.71 and a significance value of 0.00 indicated that this difference was highly statistically significant. In addition, the percentage difference between the two types of exercises was approximately 53.7%, indicating that structured motor skill trainingprovided greater improvement compared to unstructured motor skill training. A planned and structured exercise program can result in more significant improvements in children's coordination, balance, strength and agility. These findings support the use of structured motor skill training programs in the development of children's movement skills in schools or physical education environments.*

Keywords: *Physical Activity, Motor Skill Training, Movement Ability, Children.*

Introduction

Motor training plays an important role in the development of children's movement abilities, which include gross and fine motor skills. Gross motor skills involve the use of large muscles, such as running, jumping and climbing (Farida, 2016), while fine motor skills focus on more detailed movements, such as grasping small objects or tying shoelaces (Khadijah & Amelia, 2020). Various forms of motor exercises can help children develop these two aspects optimally, which in turn supports their physical, social and cognitive development. Good motor practice involves a variety of activities that challenge children's bodies to move in different ways. By stimulating varied movements, motor exercises help strengthen muscles, improve flexibility, and develop balance and coordination (Sudirjo & Alif, 2018). Activities such as jumping, kicking or catching a ball train a child's sensorimotor skills, integrating information from the nervous system and muscles to produce efficient and controlled movements. It also helps improve a child's awareness of his or her own body, known as proprioception, or the ability to sense body position and movement.

Children's motor development falls into two main types of approaches: structured motor skill training and unstructured motor skill training. These two methods have different characteristics and impacts on children's movement abilities. Comparative studies examining the effectiveness of these two approaches provide an important foundation for educators, coaches and parents in selecting optimal motor development strategies. Structured motor skill training is an approach in which children are engaged in systematically designed activities, with clear goals and rules (Jafar et al., 2023). These activities are usually guided by an instructor or teacher, and are designed to develop specific motor skills such as balance, coordination, strength and flexibility. Examples of structured motor skill traininginclude

gymnastics classes, formal sports training, or organized physical activities at school. The advantage of structured motor skill training is that it allows for close control and supervision of the child's progress, ensuring that they develop basic motor skills according to the expected stages of development (Gallahue & Donnelly, 2007). Studies show that children who engage in structured motor skill trainingtend to experience more significant improvements in specific motor skills (Tortella et al., 2016), as the exercises are designed to target specific abilities. In addition, this approach also helps build discipline, focus and perseverance in children.

In contrast, free motor practice gives children the freedom to explore and move without strict rules or instructions. These activities often occur spontaneously in unstructured play environments, such as running in the park, climbing trees, playing ball without rules, or simply running around with friends. Unstructured motor skill training emphasizes freedom of movement exploration, creativity and improvisation (Hanson, 1992). Research shows that free motor practice plays an important role in developing children's creativity and ability to find more diverse movement solutions. By participating in free motor activities, children learn to organize their movements naturally and independently, which can improve their body understanding and foster confidence in their physical abilities. Free motor activities also contribute to children's mental health as they are more relaxed and fun (Darmadi & MM, 2018). This study was conducted because of the debate about which is more effective in improving children's movement skills. Experts suspect that structured exercises may provide more targeted and rapid results in the development of specific skills, while free exercises may be more beneficial in providing a more holistic and flexible experience in motor development. Through this study, the researchers sought to answer the question of which approach is more optimal in developing children's motor abilities, especially in the context of education and child health. Another factor underlying this study is the increasing awareness of the importance of physical activity amidst the global trend of sedentary lifestyles that reduce children's opportunities to be active (Hills et al., 2007). By understanding the different benefits of these two types of exercises, the results of this study are expected to provide recommendations for parents, teachers and coaches to integrate appropriate methods in children's physical exercise programs, so as to support optimal motor development.

Materials and Methods

Study Participants.

This study used a quasi-experimental design with a pre-test and post-test approach in two independent groups. The first group was given structured motor skill trainings, while the second group underwent unstructured motor skill training. The duration of the study was 6 weeks, with a frequency of training 2 times per week.

The sample of this study was 40 children aged 7-10 years who were purposively selected from several elementary schools in Makassar city. With the criteria of not having significant motor or health disorders. The sample was randomly divided into two groups:

1. Group A (Structured Motor Skill Training): 20 children.
2. Group B (Unstructured Motor Skill): 20 children.

Study organization.

In this study, the instruments used to measure children's motor skills were the Test of Gross Motor Development (TGMD-2) as well as qualitative observations. The TGMD-2 is a standardized test designed to assess gross motor skills of children aged 3 to 10 years (Logan et al., 2014). The test consists of two main subtests, i.e:

1. Locomotor Skills: Measures a child's ability in movements that involve body displacement, such as running, jumping, stepping, and sprinting.
2. Object Manipulative Skills: Measures a child's ability to interact with objects, such as throwing, catching, and kicking a ball.

The use of the TGMD-2 is because this test has been validated to measure gross motor skills in the pediatric population (Valentini, 2012), especially in the context of sports or physical activity. In addition, the TGMD-2 provides quantitative scores that can be used to analyze differences in pre- and post-intervention outcomes, making it easier to see the effects of structured and unstructured motor skill training. Meanwhile, qualitative observations are important because they provide a more in-depth perspective on how children respond to unstructured motor skill trainingenvironments, which tend to be more spontaneous and varied compared to structured exercises.

Test Procedures.

- **Preparation Stage:**

1. Identify and recruit 40 child participants aged 7-10 years old.
2. Informed parents or guardians about the purpose and methods of the study.
3. Randomized division of children into two groups: Group A (Structured motor skill training) and Group B (Unstructured motor skill training).
4. Pre-Test: Prior to the implementation of the exercise program, a pre-test was conducted on all participants using the TGMD-2 instrument. This measurement served as a baseline to compare the changes that occurred after the intervention.
5. Intervention:

- **Group A (Structured Motor Skill Training):** The children follow exercise sessions designed with strict instructions and supervision. Each session involves specific activities such as zig-zag running, rope jumping, ball throwing and catching, and muscle strengthening activities with predetermined repetitions and duration.
- **Group B (Unstructured Motor Skill):** Children are given the freedom to play in an environment filled with various physical play tools such as balls, jump ropes, cones and climbing structures. No specific instructions are given, and the children are allowed to move as they wish.

6. Both groups trained for 6 weeks, with a frequency of 2 times a week, and each session lasting 45 minutes.
7. Post-Test: After 6 weeks of intervention, a post-test was conducted using the same TGMD-2 instrument as the pre-test. The results of the post-test will be used to measure changes in motor skills in both groups.

The study was approved by the ethics committee by ensuring that all participants and their guardians gave informed consent. The safety and comfort of the children were prioritized during the study.

Statistical analysis.

In this study, the statistical test used to analyze the difference in effectiveness between structured motor skill training and unstructured motor skill training in improving children's movement skills is the ANOVA (Analysis of Variance) test. The ANOVA test was chosen because this method can identify whether there are significant differences between more than two or more groups on the variable being measured, in this case, children's movement ability as influenced by the type of exercise. The ANOVA test process begins by formulating the null hypothesis (H_0) which states that there is no significant difference in movement ability between the groups of children who participated in structured motor skill training, unstructured motor skill training, and the control group if any. Conversely, the alternative hypothesis (H_1) states that there is at least one group that is significantly different in terms of improvement in movement ability.

In this analysis, data from each exercise group (structured and unstructured) was measured before and after the exercise period. Next, the variance in the movement ability results is measured to determine whether the between-group variability is greater than the within-group variability. The ANOVA test will produce an f-statistic value comparing the ratio of between-group and within-group variances. The p-value resulting from this test will indicate whether the observed differences are significant enough to reject the null hypothesis. If the ANOVA test results show a p value that is smaller than the set significance level (e.g., $p < 0.05$), then it can be concluded that there is a significant difference in movement ability between the different groups.

Results

Descriptive Data

Table 1. *Descriptive Statistics*

Group Data		Mean	Std. Deviation	Variance	Minimum	Maximum
Structured Motor Skill Training	Pre-test	57.70	1.92	3.69	54	61
	Post-test	77.45	3.60	12.99	71	84
Unstructured Motor Skill Training	Pre-test	55.45	2.50	6.26	52	60
	Post-test	68.30	4.23	17.90	62	75

This table presents a summary of descriptive statistics for pre-test and post-test results for the two research group data. in the structured motor skill training group, the Pre-test mean value was 57.70 with a standard deviation of 1.92 and a variance of 3.69, with a minimum score of 54 and a maximum of 61. And the Post-test mean was 77.45 with a standard deviation of 3.60 and a variance of 12.99, with scores ranging from 71 to 84. Then in the unstructured motor skill training group, the Pre-test mean value was 55.45 with a standard deviation of 2.50 and a variance of 6.26, with a minimum score of 52 and a maximum of 60. And the Post-test mean value was 68.30 with a standard deviation of 4.23 and a variance of 17.90, with a minimum score of 62 and a maximum of 75.

Normality Test

The Kolmogorov-Smirnov statistical test results in the structured motor skill training and unstructured motor skill training groups showed that the data were normally distributed.

Table 2. *Kolmogorov-smirnov Normality Test*

Group Data		Statistic	df	Sig.	Ket.
Structured Motor Skill Training	Pre-test	0.11	20	.200*	Normal
	Post-test	0.10	20	.200*	Normal
Unstructured Motor Skill Training	Pre-test	0.12	20	.200*	Normal
	Post-test	0.11	20	.200*	Normal

In the structured motor skill training group, the statistical value for the Pre-test was 0.11 with a df (degree of freedom) of 20 and a significance value of 0.200, indicating normal distribution. For the Post-test, the statistical value was 0.10 with a df of 20 and a significance of 0.200, also indicating a normal distribution. Similarly, in the unstructured motor skill training group, the Pre-test statistical value was 0.12 with df 20 and a significance of 0.200, indicating a normal distribution. The post-test had a statistical value of 0.11 with a df of 20 and a significance value of 0.200, which also indicated that the data was normally distributed. All significance values are above the 0.05 threshold, so both groups of data can be said to have a normal distribution.

Homogeneity Test

The results of the levene test analysis showed the homogeneity value of structured motor skill training and unstructured motor skill training.

Table 3. *Test Of Homogeneity of Variances*

Group Data	Levene Statistic	Sig.	Ket.
Structured Motor Skill Training	5.33	0.26	Homogen
Unstructured Motor Skill Training	7.67	0.38	Homogen

In the structured motor skill training group, the levene statistic value was 5.33 with a significance value (sig.) of 0.26, indicating that the variance between groups was homogeneous. Likewise, in the unstructured motor skill training group, the levene statistic value was recorded as 7.67 with a sig. value of 0.38, which also indicated homogeneity. 0.38, which also indicated homogeneity of variance. All significance values were ≥ 0.05, thus, both groups of data met the assumption of homogeneity.

Hypothesis Test

1. First Hypothesis test

Based on the results of statistical tests, it shows that there is a significant difference between the Pretest and Posttest scores after the implementation of structured motor skill training.

Table 4. *Summary of The First Hypothesis Test Data (Paired Samples Test)*

Structured Motor Skill Training	Paired Differences			t	Sig. (2-tailed)	Ket.
	Mean	Std. Deviation	Std. Error Mean			
PreTest - PostTest	19.75	2.86	0.64	30.84	0.00	Sig.

The mean difference between the Pretest and Posttest was 19.75, indicating a considerable improvement. The t-value of 30.84 confirms a significant difference between the two scores, and the significance value (Sig. 2-tailed) of 0.00 confirms that this difference is statistically significant. Since the significance value is smaller than 0.05, we can conclude that the structured motor skill training had a positive and significant impact on improving the participants' motor performance.

2. Second Hypothesis Test

The statistical test results for unstructured motor skill training showed an improvement between the Pretest and Posttest scores.

Table 5. *Summary of The Second Hypothesis Test Data (Paired Samples Test)*

Unstructured Motor Skill Training	Paired Differences			t	Sig. (2-tailed)	Ket.
	Mean	Std. Deviation	Std. Error Mean			
PreTest - PostTest	12.85	2.79	0.62	20.55	0.00	Sig.

The mean difference between the Pretest and Posttest scores was 12.85, indicating an improvement in motor performance after the implementation of unstructured motor skill training. The t-value of 20.55 shows that the difference between the Pretest and Posttest scores, with a significance value (Sig. 2-tailed) of 0.00. Since this significance value is smaller than 0.05, it can be concluded that the difference between the Pretest and Posttest is significant.

3. Third Hypothesis Test

The results of the Independent T-test showed a significant difference between structured motor skill training and unstructured motor skill training in improving motor skills.

Table 6. *Summary of The Second Hypothesis Test Data (Independent T-Test)*

Group Data	N	Mean	Std. Deviation	t	Mean Difference	Sig. (2-tailed)	Ket.
Structured Motor Skill Training	20	19.75	2.86	7.71	6.90	0.00	Sig.
Unstructured Motor Skill Training	20	12.85	2.79				

The group that followed structured motor skill training had an average improvement of 19.75 with a standard deviation of 2.86, while the group that followed unstructured motor skill training had an average improvement of 12.85 with a standard deviation of 2.79. The mean difference between the two groups was 6.90, indicating that structured motor skill training provided better results.

The t-value of 7.71 and the significance value of 0.00 indicate that this difference is highly statistically significant. In addition, the percentage difference between the two types of training was approximately 53.7%, indicating that structured motor skill training provided greater improvement compared to unstructured motor skill training. Thus, it can be concluded that the structured motor skill training method is significantly more effective in improving motor performance than unstructured motor skill training.

Discussion

The results of studies on Structured motor skill training and Unstructured motor skill training show significant differences in their impact on children's movement abilities, with each approach offering unique benefits.

Structured motor skill training offers a number of advantages, especially when it comes to developing specific motor skills. This approach involves a well-planned program, where children follow a set of predetermined and directed movements to achieve specific goals. Past research studies have shown that children who participated in structured exercises experienced improvements in gross and fine motor skills, such as coordination and balance (Dapp et al., 2021). This is because structured exercises usually involve repetition of movements that focus on specific techniques, allowing children to build a strong foundation of motor skills. Furthermore, research by (Wilson et al., 2020) showed that children with developmental coordination disorder (DCD) showed significant improvements in motor skills through structured exercises. This suggests that structured approaches are not only beneficial for children with normal motor development but also for those who require specialized interventions. These exercises usually include clear instructions, continuous feedback, and regular assessment of progress, which helps children to understand and master specific motor skills more effectively.

This is supported by field observations showing that children who participated in structured motor skill training programs mastered specific motor skills such as jumping rope, running with correct technique, and hand-eye coordination faster (Sepriadi, 2023). For example, in structured gymnastic exercise programs, observations show improvements in children's ability to follow instructions with precision and perform movements with better control. These exercises often include clear instructions, ongoing feedback and regular progress assessments, which help children understand and master specific motor skills more effectively.

Unstructured motor skill training, on the other hand, provides benefits in terms of creativity and movement adaptability. In free practice, children are given the freedom to explore their own movements, which can encourage the development of creativity and innovation in physical activity. Free play supports the development of adaptation and problem-solving skills, which are important for cognitive and social development (Pellegrini, 2009). Other research suggests that free play also supports emotional and social development by providing opportunities for children to interact with their environment and practice social skills in a more natural context (Ginsburg et al., 2007).

However, while free motor practice has many benefits, this approach can have limitations in terms of focus and structure. Children may not always explore movements that are specifically required for the development of certain motor skills without clear direction. Without clear direction, these children may not develop specific motor skills in a systematic way (Goodway et al., 2013). In some cases, observations suggest that without adequate guidance, children may get stuck in ineffective or less varied movement patterns. Therefore, unstructured motor skill training are often more effective when used as a complement to structured exercise programs. Unstructured motor skill training can provide opportunities for children to apply the skills they have learned in a freer and more creative context, as well as assist them in developing adaptation and exploration skills that are not always covered in structured exercise. this research emphasizes the importance of integrating these two approaches. This research emphasizes the importance of integrating these two approaches. This is supported by other research showing that a combination of structured and free practice allows children to benefit from both: the development of specific motor skills through structured practice, and the development of creativity and flexibility through free practice (Dapp et al., 2021). This integration supports a more holistic approach to children's motor development, where children not only learn the necessary techniques but are also given the space to innovate and explore movements independently. In addition, the play approach is very supportive in children's motor development and thinking (Susanto et al., 2022), (Susanto et al., 2024).

Overall, although structured and unstructured motor skill training each have their advantages and disadvantages, a combination of both approaches can provide optimal benefits in children's motor development. Structured approaches ensure that basic motor skills are well developed, while free practice allows children to apply and explore those skills in more creative and adaptive contexts. In this way, a balanced exercise program can maximize children's motor development and support their cognitive, social and emotional aspects.

Conclusion

Comparative studies between structured motor skill trainingand unstructured motor skill training show that while both approaches have their benefits, structured motor skill training often yield more significant results in the development of children's motor skills. Structured exercises, with an organized plan and clear instructions, allow children to focus on mastering specific motor skills such as coordination, balance and strength. Research by (Hollis et al., 2016) and (Van Dyck et al., 2022) shows that this approach effectively improves gross and fine motor skills, and

provides a beneficial intervention for children with developmental coordination disorders. The advantage of structured motor skill training lies in its ability to provide a solid foundation in motor skills through planned repetition and consistent feedback. These programs are designed to achieve specific goals by providing clear directions, which facilitates the learning of motor skills more efficiently. This makes structured exercise a highly effective approach to developing basic motor skills required for daily activities and sports.

However, a combination of both approaches, structured and free practice can provide comprehensive benefits. However, a heavy emphasis on structured practice is essential to ensure that children acquire solid basic motor skills. A well-designed exercise program should integrate structured exercises to build a strong foundation of skills and free exercises to support creativity and exploration. In this way, we can maximize children's overall motor development, balancing between mastery of specific skills and the ability to adapt and innovate in movement.

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Development of an External Load Physical Training Model to Increase Strength in Shotokan Karate

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Abstract: *This research aims to determine the effect of the developed external load physical training model on efforts to increase strength in the sport of shotokan karate. The participants in this study were 20 shotokan karate athletes and students at Universitas Negeri Makassar. This research was conducted on the Universitas Negeri Makassar campus for three months. The research design used was research and development (R & D) with a purposive sampling technique. We also conducted experiments to measure the effectiveness of the external weight training model we developed. Participants were given treatment in ten meetings. To measure the level of improvement in the treatment given, we conducted a pre-test and post-test in the experimental group. The results showed that the external load physical training model proved effective in increasing strength in shotokan karate athletes. Of course, after going through the revision stages to perfect the training model. Therefore, we recommend that future researchers re-test the effectiveness of the external load physical training model that we developed with other research methods to test the validity and reliability of this training model.*
Key Words: *External weights, Karate shotokan, Model training.*

Introduction

One of the sports that improves and maintains balanced physical and spiritual growth and then develops rapidly in Indonesia is the sport of karate. This is because the sport of karate not only focuses on the physical but also the spiritual to form a balanced mental and psychological state. In general, people understand that martial arts, apart from sport, is also a way that can be used to respond and anticipate enemy attacks. Understanding self-defense is very important in avoiding and preventing the risk of harm from physical attacks that attack suddenly and can occur at any time. The sport of karate is a martial art that is used by a person to defend themselves without using sharp and deadly tools or objects. Chaabène et al. (2012) revealed that karate athletes need an optimal combination of muscle strength, speed and endurance to be able to compete in high-level championships. This is in line with a study conducted by Wahyudi et al (2019) which explains that karate martial arts is indeed a type of sport that does not use weapons. The word karate martial arts uses all parts of the body as natural weapons that are effective and powerful, and practical, such as hands, knees. , feet and so on.

Historically, the sport of karate as a martial art is known to have been born in the 19th century, with Matsumara Shukon (1797-1896), a samurai warrior and protector of King Sokookinawa. In the sport of karate there are very systematic and well-patterned regularities relating to the rules of ethical-aesthetic values in social life. Susanto (2021) suggests that there are three regularities that must be distinguished in people's lives, the first is the natural order, the order of social life in society, and the order of technological engineering. Likewise, in the sport of karate, order and discipline are absolute. The sport of karate is a cultural heritage from Far East Asia that is very close to Indonesian society. So that in the sport of karate we are empirically confronted with two facts, namely the first is the reality about form, whether it is an object or creature, and the second is the reality about the soul or spirit. These two facts unite the character of the sport of karate, namely the combination of body and soul in martial arts.

These basic karate movements require consistent and well-planned practice to form a physique that supports training activities for several things such as mental formation, sporting values, and the value of martial arts itself. One thing that is no less important than the sport of karate which has become a culture is the implementation of evaluations in all dimensions, both physical, mental and technical. This evaluation activity is exactly the same as expressed

by (Nusufi Maimun, Rinaldy Alfian, 2019) who said that physical condition for karateka is something that is absolute and must be possessed by a katareka, even including in other sports, physical condition is the basic foundation in efforts to perfect karate movement techniques to achieve sustainable peak performance, so that every athlete has an obligation to improve their prime physical condition. Soriano, Jiménez-Reyes, Rhea, and Marín (2015) showed that the use of external loads with appropriate intensity can maximize power production in lower body movements, which is very relevant in the discipline of karate.

One component of physical condition that is very important for a karate athlete is strength. Strength is a very meaningful word, especially in the world of sports. Where strength has very important uses, including helping to strengthen the stability of joints, the driving force of every physical activity and strength plays a role in protecting against the possibility of injury (Harsono, 2016). Physical aspects function as a driver or director of athlete performance, such as strength when performing punches or kicks. Every basic karate technique requires strength to support the movement. Apart from strength, no less important is endurance, this endurance can be obtained through regular training and modifying various kinds of physical activities (Susanto et al., 2021), (Susanto et al., 2024). Variation of exercise with various forms of physical games can also help in physical fitness (Susanto et al., 2022).

The training method to increase strength is with an external load physical training model. This training medium with added weights is considered very effective. Weight training can be done on muscles that have special functionality or are specific to movement needs. Behm et al. (2017) explained that strength training with a progressive and biomechanics-based approach can improve athlete performance without increasing the risk of overtraining. If we talk about weight training given to athletes, of course there will be positive and negative impacts. If the load and training program are given effectively and efficiently, it will be very beneficial for the athlete's muscle strength, however, if the load given is inappropriate and not based on a clear theory, it will cause a very fatal impact on the athlete, namely overuse injuries. As stated (Sidik, 2019. pp: 49-51) that if the training is too light, the level of fatigue is low, the recovery time is short and the effect of the training is small and too early, but if the training is too heavy then the level of fatigue is high requiring a long recovery so the effect exercise is low and new stimulus becomes late. If training is given adequately (appropriately) according to needs and portions, there will be a good training effect. Therefore, the author wants to elaborate on a training model that uses external loads to increase strength in the sport of Shotokan karate.

Literature Review

The essence of the basic movements of Shotokan Karate

Karate is an empty-handed martial art that is rich in basic movements or basic techniques and makes all body components into deadly weapons. The basic techniques of karate are kihon, kata, and committee kihon. Kumashiro (2004) explains in his book, Karate-Do: My Way of Life, that basic techniques in karate such as kihon, kata, and waza are not only to increase physical strength, but also to form deep mental control and concentration. Kihon dachi waza or basic stance techniques include haiko dachi, musubi dachi, hachinoci dachi, uchi hacinochi dachi, haiko dachi, teiji dachi, renoji dachi, zenkutsu dachi, kokutsu dachi, kiba dachi, sanchin dachi, shocin dachi, hangetsu dachi, shiko dachi, sagi ashi dachi, neko ashi dachi, tsuru ashi dachi, fudo dachi, and kosa dachi. The things that are mandatory and dominant in practice are haiku dachi, musubi dachi, hachinoci dachi, haiko dachi, zenkutsu dachi, kokutsu dachi. Then kihon uke or parrying techniques include gedan barai, ude uke, uchi uke, age uke, and shuto uke. Next are the tsuki techniques, namely cudan tsuki, yodan tsuki, geaku tsuki, kisame tsuki, uraken tsuki, ura tsuki, and mawashi tsuki.

Types of Basic Movements required in Shotokan Karate

1. Parry movements include: gedan barai, age uke, uchi uke, ude uke, shuto uke.
2. Tzuki punching movements include: chudan tzuki, jodan tzuki, geaku tzuki, qhisami tzuki.
3. Kick movements include: maegeri cudang, maegeri jodan, mawashi geri, kekomi geri, keange geri, ushiro geri.

External Load Physical Training Model in Shotokan Karate

In various literature, physical condition in each sport is a primary aspect that is mandatory to support training activities in sports. according to (Wibisana et al., 2016) that for every athlete who is coached in a sport, physical

condition is absolute, because to achieve maximum performance for every athlete the physical condition must be good. Maifitri (2012) emphasized that four components are considered to support the achievements of karate athletes, including physical elements, technical elements, tactical elements and mental elements. Nakayama (1978) explains that karate training not only focuses on improving physical skills, but also involves character building and discipline. However, the first thing that coaches must pay attention to is the physical element, because physicality is the basic foundation in order to achieve maximum breakthrough.

Therefore, physical and technical are a complete unity of all basic components and cannot be separated in an effort to achieve sustainable achievements for every athlete in a sport. The physical training model in question is the model or form of physical training that will be applied in the research, namely the external weight training model. External load is a physical training method that utilizes additional load outside of body weight, such as machine weight training which is used with certain movement patterns to develop and improve the physical elements in sports.

Strength Aspects of Basic Shotokan Karate Movements

Karate is also known as part of the sports achievements that are recognized and competed in Indonesia. Therefore, karate can be said to be a self-defense martial art with its own method of utilizing body parts as weapons which are trained naturally in accordance with eastern cultural values. To achieve achievements as indoctrinated in the traditional karate rituals at the opening and closing ceremonies of training, namely being able to increase performance, the physical components must continue to be studied. The aim is to accelerate physical and technical aspects as very basic factors in order to produce good quality movement techniques and character.

The physical elements in the sport of karate martial arts (Asnaldi, 2015) are: "strength, speed, agility, power, coordination, reaction time, and flexibility, as well as endurance. This research will focus on the physical elements of strength, because the physical elements of strength play a very important role for elite karate athletes to perform optimally.

Method

This study uses research methods to develop a shotokan training model. This research emphasizes efforts to produce something, test it in the field, revise it until the results obtained are certain to be satisfactory. Development research always begins with a needs analysis, a problem that requires solving using a particular product. The development model used by researchers is the Borg and Gall (2017) research and development model.

Development Procedure

The steps are: a). Information gathering, b) planning, c). Product draft development, d). Initial field trials, e) revision of trial results, f). Field trials, g). Product refinement and revision, h). Field implementation test, i). Product refinement and final revision, j). Dissemination. The research design developed in the research is the development of an external load physical training model to increase strength in the Shotokan karate sport. The steps taken in this trial include; (1) determine the research subject group; (2) carry out the pre-test (O1); (3) try the model that has been developed; (4) carry out post-test (O2); (5) look for the average score of the pre-test and post-test and compare the two; (6) look for the difference between the two averages using statistical methods (t-test) to determine whether there is a significant effect from using the training model. The research subjects in this study were karate athletes who were divided into 20 people.

Data Collection

The data collection method for needs analysis uses interviews with shotokan karate athletes to distribute surveys to research participants. Data collection techniques for efficacy testing use quantitative experimental methods. The instrument used is a Likert Scale: (1) very unsuitable, (2) not suitable, (3) quite suitable, (4) suitable, (5) very suitable, while the instrument for the ability to perform basic Shotokan karate techniques points is calculated from the total valid value. Including to measure the level of strength when performing basic Shotokan techniques.

Data Analysis

The effectiveness test used was an experiment with a one group pretest-posttest research design. Hypothesis

testing using the nonparametric Wilcoxon test compares the pretest and posttest results of paired groups. Then the collected data was analyzed using the SPSS version 21 application.

Result

The research was conducted for three months and found empirical data in the form of the influence of external load physical training models to increase strength in Shotokan karate athletes. The following is a summary of the analysis of the influence of the external load physical training model that has been developed.

Descriptive Statistics

Table 1. *Data on physical training with external loads to increase strength in Shotokan karate*

	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation
Pre Test Arm Muscle Strength	20	17.50	29.50	47.00	778.50	38.9250	4.12079
Pre Test Leg Muscle Strength	20	77.00	154.00	231.00	3668.50	1.83422	28.18747
Post Tes Arm Muscle Strength	20	7.50	41.00	48.50	876.00	43.8000	2.30788
Post Test Leg Muscle Strength	20	49.00	181.00	230.00	4049.50	2.02482	18.01715
Pre Test Control Group Arm Muscle Strength	20	9.50	19.00	28.50	470.50	23.5250	3.25445
Pre Test Control Group Leg Muscle Strength	20	50.00	104.00	154.00	2764.00	1.38202	14.31084
Post Test Control Group Arm Muscle Strength	20	14.00	21.50	35.50	522.50	26.1250	5.16026
Post Test Control Group Leg Muscle Strength	20	42.50	113.00	155.50	2856.00	1.42802	12.53248

From table 1, the data obtained on the influence of external load physical training to increase strength in the sport of shotokan karate are as follows:

1. For the Pre Test data on Arm Muscle Strength, the N value was 20, range 17.50, minimum 29.50, maximum 47.00, Sum 778.50, mean 38.9250, Standard Deviation 4.224.
2. For the Pre Test data on leg muscle strength, the N value was 20, range 77.00, minimum 154.00, maximum 231.00, Sum 3668.50, mean 1.83422, Standard Deviation 28.18747.
3. For Post Test data on Arm Muscle Strength, the N value was 20, range 7.50, minimum 41.00, maximum 48.50, Sum 876.00, mean 43.8000, Standard Deviation 2.30788.
4. For Post Test data on leg muscle strength, the N value was 20, range 49.00, minimum 181.00, maximum 230.00, Sum 4049.50, mean 2.02482, Standard Deviation 18.01715
5. For the Control Group Arm Muscle Strength Pre Test data, the N value was 20, range 9.50, minimum 19.00, maximum 28.50, Sum 470.50, mean 23.5250, Standard Deviation 3.25445.
6. For the Pre Test data on leg muscle strength for the control group, the N value was 20, range 50.00, minimum 104.00, maximum 154.00, Sum 2764.00, mean 1.18202, Standard Deviation 14.31084.
7. For the control group Arm Muscle Strength Post Test data, the N value was 20, range 14.00, minimum 21.50, maximum 35.50, Sum 522.50, mean 26.1250, Standard Deviation 5.16026.
8. For post test data on leg muscle strength for the control group, the N value was 20, range 42.50, minimum 113.00, maximum 155.50, Sum 2856.00, mean 1.42802, standard deviation 12.53248.

Table 2. *T test data External load physical training to increase strength in the Shotokan karate sport*

Variabel		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre Test Arm Muscle Strength	38.9250	20	4.12079	.92144
	Post Tes Arm Muscle Strength	43.8000	20	2.30788	.51606
Pair 2	Pre Test Leg Muscle Strength	1.83422	20	28.18747	6.30291
	Post Test Leg Muscle Strength	2.02482	20	18.01715	4.02876
Pair 3	Pre Test Control Group Arm Muscle Strength	23.5250	20	3.25445	.72772
	Post Test Control Group Arm Muscle Strength	26.1250	20	5.16026	1.15387
Pair 4	Pre Test Control Group Leg Muscle Strength	1.38202	20	14.31084	3.20000
	Post Test Control Group Leg Muscle Strength	1.42802	20	12.53248	2.80235

Based on table 2 above, it can be seen that the T test results of the external load physical training data variables to increase strength in the Shotokan karate sport are as follows:

1. Pre test data on arm muscle strength obtained an N value (sample) of 20 people, the mean pre test value for arm muscle strength was 38.9250 and the post test value for arm muscle strength was 43.8000, with a sig value of 0.000. and obtained a difference of 48,750. So this difference is an influence or improvement in the external load physical training program to increase strength in the sport of shotokan karate.
2. Pre-test data on leg muscle strength obtained an N value (sample) from 20 people, the mean pre-test value for leg muscle strength was 1.83422 and the post-test value for leg muscle strength was 2.02482, with a sig value of 0.000. and obtained a difference of 19,060. So this difference is an influence or improvement in the external load physical training program to increase strength in the sport of shotokan karate.
3. Pre test data on control arm muscle strength obtained an N value (sample) of 20 people, the mean pre test arm muscle strength value was 23.5250 and the post control arm muscle strength test value was 26.1250, with a sig value of 0.000. and obtained a difference of 26,000. So this difference becomes an influence or increased control in the external load physical training program to increase strength in the sport of shotokan karate.
4. Pre test data on muscle strength of the control leg obtained an N value (sample) of 20 people, the mean pre test value of leg muscle strength was 1.38202 and the post test value of muscle strength of the control leg was 1.42802, with a sig value of 0.000. and obtained a difference of 4,600. So this difference becomes an influence or increased control in the external load physical training program to increase strength in the sport of shotokan karate.

Discussion

This research began by taking pretest data, this was done to describe the initial condition of the sample before being given treatment in the form of an external load physical training program to increase strength in the sport of shotokan karate. For the data collection process, the author measured arm and leg muscle strength tests, this was done to place greater emphasis on the objectivity of the research results. In this study, the sample consisted of 20 shotokan karate athletes from South Sulawesi Province.

Based on data from previous research, it shows that there has been an escalation. This study also uses the interview method to validate research results in the form of quantitative data. The purpose of holding interviews is to find out in depth each process carried out during the treatment provided. At the first and second meetings, several athletes still seemed unfamiliar with following the external load physical training program to increase strength in the sport of shotokan karate. This is in accordance with what the sample said.

This special strength training program is something new that I discovered, but it is very good for increasing strength in karate because it is very detailed. Sample #1, in-depth interview, January 17, 2023).

The findings are in line with the theory explained by Haff and Triplett (2016), which states that strength training that focuses on developing large muscles through external loads can increase athlete strength and power. From our observations, it was found that at the fourth meeting the athletes had started to get used to it and the author provided knowledge on how to quickly adapt to the strength training program in the karate training session. The author also observed athletes who followed this training program to check whether it was correct or not. This is done because there are three aims of experimental research, namely changing conditions, changing thought patterns and changing behavior. However, in this study the author only took data on the aspect of changing conditions, which in the context of this research is strength. For the other two aspects, the author still focuses on providing knowledge of the biomechanics of strength and informing you that when you want to improve your karate performance skills you can use this type of training program. This is in line with the training principle put forward by Bompa and Buzzichelli (2019) that training is a systematic sports activity over a long period of time, increased progressively and individually which leads to the characteristics of human psychological and physiological functions to achieve specified targets.

At the fifth meeting, progress began to be seen, therefore the author took the initiative to carry out the posttest again and it turned out that the results had improved. This can be seen from the movement patterns displayed by athletes, the strength when performing basic karate techniques when playing. In this case, the posttest is to measure the escalation caused by the treatment given. The author synthesizes that there has been an increase, although it is still in the not significant category. Therefore, the author continued the treatment given until the improvement was

considered statistically significant.

At the sixth meeting, the athletes were very used to and felt comfortable doing a special training program that emphasized the strength of each movement. This is illustrated from the results of interviews with the following samples:

I have become accustomed to doing this exercise, and I also feel the positive impact directly. When playing I feel my movements increase or have power (Sample #3, in-depth interview, January 23 2023).

From the narrative of this sample, the effectiveness of this training program is clearly illustrated. This effectiveness is because this training program specifically focuses on strength in basic karate techniques, so the sample only focuses on that aspect. This emphasizes the explanation that in principle, training is a process of change for the better, namely to improve the physical quality, functional abilities of the body's equipment and the psychological quality of the training child. When the sample's attention is not divided between other exercises, concentration and focus can be used optimally. This was also validated through interviews with the following samples:

This training program is very simple, as it focuses only on strength. I enjoyed doing this exercise because it was new to me (Sample #6, in-depth interview, January 26, 2023).

This effectiveness is not only due to the fact that the training program is very detailed and specific, the program being carried out repeatedly is also a factor in the effectiveness and efficiency of the training program. This is explained by Harsono (2016) that training can also be said to be a systematic training process that is carried out repeatedly and the amount of training load increases day by day.

The treatment in this research was carried out in eight meetings. At the eighth meeting the author found that physical training with external loads to increase strength in the sample sport of shotokan karate had developed and experienced a very significant escalation. Therefore, the treatment was stopped. Another factor that causes the training program to be able to develop basic karate skills is that the sample is motivated to do this training program because it is different from the training they usually do. Of the fifteen samples, the strength when performing basic karate movements has increased. In line with these findings, Bishop et al. (2006) explained that systematic and measured strength training, as applied in this study, can lead to significant strength increases in a relatively short period of time. It is therefore certain that a physical training program with external loads increases strength in the sport of shotokan karate.

Conclusions and Suggestions

From the conclusions of this research, recommendations will be put forward in the form of suggestions for the application and development of research results. With the title of the research, namely Development of an external load physical training program to increase strength in the sport of shotokan karate for male athletes in South Sulawesi.

Conclusion

Based on the results of the data and discussion from this research, it can be concluded that the development of an external load physical training program to increase strength in the sport of Shotokan Karate for South Sulawesi athletes obtained variable values for the influence of external load physical training to increase strength in the sport of Shotokan Karate. The pre-test for arm muscle strength obtained an N value (sample) of 20 people, the mean pre-test value for arm muscle strength was 38.9250 and the post-test value for arm muscle strength was 43.8000, with a sig value of 0.000. and obtained a difference of 48,750. So this difference is an influence or improvement in the external load physical training program to increase strength in the sport of shotokan karate and the pre-test data on leg muscle strength obtained an N value (sample) of 20 people, the mean pre-test value of leg muscle strength was 1.83422 and the post-test value for leg muscle strength was 2.02482, with a sig value of 0.000. and obtained a difference of 19,060. So this difference is an influence or improvement in the external load physical training program to increase strength in the sport of shotokan karate.

Suggestions

The recommended suggestions are as follows:

1. It is recommended that coaches and sports coaches pay attention to the training program and body structure of each prospective athlete

2. It is recommended that athletes do more individual training so that stamina and basic karate techniques are maintained so that performance can be maximized.
3. Researchers who are interested in researching strength variables are advised to look for other variables that can improve basic techniques in karate sports.

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Differences in the Intercorrelations of Psychological Characteristics in Karate Competitors and Representatives

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Abstract: *This research was conducted on a purposive sample of 32 respondents, 16 karate competitors and 16 karate national team members, men, seniors (according to WKF) from the Republic of North Macedonia. The main objective of this research was to determine the differences in the interrelations between the psychological characteristics of karate competitors and members of the karate national team. A total of 13 variables of psychological characteristics were used in the research: one variable for assessing general intellectual abilities, three variables for assessing specific intellectual abilities, six variables for assessing emotional characteristics, and three variables for assessing motivational dispositions. To determine the differences in the mutual relationships, first the intercorrelation matrices of the competitors and the national team members were calculated, then the Fisher transformed matrices were calculated, i.e. r1 and r2 - the correlation coefficients for each group, Z-statistics that measure the difference between the two correlation values and p-value - which determines whether the difference in the correlation is statistically significant. The results of the Z-test obtained in the study show statistically significant differences only in 5 pairs of variables from the two intercorrelation matrices.*
Keywords: *psychological characteristics, karate competitors, karate national team members, descriptive statistics, Z-test.*

Introduction

The value of research on psychological differences between karate competitors (karate athletes who practice and compete at different levels), and karate representatives (elite athletes who represent their country), lies in finding and determining the differences that can reveal what separates elite karate athletes from regular competitors. Studies suggest that elite athletes in combat sports tend to have higher levels of self-discipline, self-confidence, and lower levels of cognitive and somatic anxiety (D., Mojtahedi, et all. 2023). Research on these traits can help identify potential future representatives and improve talent selection. Precisely because of this, in their research, Soklevska, I.E., Kostovski, Ž., Mikic. B. (2018), determined the factor structure of the psychological characteristics of karate representatives (members of the national selection) and karate competitors from the Republic of North Macedonia, in order to achieve the desired goal, since as much information as possible is needed that will be properly incorporated and used in the process of building the personality of the karate athlete. Therefore, determining the differences between the examined groups and relating to the intercorrelations of the psychological characteristics of karate athletes is of great importance in karate sport.

Methods Of Work

The research was conducted on a purposive sample of a total of 32 respondents divided into two subsamples, of which 16 karate competitors and 16 karate representatives, male, seniors (according to WKF) from the Republic of North Macedonia. The respondents were subjected to tests to determine psychological characteristics that were conducted in the clubs in which the competitors conduct their daily training).

A total of 13 variables of psychological characteristics were applied in the research (according to the doctoral dissertation of Aleksovska, V., L. 2002), divided into 4 areas, of which:

- one variable for assessing general intellectual ability - IQ Test
- three variables for assessing specific intellectual abilities (sports intelligence) - F1, F2, S1, i.e. the ability for perceptual reasoning, the ability for speed of observation of perceptual structures, and the specific intellectual ability for deriving spatial relations.
- six variables for assessing emotional traits - anxiety (TAI), aggressiveness (T-15), extraversion/introversion,

neuroticism, psychoticism, social desirability (EPQ)
- three variables for assessing motivational dispositions - P2, F+, F-, i.e. the sports motive of achievement through the desire to stand out, for success in basic life activities, the degree of positive emotional engagement and emotional self-control in situations of sports achievement and the degree of negative emotional reaction in situations of sports achievement which is manifested through fear of uncertainty of the outcome.

The data obtained from this research according to the characteristics and size of the selected sample were processed with adequate statistical programs. For the purposes of this research, the following were calculated: the intercorrelation relationship of the variables, Fisher's test which is used to examine the relationship between two categorical variables, usually when the sample size is small or when the expected frequencies in any cell are less than 5, r1 and r2 - the correlation coefficients for each group, Z-statistic - measures the difference between the two correlation values and p-value - tests whether the difference in the correlation is statistically significant ($p < 0.05$ indicates a significant difference).

Results and Discussion

From the analysis of the intercorrelation matrix in Table 1, it can be concluded that the correlation coefficient between the applied variables results in different values. The variable PM or general intelligence has a medium positive correlation with the variable from the space of sports intelligence, which represents a specific intellectual ability to perform spatial relations (S1 = .55). The positive correlation of these two variables actually indicates that they belong to a single system in the space of specific intellectual abilities. (Aleksovska, L., 2002). A significant correlation with medium values can also be observed in the variable (F2), which represents a specific intellectual ability for the speed of observation of perceptual structures, with the variable neuroticism/stability (N =.51) which is characterized by high levels of negative effects, such as depression and anxiety. A statistically significant positive correlation exists between the variables TAI and P (= .64), i.e. between anxiety and psychoticism.

Table 1. *Correlation of psychological characteristics among the contestant respondents*

	PM	F1	F2	S1	TAI	P	N	E	L	P2	F+	F-	T-15
PM	1.00												
F1	0.42	1.00											
F2	0.45	0.31	1.00										
S1	**0.55**	0.24	0.36	1.00									
TAI	-0.28	0.33	0.14	-0.05	1.00								
P	-0.17	0.32	0.00	0.36	**0.64**	1.00							
N	0.11	0.03	**0.51**	-0.12	0.04	-0.37	1.00						
E	0.27	0.03	0.29	0.21	0.16	0.15	0.22	1.00					
L	-0.05	-0.06	0.07	-0.23	0.14	-0.05	0.25	**0.51**	1.00				
P2	0.41	-0.02	0.16	0.20	0.00	0.31	-0.29	0.23	-0.10	1.00			
F+	0.28	0.41	0.03	0.41	-0.02	0.29	-0.38	-0.17	-0.30	-0.05	1.00		
F-	0.44	0.23	0.43	0.03	-0.07	-0.16	0.21	0.03	0.26	0.36	-0.21	1.00	
T-15	-0.04	-0.40	-0.20	0.33	-0.19	-0.20	0.01	0.16	-0.18	-0.04	-0.36	-0.20	1.00

Also between the variables E (extraversion/introversion) and L (social desire), a correlation with mean values (= .51) is observed. The positive interrelationships obtained based on the intercorrelation matrix are logical and expected. The variables TAI (anxiety) and P (psychotism) belong to the emotional characteristics of the personality according to which the individual is inclined to react to different situations with anxious reactions. The variables E (extraversion/introversion) and L (social desire) also belong to this space. Based on the intercorrelation matrix where the mutual relationship of the applied variables is presented, a small number of mutual relations are observed. Statistical significance at the $p<0.05$ level exists between the variables PM (general intelligence) and S1 (spatial relations = .55), F2 (perceptual structures) and N (neuroticism/stability =.51), and E (extraversion/introversion) and (L social desirability =.51), while at the $p<0.01$ level it exists only among the variables TAI (anxiety) and P (psychotism) (= .64).

Table 2. *Correlation of psychological characteristics among representative respondents*

	PM	F1	F2	S1	TAI	P	N	E	L	P2	F+	F-	T-15
PM	1.00												
F1	0.66	1.00											
F2	**0.62**	**0.74**	1.00										
S1	**0.77**	**0.57**	0.37	1.00									
TAI	-0.26	-0.08	-0.31	-0.20	1.00								
P	-0.18	-0.17	-0.27	-0.21	0.42	1.00							
N	-0.41	-0.36	-0.45	-0.37	**0.60**	0.47	1.00						
E	0.15	0.17	-0.15	0.35	0.11	-0.09	0.09	1.00					
L	-0.43	-0.14	-0.25	-0.41	**0.60**	-0.02	**0.73**	0.17	1.00				
P2	0.02	0.09	0.17	0.29	0.41	-0.04	0.01	0.15	0.10	1.00			
F+	-0.10	-0.04	-0.25	0.17	0.25	0.42	0.38	0.48	0.27	0.04	1.00		
F-	**0.52**	0.44	0.25	**0.57**	-0.34	-0.47	**-0.61**	0.44	-0.45	-0.05	-0.32	1.00	
T-15	-0.03	-0.16	-0.27	-0.05	**0.80**	0.36	0.42	0.05	0.37	0.39	0.11	-0.25	1.00

In a sample of 16 respondents, coefficients greater than 0.49 are considered statistically significant at the $p<0.05$ level, and coefficients greater than 0.62 are considered statistically significant at the $p<0.01$ level.

By inspecting Table 2, where the obtained results are presented, it can be observed that the variable PM or general intelligence has a statistically significant positive correlation with the variables from the space of sports intelligence, i.e. perceptual reasoning (F1= .66), the ability to speed up the observation of perceptual structures (F2= .62) and the ability to perform spatial relations (S1= .77). A medium positive connection is observed with the variable (F- =.52) that examines the degree of negative emotional reaction. The three variables that define the space of sports intelligence are interconnected with medium to moderately high positive correlations. Correlation with medium and high values exists with the TAI - anxiety variable: with the neuroticism variable (N= .60), social desire (L= .60), and with the aggressiveness variable (T-15 =.80) with which it is in a statistically significant high positive relationship. The degree of connection of the applied neuroticism/stability variable (N) with the variable L (social desire) from the space of emotional characteristics is .73, which indicates a statistically significant correlation. With the variable F- (which examines the degree of negative emotional reaction in situations of sports achievement) it is in a moderate inverse relationship, which is represented by a coefficient of -.61.

Table 3. *Fisher's Z-test for independent correlations for pairs of variables: F1, PM, F2, S1, TAI, P, and N*

Variable 1	Variable 2	r1 (Group 1)	r2 (Group 2)	Z-Statistic	p-Value
F1	PM	0.42	0.66	-0.88	0.38
F2	PM	0.45	0.62	-0.61	0.54
F2	F1	0.31	0.74	-1.61	0.11
S1	PM	0.55	0.77	-1.02	0.31
S1	F1	0.24	0.57	-1.03	0.30
S1	F2	0.36	0.37	-0.03	0.98
TAI	PM	-0.28	-0.26	-0.06	0.96
TAI	F1	0.33	-0.08	1.08	0.28
TAI	F2	0.14	-0.31	1.18	0.24
TAI	S1	-0.05	-0.20	0.39	0.70
P	PM	-0.17	-0.18	0.03	0.98
P	F1	0.32	-0.17	1.28	0.20
P	F2	0.00	-0.27	0.71	0.48
P	S1	0.36	-0.21	1.50	0.13
P	TAI	0.64	0.42	0.79	0.43

N	PM	0.11	-0.41	1.39	0.16
N	F1	0.03	-0.36	1.04	0.30
N	F2	0.51	-0.45	2.67	**0.01***
N	S1	-0.12	-0.37	0.68	0.49
N	TAI	0.04	0.60	-1.67	0.10
N	P	-0.37	0.47	-2.29	**0.02***

Table No.3 presents the analysis of Fisher's Z-test for two independent correlations for each pair of variables, the Z-statistic that measures the difference between the two correlation coefficients, and the p-value that indicates whether the difference is statistically significant. Statistically significant differences at the level of ($p < 0.05$) are observed only in two pairs of variables: N and F2 ($p = 0.01$) i.e. neuroticism and perceptual structures where in group 1 there is a moderate positive correlation (0.51) which means that as the value of one variable increases, the value of the other variable also increases, while in group 2 we have a moderate negative correlation (-0.45), where the relationship turns negative (as one increases, the other decreases). The other statistically significant relationship is between the pair of variables N and P ($p = 0.02$), neuroticism and psychoticism. In group 1, N and P have a negative relationship (higher N means lower P) and are accompanied by a moderate negative correlation (-0.37). In group 2, the relationship is reversed (higher N means higher P). This relationship is accompanied by a moderate positive correlation (0.47). The statistically significant p-value (0.02) suggests that this change is not due to chance. In their research, Friesen, A., et al. (2018) indicate that there are correlations between performance and perceived congruence in desired and actual emotions. Kostovski, Z., et al. (2019), also examined psychological characteristics as a factor for success in karate athletes and concluded that there are statistically significant differences in the entire examined space except for the variables L and P (L - social desire and P - psychoticism).

Table 4, which is a continuation of Table 3, shows that none of the differences are statistically significant, but some correlations change direction or strength between groups. The most notable trend is between variables L and N, i.e. social desirability and neuroticism, which has a much stronger positive relationship in group 2, and $p = 0.09$, or close to significant. The stronger relationship among national team members, i.e. national team players who show a higher positive correlation between social desirability and neuroticism compared to competitors, may suggest that in the national team, individuals who tend to present themselves in a socially desirable manner may also experience higher levels of neuroticism (e.g., anxiety, emotional instability). Karate competitors who are still developing and are considered younger and less experienced than national team members may not feel the same pressure that allows them to focus more on self-improvement than on social expectations. According to research by Shkelzen S., et al. (2022), younger respondents focused more on developing and improving their competence and putting effort into activities, trying to find a strategy to successfully solve the tasks at hand, and less on achieving results and relying on their abilities.

Table 4. *(continued from Table 3), Fisher's Z-test for independent correlations for pairs of variables: E, L, P2, PM, F1, F2, S1, TAI, P, N*

Variable 1	Variable 2	r1 (Group 1)	r2 (Group 2)	Z-Statistic	p-Value
E	PM	0.27	0.15	0.32	0.75
E	F1	0.03	0.17	-0.36	0.72
E	F2	0.29	-0.15	1.15	0.25
E	S1	0.21	0.35	-0.39	0.70
E	TAI	0.16	0.11	0.13	0.90
E	P	0.15	-0.09	0.62	0.54
E	N	0.22	0.09	0.34	0.73
L	PM	-0.05	-0.43	1.04	0.30
L	F1	-0.06	-0.14	0.21	0.84
L	F2	0.07	-0.25	0.83	0.41
L	S1	-0.23	-0.41	0.51	0.61

L	TAI	0.14	0.60	-1.41	0.16
L	P	-0.05	-0.02	-0.08	0.94
L	N	0.25	0.73	-1.72	0.09
L	E	0.51	0.17	1.00	0.32
P2	PM	0.41	0.02	1.06	0.29
P2	F1	-0.02	0.09	-0.28	0.78
P2	F2	0.16	0.17	-0.03	0.98
P2	S1	0.20	0.29	-0.24	0.81
P2	TAI	0.00	0.41	-1.11	0.27
P2	P	0.31	-0.04	0.92	0.36
P2	N	-0.29	0.01	-0.79	0.43
P2	E	0.23	0.15	0.21	0.83
P2	L	-0.10	0.10	-0.51	0.61

From the inspection of table no. 5 (continued from table no. 3), it is noticed that the largest statistically significant difference (0.00) occurs in the pair of variables aggression and anxiety T-15 and TAI. In competitors, aggression is slightly related to anxiety (r1=−0.19 - weak negative correlation), which may mean that they use aggression as a mechanism for coping with stress. In national team players, r2=0.80 (strong positive correlation), where aggression is highly correlated with anxiety, which suggests that as their anxiety increases, so does their aggressive behavior. Anxiety is associated with impaired cognitive-motor performance and increased release of cortisol, a stress hormone that is associated with poorer physical performance and recovery (Lo, L.C., et al. 2019). Aggression can help control anxiety, which is essential for performance and a key area of focus for psychological support and training, emphasize Valentin et al. (2022).

Table 5. *(continued from Table No. 3) Fisher's Z-test for independent correlations for pairs of variables: F+, F-, T15, PM, F1, F2, S1, TAI, P, N, E, L, P2*

Variable 1	Variable 2	r1 (Group 1)	r2 (Group 2)	Z-Statistic	p-Value
F+	PM	0.28	-0.10	0.99	0.32
F+	F1	0.41	-0.04	1.21	0.23
F+	F2	0.03	-0.25	0.73	0.47
F+	S1	0.41	0.17	0.67	0.50
F+	TAI	-0.02	0.25	-0.70	0.48
F+	P	0.29	0.42	-0.38	0.70
F+	N	-0.38	0.38	-2.04	0.04*
F+	E	-0.17	0.48	-1.77	0.08
F+	L	-0.30	0.27	-1.49	0.13
F+	P2	-0.05	0.04	-0.23	0.82
F-	PM	0.44	0.52	-0.27	0.79
F-	F1	0.23	0.44	-0.61	0.54
F-	F2	0.43	0.25	0.52	0.60
F-	S1	0.03	0.57	-1.57	0.12
F-	TAI	-0.07	-0.34	0.72	0.47
F-	P	-0.16	-0.47	0.89	0.37
F-	N	0.21	-0.61	2.35	0.02*
F-	E	0.03	0.44	-1.13	0.26
F-	L	0.26	-0.45	1.91	0.06
F-	P2	0.36	-0.05	1.09	0.28
F-	F+	-0.21	-0.32	0.30	0.76
T-15	PM	-0.04	-0.03	-0.03	0.98

T-15	F1	-0.40	-0.16	-0.67	0.50
T-15	F2	-0.20	-0.27	0.19	0.85
T-15	S1	0.33	-0.05	1.00	0.32
T-15	TAI	-0.19	0.80	-3.29	**0.00***
T-15	P	-0.20	0.36	-1.48	0.14
T-15	N	0.01	0.42	-1.12	0.26
T-15	E	0.16	0.05	0.28	0.78
T-15	L	-0.18	0.37	-1.45	0.15
T-15	P2	-0.04	0.39	-1.15	0.25
T-15	F+	-0.36	0.11	-1.24	0.21
T-15	F-	-0.20	-0.25	0.13	0.89

The second statistically significant relationship is between the pair of variables F+ and N (0.04), where there is a moderately low correlation for competitors and a moderately positive correlation for national team players. It can be assumed that for competitors, higher positive feelings are associated with lower neuroticism, meaning that they may experience emotional stability when they feel good. In contrast, national team players show the opposite pattern - those with higher positive feelings also tend to have higher neuroticism. This may indicate that national team players experience greater emotional highs and lows, possibly due to the stress and expectations of performing at the level of elite karate athletes. Negative feelings and neuroticism are the third pair of variables where there is significance ($p = 0.02$). For competitors, negative feelings are slightly related to neuroticism (0.21), which is expected. However, among national team players, negative feelings are inversely related to neuroticism, suggesting that those who report fewer negative feelings actually show higher neuroticism (0.80). C., Kuśnierz et al. (2023), recommend introducing emotional intelligence training into martial arts programs to improve mental and emotional resilience, which leads to improved performance results and reduced aggression. According to Faro, H.K., et al. (2020), negative emotions can be more effectively controlled by individuals with higher levels of self-esteem who also show lower levels of somatic and cognitive anxiety. Statistically significant differences appear in the examined psychological characteristics between competitors and national team members, which represent a very good indicator of the existence of a specific psychological structure, relevant to achieving sporting success, and according to which competitors are separated from national team members (Soklevska, I.E., Kostovski, Ž., Alaj.,I. 2018).

Conclusion

Using Fisher's exact method for transformation of the intercorrelation matrices and a calculated Z-test, results were obtained indicating that a statistically significant difference exists only in 5 pairs of the examined variables. These significant results suggest that the relationships between certain variables are dramatically different between the two groups. For example, in the pair of variables L and N, the p-value (0.09) suggests that this difference is not very significant, but indicates a significant psychological trend. Athletes who feel externally controlled or pressured (social desirability, national team expectations) experience higher physiological stress (Self-Determination Theory - SDT), which in this case, matches the findings in national team candidates. It would be interesting to conduct research with this sample of respondents that would measure the level of stress in the blood, how it would affect some psychological characteristics that we consider decisive for success or failure and how is link between psychological traits to physiological reactions.The statistically significant differences in heart rate and blood lactate levels between training and competition (Zaborski, B., et al. 2015), indicate that elite athletes maybe experience substantially higher physiological stress in real competition scenarios. According to the results obtained in the pair T-15 and TAI, it could be said that elite athletes experience stress differently, perhaps feeling greater pressure to perform, which causes both anxiety and aggression. Competitors show more conventional relationships (e.g., negative feelings are related to neuroticism as expected). National team members show more complex and sometimes opposite patterns, possibly due to greater psychological pressure, emotional regulation strategies, or environmental expectations. Key differences in neuroticism and emotional regulation suggest that elite athletes may experience stress and emotional highs and lows differently than competitors.

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Factor Structure of Motor Abilities in Judo Athletes

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Abstract: *Regular judo practice over a long period of time affects the optimal development of athletes, improves the structure of their psychosomatic status, and affects their morphological characteristics and motor skills. This research was conducted on a purposive sample of respondents with the primary aim of determining the factor structure of the motor abilities of judokas, using a cross-sectional model. The sample consisted of members of the wider male judo national team of Serbia, specifically 25 cadet and junior competitors between the ages of 15 and 21, who were in final preparations for the European Championships in Lithuania and EYOF in Hungary. The weight categories included in the study ranged from 50 to 100 kilograms. A total of 9 variables were used to assess the motor abilities of judokas, namely: three variables for assessing repetitive strength (push-ups, bench press and trunk hyperextension), three variables for evaluating explosive strength (vertical jump with arm swing, vertical jump after a drop in depth and bench press) and three variables for evaluating isometric strength (arm dynamometry, isometric back strength and isometric leg strength). By applying factor analysis, orthogonal and Varimax solutions and the Guttman-Kaiser criterion, the structure of the examined motor abilities space was determined, which resulted in the extraction of two dominant factors: a mechanism for regulating the intensity of excitation and a mechanism for regulating the duration of excitation.*

Keywords: *judo national team, cadet and junior competitors, factor structure, motor abilities.*

Introduction

Movements during sports activities, as well as in everyday life, require a high degree of efficiency. These processes aim for greater synchronization, automation, and optimization. Typically, such movements are learned to a certain extent in order to perform the appropriate motor task and represent an appropriate way to achieve the required level of motor ability.

Judo falls into the category of polystructural acyclic activities, which are characterized by alternating periods of high load, such as rapid changes of direction, sudden pauses, and fast reaction times in response to changes in the opponent's movements. This requires not only a strong dynamic stereotype of throws and holds, but also the capacity to efficiently reorganize dynamic stereotypes and constantly create new programs. Due to the complex nature of this sport, young judokas must acquire a high degree of motor skills (Nurkić, M., Bratić, M., Mitić, D., & Kafentarakis, D. 2017). Modern judo requires that the fight progresses in a relatively short period of time, at a very fast pace, and includes a multitude of tactical and technical elements. Judo is characterized by a very large number of techniques and their complexity. Judo is excellent for the development and improvement of almost all physiological systems. It is recommended for all age categories, and even individuals with disabilities successfully practice it (Milošević N, et al. 2012). Judo practice has been linked to several health advantages, including as higher-than-average VO2max, better body composition, higher bone mineral density, and higher bone mineral content (Drid, P., et al 2021). The agonistic nature of judo as a sport contributes, in addition to the development of physical abilities, to the development of psychological abilities such as perseverance, concentration, communication, and control of aggression (Bratić, M. 2003). Regarding the societal importance of judo, it should be emphasized that the sports aspect of judo holds a special significance. Many attractive judo competitions attract significant attention from sports audiences and help recruit new members. In competitive judo, all performances (as well as shortcomings) of an athlete can be highlighted during training and even more so during the actual fight. By becoming familiar with them, athletes can learn to further develop them or, if necessary, correct them. Therefore, in many clubs, the fight is considered the ultimate goal of

training, and all the efforts of coaches and athletes are focused on creating good fighters and achieving sports results. This approach is certainly useful, but it is not sufficient because the significance of judo is much broader and much greater. Judo training is about understanding the true meaning of life through mental and physical attack and defense training (Kostovski, 2017).

Regular practice of judo over a long period of time influences the optimal development of athletes, improves the structure of their psychosomatic status, affects their morphological characteristics and motor abilities, allows for the guidance and control of innate reflex movements, and has a significant impact on all anthropological domains (cognitive, conative, motor, functional, sociological, and health). According to Protić-Gava, B., Drid, P., & Krkeljaš, Ž. (2019) study, young judo athletes outperformed their classmates who did not practice judo in terms of shoulder alignment, chest development, and abdominal wall alignment, as well as improved strength, flexibility, explosive power, and motor coordination.

Materials and Methods of Work

This research was conducted on a deliberate sample of respondents with the primary goal of determining the factor structure of the motor abilities of judokas, using a cross-sectional model. The sample consisted of members of the broader male judo national team of Serbia, specifically 25 cadet and junior competitors who were in their final preparations for the European Championship in Lithuania and the EYOF in Hungary. The respondents were between 15 and 21 years old. The weight categories included in the study ranged from 50 to 100 kilograms. The main criteria for participation in the study were that each respondent had undergone a medical examination, had no health issues in the 10 days preceding the testing, and had no injuries that could affect the test results. The following variables were used to assess the motor abilities of the judokas: For evaluating repetitive strength: Push-ups (PUSH-UPS), Trunk lifts on a bench (ABDOMINAL STRENGTH), and Trunk hyperextension (HYPEREXTENSION). For evaluating explosive strength: Vertical jump with arm swing (CMJ), Vertical jump after depth drop (DJ), and Bench press (BPRES). For evaluating isometric strength: Hand dynamometry (HAND), Isometric back strength (BACK), and Isometric leg strength (LEGS).

The data obtained in this research were processed using several programs based on the characteristics and size of the selected sample. The statistical package SPSS v.20 was used for data processing and analysis. The following measures were calculated for the study: Basic parameters of descriptive statistics for each variable. Verification of result distribution using the following parameters: Mean – arithmetic mean, Std.Dev. – standard deviation, Min. – minimum result, Max. – maximum result, Skew. – symmetry of result distribution, Kurt. – kurtosis of result distribution, K-S – Kolmogorov-Smirnov test, determining the normal distribution of results, Factor analysis, using orthogonal and Varimax rotation with the Guttman-Kaiser criterion to determine structure. H – the first principal component, explaining most of the total variance. λ – eigenvalue explaining the common variance of each isolated principal component. χ^2 – usefulness, indicating the proportion of explained total variance for each variable.

Results and Discussion

For this purpose, the basic descriptive statistical parameters were calculated for all applied variables in the study. These include: Arithmetic mean (X), Standard deviation (SD), Lower and upper range limits (min–max), Coefficient of variability (CV%), Coefficient of skewness (Skew), Kurtosis (Kurt) – measuring the peak or flatness of the distribution, Kolmogorov–Smirnov test (KS) – used to test the normality of distribution.

From Table 1, it can be observed that the skewness values for most motor tests in the initial measurement fall within the recommended range of -1 to +1, indicating that the distribution of results is approximately symmetrical. Positive skewness, or leptokurtosis (a higher concentration of results in the range of better values), was found in the motor test “trunk lifts on a bench” (Sk = 1.63). The kurtosis values (Table 1) show that most motor tests exhibit a flattened distribution (platykurtic distribution). Only the “trunk lifts on a bench” test shows a mesokurtic distribution (Kurt = 3.03).

The calculated coefficients of variability indicate that, in most motor tests, variability remains within normal limits, as the coefficient of variability is below 30%. However, a coefficient of variability above 30% was observed in the following motor tests: Bench press (CV = 31.60), Trunk lifts on a bench (CV = 31.20), Push-ups (CV = 59.19), Trunk hyperextension (CV = 35.07). The highest homogeneity (lowest coefficient of variability) was observed in the isometric leg strength test (CV = 14.13).

Table 1. *Descriptive statistics and normality of distribution of motor tests*

	Mean	Min	Max	SD	KV%	S.E.	Skew	Kurt	max D	K–S
BPRES	1170.62	578.50	1991.40	369.92	31.60	77.13	0.53	-0.36	0.130	p > .20
CMJ	34.05	24.60	48.50	4.92	14.45	1.03	0.83	2.33	0.111	p > .20
DJ	39.76	23.90	48.70	6.30	15.84	1.31	-0.51	0.16	0.087	p > .20
X	34.64	23.49	46.19	4.99	14.40	1.04	0.20	0.56	0.111	p > .20
BACK	1586.52	1224.00	2182.00	236.11	14.88	49.23	0.61	0.47	0.095	p > .20
LEGS	1418.70	1091.00	1834.00	200.46	14.13	41.80	0.09	-0.51	0.086	p > .20
HAND	420.22	326.00	575.00	67.36	16.03	14.05	0.69	-0.11	0.198	p > .20
PUSH-UPS	45.30	25.00	73.00	14.14	31.20	2.95	0.32	-0.73	0.105	p > .20
ABDOM.	105.74	40.00	300.00	62.58	59.19	13.05	1.63	3.03	0.181	p > .20
HYPER.	73.74	32.00	140.00	25.86	35.07	5.39	0.93	0.61	0.183	p > .20

Based on the values of the standard deviation (SD) and its relationship to the arithmetic mean (Mean), it can be concluded that in most motor tests do not exhibit statistically significant deviation of the results from the arithmetic mean.

Table 2. *Intercorrelation matrix of motor tests*

	BPRES	CMJ	DJ	BACK	LEGS	FI ST	PUSH-UPS	ABDOM	HYPEREX.
BPRES	1.00								
CMJ	.72	1.00							
DJ	.53	.63	1.00						
BACK	.48	.36	.53	1.00					
LEGS	.34	.32	.65	.79	1.00				
HAND	.63	.58	.64	.78	.69	1.00			
PUSH-UPS	-.08	-.11	.04	-.02	.27	.06	1.00		
ABDOM.	-.28	-.22	.02	.05	.18	.11	.44	1.00	
HYPEREXT.	-.35	-.13	.23	.06	.27	.09	.52	.62	1.00

The value of the basic central and dispersion parameters of the applied motor tests, in the intervals of the minimum (Min) and maximum (Max) results, contains about four or more standard deviations (SD), based on which a satisfactory sensitivity of most variables can be determined. The results of the Kolmogorov–Smirnov test (Table 1) confirm that all motor tests exhibit a normal distribution.

The intercorrelation matrix (Table 2) illustrates the relationships between various motor tests. This matrix is symmetric, with ones on the diagonal, and is derived from the correlation coefficients between motor test results. The correlation coefficients indicate the degree of association between tests but do not imply causation. In this study, correlation significance was determined at the $p = 0.05$ level.

Key Observations from the Intercorrelation Matrix: A significant number of motor test pairs exhibit strong correlations, while some show weak relationships, and a few have negligible connections. A positive correlation was found between explosive strength tests (vertical jump with arm swing, bench press, vertical jump after depth drop) and isometric strength tests (isometric back strength, isometric leg strength, and hand dynamometry). A positive statistical correlation was also established among repetitive strength tests (trunk lifts on a bench, push-ups, and trunk hyperextension). A low negative correlation was observed between explosive strength tests (bench press and vertical jump) and repetitive strength tests (trunk lifts on a bench and trunk hyperextension). The results of the research conducted by Kostrzewa, M., et al. (2020), on correlation analyses between variables of explosive strength and endurance of the lower and upper extremities in elite male judokas also show positive statistically significant correlations at the $p < 0.05$ level.

By factorizing the intercorrelation matrix in a hyperdimensional space, latent dimensions (principal components) were extracted, explaining the underlying factor structure.

The Guttman–Kaiser criterion was applied to evaluate the significance of these latent dimensions. According to this criterion, only latent dimensions with eigenvalues equal to or greater than one are considered significant.

Results of Factor Analysis: Two principal components were identified, explaining 69.74% of the total variance in the system (Table 4). The first principal component accounts for 43.41% of the total variance and is strongly correlated with explosive and isometric strength tests. The motor tests with the highest projection on the first principal component include: Bench press, Vertical jump with arm swing, Vertical jump after depth drop, Isometric back strength, Isometric leg strength, Hand dynamometry. The second principal component explains 26.33% of the total variance and is primarily associated with repetitive strength tests. The tests with the highest projection on the second principal component include: Push-ups, Trunk lifts on a bench, Trunk hyperextension. These findings suggest that the motor tests used in this study can be grouped into two primary dimensions—explosive/isometric strength and repetitive strength, each contributing significantly to the assessment of judokas' motor abilities.

Table 3. *Characteristic roots and explained parts of the common variance of motor tests*

	Λ	%	Cumulative %
1	3.91	43.41	43.41
2	2.37	26.33	69.74

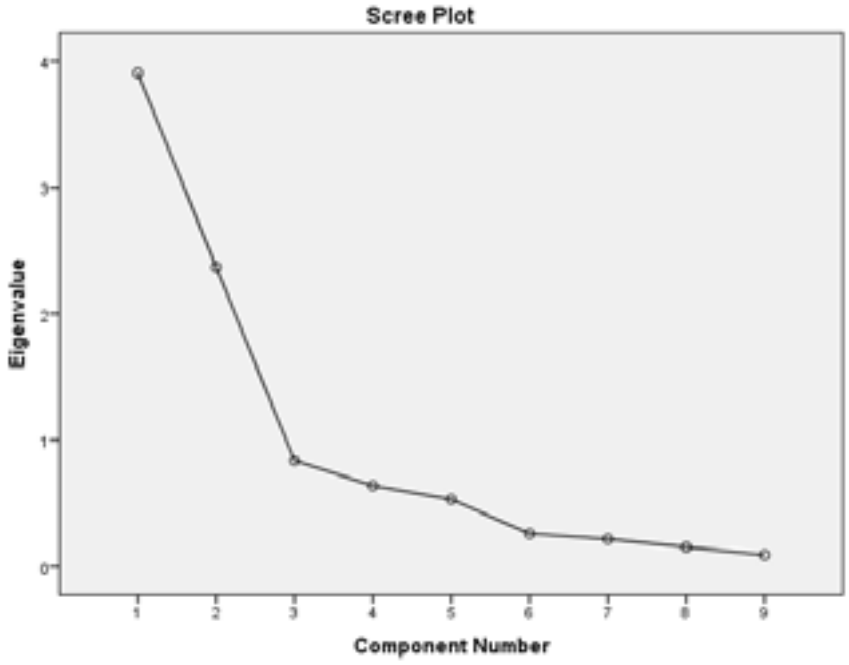

Chart 1.

Table 4. *Hotaling's method of testing main components*

Variables	H1	H2	χ^2
BPRES	.74	-.43	.74
CMJ	.73	-.34	.64
DJ	.83	.07	.69
BACK	.83	.08	.69
LEGS	.80	.34	.76
HAND	.90	.06	.82
PUSH-UPS	.06	.72	.52
ABDOM.	.00	.82	.67
HYPEREX.	.07	.87	.76

To achieve the simplest possible structure, the initial coordinate system was rotated using the Varimax method. This technique enhances the interpretability of factor loadings by maximizing the variance of squared loadings within each factor.

The first latent dimension shows high saturation in motor tests evaluating explosive and isometric strength, with the following loadings: Bench press: (.76), Vertical jump with arm swing: (.74), Vertical jump after depth drop: (.82), Isometric back strength: (.82), Isometric leg strength: (.79), Hand dynamometry: (.90). Among these, the tests with the highest projection (and thus the strongest diagnostic validity for this latent dimension) are: Hand dynamometry: (.90), Vertical jump after depth drop: (.82), Isometric back strength: (.82), Isometric leg strength: (.80).

According to the functional approach in defining motor abilities, the first factor can be interpreted as a mechanism for regulating excitation intensity. This suggests that it represents the ability to generate and sustain high levels of force and power, crucial for athletic performance in judo.

Table 5. *Varimax rotation of motor tests*

Variables	V1	V2
BPRES	**.76**	-.41
CMJ	**.74**	-.31
DJ	**.82**	.10
BACK	**.82**	.10
LEGS	**.79**	.36
HAND	**.90**	.09
PUSH-UPS	.04	**.72**
ABDOM.	-.02	**.82**
HIPEREXT.	.05	**.87**

The second latent dimension exhibits high projections in motor tests that assess repetitive strength, with the following loadings: Push-ups: (.72), Trunk lifts on a bench: (.82), Trunk hyperextension: (.87). Among these, the trunk hyperextension test has the highest projection (.87), making it the most diagnostically valid test for this latent dimension.

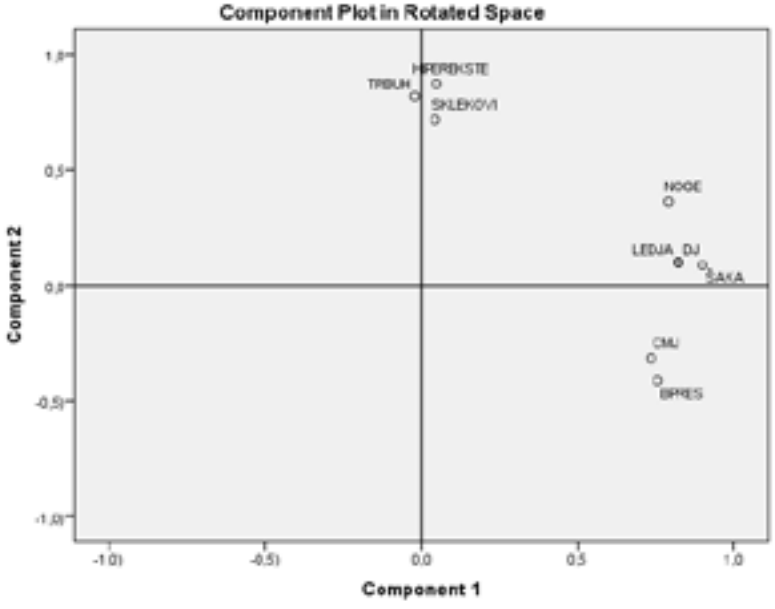

Chart 2.

According to the functional approach in defining motor abilities, the second factor can be described as a mechanism for regulating the duration of excitation. This suggests that it represents the ability to sustain prolonged muscle

contractions, which is essential for endurance-based strength performance in judo. In the context of the obtained results, the research of Zekrin, A., et al. (2024) is also connected, which determined the factor structure of the physical and functional readiness of judokas determined by correlation analysis (Spearman's rank correlation method), according to which the greatest contribution to sports results is made by the factors of speed and strength abilities, endurance, coordination, cardiovascular and respiratory capacities.

Judo is classified as a polystructural acyclic activity, where the final outcome is a binary variable: win or lose. The main goal of training in judo is to perfect the techniques that will be performed in competition against an opponent.

Judo is a sport where the dominant motor abilities include: Balance, Coordination, Strength, Speed, Endurance (Bratić, M. 2003). The complex structure of judo is further influenced by its weight category system, as different categories require specific technical and tactical adaptations, as well as distinct physiological and morphological characteristics (Drid et al., 2012). Additionally, the vast number of techniques and their effective, timely application in combat—which varies depending on the opponent—creates a significant challenge for coaches in defining the key abilities needed for success.

A higher diversity of techniques in a given sport increases the importance of coordination (Lech et al., 2014). This is especially evident in higher weight categories, where, alongside maximum strength, which enables dominance over the opponent, a high level of coordination facilitates the execution of techniques in all directions.

The technical preparation of a judoka involves developing motor habits, including: Throws, Holding techniques, Locks, Chokes, their combinations which are all applied in competitive matches.

During beginner training, judokas learn basic technical elements, while advanced training focuses on refining techniques for real combat scenarios. In this stage, the range of techniques expands significantly, along with the development of motor skills and specific coordination abilities.

The process of refining motor habits follows a structured approach, where technical mastery can be divided into: Basic technical preparation – Forming fundamental motor habits through various technical solutions in controlled conditions. Specialized technical preparation – Developing motor habits under realistic combat conditions, directly linked to tactical execution and focused on achieving optimal performance (Mikić & Redžić, 1995).

A complex set of specific motor exercises has a positive transfer effect on the development of sport-specific motor abilities and judo technique quality. Therefore, coaches are encouraged to integrate these exercises into their training process to enhance performance.

Conclusion

This study follows a transversal model and was conducted on a deliberate sample of elite judo athletes. The research employed appropriate methodological procedures, aligned with the subject, goals, and tasks of the study, with the primary objective of determining the structure of motor abilities (strength) in judokas.

By analyzing previous research on this topic, it is evident that gathering as much relevant information as possible is crucial for providing reliable support to coaching practice. Achieving elite-level performance in judo is possible when the key abilities for success reach their optimal level and are in balanced relationships with one another. Thus, a key research question arises: Which motor abilities are dominant in judokas, and what is their optimal level across different weight categories (Sterkowicz et al., 2011).

Through factor analysis**,** using orthogonal Varimax rotation with the Guttman–Kaiser criterion**,** the structure of the examined motor ability space was determined, resulting in two dominant factors**:** Mechanism for regulating excitation intensity**,** Mechanism for regulating excitation duration

These factors align with the functional approach to defining motor abilities**,** emphasizing how strength and endurance manifest in judo performance.

Objective measurement data not only aid in monitoring, directing, and adjusting the **t**raining process but also serve as a tool for self-assessment of subjective coaching observations. Additionally, the results of this study allow for comparative analysis of motor ability dimensions: Between different sports, between elite athletes and the general population (Lolić & Nurkić, 2012). Also, in the study conducted by Kuvačić, G. et al. (2017), where the motor abilities of Croatian judokas in the cadet age category were tested, it was identified which physical and anthropometric factors contribute most to success in judo: explosive strength, agility and grip strength were the most important discriminators of competitive success.

In judo training, great emphasis is placed on the development of motor abilities, including: strength, speed, coordination, balance, endurance and flexibility.

Although these abilities are likely the most crucial for success in judo combat, determining which one is the most important and should be prioritized in training remains a challenge (Lulzim, 2012).

The study assessed the importance of throwing techniques in relation to key characteristics of judo combat and the applicability of motor abilities. The findings can assist: Coaches in selecting the most effective technical and tactical preparation strategies, Trainers in developing new methodological approaches, and sport scientists in making evidence-based recommendations for optimizing training programs.

Furthermore, the results of this research can aid in rational planning, programming, and organization of judo training**,** providing direct practical contributions to enhancing performance and training efficiency**.**

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Improvement in 50-Meter Freestyle Swimming Speed Following 6 Weeks of Plyometric Training in 12-13 Years Old

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Abstract: *Swimming is a fantastic sport to enjoy at all ages, but increasing swimming speed requires proper training. This research aims to determine the effect of 6 weeks of plyometrics exercise on 50-meter freestyle swimming in the 12-13 age group. This study follows a pre-experimental research design, specifically utilizing a One Group pretest-posttest design. The participants in this research were drawn from the Arwana Swimming Club in Bangkalan, East Java, Indonesia male swimmers aged 12-13 with 20 participants. The Plyometric Training Program was implemented for 6 weeks, scheduled for three days each week. The results obtained from this study indicate a significant value of 0.00, which is less than 0.05. The mean values of the pretest (50.1545) and the posttest (49.264). This conclusion shows that there was an improvement in swimming speed, as evidenced by the lower time recorded in the posttest. Therefore, from this research, 6 weeks of plyometric exercises have a significant effect on the performance of 50-meter freestyle swimming in the 12-13 age group. Consequently, it is recommended that training programs be tailored to address the unique needs of male and female swimmers.*
Keywords: *freestyle swimming, speed, plyometric, 12-13 years old.*

Introduction

Swimming is a fantastic sport that people of all age groups can enjoy (Fadhlillah Aufar et al., 2020; Kattoof, Soni & Vedawala, 2022), popular recreational exercises and sports (Ábel et al., 2022), so swimming is a widely embraced mode of physical exercise (Jakubczyk et al., 2019). Inadequate physical activity stands as a distinct risk factor for a range of illnesses (Purwoto et al., 2024). Hence, examining the efficacy of a particular training approach, such as low volume, high intensity training, holds practical importance in enhancing well-being and averting diseases (Nurmukhanbetova et al., 2023). The psychological advantages of swimming are widely recognized, leading to reduced levels of anger, confusion, depression, and increased vitality following a swim. Mood changes indicate a decrease in swimmers' tension and confusion (Ábel et al., 2022). Swimming is an athletic discipline demanding a combination of muscular strength and sustained endurance (Cañas-Jamett et al., 2020a; Fadhlillah Aufar et al., 2020; Vašíčková et al., 2017). Therefore, when incorporating plyometric exercises into your training regimen, the primary focus should be on enhancing muscle strength while concurrently improving endurance capacities (Krzysztofik et al., 2024; Kumar, 2014; Patel, 2014; Sáez De Villarreal et al., 2021). Other research also explains that enhancing swimming performance can be achieved not solely through in-water, sport-specific training, but also through dry land training, particularly in the form of plyometric jump training (Sammoud et al., 2019).

Plyometric jump training stands as a potent technique for enhancing physical fitness indicators, such as muscle strength and power, while also augmenting sport-specific performance, such as time-trial speed, among athletes in water sports (Ramirez-Campillo et al., 2021; Soni & Vedawala, 2022). Plyometric exercises are specifically crafted to optimize the rapid generation of muscular force within the briefest time frame achievable (Kumar, 2014). Plyometric workouts, being a form of exercise that engages every muscle in an athlete's body, are employed as an efficient approach to boost the power and speed capabilities of athletes (Gencer et al., 2018; Ramirez-Campillo et al., 2020, 2021).

Plyometric training proves to be a highly effective method for enhancing force, which is crucial in swimming for the purpose of augmenting speed (Chen et al., 2023). Plyometric training offers numerous benefits compared to other

dry-land training techniques (Ghosh & Biswas, 2020; Pereira et al., 2023). These advantages encompass the convenience of seamlessly integrating such training into regular training sessions and the cost-effectiveness, as it doesn't necessitate specialized equipment (Hermosilla et al., 2021). Plyometric training enhances vertical jump height, flexibility, and the performance in the 200m swim for adult swimmers who engage in recreational training (Cañas-Jamett et al., 2020b). Plyometrics leads to enhancements in physical fitness, encompassing areas such as vertical jumping ability, sprint speed, muscular strength, and endurance (Sole et al., 2021). In the realm of plyometric training, the experimental group has shown notable enhancements in the performance of the 50-meter backstroke (Kumar, 2014). An 8-week plyometric training program has been observed to significantly improve vertical leap performance. However, it did not exhibit the same impact on parameters such as anaerobic power, 30-meter sprint times, and hand grip strength for both right and left hands, as well as 25 and 50-meter freestyle swimming parameters of male swimmers aged 10-11 years (Gencer et al., 2018). Plyometric training for 6 weeks is effective for improving speed and agility abilities in young beginner swimmers (Soni & Vedawala, 2022). Speed plays a pivotal role in sports, particularly in swimming, as it is imperative during competitions to attain peak performance (Shava et al., 2017). The combination of equal-volume plyometric jump training with regular swimming training has proven to be more effective than solely relying on regular swimming training for improving both jump and swim performances (Sammoud et al., 2021a). The performance of young swimmers is a complex, multifaceted, and continually evolving phenomenon that depends on various factors. So, it is very interesting to study (Morais et al., 2021). Observations at the Arwana Swimming Club in Bangkalan, East Java, Indonesia, indicated that swimming speed has not improved with the current training methods. Additionally, the trainer observed that the athletes were unable to follow the training optimally. Therefore, a new training method is needed at the Arwana Swimming Club in Bangkalan.

The study mentioned above has sparked an ongoing debate. While some argue that plyometric training may influence speed, others contend that its impact is not substantial. Plyometric training for freestyle swimming is still limited. Furthermore, the applicability of plyometric training for swimmers in the 12-13 age group remains uncertain. Hence, the objective of this research is to investigate the impact of a 6-week plyometric training regimen on the performance of 50-Meter Freestyle Swimming in individuals aged 12-13.

Materials and Methods

Participants

The participants in this research were drawn from the Arwana Swimming Club in Bangkalan, East Java, Indonesia. Inclusion criteria for this study encompassed male swimmers aged 12-13, with a minimum of one year of consistent swimming practice. Sample selection was conducted using purposive sampling techniques (Syahza, 2021), adhering to the specified criteria, which yielded a total of 20 participants.

Table 1. *Participants characteristic*

Variables	Test	N	Mean	Std.Deviation
Age	Pretest	20	12.45	0.51
	Posttest	20	12.45	0.51
Weight	Pretest	20	35.69	0.85
	Posttest	20	35.15	2.34
Height	Pretest	20	1.40	0.082
	Posttest	20	1.40	0.082

Experimental approach

This study employs a pre-experimental research design, specifically a one-group pretest-posttest design. This method assesses the impact of an intervention on a single group by measuring outcomes before and after the treatment. Within the scope of this study, a Plyometric Training Program was implemented during 6 weeks (Plyometric Exercise on Table 2) which modifies previous research (Cañas-Jamett et al., 2020b), scheduled for three days each week (specifically on Monday, Wednesday, and Friday) (Gencer et al., 2018), with careful consideration given to rest intervals. This research has been declared ethically acceptable by the STKIP PGRI Bangkalan Ethics Committee with the number 016/C8/6/I/2024.

Table 2. *Plyometric Exercise for 6 Weeks*

Weeks	(Sets and Repetition)	Recovery Time
1-2	20 cm drop jump (2x9)	5 x 60 seconds
	30 cm drop jump (2x9)	5 x 60 seconds
	Long Jump (2x9)	10x20 seconds
3-4	30 cm drop jump (2x9)	5 x 60 seconds
	40 cm drop jump (2x9)	5 x 60 seconds
	Long Jump (2x9)	10x20 seconds
5-6	50 cm drop jump (2x10)	5 x 60 seconds
	60 cm drop jump (2x10)	5 x 60 seconds
	Long Jump (2x10)	10x20 seconds

Statistical Analysis

The primary statistical test used to analyze data from a one-group pretest-posttest design is the paired sample t-test. This test compares the means of the pretest and posttest scores to determine if there is a statistically significant difference. Data analysis for this study included descriptive statistics, normality testing using the Shapiro-Wilk test, and Hypothesis testing was performed using the paired sample t-test, with statistical significance set at $p < 0.05$. All data analyses were conducted using SPSS version 25 (Krzysztofik et al., 2019; Purwoto et al., 2024).

Results

The descriptive sample above explains the age, weight and height of the sample. Mean age on pretest 12,45 years and post test 12,45. Mean weight on pretest 35,69 kg and post test 35,15 kg. Mean height on pretest 1,40 m and posttest 1,4 m. (Table 1)

Table 3. *Descriptive Results*

No	Pre Test	Post Test	Difference
1	45.2	45.1	0.1
2	51.78	51.69	0.09
3	54.33	53.47	0.86
4	48.83	48.31	0.52
5	55.45	54.76	0.69
6	44.33	43.71	0.62
7	47.68	47.58	0.1
8	56.87	55.02	1.85
9	52.03	51.49	0.54
10	48.96	47.96	1
11	48.6	48.48	0.12
12	55.45	54.76	0.69
13	44.4	43.75	0.65
14	47.6	47.51	0.09
15	51.72	50.89	0.83
16	53.78	52.76	1.02
17	48.9	47.23	1.67
18	47.58	45.9	1.68
19	55.4	53.87	1.53
20	44.2	41.04	3.16
Sum	1003.09	985.28	17.81
Mean	50.1545	49.264	0.890
Std.Dev.	4.112	4.161	0.772

The table above presents the results of the pretest and posttest, including the sum, mean, and standard deviation. The mean results are illustrated in the image below:

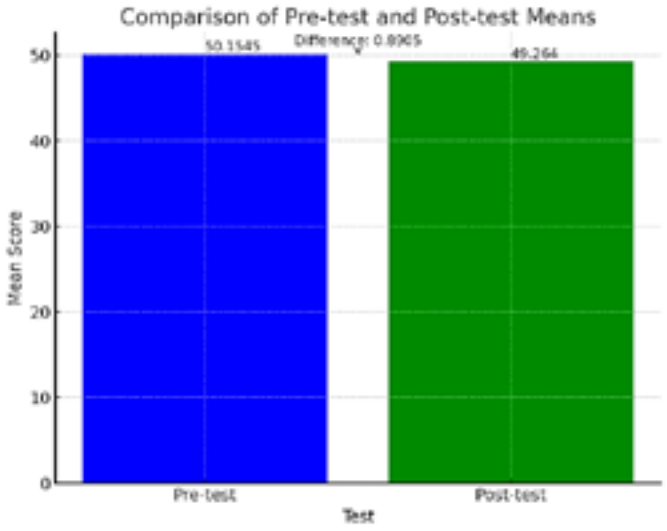

Figure 1. *Pre test and Post test of 50 Meter Freestyle Swimming*

Based on Table 3 and Figure 1, it shows that the post test score is lower than the pretest, this shows that the swimming speed after plyometric training is better than the pretest. Next, the results of the normality test will be presented.

Tabel 4. *Normality Test*

	Shapiro-Wilk		
	Statistic	**df**	**Statistic**
Pretest	0.929	20	0.149
Posttest	0.948	20	0.334

The results of the Shapiro Wilk normality test showed that the data distribution was normal (Sig > 0,05) so that the parametric paired sample test could be continued.

Table 5. *Paired Samples Test*

Pair 1	**Pretest-Posttest**	**Mean**	**Std.Deviation**	**Std. Error Mean**	**Sig. (2-tailed)**
		0.895	0.767	0.176	0.000

The results of the paired sample test show that the significance value is 0.000, this shows that sig 0.000 < 0.05 so there is a significant influence.

Discussion

The findings from this research demonstrate that plyometric training has the potential to enhance the 50-meter freestyle swimming speed in novice swimmers aged 12-13 years. In line with previous research that plyometric training for 6 weeks is effective for improving speed and agility abilities in young beginner swimmers (Soni & Vedawala, 2022). The improvement in swimming speed is likely attributable to the efficacy of the plyometric exercises undertaken. Enhancements in swimming performance may result from an increase in muscle activation in the targeted muscle groups (Rodríguez González et al., 2023). Plyometric exercises induce modifications in muscle power, which are conducive to extending the distance that a swimmer's body can reach before entering the water (Jastrzebski et al., 2014; Pereira et al., 2023). Plyometric training consists of rapid lower body muscle contractions over a short

time frame, involving high velocity eccentric contractions followed by swift concentric contractions. Over a span of several weeks, this training prompts neural adaptations in swimmers, resulting in substantial enhancements in their capacity for greater force production, ultimately contributing to improved speed (Yu Kwok et al., 2021).

The rise in speed for the 50-meter freestyle swim could also be attributed to the appropriateness of plyometric training for the 12-13-year-old participants. This is corroborated by the rationale that plyometric training resulted in a substantial rise in quadriceps muscle thickness, leg muscle volume, and the average cross-sectional area of the thigh in young athletes (Cañas-Jamett et al., 2020b). Enhancements in swimming speed can be attributed to plyometric training, which has the capacity to augment the explosive power of leg muscles, subsequently influencing speed (Wicaksono & Putri, 2020). Between the ages of 10-12, significant distinctions exist among muscle groups, and it is advisable to incorporate the lessons that facilitate skill development. One of these attributes is motor skills, which, in turn, enhances technique and promotes the perception and execution of movements in each lesson (Alin Adrian et al., 2021). This deserves attention, because the sample in this study was 12-13 years old.

Physiologically, six weeks of plyometric training can enhance freestyle swimming speed due to the specific effects of plyometric exercises. Plyometric training stimulates the stretch-shortening cycle (SSC) of the musculotendinous system, which involves an eccentric muscle action followed immediately by a concentric muscle shortening (Sammoud et al., 2021b). The goal of plyometrics is to generate maximal forces in the shortest possible time (Abi et al., 2022). Consequently, plyometrics effectively bridges the gap between strength and speed adaptations (Cañas-Jamett et al., 2020a), leading to improved freestyle swimming speed in the 12-13 age group after six weeks of training.

The training program used in this exercise is effective because it has been shown to increase speed. For the 12-13 age group, training three times a week has led to significant improvements (Demirkan et al., 2023; Gencer et al., 2018). This indicates that the 6-week plyometric training program for this age group is implemented successfully.

Conclusions

Based on the results of the paired sample t-test and the difference between the mean pretest and posttest scores, it can be concluded that six weeks of plyometric training improves the speed of 50-meter freestyle swimming in the 12-13 age group. This study recommends continuing to develop plyometric training to accommodate all swimming styles.

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Differences in Morphological Characteristics and Motoric Abilities Between Boys and Girls From II to V Grades of Elementary School

Razlike u morfološkim karakteristikama i motoričkim sposobnostima između dječaka i djevojčica od II do V razreda

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Abstract: *The research was conducted on a sample of N=1850 students from the 2nd to the 5th grade of elementary school, of which there were N=989 (53%) male respondents and N=861 (47%) female respondents. The research aimed to determine the differences in morphological characteristics and motor abilities between boys and girls from the 2nd to the 5th grade of elementary school. The descriptive statistical method and the t-test for independent samples were applied from the statistical methods. The statistical program for personal computers, SPSS for Windows version 22, was used for data processing. Analyzing the results of morphological characteristics, it was determined that boys have a higher body mass index (BMI) and skin fold on the back (subscapular) than girls. No differences were found in the skin fold of the upper arm (triceps) and the skin folds on the abdomen (suprailiac). Analyzing the results of motor skills, it was determined that boys are better at reaching in a squat (flexibility), lying/squatting (trunk strength), and resisting in a push-up (functional strength). At the same time, girls are better at the standing long jump (explosive leg strength) and hand strength (static strength). All the mentioned tests were statistically significant at the level of less than 1% ($p<0.01$), only the flexion endurance test (functional strength) was statistically significant at the level of $p<0.05$. In the flamingo tests (balance) and running 10x5 m back and forth (running speed and agility), the results were in favor of girls, and in the hand tapping test (movement speed), the results were in favor of boys, but these differences were not statistically significant. It is necessary to act preventively and carry out more frequent tests and measurements of elementary school-aged students to monitor changes in growth and development.*

Keywords: *morphology, motor skills, Eurofit, younger school age, differences.*

Sažetak: *Istraživanje je sprovedeno na uzorku od ukupno N=1850 učenika od II do V razreda osnovne škole, a od toga je bilo N=989 (53%) muških ispitanika i N=861 (47%) ženskih ispitanika. Cilj istraživanja bio je utvrditi razlike u morfološkim karakteristikama i motoričkim sposobnostima između dječaka i djevojčica od II do V razreda osnovne škole. Od statističkih metoda primijenjeni su deskriptivno statistički metod i t-test za nezavisne uzorke. Za obradu podataka korišten je statistički program za personalne računare SPSS za Windows verzija 22. Analizirajući rezultate morfoloških karakteristika utvrđeno je da dječaci u odnosu na djevojčice imaju veći indeks tjelesne mase (BMI) i kožni nabor na leđima (subscapular). Nisu utvrđene razlike u kožnom naboru nadlaktice (triceps) i kožnom naboru na stomaku (suprailiac). Analizirajući rezultate motoričkih sposobnosti utvrđeno je da su dječaci bolji u: dohvatu u sijedu (gipkost), ležanje/sijedu (snaga trupa) i izdržaju u zgibu (funkcionalna snaga), dok su djevojčice bolje u skoku u dalj iz mjesta (eksplozivna snaga nogu) i snazi šaka (statička snaga). Svi navedeni testovi su bili statistički značajni na nivou manjem od 1% ($p<0,01$), samo je test izdržaj u zgibu (funkcionalna snaga) bio statistički značajan na nivou od ($p<0,05$). U testovima flamingo (ravnoteža) i trčanje 10x5m tamo-ovamo (brzina trčanja i agilnost) rezultati su bili u korist djevojčica, a kod testa taping rukom (brzina pokreta) rezultati su bili u korist dječaka ali ove razlike nisu bile statistički značajne. Potrebno je preventivno djelovati na vrijeme i vršiti češća testiranja i mjerenja učenika osnovnoškolskog uzrasta u cilju praćenja promjena rasta i razvoja.*

Ključne riječi: *morfologija, motorika, eurofit, mlađi školski uzrast, razlike.*

Introduction

According to Malina, Bouchard, and Bar-Or (2004), the acquisition of motor skills during childhood is an important developmental task of every child because, through the development of motor skills, the child acquires movement skills, and through movement, the child discovers the world and gains first-hand experiences. How important is the time a child spends doing physical activity, and how does it affect their motor skills? Aaltonen et al. (2015) explain the research results that children with the best coordination are also the most active and that children with motor problems participate less in regular physical activities. The term "motor development" is the association of movement development with age (Aaltonen et al., 2015). Motor (movement) abilities are abilities that participate in solving motor (movement) tasks and are responsible for movement efficiency. Primary motor skills are coordination, balance, precision, speed, strength, and flexibility. Some motor abilities are more and some less innate, that is, genetically conditioned. It is possible to influence certain motor abilities to a greater or lesser extent than others, which depends on the coefficient of innateness of the individual ability, gender, and age. Strength development can be effectively influenced throughout life, while abilities such as speed, coordination, and agility can only be influenced in early childhood. Strength is a motor ability that is 50% genetically determined, and 50% of this significant motor ability is subject to development throughout life. Unlike strength, speed is 80-95% innate, so the influence on speed development is much less possible compared to strength and ranges from 5-20% (Pistotnik, 2003). Motor skills are important for development. Age norms for the assessment of basic motor skills provide useful diagnostics for "typical" development, but cultural differences in child-rearing practices affect the age at which skills are acquired (Adolph and Hoch, 2020). Rodić (2002) investigated the influence of morphological characteristics on the motor skills of students in lower grades of elementary school. The sample of respondents consisted of 430 students (203 boys and 227 girls) in the lower grades of elementary school. Five motor and two morphological variables were used in the research. Regression analysis determined that there are statistically significant relationships between the system of morphological 41 characteristics and motor skills according to the age and gender of students in the lower grades of elementary school. The positive influence of both morphological properties on explosive power type motor ability indicates that the longitudinal dimensionality of the skeleton represents a bio-

Uvod

Prema Malina, Bouchard i Bar-Or (2004) sticanje motoričkih sposobnosti tokom djetinjstva važan je razvojni zadatak svakog djeteta jer kroz razvoj motorike dijete stiče vještine kretanja, a kretanjem dijete otkriva svijet i stiče prva iskustva. Koliko je važno vrijeme koje dijete provede baveći se tjelesnom aktivnošću i kako utiče na motoriku djeteta Aaltonen, i sar. (2015) objašnjavaju rezultatima istraživanja da su djeca s najboljom koordinacijom ujedno i najaktivnija, a da djeca koja imaju problema u motorici manje učestvuju u regularnim tjelesnim aktivnostima. Termin „razvoj motorike" definisan je kao povezanost razvoja pokreta s godinama (Aaltonen i sar., 2015). Motoričke (kretne) sposobnosti su sposobnosti koje učestvuju u rješavanju motoričkih (kretnih) zadataka i odgovorne su za efikasnost kretanja. Primarne motoričke sposobnosti su (koordinacija, ravnoteža, preciznost, brzina, snaga, fleksibilnost). Neke motoričke sposobnosti su više, a neke manje urođene, odnosno genetski uslovljene. Na pojedine motoričke sposobnosti je moguće utjecati u većoj ili manjoj mjeri nego na druge, što zavisi od koeficijenta urođenosti pojedine sposobnosti, spolu i životnoj dobi. Na razvoj snage može se efikasno djelovati tokom cijelog života, dok se na sposobnosti kao što su brzina, koordinacija i gibljivost može utjecati samo u ranom djetinjstvu. Snaga je motorička sposobnost koja je 50% genetski određena, a 50% ove značajne motoričke sposobnosti je podložno razvoju tokom cijelog života. Za razliku od snage, brzina je 80-95% urođena, te je utjecaj na razvoj brzine znatno manje moguć u odnosu na snagu i kreće se u rasponu 5-20% (Pistotnik, 2003). *Motoričke sposobnosti važne su za razvoj. Dobne norme za ocjenu bazičnih motoričkih sposobnosti pružaju korisnu dijagnostiku za "tipičan" razvoj, ali kulturološke razlike u praksama odgoja djece utječu na dob sticanja vještina (Adolph* i Hoch, 2020). Rodić (2002) je istraživao uticaj morfoloških karakteristika na motoričke sposobnosti učenika nižih razreda osnovne škole. Uzorak ispitanika činilo je 430 učenika (203 dječaka i 227 djevojčica) nižih razreda osnovne škole. U istraživanju je korišteno 5 motoričkih i 2 morfološke varijable. Regresionom analizom utvrđeno je da između sistema morfoloških 41 karakteristika i motoričkih sposobnosti prema dobu i spolu učenika nižih razreda osnovne škole postoje statistički značajne relacije. Pozitivan utjecaj oba morfološka svojstva na motoričku sposobnost tipa eksplozivne snage ukazuje da longitudinalna dimenzionalnost skeleta predstavlja biomehaničku osnovu za efikasnu realizaciju nekih motoričkih zadataka, a da se masa ti-

mechanical basis for the efficient realization of some motor tasks. That body mass is determined by active muscle mass. The negative influence of both morphological properties on motor ability, such as static strength, shows the gap in physical development, morphological properties, and motor abilities of children in that period. Pejčić and Malacko (2005). A standard set of four morphological and seven motor variables was applied to a sample of 4,420 students (2,202 boys and 2,227 girls), 7-11 years old. To determine the differences within and outside the groups, the statistical method MANOVA/ANOVA was applied. The results of the research showed that anthropometric and motor variables develop equally and stably in the observed age groups. Motor variables in boys and girls increase equally through defined ages (grades 1-4). Boys achieved better results in the following variables: hand tapping, standing long jump, back squats, squats in 60 seconds, squat height, and aerobic endurance test F3-running for 3 minutes. Girls achieved better results only in the variable of flexibility, deep bending. Physical activity plays a key role in a child's physical development (C., Dapp et al., 2021). The World Health Organization, as an umbrella organization that controls various segments of health status based on certain indicators, recommends daily movement for 60 minutes at a moderate to intense pace to suppress the effects of a sedentary lifestyle successfully, but also to influence the development of basic motor skills. Thanks to the positive health effects of physical exercise, physical education is an integral part of the educational system, with two lessons a week, which is insufficient to achieve the optimal effect in transforming the anthropological status of children (Nikšić et al., 2019a). Success in any sport depends on anthropological characteristics and abilities, as well as their mutual connection (Nikšić et al., 2019b). The need for physical exercise is one of the general biological needs of the organism and plays an important role in its life. The connection of physical activity with the state of human health is indisputable; it is the basic factor in determining the level of changes in the organism and the state of its bones, muscles, cardiovascular, and nervous systems. The process of physical exercise leads to certain transformations and improvements in functional abilities and individual organ systems (Nikšić et al., 2019c). Morphology/anthropometry is important in every sport, based on which athletes are selected for a particular sport. In any sport, success is determined by analyzing various interconnected anthropological dimensions (Nikšić et al., 2020b).

jela determiniše aktivnom mišićnom masom. Negativan utjecaj oba morfološka svojstva na motoričku sposobnost, tipa statičke snage, pokazuje raskorak u tjelesnom razvoju, morfološkim svojstvima i motoričkim sposobnostima djece u tom razdoblju. Pejčić i Malacko (2005). Standardna garnitura od četiri morfološke i sedam motoričkih varijabli bila je primijenjena na uzorku 4.420 učenika (2.202 dječaka i 2.227 djevojčica), 7-11 godina starosti. Da bi se utvrdile razlike unutar i izvan grupa, primijenjena je statistička metoda MANOVA/ANOVA. Rezultati istraživanja pokazali su da se antropometrijske i motoričke varijable razvijaju jednako i stabilno u posmatranim starosnim grupama. Motoričke varijable kod dječaka i djevojčica podjednako se povećavaju kroz definisane uzraste (1-4 razred). Dječaci su postigli bolje rezulate u slijedećim varijablama: taping rukom, skok u dalj iz mjesta, poligon natraške, čučnjevi u 60 sekundi), vis u zgibu, i test aerobne izdržljivosti F3-trčanje 3 minute. Djevojčice su postigle bolje rezultate samo u varijabli fleksibilnosti – duboki pretklon. *Fizička aktivnost igra ključnu ulogu u fizičkom razvoju djeteta (C., Dapp. et al., 2021).* Svjetska zdravstvena organizacija, kao krovna organizacija koja kontroliše različite segmente zdravstvenog statusa, na osnovu određenih pokazatelja preporučila je svakodnevno kretanje u trajanju od 60 minuta, umjerenim do intenzivnim tempom, kako bi potiskivanje efekata sedentarnog načina života bilo uspješno, ali da se ujedno utječe i na razvijanje bazičnih motoričkih sposbnosti. *Zahvaljujući pozitivnim zdravstvenim efektima fizičkog vežbanja, fizičko vaspitanje je sastavni dio obrazovnog sistema, sa dva časa sedmično, što je nedovoljno za postizanje optimalnog efekta u transformaciji antropološkog statusa djece (Nikšić et al., 2019a).* Uspjeh u bilo kojem sportu, zavisi od antropoloških karakteristika i sposobnosti, kao i njihove međusobne povezanosti (Nikšić i sar., 2019b). Potreba za fizičkim vježbanjem jedna je od općih bioloških potreba organizma i igra važnu ulogu u njegovom životu. Veza fizičke aktivnosti sa stanjem ljudskog zdravlja je neosporna, ona je osnovni faktor u određivanju nivoa promjena u organizmu i stanju njegovih kostiju, mišića, kardiovaskularnog i nervnog sistema. Proces fizičkog vježbanja dovodi do određenih transformacija i poboljšanja funkcionalnih sposobnosti i pojedinih organskih sistema (Nikšić i sar., 2019c). Morfologija/antropometrija je važna u svakom sportu, na osnovu čega se biraju i sportisti za određeni sport. U bilo kojem sportu uspjeh se određuje analizom različitih međusobno povezanih antropoloških dimenzija (Nikšić i sar., 2020b).

Material and Methods

Participants

The research included a sample of N=1850 students from II to V grades of elementary school, of which 989 (53%) were male respondents and 861 (47%) were female respondents. The research included students from a total of 8 elementary schools, i.e., one school from each municipality at the level of Sarajevo Canton. In each school, two classes of the same generation were included using a random sample of respondents.

The sample of variables

The anthropometric variables used for this research are Body Height (BH), Body Weight (BW), Body Mass Index (BMI), upper arm skin fold - triceps, back skin fold - subscapular, and abdominal skin fold - suprailiac. Body composition was measured with the InBody120 Body Mass Analyzer (Aandstad, Holtberget, Hageberg, Holme, & Anderssen, 2014). The variables that were used to assess basic motor skills are the variables that were taken from the Eurofit battery of tests, namely: Flamingo (balance), Taping with the hand (speed of movement), Reach in gray (flexibility), Long jump from a standing position (explosive leg strength), Hand strength (static strength), Lying down (trunk strength), Push-up endurance (functional strength), Running 10x5 meters back and forth (running speed and agility).

Research Desing

Anthropometric variables were measured according to standard procedures of the International Society for the Advancement of Kinanthropometry (ISAK) (Marfell-Jones et al. 2006). Based on the variables BH and BW, BMI [BMI = BH (kg) / BW (cm^2 ^{2}] was calculated. BMI values for both subsamples were classified into four nutritional levels, according to the recommendations of the Centers for Disease Control and Prevention 2000 (Kuczmarski et al., 2000).

Statistical Analaysis

Of the statistical methods, descriptive statistics was applied. Statistical processing of the data in this research was done using the computer software SPSS Statistics 20.0 in the Windows 10 operating system. The statistical program for personal computers, SPSS for Windows version 22, was used for data processing.

Materijal i Metod

Uzorak ispitanika

Istraživanjem je obuhvaćen uzorak od N=1850 učenika od II do V razreda osnovne škole, od čega je bilo 989 (53%) ispitanika muškog spola i 861 (47%) ispitanika ženskog spola. Istraživanjem su obuhvaćeni učenici iz ukupno 8 osnovnih škola, odnosno po jedna škola iz svake opštine na nivou Kantona Sarajevo. U svakoj školi metodom slučajnog uzorka ispitanika su obuhvaćena po dva razreda iste generacije.

Uzorak varijabli

Antropometrijske varijable koje su korištene za ovo istraživanje su: tjelesna visina, tjelesna masa, indeks tjelesna mase (BMI), kožni nabor nadlaktice – triceps, kožni nabor leđa – subscapular, kožni nabor stomaka – suprailiac. Tjelesna kompozicija mjerena je Analizatorom tjelesne mase InBody120 (Aandstad i sar., 2014). Varijable koje su korištene za procjenu bazičnih motoričkih sposobnosti su varijable koje su uzete iz kartona eurofit baterije testova, a to su: Flamingo (ravnoteža), Taping rukom (brzina pokreta), Dohvat u sijedu (gipkost), Skok u dalj iz mjesta (eksplozivna snaga nogu), Snaga šaka (statička snaga), Ležanje sijed (snaga trupa), Izdržaj u zgibu (funkcionalna snaga), Trčanje 10x5 metara tamo-ovamo (brzina trčanja i agilnost).

Dizajn istraživanja

Antropometrijske varijable su mjerene prema standardnim procedurama Međunarodnog društva za unapređenje kinantropometrije (ISAK) (Marfell-Jones i sar. 2006). Na osnovu varijabli tjelesne visine i tjelesne mase, izračunat je indeks tjelesne mase - BMI [BMI = BH (kg) / BW (cm^2]. Vrijednosti BMI za oba poduzorka su klasifikovane u 4 nutritivna nivoa, prema preporukama Centra za kontrolu i prevenciju bolesti, 2000. (Kuczmarski i sar., 2000.)

Statistical Analaysis

Od statističkih metoda primijenjena je deskriptivna statistika i i t-test za nezavisne uzorke. Statistička obrada podataka u ovom istraživanju rađena je pomoću kompjuterskog softvera SPSS statistics 20.0 u operativnom sistemu Windows 10. Za obradu podataka korišten je statistički program za personalne računare SPSS za Windows verzija 22.

Results

Table 1. *Differences in Body Mass Index (BMI) between boys and girls from 2nd to 5th grade of primary school – Descriptive statistics, t-test*

Varijables / Varijable	*Gender /* Spol	*Mean ± Std.Dev.*	*t-test*	
			t-value	*p*
Body Mass Index (kg/m²)	♂ / M	18.68 ± 4.01	16.07	0.00 **
	♀ / Ž	18.09 ± 3.68	13.52	
Triceps (mm)	♂ / M	12.87 ± 6.36	39.27	0.09
	♀ / Ž	13.96 ± 5.90	34.83	
Subscapular (mm)	♂ / M	11.00 ± 7.54	53.40	**0.04 ***
	♀ / Ž	11.49 ± 7.24	52.39	
Suprailiac (mm)	♂ / M	14.36 ± 8.91	79.37	0,97
	♀ / Ž	14.38 ± 8.18	66.89	

Legend: *male – ♂; female – ♀; mean – arithmetic mean; std. Dev. (standard deviation p-level of significance; * t-test is statistically significant at the level of less than 5%; ** t-test is statistically significant at the less than 1% level.*

Analyzing the results shown in Table 1, we can notice that there are statistically significant differences between boys and girls from II to V grades of elementary school in Body Mass Index (BMI) and skinfold on the back (subscapular). No differences were identified in the triceps and suprailiac folds.

Table 2. *Frequencies and percentage values of BMI by category by gender for students from II to V grades of elementary school*

Nutritional status / Status uhranjenosti	*Boys /* Dječaci	*Percentiles*	*%*	*Girls /* Djevojčice	*Percentiles*	*%*
Obesity / Gojaznost	19	≥95	1.92	6	≥95	0.70
Overweight / Prekomjerna uhranjenost	67	85-95	6.77	48	85-95	5.57
Normal weight / Normalna uhranjenost	338	5-85	34.18	269	5-85	31.24
Malnutrition / Neuhranjenost	565	<5	57.13	538	<5	62.49
Total / Ukupno	989		100.0	861		100,0

Table 2 shows the values for the BMI variable, based on which it is possible to see the state of nutrition of students from the 2nd to the 5th grade of elementary school according to gender and level of nutrition. Looking at boys and girls separately, it can be noted that obesity and overnutrition are more prevalent in boys than in girls. Out of a total of 989 (53.46%) boys, 19 of them belong to the category of obese, 67 boys to the category of excessive nutrition, 338 boys are normally nourished, and 565 boys are malnourished. Out of a total of 861 (46.54%) girls, 6 of them belong to the category of obese, 48 girls to the category of excessive nutrition, 269 girls

Rezultati

Tabela 1. *Razlike u indeksu tjelesne mase (BMI) i kožnim naborima između dječaka i djevojčica od II do V razreda osnovne škole – Descriptive statistic*

Varijables / Varijable	*Gender /* Spol	*Mean ± Std.Dev.*	*t-test*	
			t-value	*p*
Body Mass Index (kg/m²)	♂ / M	18.68 ± 4.01	16.07	0.00 **
	♀ / Ž	18.09 ± 3.68	13.52	
Triceps (mm)	♂ / M	12.87 ± 6.36	39.27	0.09
	♀ / Ž	13.96 ± 5.90	34.83	
Subscapular (mm)	♂ / M	11.00 ± 7.54	53.40	**0.04 ***
	♀ / Ž	11.49 ± 7.24	52.39	
Suprailiac (mm)	♂ / M	14.36 ± 8.91	79.37	0,97
	♀ / Ž	14.38 ± 8.18	66.89	

Legenda: *M - muško; Ž - žensko; Mean – aritmetička sredina; Std. Dev. – standardna devijacija p-razina značajnosti; * t-test je statistički značajan na nivou manjem od 5%; ** t-test je statistički značajan na nivou manjem od 1%*

Analizirajući rezultate prikazane u tabeli 1, možemo primjetiti da postoje statističi značajne razlike između dječaka i djevojčica od II do V razreda osnovne škole u indeksu tjelesne mase (BMI) i kožnom naboru na leđima (subscapular). Nisu identificirane razlike u kožnom naboru nadlaktice (triceps) i kožnom naboru na stomaku (suprailiac).

Tabela 2. *Učestalosti i procentualne vrijednosti BMI po kategorijama prema spolu za učenike od II do V razreda osnovne škole*

Nutritional status / Status uhranjenosti	*Boys /* Dječaci	*Percentiles*	*%*	*Girls /* Djevojčice	*Percentiles*	*%*
Obesity / Gojaznost	19	≥95	1.92	6	≥95	0.70
Overweight / Prekomjerna uhranjenost	67	85-95	6.77	48	85-95	5.57
Normal weight / Normalna uhranjenost	338	5-85	34.18	269	5-85	31.24
Malnutrition / Neuhranjenost	565	<5	57.13	538	<5	62.49
Total / Ukupno	989		100.0	861		100,0

U tabeli 2., prikazane su vrijednosti za varijablu BMI, na osnovu kojih je moguće sagledati stanje uhranjenosti učenika od II do V razreda osnovne škole prema spolu i nivou uhranjenosti. Posmatrajući odvojeno dječake i djevojčice, može se primijetiti da su gojaznost i prekomjerna uhranjenost zastupljeniji kod dječaka, nego kod djevojčica. Od ukupno 989 (53.46%) dječaka, njih 19 spada u kategoriju gojaznih, 67 dječaka u kategoriju prekomjerne uhranjenostti, 338 dječaka je normalno uhranjeno, dok je 565 dječaka neuhranjeno. Od ukupno 861 (46.54%) djevojčica, njih 6 spada u kategoriju gojaznih, 48 djevojčica u kategoriju prekomjerne uhranjenosti, 269

are normally nourished, and 538 girls are malnourished. Today's big problem is not only obesity in children but also the most prevalent malnutrition.

djevojčica je normalno uhranjeno, dok je 538 djevojčica neuhranjeno. Veliki problem današnjice nije samo gojaznost kod djece, već i pothranjenost koja je bila najviše zastupljena kod učenika od II do V razreda osnovne škole.

Table 3. *Differences in motor abilities between boys and girls from II to V grades of primary school – Descriptive statistics, t-test*

Tabela 3. *Razlike u motoričkim sposobnostima između dječaka i djevojčica od II do V razreda osnovne škole – Descriptive statistic, t-test*

Variables / **Varijable**	***Gender /*** ***Spol***	***Mean ± Std.Dev.***	***t-test***	
			t-value	***p***
Balance / Ravnoteža	♂ / M	00:11:40 ± 0.01	0.000182	0.23
Flamingo / Flamingo	♀ / Ž	00:12:45 ± 0.01	0.000180	
Movement speed / Brzina pokreta	♂ / M	00:18.23 ± 0.02	0.000405	0,60
Typing by hand / Taping rukom	♀ / Ž	00:17:51 ± 0.01	0.000075	
Flexibility / Gipkost	♂ / M	5.89 ± 9.19	84.49	**0.00 ****
Reach in gray / Dohvat u sijedu	♀ / Ž	10.92 ± 10.99	120.70	
Explosive leg power / Eksplozivna snaga nogu	♂ / M	130.25 ± 27.72	768.32	**0.00 ****
Standing long jump / Skok u dalj iz mjesta	♀ / Ž	122.01 ± 24.91	620.68	
Static power / Statička snaga	♂ / M	15.21 ± 5.24	27.46	**0.00 ****
Fist strength / Snaga šaka	♀ / Ž	14.18 ± 6.41	41.05	
Troop strength / Snaga trupa	♂ / M	17.89 ± 5.18	26.81	**0.00 ****
Lying gray / Ležanje sijed	♀ / Ž	16.59 ± 5.30	28.05	
Functional strength / Funkcionalna snaga	♂ / M	00:18:51 ± 0.01	0.000170	**0.03 ***
Push-up endurance / Izdržaj u zgibu	♀ / Ž	00:17:01 ± 0.01	0.000138	
Running speed and agility / Brzina trčanja i agilnost	♂ / M	00:34:24 ± 0.08	0.00670	0,70
Running 10x5 m back and forth / Trčanje 10x5m tamo-ovamo	♀ / Ž	00:32:25 ± 0.07	0.00547	

Legend: *male – ♂; female – ♀; mean – arithmetic mean; std. Dev. – standard deviation; p – significance level; * t – the test is statistically significant at the less than 5% level; ** t - the test is statistically significant at the less than 1% level.*

Legenda: *Mean – aritmetička sredina; Std. Dev. – standardna devijacija; p-razina značajnosti; * t-test je statistički značajan na nivou manjem od 5%; ** t-test je statistički značajan na nivou manjem od 1%*

Analyzing the results shown in Table 3, it is noticeable that there are certain differences in motor abilities between boys and girls from II to V grades of elementary school. Analyzing the results of the t-test, it was determined that there are statistically significant differences in the following tests: reaching in a squat (flexibility), lying in a squat (trunk strength), and standing in a squat (functional strength) in favor of boys, and long jump from a standing position (explosive strength legs) and hand strength (static strength) in favor of girls. All the mentioned tests were statistically significant at the level of less than 1% ($p<0.01$), only the flexion endurance test (functional strength) was statistically significant at the level of less than ($p<0.05$). In the flamingo tests (balance) and running 10x5 m back and forth (running speed and agility), the results were in favor of girls, and in the hand tapping test (movement speed), the results were in

Analizirajući rezultate prikazane u tabeli 3, uočljivo je da postoje izvjesne razlike u motoričkim sposobnostima između dječaka i djevojčica od II do V razreda osnovne škole. Analizom rezultata t-testa utvrđeno je da postoje statistički značajne razlike u sljedećim testovima: dohvat u sijedu (gipkost), ležanje sijed (snaga trupa) i izdržaj u zgibu (funkcionalna snaga) u korist dječaka, a skok u dalj iz mjesta (eksplozivna snaga nogu) i snaga šaka (statička snaga) u korist djevojčica. Svi navedeni testovi su bili statistički značajni na nivou manjem od 1% ($p<0,01$), samo je test izdržaj u zgibu (funkcionalna snaga) bio statistički značajan na nivou manjem od ($p<0,05$). U testovima flamingo (ravnoteža) i trčanje 10x5m tamo-ovamo (brzina trčanja i agilnost) rezultati su bili u korist djevočica, a kod testa taping rukom (brzina pokreta) rezultati su bili u korist dječaka i ove razlike nisu bile statistički značajne. Rezultati testa dohvat u si-

favor of boys, and these differences were not statistically significant. The results of the gray reach test (flexibility) were in favor of boys, although girls were expected to do better because they are considered to be more flexible than boys, which is confirmed by numerous studies. The differences were relatively small, but it should not be ignored that the total number of boys was higher by 128 respondents compared of girls.

Discussion

There are differences between children depending on their capabilities and abilities, as well as their gender. Any additional sports activity leads to a certain transformation of the morphological and motor status. The most important thing is to adapt a certain sports activity to the age at which it is practiced so that this activity affects the transformation of students (Rašidagić et al., 2000). Balance and precision are the least monitored of motor skills in classroom teaching due to a lack of time. There is a whole series of research on the anthropological characteristics of students, both in BiH, Croatia, and abroad. Research is of various types and for various purposes. Investigating gender differences in the condition of motility by hereditary factors, it was concluded that genetic factors are more pronounced in females (Mikić, 2000). Pejčić (2001) researched 655 students from the 1st to 4th grade. The students were examined in 4 morphological variables and six motor variables (long jump, 20 m sprint, stand-up with a pull-up, lifting the trunk, and the backstroke polygon). The conclusion is that girls have better results only in mobility, and that physical activity, i.e., sports, can affect changes in morphological characteristics and motor skills. The development of motor skills should be the key to development in childhood, which will continue later and in adolescence (Barnett et al., 2008). In the physical development of children of younger school age between the ages of 9 and 11, the ratio of body mass and body height is favorable (Nićin and Stjepić, 2008), so probably because of this fact, there are no statistically significant differences between boys and girls in basic morphological variables. Fewer changes occur in the body, and the amount of muscle mass lags significantly less about body weight, children are not durable and strong enough, so it is likely that the differences that occurred between boys and girls in the strength of the arms and shoulder girdle are the result of a greater number individuals who are at a higher level in this motor ability. Krsmanović and Radosav (2008) state that boys are more dominant in tests of strength and running speed, and girls in tests of flexibility. Transversal research (Prskalo et al., 2009) on a sample of 128 male and 117 female students from the 1st to 3rd grade of primary school, divided into subsamples

jedu (gipkost) su bili u korist dječaka, iako se očekivalo da djevojčice budu bolje, jer se smatra da su fleksibilnije od dječaka, što potvrđuju i brojna istraživanja. Razlike su bile relativno male, ali ne treba zanemariti da je ukupan broj dječaka bio veći za 128 ispitanika u odnosu na djevojčice.

Diskusija

Postoje razlike između djece u zavisnosti od njihovih individualnih mogućnosti i sposobnosti, kao i samog spola. Bilo koja dodatna sportska aktivnost dovodi do određene transformacije morfološkog i motoričkog statusa. Najbitnije je određenu sportsku aktivnost prilagoditi uzrastu sa kojim se radi, kako bi ta aktivnost utjecala na transformaciju učenika (Rašidagić et al., 2000). U razrednoj nastavi od motoričkih sposobnosti se najmanje prate ravnoteža i preciznost, zbog nedostatka vremena. Postoji čitav niz istraživanja antropoloških obilježja učenika, kako u BiH, Hrvatskoj, tako i u inozemstvu. Istraživanja su razne vrste i raznih ciljeva. Istražujući spolne razlike u uslovljenosti motorike nasljednim faktorima, zaključeno je da su genetski faktori više izraženi kod ženskog pola (Mikić, 2000). Pejčić (2001) istražuje 655 učenika od 1. do 4. razreda. Učenici su ispitani u 4 morfološke varijable i 6 motoričkih (skok u dalj, 20 m sprint, izdržaj u visu zgibom, podizanje trupa i poligon natraške). Zaključak je da djevojčice imaju bolje rezultate samo u gibljivosti i da tjelesna aktivnost, odnosno sport mogu uticati na promjene morfoloških karakteristika i motoričkih sposobnosti. Razvoj motoričkih sposobnosti treba da bude ključ razvoja u detinjstvu, koji će se nastaviti kasnije i u adolesenciji (Barnett i sar., 2008). U tjelesnom razvoju djece mlađeg školskog uzrasta između 9. i 11. godine, povoljan je odnos tjelesne mase i tjelesne visine (Nićin i Stjepić, 2008), pa vjerovatno zbog te činjenice i ne postoje statistički značajne razlike između dečaka i djevojčica u osnovnim morfološkim varijablama. U organizmu se dešavaju nešto manje promjene, a količina mišićne mase znatno manje zaostaje u odnosu na težinu tijela, te djeca nisu dovoljno izdržljiva i snažna, pa su vjerovatno razlike koje su se javile između dječaka i djevojčica u snazi ruku i ramenog pojasa rezultat većeg broja pojedinaca koja su na višem nivou u ovoj motoričkoj sposobnosti. Krsmanović i Radosav (2008), navode da su dječaci dominantniji u testovima snage i brzine trčanja, a dejvojčice u testovima gipkosti. Transverzalno istraživanje (Prskalo et al., 2009) na uzorku od 128 učenika i 117 učenica od 1. do 3. razreda osnovne škole podijeljenih na subuzorke po dobi i spolu istraženo je u 19 antropometrijskih varijabli i 12 motoričkih varijabli (koraci u stranu, poligon

by age and gender, was investigated in 19 anthropometric variables and 12 motor variables (steps to the side, polygon backbends, various bends, bends on the bench, hand tapping, hand tapping 10'', foot tapping on the wall, long jump from a standing position, standing high with a pull-up, raising the trunk and high jump). The conclusion is that the results of motor skills do not show statistically significant differences, justifying the joint organization of work for boys and girls from the 1st to the 3rd grade of elementary school. The research was conducted on a sample of 400 students of early school age. In most motor skills, boys are better than girls. A higher level of motor skills in boys is due to a faster flow of impulses from the cerebral cortex to the effectors in the muscles. Each newly learned activity enriches the motor skills of a child at a younger school age, which is particularly reflected in their general motor ability (Lončar, 2011). On a sample of 324 respondents aged 6 to 11, the authors investigated the difference in motor skills between boys and girls. To assess motor skills, 14 field tests were applied that tested aerobic and anaerobic endurance, flexibility, repetitive strength, explosive strength, speed, agility, balance, and maximal isometric strength. Boys proved to be dominant and statistically significantly better than girls in aerobic and anaerobic endurance, speed, agility, explosive strength, and maximal isometric strength. Girls are statistically significantly better in flexibility and balance (Marta et al. 2012). On a total sample of 568 subjects, of which 273 were boys and 295 were girls, the authors investigated the differences in motor abilities between boys and girls in the fourth and fifth grades of elementary school. Tests were applied that measured speed, where boys in both classes showed statistically significantly better results. In the fourth grade, girls showed better results in bending forward and sitting, and, with that, better flexibility. The boys had the repetitive strength of the abdominal muscles and showed better results in both classes. Boys in both classes showed better results in long jump tests to assess explosive strength and hand grip to assess maximal isometric strength (Flanagan et al., 2012). The results showing that boys achieve better results in most motor tests can be explained by the different habits of boys and girls of the same age. Boys are still playing outdoors, running and eager for outdoor games, practicing various ball games (soccer and many other games), and climbing trees, imitating their cartoon heroes, where static and explosive arm strength and speed dominate running, longer physical activities. The different life habits of children of different sexes can affect the existence of differences in the manifestation of motor skills. Such results may have been influenced by the environment (physical activity of children), the genetic potential of boys to achieve success in

natraške, pretklon raznožno, pretklon na klupi, taping rukom, taping rukom 10'', taping nogom o zid, skok u dalj s mjesta, izdržaj u visu zgibom, podizanje trupa i skok u vis). Zaključak je da rezultati motoričkih sposobnosti ne pokazuju statistički značajne razlike opravdavajući zajedničku organizaciju rada za dječake i djevojčice od 1. do 3. razreda osnovne škole. Istraživanje provedeno je na uzorku od 400 učenika rane školske dobi.

U većini motoričkih sposobnosti dječaci su bolji od djevojčica. Viši nivo motoričkih sposobnosti kod dječaka uslovljen je bržim protokom impulsa od kore velikog mozga ka efektorima u mišićima. Svaka nova naučena aktivnost bogati motoriku djeteta u mlađem školskom uzrastu, što se posebno odražava na njegovu generalnu motoričku sposobnost (Lončar, 2011). Na uzorku ispitanika od 324 ispitanika u dobi od 6 do 11 godina autori su istražili razliku u motoričkim sposobnostima između dječaka i djevojčica. Za procjenu motoričkih sposobnosti primijenjeno je 14 terenskih testova koji testiraju aerobnu i anaerobnu izdržljivost, fleksibilnost, repetitivnu snagu, eksplozivnu snagu, brzinu, agilnost, ravnotežu i maksimalnu izometričku snagu. Dječaci su se pokazali dominantni i u rezultatima statistički značajno bolji od djevojčica u aerobnoj i anaerobnoj izdržljivosti, brzini, agilnosti, eksplozivnoj snazi i maksimalnoj izometrijskoj snazi. Djevojčice su statistički značajno bolje u fleksibilnosti i ravnoteži (Marta i sar. 2012). Na ukupnom uzorku od 568 ispitanika, od kojih su 273 dječaka i 295 djevojčica, autori su istraživali razlike u motoričkim sposobnostima između dječaka i djevojčica u četvrtom i petom razredu osnovne škole. Primijenjeni su testovi koji su mjerili brzinu gdje su dječaci u oba razreda pokazali statistički značajno bolje rezultate. U četvrtom razredu su djevojčice pokazale bolje rezultate u pretklonu i sjedu, te s tim bolju fleksibilnost. Repetitivnu snagu trbušne muskulature imali su dječaci i pokazali su u oba razreda bolje rezultate. U testovima skok udalj za procjenu eksplozivne snage i stisak šake za procjenu maksimalne izometričke snage su dječaci u oba razreda pokazali bolje rezultate (Flanagana i sar., 2012). Rezultati koji pokaju da dječaci postižu bolje rezultate u većini motoričkih testova mogu se objasniti drugačijim navikama dječaka i djevojčica istog uzrasta. Dječaci se i dalje igraju na otvorenom prostoru, trče i željni su igara na otvorenom, upražnjavaju razne igre sa loptom (fudbal i mnoge druge igre) i penju se po drveću, imitirajući svoje crtane junake, prilikom čega dominira statička i eksplozivna snaga ruku i brzina trčanja, dugotrajnije fizičke aktivnosti. Različite životne navike djece različitog pola, mogu uticati na postojanje razlika u ispoljavanju motoričkih sposobnosti. Na ovakve rezultate je možda mogla

motor tasks and competitions, struggle, and a greater desire to succeed in tasks dominated by strength and speed (Carlos et al., 2014). Halaši (2016), in his research on a sample of a total of 214 respondents, of whom 101 girls and 113 boys aged 8 years from Subotica, under the title "Body structure and motor status as predictors of the quality of life of younger school-aged children," tested motor skills, anthropometric measures, assessment of body composition, tests to assess the development of gross motor skills and measures related to health-related quality of life. According to his conclusion, there is a statistically significant difference between boys and girls in running 20 meters and the long jump from a standing position in favor of boys, while squatting showed better results in favor of girls. The results of research into the motor abilities of younger school-aged students show a trend of decreasing motor abilities among students (Kraljević, Gadžić, and Vučković, 2013). The research was conducted on a sample of 70 subjects (36 boys and 34 girls) of younger school age, that is, 9 - 11 years old, students of Elementary School "Mića Stojković" in Umčari. The research aimed to determine the differences in morphological characteristics and motor abilities between girls and boys of a younger school age. Two anthropological measures and eight motor tests were applied. There were no statistically significant differences in body height and mass between girls and boys. Using a multivariate analysis of variance, the existence of a statistically significant difference in the motor area of girls and boys was determined. At the level of individual variables, significant differences were found in the variables: Running 30 m from a high start, Endurance in a push-up, Throwing a medicine bag (1kg) from a lying position on the back, and Running for 6 minutes in favor of boys, that is, in the variables Bouncing the ball off the wall and Leaning on the bench in favor of the girls. Boys exhibited significantly higher levels of strength, speed, and aerobic endurance, while girls were more successful in tests of coordination and flexibility. The obtained results can be interpreted by differences in the level of physical activity of girls and boys and differences in body composition and structure (Smajić et al., 2017). Modern society is characterized by markedly reduced motor activity, improper nutrition, and an increasing number of people whose lifestyles can be described as sedentary. It is necessary to act preventively by more frequent monitoring and analyzing the correctness of growth and development, and by motivating young people to actively or recreationally engage in sports (Nikšić et al., 2020a). It is necessary to monitor, measure, and analyze all segments of the students' anthropological status daily to influence the development of basic motor skills and act preventively in the fight against obesity,

da utiče i okolina (fizička aktivnost djece), genetski potencijali dječaka za ostvarivanjem uspjeha u motoričkim zadacima i nadmetanjima, borba i veća želja za uspjehom u zadacima u kojima dominira snaga i brzina (Carlos i sar., 2014). Halaši (2016) je u svom istraživanju na uzorku od ukupno 214 ispitanika, od kojih su 101 djevojčica i 113 dječaka uzrasta 8 godina iz Subotice, pod nazivom „Tjelesna struktura i motorički status kao prediktori kvalitete života djece mlađeg školskog uzrasta", testirao motoričke sposobnosti, antropometrijske mjere, procjenu tjelesne strukture, testove za procjenu razvoja vještina krupne motorike i mjere koje se odnose na kvalitetu života povezanu sa zdravljem. Prema njegovom zaključku, postoji statistički značajna razlika između dječaka i djevojčica u trčanju na 20 metara, skoku u dalj iz mjesta u korist dječaka, dok je pretklon u sjedu raznožno pokazao bolje rezultate u korist djevojčica. Rezultati istraživanja motoričkih sposobnosti učenika mlađeg školskog uzrasta, pokazuju trend opadanja motoričkih sposobnosti kod učenika (Kraljević, Gadžić i Vučković, 2013). Istraživanje je sprovedeno na uzorku od 70 ispitanika (36 dječaka i 34 djevojčice) mlađeg školskog uzrasta, odnosno uzrasta od 9 - 11 godina, učenika OŠ „Mića Stojković" u Umčarima. Cilj istraživanja bio je utvrđivanje razlika u morfološkim karakteristikama i motoričkim sposobnostima između djevojčica i dječaka mlađeg školskog uzrasta. Primijenjene su dvije antropološke mjere i osam motoričkih testova. Između djevojčica i dječaka nisu konstatovane statistički značajne razlike u tjelesnoj visini i masi. Primjenom multivarijantne analize varijanse utvrđeno je postojanje statistički značajne razlike u motoričkom prostoru djevojčica i dječaka. Na nivou pojedinačnih varijabli, značajne razlike su utvrđene u varijablama: Trčanje 30 m iz visokog starta, Izdržaj u zgibu, Bacanje medicinke (1kg) iz ležećeg položaja na leđima i Trčanje 6 minuta u korist dječaka, odnosno, u varijablama Odbijanje lopte od zid i Pretklon na klupici u korist djevojčica. Dječaci su ispoljili značajno viši nivo snage, brzine i aerobne izdržljivosti, dok su djevojčice bile uspješnije u testovima koordinacije i gipkosti. Dobijeni rezultati se mogu tumačiti razlikama u nivou fizičke aktivnosti djevojčica i dječaka, i razlikama u tjelesnoj građi i strukturi (Smajić i sar., 2017). Moderno društvo karakteriše izrazito smanjena motorička aktivnost, nepravilna ishrana i sve veći broj ljudi čiji se životni stil može opisati kao sedentarni. Potrebno je preventivno djelovati češćim praćenjem i analizom ispravnosti rasta i razvoja i motivisanjem omladine da se aktivno ili rekreativno bave sportom (Nikšić i sar., 2020a). Potrebno je svakodnevno vršiti praćenja, mjerenja i analizu svih segmenata antropološkog statusa učenika, kako bi se utjecalo na

which is the leading epidemiological health problem of today. It is obvious that physical activity based on physical and health education classes is not enough or is not represented enough to respond to the challenges of the modern sedentary lifestyle, which was even more exacerbated by the COVID-19 pandemic and online teaching (Nikšić et al., 2021).

Conclusion

This research was conducted to determine the differences in morphological characteristics and motor abilities between boys and girls from the 2nd to the 5th grade of elementary school. The research was conducted on a sample of N=989 (53%) male respondents and N=861 (47%) female respondents. The results of the research showed that in terms of morphological characteristics, there are statistically significant differences between boys and girls from the 2nd to the 5th grade of elementary school in Body Mass Index (BMI) and skinfold on the back (subscapular), while no differences were identified in the skinfold of the upper arm (triceps). And a skin fold on the stomach (suprailiac). Obesity and overnutrition are more prevalent in boys than in girls. Today's big problem is not only obesity in children but also malnutrition, which is most prevalent among students from the 2nd to the 5th grade of elementary school. It was found that there are statistically significant differences in flexibility, trunk strength, and functional strength in favor of boys and explosive leg strength and static strength in favor of girls. The results for balance running speed and agility were in favor of girls, and movement speed was in favor of boys, these differences were not statistically significant. Today's fast-paced lifestyle has led to a decrease in physical activity and an increase in a sedentary lifestyle, which has further influenced the irregular growth and development of students. Reduced physical activity in children leads to major changes in their overall development, especially in motor skills and nutritional status. To enable maximum growth and development in children, it is necessary to perform tests and measurements of data on anthropological status. Indicators are important to indicate to parents the current state of development of the anthropological status of the student population. Any sporting activity leads to a certain transformation. The most important thing is to adapt a certain sports activity to the age at which it is being worked so that the activity affects the transformation of the student.

Conflicts of Interest
The authors would like to thank all participants for the effort and time spent on the tattooing and measurement processes.

razvijanje bazičnih motoričkih sposobnosti i preventivno djelovalo u borbi protiv gojaznosti, kao vodećeg epidemiološkog zdravstvenog problema današnjice. Očito je da tjelesna aktivnost zasnovana na časovima tjelesnog i zdravstvenog odgoja nije dovoljna ili nije dovoljno zastupljena da odgovori na izazove savremenog sedentarnog načina života, što je još više prouzrokovala pandemija COVID – 19 i online nastava (Nikšić i sar., 2021).

Zaključak

Ovo istraživanje je provedeno s ciljem utvrđivanja razlika u morfološkim karakteristikama i motoričkim sposobnostima između dječaka i djevojčica od II do V razreda osnovne škole. Istraživanje je provedeno na uzorku od N=989 (53%) muških ispitanika i N=861 (47%) ženskih ispitanika. Rezultati istraživanja su pokazali da kod morfoloških karakteristika postoje statističi značajne razlike između dječaka i djevojčica od II do V razreda osnovne škole u Body Mass Indexu (BMI) i kožnom naboru na leđima (subscapular), dok nisu identificirane razlike u kožnom naboru nadlaktice (triceps) i kožnom naboru na stomaku (suprailiac). Gojaznost i prekomjerna uhranjenost zastupljeniji su kod dječaka, nego kod djevojčica. Veliki problem današnjice nije samo gojaznost kod djece, već i pothranjenost koja je bila najviše zastupljena kod učenika od II do V razreda osnovne škole. Utvrđeno je da postoje i statistički značajne razlike u gipkosti, snazi trupa i funkcionalnoj snazi u korist dječaka, a eksplozivna snaga nogu i statička snaga u korist djevojčica. Rezultati kod ravnoteže i brzine trčanja i agilnosti su bili u korist djevočica, a brzina pokreta u korist dječaka i ove razlike nisu bile statistički značajne. Današnji ubrzani način života doveo je do smanjenja tjelesne aktivnosti, a povećanja sedentarnog načina života, što je dodatno utjecalo na nepravilan rast i razvoj učenika. Smanjena tjelesna aktivnost kod djece dovodi do velikih promjena u njihovom cjelokupnom razvoju, a posebno u motoričkim sposobnostima i stanju uhranjenosti. Da bi se omogućio maksimalni rast i razvoj kod djece, neophodno je uraditi testiranja i mjerenja, podataka o antropološkom statusu. Pokazatelji su važni kako bi se roditeljima ukazalo na trenutno stanje razvijenosti antropološkog statusa kod učeničke populacije. Bilo koja sportska aktivnost dovodi do određene transformacije. Najbitnije je određenu sportsku aktivnost prilagoditi uzrastu sa kojim se radi, kako bi ta aktivnost utiecala na transformaciju učenika

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Differences in the Prevalence of Postural Disorders of the Spine in Lower Grades of Elementary School Students

Razlike u zastupljenosti posturalnih poremećaja kičmenog stuba kod učenika nižih razreda osnovne škole

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Abstract: *The study was conducted on a sample of 146 respondents - lower grade elementary school students, chronological age 7 - 11 years old, in the urban area of the city of Banja Luka. The total sample of respondents was divided into five subsamples according to chronological age. The main objective of the study was to determine the frequency and structure of postural disorders of the spinal column in the studied sample of subjects, as well as the differences in the prevalence of postural disorders with respect to the chronological age of the subjects, using a transversal cross-section. To assess the prevalence and differences in postural disorders of the spinal column, disorders in the sagittal plane (kyphosis and lordosis) and disorders in the frontal plane (scoliosis) were analyzed. The degree of postural disorders of the spinal column was determined using Contingency Tables - calculating frequencies (F) and percentages (%). The statistical significance of the differences in the prevalence of postural disorders of the spinal column in the sagittal (kyphosis and lordosis) and frontal planes (scoliosis) in lower elementary school students was determined using Univariate Analysis of Variance (ANOVA), and the differences in relation to their chronological age for each type of disorder were determined using the analysis of the results of the Post Hock comparison test. The degree of postural disorders of the spinal column determined by Contingency Tables - by calculating the frequency (F) and percentage (%) indicates a significant percentage of spinal column disorders (kyphosis 21.2%, scoliosis 19.9%, lordosis 19.2%), mainly in the first degree of deformation (minor deviation from the normal status), which allows for correction of the condition with the application of adequate corrective exercises in working with students of this age. The results of the univariate analysis of variance (ANOVA) show that the prevalence of kyphosis is statistically significant at the level of statistical significance p<.007 and scoliosis*

Sažetak: *Istraživanje je provedeno na uzorku od 146 ispitanika-učenika nižih razreda osnovne škole, hronološke dobi 7 – 11 godina urbanog područja grada Banja Luka. Ukupan uzorak ispitanika podijeljen je na pet subuzoraka u odnosu na hronološku dob. Osnovni cilj istraživanja bio je da se transverzalnim presjekom utvrdi frekvencija i struktura posturalnih poremećaja kičmenog stuba kod ispitivanog uzorka ispitanika kao i razlike u zastupljenosti posturalnih poremećaja s obzirom na hronološku dob ispitanika. Za procjenu zastupljenosti i razlika posturalnih poremećaja kičmenog stuba analizirani su poremećaji u sagitalnoj ravni (kifoza i lordoza), te poremećaj u frontalnoj ravni (skolioza). Stepen posturalnih poremećaja kičmenog stuba utvrđen je Kontigencijskim tablicama – izračunom frekvencija (F) i postotka (%). Statistička značajnost razlika zastupljenosti posturalnih poremećaja kičmenog stuba u sagitalnoj (kifoza i lordoza) i frontalnoj ravni (skolioza) kod učenika nižih razreda osnovne škole utvrđena je primjenom Univarijantne analize varijanse (ANOVA), a razlike u odnosu na njihovu hronološku dob za svaku vrstu poremećaja ponaosob utvrđena je primjenom analize rezultata Post Hock testa upoređivanja. Stepen posturalnih poremećaja kičmenog stuba utvrđivan Kontigencijskim tablicama – izračunavanjem frekvencije (F) i postotka (%) ukazuje na značajan postotak zastupljenosti poremećaja kičmenog stuba (kifoza 21,2%, skolioza 19,9%, lordoza19,2%) i to uglavnom u prvom stepenu deformacija (manje odstupanje od normalnog statusa), što omogućava korekciju stanja uz primjenu adekvatnih korektivnih vježbi u radu sa učenicima ovog uzrasta. Rezultati univarijantne analize Varijanse (ANOVA) pokazuju da je zastupljenost kifoze statistički značajna na nivou statističke značajnosti p<.007 i skolioze p<.001 kod ispitivanog uzorka učenika. Statistička značajnost zastupljenosti lordoze*

p<.001 in the studied sample of students. The statistical significance of the prevalence of lordosis in the studied sample of students was not determined (p= .255). The results of the LSD Post Hock comparison test show that there is a statistically significant difference in the prevalence of kyphosis and scoliosis between groups of students with regard to their chronological age.

Keywords: *spinal column, postural disorders, differences, students, Post Hock test.*

Introduction

One of the priority tasks in working with children is undoubtedly taking care of their health, and proper growth and development. Proper posture is a basic prerequisite for good health, proper growth and development of children, which is why it is very important that posture education begins as early as possible. A particularly sensitive period of children's development is the primary school age because it is during this period that critical periods in children's development occur. Therefore, it is very important to continuously monitor the process of children's growth and development in which to insist on educating them about proper posture. It is especially important that it begins as early as possible. According to Kosinac (2008), proper posture creates favorable conditions for the activity of the locomotor apparatus. The muscles that maintain the body's balance are in normal tone (tension). Their tone is even, and this ensures the readiness of the muscles for movement. However, uneven tone and weakness of certain muscle regions, primarily the muscles of the back, chest and abdomen, are the primary causes of disorders in proper posture in children. Likewise, weakness of the pelvic girdle muscles and lower extremities can lead to secondary disorders in the upper body.

Karaiković, (1984) also points out that proper posture is influenced by the correct structure of the skeleton, the correct distribution of muscles, mass and strength, as well as the symmetry of paired body parts. Weakness or shortening of muscles can lead to poor body posture. This can be caused by everyday bad habits such as inadequate sitting and lack of motor activity that can cause poor posture or body deformities (Peterson-Kendall et al., 2005; Skender, N. 2001).

In this process, it is necessary to engage all participants in educational work (parents, teachers, medical staff) in order to achieve the integral development of all anthropological characteristics and abilities of children.

Previous experiences show that environmental characteristics influence lifestyle, including body posture, which is later reflected in the life cycle of each individual. The fact is that in the physical education of

kod ispitivanog uzorka učenika nije utvrđena (p= .255). Rezultati LSD Post Hock testa upoređivanja pokazuju da postoji statistički značajna razlika zastupljenosti kifoze i skolioze između grupa učenika s obzirom na njihovu hronološku dob.

Ključne riječi: *kičmeni stub, posturalni poremećaji, razlike, učenici, Post Hock test.*

Uvod

Jedan od prioritetnih zadataka u radu sa djecom neosporno se odnosi na brigu o njihovom zdravlju, te pravilnom rastu i razvoju. Pravilno držanje tijela je osnovni preduslov dobrog zdravlja, pravilnog rasta i razvoja djece, zbog čega je vrlo važno da vaspitanje držanja tijela počne u što ranijem uzrasnom dobu. Posebno osjetljiv period razvoja djece je vrijeme osnovnoškolskog uzrasta jer se u njemu i javljaju kritični periodi u razvoju djece. Zbog toga je vrlo važno neprekidno pratiti proces rasta i razvoja djece u kome insistirati na vaspitanju pravilnog držanja tijela. Posebno je značajno da ono počne u što ranijem uzrasnom dobu. Prema Kosincu, (2008), pravilno držanje tijela stvara povoljne uslove za aktivnost lokomotornog aparata. Mišići koji održavaju ravnotežu tijela nalaze se u normalnom tonusu (napetosti). Njihov tonus je ravnomjeran, a to obezbjeđuje spremnost mišića za kretanje. Međutim, neravnomjernost tonusa i slabost pojedinih mišićnih regija, u prvom redu mišića leđa, grudnog koša i trbuha primarni su uzroci nastanka poremećaja u pravilnom držanju tijela kod djece. Isto tako, slabost mišića karličnog pojasa i donjih ekstremiteta može dovesti do sekundarnih poremećaja u gornjim dijelovima tijela.

Karaiković, (1984) takođe ističe da na pravilno držanje utiče pravilnoa građe skeleta, pravilan rasporeda muskulature, mase i snage, kao i simetrija parnih dijelova tijala. Slabost ili skraćenje mišića mogu dovesti do lošeg položaja tijela. Ovo može biti izazvano svakodnevnim lošim navikama kao što su neadekvatno sjedenje i nedostatak motoričke aktivnosti koji mogu izazvati loša tjelesna držanja ili deformitete tijela (Peterson-Kendall i sar., 2005.; Skender, N. 2001).

U tom procesu neophodno je angažovanje svih učesnika u vaspitno-obrazovnom radu (roditelji, učitelji/nastavnici, medicinsko osoblje) kako bi se postigao integralni razvoj svih antropoloških karakteristika i sposobnosti djece.

Dosadašnja iskustva govore da karakteristike sredine utiču na način života, pa tako i na držanje tijela, koje se kasnije odražava na životni ciklus svakog pojedinca.

children there are a number of shortcomings that need to be eliminated. Incorrect posture is increasingly present in the young population.

The causes of incorrect posture are numerous. If we were to look for the causes of incorrect posture in children of primary school age, then they should certainly be sought first in the family, and then in school institutions, because the correct approach and understanding of the importance of physical activity in general by parents and educators represents prevention for school children.

Problems with postural disorders are very common. Many previous studies by various authors in the area of postural disorders and physical deformities in the school population in primary schools (Bogdanović, Z., Koničanin, A., 2009), indicate that the number of children with impaired postural status of the locomotor system is constantly increasing every year. In addition, physical education teachers and administrators play a significant role in the timely detection of postural disorders, the implementation of corrective treatments, as well as the process of educating children about proper posture (Koturović, Lj., Jaričević, D., 1984; Bogdanović, 2007; Bajrić, S., 2021),

This leads to the conclusion that physical and health education of children in this period is a very delicate process and that, due to possible complications (especially health complications), it should be approached very carefully and seriously. The practice is that, regardless of the sphere of human activity, the most complex and most responsible tasks are entrusted to the best experts: specialists, subspecialists, experts, etc. Is this also the case in physical and health education teaching? Except for individual cases, physical and health education teaching is not given nearly the importance it deserves. There are many objective and subjective reasons. The expertise of those who conduct the teaching is certainly one of them.

Today, it is still not sufficiently determined what teaching content and workload are needed in order to achieve optimal effects of desired transformations with a limited (insufficient) number of hours.

Due to all the above, the issue of this research is precisely related to determining the presence and possible group differences in the postural status of the spinal column among students of lower grades of elementary school in the city of Banja Luka.

Method Of Work

A sample of respondents

The research was conducted on a sample of 146 respondents-students of lower grades of elementary school,

Činjenica je da u tjelesnom odgoju djece postoji čitav niz nedostataka koje je potrebno otkloniti. Nepravilno držanje tijela je sve više prisutno kod mlade populacije.

Uzroci nepravilnog držanja tijela su brojni. Ako bi tražili uzroke nepravilnog držanja tijela kod djece osnovnoškolskog uzrasta onda ih zasigurno treba tražiti prvo u porodici, a zatim u školskim ustanovama, jer pravilan pristup i shvatanje značaja tjelesne aktivnosti uopšte od strane roditelja i vaspitača, predstavlja preventivu za školsku djecu.

Problemi sa posturalnim poremećajima su vrlo česti. Mnoga dosadašnja istraživanja različitih autora u prostoru posturalnih poremećaja i tjelesnih deformiteta kod školske populacije u osnovnim školama (Bogdanović, Z., Koničanin, A., 2009), ukazuju da se broj djece sa narušenim posturalnim statusom lokomotornog sistema svake godine stalno povećava. Pored rofitelj i prpfesori fizičkog vaspitanja imaju značajnu ulogu u pravovremenoj detekciji posturalnih poremećaja, sprovođenju korektivnih tretmana, kao i procesu vaspitanja pravilnog držanja tijela (Koturović, Lj., Jaričević, D., 1984; Bogdanović, 2007; Bajrić, S., 2021),

To navodi na zaključak da je fizičko i zdravstveno vaspitanje djece u ovom periodu vrlo delikatan proces i da mu, zbog mogućih komplikacija (posebno zdravstvenih), treba pristupiti vrlo oprezno i ozbiljno. Praksa je da se, bez obzira na sferu ljudskog djelovanja, najsloženiji i najodgovorniji poslovi povjeravaju najboljim stručnjacima: specijalistima, subspecijalistimam ekspertima i sl. Da li je tako i u nastavi fizičkog i zdravstvenog vaspitanja? Izuzev pojedinačnih slučajeva nastavi fizičkog i zdravstvenog vaspitanja se ni približno ne pridaje značaj koji zaslužuje. Objektivnih i subjektivnih razloga je mnogo. Stručnost onih koji izvode nastavu je, svakako, jedan od njih.

Danas još uvijek nije u dovoljnoj mjeri utvrđeno, kakvi su nastavni sadržaji i opterećenja potrebni da bi se, s jedne strane, pomoću ograničenog (nedovoljnog) broja sati postigli optimalni efekti željenih transformacija.

Zbog svega nevedenog, problematika ovog istraživanja upravo se odnosi na utvrđivanje zastupljenosti i eventualnih grupnih razlika u posturalnom statusu kičmenog stuba kod učenika nižih razreda osnove škole grada Banja Luka.

Metod rada

Uzorak ispitanika

Istraživanje je provedeno na uzorku od 146 ispitanika-učenika nižih razreda osnovne škole, hronološ-

chronological age 7-11 years, from the urban area of the city of Banja Luka.

The total sample of respondents was divided into five subsamples: the first subsample (19) consisted of 1st grade students, chronological age 7 years, the second subsample (45) consisted of 2nd grade students, chronological age 8 years, the third subsample (49) consisted of 3rd grade students, chronological age 9 years, the fourth subsample (23) consisted of 4th grade students, chronological age 10 years and the fifth subsample (7) consisted of 5th grade students, chronological age 11 years.

Sample variables

The data were obtained by assessing postural disorders of the spinal column in the frontal and sagittal planes.

Variables for assessing the degree of postural disorders of the spinal column in the sagittal plane:

• Kyphosis (kipyphosis)	
- normal status	KIFONO
- kyphosis (kipyphosis) I degree	KYPHOS 1
- kyphosis (kipyphosis) II degree	KYPHOS 2
• Lordosis	
-normal status of the spinal column	LORDNO
- lordosis and degree	LORDO 1
- lordosis (lordosis) II degree	LORDO 2

Variables for assessing the degree of postural disorders of the spinal column in the frontal plane:

• Scoliosis	
- normal status of the vertebral column	SKOLNO
- scoliosis (scoliosis) I degree	SCOLI 1
- scoliosis (scoliosis) II degree	SCOLI 2

Data processing

Degree of postural disorders of the spinal column was determined by Contingency Tables - by calculating frequencies (F) and percentage (%).

The statistical significance of differences in the presence of postural disorders of the spinal column in the sagittal (kyphosis and lordosis) and frontal (scoliosis) planes in lower grade elementary school students was determined using Univariate Analysis of Variance (ANOVA), and the differences in relation to their chronological age for each type of disorder was determined using the analysis of the results of the Post Hock comparison test.

Results With Discussion

Analysis of the frequency and structure of spinal column disorders in the total sample of respondents

ke dobi 7 – 11 godina urbanog područja grada Banja Luka.

Ukupan uzorak ispitanika podijeljen je na pet subuzoraka i to: prvi subuzorak (19) činili su učenici 1. razreda, hronološke dobi 7 godina, drugi subuzorak (45) činili su učenici 2. razreda, hronološke dobi 8 godina, reći subuzorak (49) činili su učenici 3. razreda, hronološke dobi 9 godina, četvrti subuzorak (23) činili su učenici 4. razreda, hronološke dobi 10 godina i peti subuzorak (7) činili su učenici 5. razreda, hronološke dobi 11 godina.

Uzorak varijabli

Podaci su dobijeni procjenom posturalnih poremećaja kičmenog stuba u frontalnoj i sagitalnoj ravni.

Varijable za procjenu stepena posturalnih poremećaja kičmenog stuba u sagitalnoj ravni:

• Kifoza (kipyphosis)	
- normalni status	KIFONO
- kifoza (kipyphosis) I stepen	KIFOZ 1
- kifoza (kipyphosis) II stepen	KIFOZ 2
• Lordoza (lordosis)	
- normalni status kičmenog stuba	LORDNO
- lordoza (lordosis) i stepen	LORDO 1
- lordoza (lordosis) II stepen	LORDO 2

Varijable za procjenu stepena posturalnih poremećaja kičmenog stuba u frontalnoj ravni:

• Skolioza (skoliosis)	
- normalni status kičmenog stuba	SKOLNO
- skolioza (skoliosis) I stepan	SKOLI 1
- skolioza (skoliosis) II stepen	SKOLI 2

Obrada podataka

Stepen posturalnih poremećaja kičmenog stuba utvrđen je Kontigencijskim tablicama – izračunom frekvencija (F) i postotka (%).

Statistička značajnost razlika prisutnosti posturalnih poremećaja kičmenog stuba u sagitalnoj (kifoza i lordoza) i frontalnoj (skolioza) ravni kod učenika nižih razreda osnovne škole utvrđena je primjenom Univarijantne analize varijanse (ANOVA), a razlike u odnosu na njihovu hronološku dob za svaku vrstu poremećaja ponaosob utvrđena je primjenom analize rezultata Post Hock testa upoređivanja.

Rezultati sa diskusijom

Analiza frekvencija i strukture poremećaja kičmenog stuba ispitanika u totalu (učenika I-V razreda)

(students in grades I-V)

Table 1 shows the frequency and structure of postural disorders of the spinal column by type of disorder for the total sample of respondents (students in grades I-V). The analysis of the frequency and percentage of kyphotic disorders shows that out of the entire sample (146) of respondents, 115 or 78.8% have a normal status (KIFONO) of the spinal column. In terms of the frequency and percentage of kyphotic disorders in the studied sample of respondents, it can be seen that the first degree of disorder (KIFOZ1) is present in 31 or 21.2% of the respondents-students. The second degree of kyphotic disorders of the spinal column (KIFOZ2) has not been determined.

In terms of the frequency and percentage of lordotic disorder in the studied sample, the attached table shows that 118 or 80.8% of the examinees have a normal status (LORDNO). The first degree of lordotic disorder (LORDO1) was determined in 27 or 18.5% of the examinees-students. The second degree of spinal column disorder (LORDO2) was determined in 1 or 0.7% of the examinees.

The analysis of the postural disorder of the spinal column in the frontal plane (scoliosis) shows that out of the entire sample (146) of examinees, 117 or 80.1% have a normal spinal column status (SKOLNO) in the frontal plane. In terms of the frequency and percentage of scoliotic disorder in the studied sample, the attached table shows that the first degree of disorder (SKOLI1) was determined in 29 or 19.9% of the examinees-students. The second degree of spinal column disorder in the frontal plane (SKOLI2) was not determined in the examined students.

Generally speaking, the obtained results of the frequency and structure of postural disorders in the sagittal (kyphosis and lordosis) and frontal plane (scoliosis) were approximately equally represented in students from grades I to V of primary school.

In the further procedure, using univariate analysis of variance (ANOVA) and Post hoc comparison test, possible differences in the presence of spinal column disorders in students based on their chronological age (from 7 to 11 years).

The statistical significance of differences in the presence of postural disorders of the spinal column in the sagittal (kyphosis and lordosis) and frontal plane (scoliosis) among students of lower grades of primary school was determined using Univariate Analysis of Variance (ANOVA) (table 2), and the differences in relation to their chronological age for each type of disorder was determined using the analysis of the results of the Post Hock comparison test (tables 3 - 5).

The value of the F-test (3.708) and its significance ($p < .007$) show that there is a statistically significant dif-

U tabeli 1 prikazana je frekvencija i struktura posturalnih poremećaja kičmenog stuba prema vrsti poremećaja za uzorak ispitanika u totalu (učenika I – V razreda). Analizom frekvencije i procentualne zastupljenosti kifotičnog poremećaja može se vidjeti da od cjelokupnog uzorka (146) ispitanika, njih 115 ili 78,8% ima normalan status (KIFONO) kičmenog stuba. U pogledu frekvencije i procentualne zastupljenosti kifotičnog poremećaja na ispitivanom uzorku ispitanika može se uočiti da je prvi stepen poremećaja (KIFOZ1) prisutan kod 31 ili 21,2% ispitanika-učenika. Drugi stepen kifotičnog poremećaja kičmenog stuba (KIFOZ2) nije utvrđen.

U pogledu frekvencije i procentualne zastupljenosti lordotičnog poremećaja na ispitivanom uzorku iz priložene tabele vidljivo je normalni status (LORDNO) ima 118 ili 80,8% ispitanika. Prvi stepen lordotičnog poremećaja (LORDO1) utvrđen je kod 27 ili 18,5% ispitanika-učenika. Drugi stepen poremećaja kičmenog stuba (LORDO2) utvrđen je kod 1 ili 0,7% učenika.

Analizom posturalnog poremećaja kičmenog stuba u frontalnoj ravni (skolioza) može se vidjeti da od cjelokupnog uzorka (146) ispitanika, njih 117 ili 80,1% ima normalan status kičmenog stuba (SKOLNO) u frontalnoj ravni. U pogledu frekvencije i procentualne zastupljenosti skoliotičnog poremećaja na ispitivanom uzorku iz priložene tabele se može vidjeti da je prvi stepen poremećaja (SKOLI1) utvrđen kod 29 ili 19,9% ispitanika-učenika. Drugi stepen poremećaja kičmenog stuba u frontalnoj ravni (SKOLI2) kod ispitivanih učenika nije utvrđen.

Generalno posmatrano, dobiveni rezultati frekvencije i strukture posturalnih poremećaja u sagitalnoj (kifoza i lordoza) i frontalnoj ravni (skolioza) približno jednako zastupljen kod učenika od I do V razreda osnovne škole.

U daljem postupku primjenom univarijantne analize Varijanse (ANOVA) i Post hock testa upoređivanja utvrđivane su eventualne razlike prisutnosti poremećaja kičmenog stuba kod učenika na osnovu njihove hronološke dobi (od 7 do 11 godina).

Statistička značajnost razlika prisutnosti posturalnih poremećaja kičmenog stuba u sagitalnoj (kifoza i lordoza) i frontalnoj ravni (skolioza) kod učenika nižih razreda osnovne škole utvrđena je primjenom Univarijantne analize varijanse (ANOVA) (tabela 2), a razlike u odnosu na njihovu hronološku dob za svaku vrstu poremećaja ponaosob utvrđena je primjenom analize rezultata Post Hock testa upoređivanja (tabele 3 – 5).

Vrijednost F-testa (3,708) i njegova značajnost ($p < .007$) pokazuju da postoji statistički značajna razlika između grupa ispitanika s obzirom na hronološku dob u

Table 1. *Presentation of the frequency distribution and structure of the presence of spinal column deformities for the sample of examinees in total (students from grades I-V)*

Tabela 1. *Prikaz raspodjele frekvencija i strukture prisutnosti deformiteta kičmenog stuba za uzorak ispitanika u totalu (učenika I-V razreda)*

Type of disorder / **Vrsta poremećaja**	***Status /*** **Status**	***Frequency /*** **Frekvencija**	***Percentage /*** **Procenat** ***(%)***
KYPHOSIS / KIFOZA	KYPOHNO	115	78.8
	KYPHOS1	31	21.2
	KYPHOS2	-	-
	Total / Ukupno	146	100
LORDOSIS / LORDOZA	LORDNO	118	80.8
	LORDO1	27	18.5
	LORDO2	1	0.7
	Total / Ukupno	146	100
SCOLIOSIS / SKOLIOZA	SKOLNO	117	80.1
	SKOLI1	29	19.9
	SKOLI2	-	-
	Total / Ukupno	146	100

ference between the groups of subjects with regard to chronological age in the presence of a postural disorder in the sagittal plane - kyphosis. Also, the value of the F-test (5.236) and its significance (p< .001) show that there is a statistically significant difference between the groups of subjects with regard to chronological age and in the presence of postural disorder in the frontal plane - scoliosis.

The value of the F test (1.435) and its significance (p= .225) show that there is no statistically significant difference between the examinees-students with regard to their chronological age in the prevalence of disorders in the sagittal plane – lordosis.

prisutnosti posturalnog poremećaja u sagitalnoj ravni – kifoza. Takođe, vrijednost F-testa (5,236) i njegova značajnost (p< .001) pokazuju da postoji statistički značajna razlika između grupa ispitanika s obzirom na hronološku dob i u zastupljenosti posturalnog poremećaja u frontalnoj ravni – skolioza.

Vrijenost F testa (1.435) i njegova značajnost (p= .225) pokazuju da ne postoji statistički značajna razlika između ispitanika-učenika s obzirom na njihovu hronološku dob u zastupljenosti poremećaja u sagitalnoj ravni – lordoza.

Table 2. *Univariate Analysis of Variance (ANOVA)*

Tabela 2. *Univarijantna analiza Varijanse (ANOVA)*

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**p**
KIFOSIS	Between Groups	2.324	4	.581	3.708	**.007**
	Within Groups	22.094	141	.157		
	Total	24.418	145			
LORDOSIS	Between Groups	.988	4	.247	1.435	.225
	Within Groups	24.252	141	.172		
	Total	25.240	145			
SKOLIOSIS	Between Groups	3.006	4	.751	5.236	**.001**
	Within Groups	20.234	141	.144		
	Total	23.240	145			

Table 3 shows the results of the LSD Post Hoc test of the prevalence of kyphosis with respect to the age of the examinees-students from 7 to 11 years. The analysis of Table 3 shows that there is a statistically significant difference in the prevalence of kyphosis between students of different chronological ages. Differences were found between students aged 11 and all other age groups. Differences between other age groups are not statistically significant.

U tabeli 3 prikazani su rezultati LSD Post Hoc testa zastupljenosti kifoze s obzirom na starosnu dob ispitanika-učenika od 7 do 11 godina. Analizom tabele 3 vidljivo je da postoji statistički značajna razlika zastupljenosti kifoze između učenika različite hronološke dobi. Razlike su utvrđene između učenika starosne dobi 11 godina sa svim ostalim dobnim grupama. Između ostalih dobnih grupa razlike nisu statistički značajne.

Table 3. *KYPHOS - comparison of differences with respect to the chronological age of students (LSD Post Hoc test)*

Tabela 3. *KIFOZA - upoređivanje razlika s obzirom na hronološku dob učenika (LSD Post Hoc test)*

Dependent Variable	(I) Male / Muški	(J) Male / Muški	Mean Difference (I-J)	Std. Error	p	95% Confidence Interval	
						Lower Bound	Upper Bound
KIFOSIS	Students 7 years / Učenici 7 godina	8 years / godina	-.08224	.10729	.445	-.2943	.1299
		9 years / godina	-.05800	.10698	.589	-.2695	.1535
		10 years / godina	-.19908	.12272	.107	-.4417	.0435
		11 years / godina	-.60902*	.17502	**.001**	-.9550	-.2630
	Students 8 years / Učenici 8 godina	7 years / godina	.08224	.10729	.445	-.1299	.2943
		9 years / godina	.02423	.08039	.764	-.1347	.1832
		10 years / godina	-.11685	.10039	.246	-.3153	.0816
		11 years / godina	-.52679*	.16015	**.001**	-.8434	-.2102
	Students 9 years / Učenici 9 godina	7 years / godina	.05800	.10698	.589	-.1535	.2695
		8 years / godina	-.02423	.08039	.764	-.1832	.1347
		10 years / godina	-.14108	.10005	.161	-.3389	.0567
		11 years / godina	-.55102*	.15995	**.001**	-.8672	-.2348
	Students 10 years / Učenici 10 godina	7 years / godina	.19908	.12272	.107	-.0435	.4417
		8 years / godina	.11685	.10039	.246	-.0816	.3153
		9 years / godina	.14108	.10005	.161	-.0567	.3389
		11 years / godina	-.40994*	.17087	**.018**	-.7477	-.0721
	Students 11 years / Učenici 11 godina	7 years / godina	.60902*	.17502	**.001**	.2630	.9550
		8 years / godina	.52679*	.16015	**.001**	.2102	.8434
		9 years / godina	.55102*	.15995	**.001**	.2348	.8672
		10 years / godina	.40994*	.17087	**.018**	.0721	.7477

**Statistical significance at the p =0.05 level*

**Statistička značajnost na nivou p =0.05*

Table 4 shows the results of the LSD Post Hoc test of the prevalence of lordosis with respect to the age of the students from 7 to 11 years. The analysis of Table 4 shows a statistically significant difference in the prevalence of lordosis between students aged 8 and 9 years, but at the global level it does not show a static significance of the prevalence of lordosis in students with respect to their chronological age.

Table 5 shows the results of the LSD Post Hoc test comparing the prevalence of scoliosis with respect to the chronological age of the students from 7 to 11 years. The analysis of Table 5 shows that there is a statistically significant difference in the prevalence of scoliosis between students of different chronological ages. Differences were found between students aged 7 and 9 and 7 and 10 years. Also, differences were found between students aged 8 and 9 and 8 and 10 years. Students aged 10 differ from students aged 7 and 8 years. The results show that the differences between students aged 11 and all other age groups are not statistically significant.

The results obtained do not deviate from the results of previous research, which also show a significant prevalence of postural disorders in lower grades of primary school

U tabeli 4 prikazani su rezultati LSD Post Hoc testa zastupljenosti lordoze s obzirom na starosnu dob ispitanika-učenika od 7 do 11 godina. Analizom tabele 4 uočava se statistički značajna razlika u zastupljenosti lordoze između učenika starosne dobi 8 i 9 godina ali na globalnom nivou ona ne pokazuje statičku značajnost zastupljenosti lordoze kod učenika s obzirom na njihovu hronološku dob.

U tabeli 5 prikazani su rezultati LSD Post Hoc testa upoređivanja zastupljenosti skolioze s obzirom na hronološku dob ispitanika-učenika od 7 do 11 godina. Analizom tabele 5 vidljivo je da postoji statistički značajna razlika zastupljenosti skolioze između učenika različite hronološke dobi. Razlike su utvrđene između učenika starosne dobi 7 i 9 te 7 i 10 godina. Takođe, razlike su utvrđene između učenika starosne dobi 8 i 9 te 8 i 10 godina. Učenici starosne dobi 10 godina se razlikuju od učenika starosne dobi 7 i 8 godina. Rezultati pokazuju da razlike između učenika uzrasne dobi 11 godina sa svim ostalim uzrasnim grupama nisu statistički značajne.

Dobijeni rezultati ne odstupaju od rezultata dosadašnjih istraživanja koja takođe pokazuju značajnu zastupljenost posturalnih poremećaja kod učenika nižih

Table 4. *LORDOSIS - comparison of differences with respect to the chronological age of students (LSD Post Hoc test)*

Tabela 4. *LORDOZA - upoređivanje razlika s obzirom na hronološku dob učenika (LSD Post Hoc test)*

Dependent Variable	(I) Male / Muški	(J) Male / Muški	Mean Difference (I-J)	Std. Error	p	95% Confidence Interval	
						Lower Bound	Upper Bound
LORDOSIS	Students 7 years / Učenici 7 godina	8 years / godina	-.02851	.11241	.800	-.2507	.1937
		9 years / godina	.16112	.11208	.153	-.0605	.3827
		10 years / godina	.08924	.12857	.489	-.1649	.3434
		11 years / godina	.12030	.18337	.513	-.2422	.4828
	Students 8 years / Učenici 8 godina	7 years / godina	.02851	.11241	.800	-.1937	.2507
		9 years / godina	.18963*	.08422	.026	.0231	.3561
		10 years / godina	.11775	.10517	.265	-.0902	.3257
		11 years / godina	.14881	.16779	.377	-.1829	.4805
	Students 9 years / Učenici 9 godina	7 years / godina	-.16112	.11208	.153	-.3827	.0605
		8 years / godina	-.18963*	.08422	.026	-.3561	-.0231
		10 years / godina	-.07187	.10483	.494	-.2791	.1354
		11 years / godina	-.04082	.16758	.808	-.3721	.2905
	Students 10 years / Učenici 10 godina	7 years / godina	-.08924	.12857	.489	-.3434	.1649
		8 years / godina	-.11775	.10517	.265	-.3257	.0902
		9 years / godina	.07187	.10483	.494	-.1354	.2791
		11 years / godina	.03106	.17902	.863	-.3229	.3850
	Students 11 years / Učenici 11 godina	7 years / godina	-.12030	.18337	.513	-.4828	.2422
		8 years / godina	-.14881	.16779	.377	-.4805	.1829
		9 years / godina	.04082	.16758	.808	-.2905	.3721
		10 years / godina	-.03106	.17902	.863	-.3850	.3229

** Statistical significance at the p =0.05 level*

**Statistička značajnost na nivou p =0.05*

Table 5. *SCOLIOSIS - comparison of differences with respect to the chronological age of students (LSD Post Hoc test)*

Tabela 5. *SKOLIOZA - upoređivanje razlika s obzirom na hronološku dob učenika (LSD Post Hoc test)*

Dependent Variable	(I) Male	(J) Male	Mean Difference (I-J)	Std. Error	p	95% Confidence Interval	
						Lower Bound	Upper Bound
SKOLIOSIS	Students 7 years / Učenici 7 godina	8 years / godina	-.06250	.10268	.544	-.2655	.1405
		9 years / godina	-.32653*	.10238	.002	-.5289	-.1241
		10 years / godina	-.34783*	.11744	.004	-.5800	-.1157
		11 years / godina	-.28571	.16749	.090	-.6168	.0454
	Students 8 years / Učenici 7 godina	7 years / godina	.06250	.10268	.544	-.1405	.2655
		9 years / godina	-.26403*	.07693	.001	-.4161	-.1119
		10 years / godina	-.28533*	.09607	.004	-.4752	-.0954
		11 years / godina	-.22321	.15326	.148	-.5262	.0798
	Students 9 years / Učenici 7 godina	7 years / godina	.32653*	.10238	.002	.1241	.5289
		8 years / godina	.26403*	.07693	.001	.1119	.4161
		10 years / godina	-.02130	.09575	.824	-.2106	.1680
		11 years / godina	.04082	.15307	.790	-.2618	.3434
	Students 10 years / Učenici 7 godina	7 years / godina	.34783*	.11744	.004	.1157	.5800
		8 years / godina	.28533*	.09607	.004	.0954	.4752
		9 years / godina	.02130	.09575	.824	-.1680	.2106
		11 years / godina	.06211	.16352	.705	-.2612	.3854
	Students 11 years / Učenici 7 godina	7 years / godina	.28571	.16749	.090	-.0454	.6168
		8 years / godina	.22321	.15326	.148	-.0798	.5262
		9 years / godina	-.04082	.15307	.790	-.3434	.2618
		10 years / godina	-.06211	.16352	.705	-.3854	.2612

** Statistical significance at the p =0.05 level*

**Statistička značajnost na nivou p =0.05*

students (Šukova, 1986; Živković, 1987; Mihajlović et al., 2003; Bjeković et al., 2006; Kosinac et al., 2007; Paušić et al., 2008, Hodžić et al., 2010; Protić-Gava et al., 2010; Živković et al., 2011; Bajrić et al., 2012, Bajrić, S. 2021; Bozoljac et al., 2023).

Many previous studies (Kosinac et al., 2007; Bogdanović et al., 2008; Hodžić et al., 2010; Protić-Gava et al., 2010; Živković et al., 2011; Bajrić et al., 2012, Bajrić, S. 2021; Bozoljac et al., 2023) indicate that the most common causes of disorders are of the spine, long-term static sitting positions at home when writing homework, studying, a large number of classes at school, short breaks between classes, unsuitable school furniture, the way the school bag is carried and the weight. The manner of carrying and the weight of the school bag disrupts the static dynamics of the entire locomotor apparatus and leads to insufficiency of postural muscles, which promotes the occurrence of improper posture and the occurrence of pain in the neck, shoulder and back area.

This conclusion is supported by research (Paušić et al., 2008) which determined that the average weight of a school bag in relation to the weight of a student is 12.5% to 13.8% in some Dalmatian primary schools.

For years, many authors have emphasized the importance of proper posture, postural attitude, as an important element in the prevention of spinal deformities. The characteristic of postural disorders, or poor posture, is that they arise as a result of uneven growth of the skeletal system and the muscular system. Muscles develop more slowly, becoming shorter in relation to the bone. Due to this disproportion, the spinal column becomes curved (Kosinac et al., 2011; Nikšić et al., 2015).

The question arises whether the education system and the 2 hours of physical and health education, which are currently provided in primary and secondary schools in Bosnia and Herzegovina, can respond to all the problems caused by physical inactivity and a sedentary lifestyle. We confidently assert that it cannot and that in the prevention of locomotor apparatus deformities in children, the Ministry of Education and schools should take a leading role through changing curricula, increasing the number of hours of physical education and health education, education and changing the menus of children who eat in schools and kindergartens.

The normal and healthy growth and development of children of preschool and primary school age is of crucial importance for the overall development and health of a person during his lifetime (Lolić et al., 2012). Children should be allowed natural and free development with plenty of physical activities and play, because the basis for the correct status of the locomotor apparatus should be created

razreda osnovnoškolskog uzrasta (Šukova, 1986; Živković, 1987; Mihajlović i sar., 2003; Bjeković i sar., 2006; Kosinac i sar., 2007; Paušić i sar., 2008, Hodžić i sar., 2010; Protić-Gava i sar., 2010; Živković i sar., 2011; Bajrić i sar, 2012, Bajrić, S. 2021; Bozoljac i sar., 2023).

Mnoga dosadašnja istraživanja (Kosinac i sar., 2007; Bogdanović i sar., 2008; Hodžić i sar., 2010; Protić-Gava i sar.,, 2010; Živković i sar., 2011; Bajrić i sar, 2012, Bajrić, S. 2021; Bozoljac i sar., 2023) ukazuju da su najčešći uzroci nastanka poremećaja kičmenog stuba dugotrajni statički položaji sjedenja kod kuće prilikom pisanja domaćih zadaća, učenje, veliki broj nastavnih časova u školi, kratki odmori između časova, neprilagođen školski namještaj, način nošenja i težina školske torbe. Način nošenja i težina školske torbe narušavaju stato-dinamiku cjelokupnog lokomotornog aparata te dolazi do nastanka insuficijencije posturalnih mišića što pospješuje nastanak nepravilnog držanja tijela te nastanak pojave boli u području vrata, ramena i leđa.

U prilog ovoj konstataciji idu i istraživanja (Paušić i sar., 2008) koji su utvrdili svojim istraživanjem da je prosječna težina školske torbe u odnosu na težinu učenika od 12,5% do 13,8% u nekim Dalamatinskim osnovnim školama.

Godinama su mnogi autori isticali značaj pravilnog držanja tijela, posturalni stav, kao bitan elemenat u prevenciji deformacija kičmenog stuba. Karakteristika posturalnih poremećaja, odnosno lošeg držanja jeste da nastaju kao posljedica nejednakog rasta koštanog sistema i mišićnog sistema. Mišići se sporije razvijaju, postaju kraći u odnosu na kost. Usljed ove disproporcije dolazi do krivljenja kičmenog stuba (Kosinac i sar., 2011; Nikšić i sar., 2015.).

Postavlja se pitanje da li obrazovni sistem i 2 sata tjelesnog i zdravstvenog odgoja, koliko ga je trenutno u osnovnim i srednjim školama u Bosni i Hercegovini, mogu da odgovore na sve probleme koje nosi tjelesna neaktivnost i sedentarni način života. Sa sigurnošću tvrdimo da ne može i da u prevenciji deformiteta lokomotornog aparata kod djece vodeću ulogu treba da zauzmu Ministarstvo obrazovanja i škole kroz izmjenu nastavnih planova i programa, povećanje broja časova nastave tjelesnog i zdravstvenog odgoja, edukaciju i izmjenu jelovnika kod djece koja se hrane u školama i vrtićima.

Normalan i zdrav rast i razvoj djece predškolske i osnovnoškolske dobi od presudnog je značaja za cjelokupni razvoj i zdravlje čovjeka tokom životnog vijeka (Lolić i sar., 2012.). Djeci treba omogućiti prirodan i slobodan razvoj sa dosta tjelesnih aktivnosti i igre, jer osnovu za pravilan status lokomotornog aparata treba stvarati

from the earliest age. Also, the need for continuous cooperation between teachers, parents and medical staff should be emphasized, which should contribute to more effective intervention. to reduce the prevalence of postural disorders, the timely identification of disorders in the earliest stages of their occurrence, as well as the development of a program of corrective exercises and methodical procedures, is of particular importance (Lovrić, 2015).

Activities and content related to the prevention of postural disorders in school-age children can be organized indoors and outdoors. The entire program should consist of exercises for the prevention of postural disorders in the spinal column (prevention of kyphotic, lordotic, scoliotic posture). The program should include: exercises for establishing the balance of the pelvic-thigh muscles, exercises for stretching the spinal column and strengthening the trunk muscles, breathing exercises, balance exercises in the correction of postural disorders, as well as elementary games.

Conclusion

The main goal of the research was to determine the frequency and structure of postural disorders of the spinal column, as well as any differences and significance of differences in relation to the chronological age of the subjects, in a sample of 146 subjects - students of lower grades of primary school, chronologically aged 7 to 11 years. The degree of postural disorders of the spinal column was determined by Contingency Tables - by calculating frequencies (F) and percentages (%). Analyzing the obtained results of postural disorders of the spinal column of students from 7 to 11 years old (grades I-V of primary school), it is observed that the highest percentage is represented by kyphosis (21.2%), followed by scoliosis (19.9%) and lordosis (19.2%). In general, it can be stated that the percentage of postural disorders of the spinal column in the studied sample of subjects - students from grades I to V of primary school is present in a significant number. Changes in the spinal column are mostly in the first degree of deformation, which allows for successful correction of the condition with the application of adequate corrective programs (exercises) in working with the student population of this age.

The statistical significance of the presence of postural disorders of the spinal column in the studied sample of respondents was determined using Univariate Analysis of Variance (ANOVA). The results of the Univariate Analysis of Variance (ANOVA) show that there is a statistical significance of the presence of kyphosis disorders ($p < .007$) and scoliosis ($p < .001$) in the studied sample of students. The statistical significance of the presence of lordosis in the studied sample of students was not determined ($p = .255$).

The results of the LSD Post Hock comparison test show

od najranijeg uzrasta. Takođe, treba istaći potrebu neprekidne saradnje učitelja, roditelja i medicinskog osoblja koja treba da doprinese efikasnijem uticaju na smanjenje zastupljenosti posturalnih poremećaja, jer od posebne je važnosti pravovremena identifikacija poremećaja u najranijoj fazi nastanka kao i izrada programa korektivnih vježbi i metodskih postupaka (Lovrić, 2015.).

Aktivnosti i sadržaji koji se odnose na prevenciju posturalnih poremećaja, u školskom uzrastu mogu se organizovati u zatvorenom i otvorenom prostoru. Cjelokupan program treba da bude sačinjen od vježbi za prevenciju posturalnih poremećaja na kičmenom stubu (prevencija kifotičnog, lordotičkog, skoliotičnog držanja). Program treba da se odnosi na: vježbe za uspostavljanje balansa karlično-butne muskulature, vježbe za istezanje kičmenog stuba i jačanje muskulature trupa, vježbe disanja, vježbe ravnoteže u korekciji posturalnih poremećaja kao i na elemetarne igre.

Zaključak

Osnovni cilj istraživanja bio je da se na uzorku od 146 ispitanika – učenika nižih razreda osnovne škole hronološke dobi od 7 do 11 godina utvrdi frekvencija i struktura posturalnih poremećaja kičmenog stuba, te eventualne razlike i značajnost razlika u odnosu na hronološku dob ispitanika. Stepen posturalnih poremećaja kičmenog stuba utvrđen je Kontigencijskim tablicama – izračunom frekvencija (F) i postotka (%). Analizirajući dobivene rezultate posturalnih poremećaja kičmenog stuba učenika od 7 do 11 godina (I - V razred osnovne škole) uočava se da je u najvećem procentu zastupljena kifoza (21,2%), zatim skolioza (19,9%) i lordoza (19,2%). Generalno, može se konstatovati da je procenat zastupljenosti posturalnih poremećaja kičmenog stuba kod ispitivanog uzorka ispitanika – učenika od I do V razreda osnovne škole prisutan u značajnom broju. Promjene na kičmenom stubu su uglavnom u prvom stepenu deformacije, što omogućava uspješnu korekciju stanja uz primjenu adekvatni korektivnih programa (vježbi) u radu sa učeničkom populacijom ovog uzrasta.

Statistička značajnost prisutnosti posturalnih poremećaja kičmenog stuba kod ispitivanog uzorka ispitanika utvrđivana je primjenom Univarijantne analize varijanse (ANOVA). Rezultati univarijantne analize Varijanse (ANOVA) pokazuju da postoji statistička značajnost zastupljenosti poremećaja kifoze ($p< .007$) i skolioze ($p< .001$) kod ispitivanog uzorka učenika. Statistička značajnost prisutnosti lordoze kod ispitivanog uzorka učenika nije utvrđena ($p= .255$).

Rezultati LSD Post Hock testa upoređivanja poka-

that there is a statistically significant difference in the presence of kyphosis and scoliosis between different age groups of students.

The results of the research impose as a primary task of teachers in school and the obligation of parents to constantly instruct children in proper body posture when sitting, standing, walking and doing physical activities. Therefore, in order to preserve and improve the health of students in school, it is necessary to ensure continuous monitoring of students' postural status with the aim of timely identification of disorders and, in this regard, undertaking the necessary activities for preventive and corrective work, as well as systematic implementation of physical exercise and systematic examinations.

zuju da postoji statistički značajna razlika prisutnosti kifoze i skolioze između različitih uzrasnih grupa učenika.

Rezultati istraživanja nameću kao primaran zadatak učitelja u školi i obavezu roditelja da djecu neprekidno upućuju u pravilno držanje tijela pri sjedenju, stajanju, hodanju i tjelesnim aktivnostima. Zbog toga je za očuvanje i unapređenje zdravlja učenika u školi potrebno je obezbijediti kontinuirano praćenje posturalnog statusa učenika s ciljem pravovremene identifikacije poremećaja i stim u vezi preduzimanje potrebnih aktivnosti na preventivnom i korektivnom radu, kao i sistematsko provođenje tjelesnog vježbanja i sistematskih pregleda.

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Relations Between the World Record in Running at 100m and Altitude and Wind Speed

Relacije svjetskog rekorda u trčanju na 100m sa nadmorskom visinom i brzinom vjetra

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Abstract: *A sprint is a dynamic and explosive cyclic movement determined by an ability to accelerate, a size of maximum speed and an ability to maintain the speed in relation to an onset of fatigue, so many factors can affect a sprint result, whether they are of an internal nature - motivation, technique, readiness and fatigue, or external - wind direction and strength, altitude, temperature, texture and hardness of substrate. The goal of the research was to determine the connection between altitude and wind speed with the achieved results in the 100m running for men, which are categorized as world records (manually and electronically measured results) and to predict the results depending on altitude and wind speed, and to determine the best achieved times in years in which no world records were recorded and their connection with altitude and wind speed, and to determine the periods of stagnation of the results, in order to determine, after specifying those periods, whether the altitude of the cities where the records were achieved and the wind speed were possible causes of the stagnation measured during the achievement of the results, which would all help to create more optimal conditions for achieving a better result and setting a new record in the 100m running discipline. After all the analyses, that is, by observing the results of recognized world records measured manually and electronically, it can be concluded that the wind speed had a connection and prediction in the achievement of the world record in the period from 1912 to 1968 when the results were measured manually (if the wind increased by 1 ms^{-1} the result improved by 0.08 sec), while the altitude value had a connection and prediction in the achievement of world records in the period from 1968 to 2009 when the results were recorded by electronic measurement (if the altitude increased by 1m the result improved by 0.00008 sec).*

Keywords: *altitude, sprint, wind speed, world record*

Sažetak: *Sprint je dinamično i eksplozivno ciklično kretanje određeno sposobnošću akceleracije, veličinom maksimalne brzine i sposobnosti da se održi brzina u odnosu na početak zamora, pa mnogi faktor mogu uticati na rezultat u sprintu bilo da su unutrašnjeg karaktera – motivacija, tehnika, spremnost i umor, ili spoljašnjeg – smjer i jačina vjetra, nadmorska visina, temperatura, tekstura i tvrdoća podloge. Cilj istraživanja bio je utvrditi povezanost nadmorske visine i brzine vjetra sa ostvarenim rezultatima u trčanju na 100m za muškarce koji su kategorisani kao svjetski rekordi (ručno i elektronski mjereni rezultati) i izvršiti predikciju rezultata u zavisnosti od nadmorske visine i brzine vjetra, te utvrditi najbolje ostvarena vremena u godinama u kojima nisu zabilježeni svjetski rekordi i njihovu povezanost sa nadmorskom visinom i brzinom vjetra, i utvrditi periode stagnacije rezultata, kako bi se nakon određivanja tih perioda utvrdilo da li su mogući uzroci stagnacije nadmorska visina gradova u kojima su rekordi postignuti i brzina vjetra izmjerena prilikom ostvarivanja rezultata, što bi sve pomoglo kreiranju optimalnijih uslova za ostvarivanje boljeg rezultata i postavljanje novog rekorda u disciplini trčanje na 100m. Nakon svih analiza, odnosno posmatranjem rezultata priznatih svjetskih rekorda mjerenih ručno i elektronski, može se zaključiti da je brzina vjetra imala povezanost i predikciju kod ostvarivanja svjetskog rekorda u periodu od 1912. do 1968. godine kada su rezultati mjereni ručno (ako se vjetar poveća za 1 ms^{-1} rezultat će se poboljšati za 0.08 s), dok je vrijednost nadmorske visine imala povezanost i predikciju u ostvarivanju svjetskih rekorda u period od 1968. do 2009. godine kada su rezultati bilježeni elektronskim mjerenjem (ukoliko se nadmorska visina poveća 1m rezultat će se poboljšati za 0.00008 s).*

Ključne reči: *sprint, svjetski rekord, nadmorska visina, brzina vjetra*

Introduction

Athletics is the main part of the program at the Olympic Games (Jotov, Perisic, Milosavljevic and Miletic, 2022), but also an important part of physical education programs at all levels of education (Stefanovic, 1992a). At the first Olympic Games, held in 776 BC, the only sprint discipline on the program was a race over one stage with a length of 192.27m (Ciric, 1996). Time measurement in athletics was made possible by the invention of George Graham, who in 1721 added a third hand to clocks which marked seconds, so at the beginning of the 19th century, time measurement began and a certain Berkeley's victory in 1803 on the 440-yard track was recorded in a time of 56.0 seconds (Stefanovic, 1992a). A parallel development of sports and technology enables a new asset of modern society, such as measuring time in different sports, as well as recording human capabilities that elite athletes strive for the most (a result that fascinates both competitors and the audience and represents a limit - a world record). In order for a performance to be recognized as a record, it must comply with specific regulations regarding a conduct of a discipline, a method of measuring results, dimensions and properties of a track, equipment used by an athlete and doping controls (IAAF, 2015). Measuring results and "breaking through" the limits of human capabilities are of great importance for the development of athletics (Perisic, Milosavljevic, Jotov and Rajkovic, 2022).

The 100m sprint is often an indicator of movement speed, and the world record holder is marked as the fastest man in the world (Stefanovic, 1992b). In 1968, Jim Haynes became the first man to run under ten seconds: his time of 9.9 was the last world record to be timed manually, and his 9.95, achieved during the Mexico Games, was the first world record timed electronically.[1] French biomechanics and sports researchers who studied human psychophysical abilities, believe that athletes in most athletic disciplines have "used up" as much as 99% of human potential, and in some as much as 99.7% (Perisic, 2011). In the period of 110 years (1912-2022), 67 world records were achieved, and Donald Lippincott's record from 1912 (10.6s) was improved by "only" one second and now stands at 9.58s (Usain Bolt). Improvement of results in the period 1968-2009 was 0.37 s which is an increase of 3.72%, and in the same period the world record for 200 m was revised six times from 19.83 s to 19.19 s which is 3.33 % (Krzysztof and Mero, 2013). In the sprint race for men, at the World Championships in Berlin in 2009, Usain Bolt, breaking two world records,

[1] 100 meter race — Wikipedia (wikipedia.org)

Uvod

Atletika je glavni dio programa na Olimpijskim igrama (Jotov, Perišić, Milosavljević i Miletić 2022), ali i važan dio programa fizičkog vaspitanja na svim nivoima obrazovanja (Stefanović,1992a). Na prvim Olimpijskim igrama, održanim 776. godine prije nove ere, jedina sprinterska disciplina na programu bila je trka na jedan stadijum dužine 192.27m (Ćirić, 1996). Mjerenje vremena u atletici omogućio je pronalazak Džordž Grejema koji je 1721. godine dodao treću iglu na satove koja je označavala sekunde, pa se početkom 19. vijeka počinje sa mjerenjem vremena gde se bilježi pobjeda izvjesnog Berklija 1803. godine na stazi od 440 jardi vremenom od 56.0 sekundi (Stefanović, 1992a). Paralelni razvoj sporta i tehnologije omogućava jednu novu tekovinu savremenog društva kao što je mjerenje vremena u različitim sportovima, kao i bilježenje ljudskih mogućnosti kojoj najviše teže elitni sportisti (rezultat koji fascinira i takmičare i publiku i predstavlja granicu - svjetski rekord). Da bi nastup bio priznat kao rekord, mora biti u skladu sa specifičnim propisima koji se tiču odvijanja discipline, metode mjerenja rezultata, dimenzija i svojstava staze, opreme koju sportista koristi i doping kontrole (IAAF, 2015). Mjerenje rezultata i „probijanje" granica ljudskih mogućnosti imaju veliki značaj za razvoj atletike (Perišić, Milosavljević, Jotov i Rajković 2022).

Sprint na 100 m često je pokazatelj za brzine kretanja, a svjetski rekorder je označavan kao najbrži čovek na svijetu (Stefanović, 1992b). Godine 1968. Džim Hejns je postao prvi čovjek koji je trčao ispod deset sekundi: njegovo vrijeme od 9.9s je posljednji svjetski rekord koji je ostvaren pomoću ručnog mjerenja vremena, a njegov rezultat od 9.95s, postignut tokom Meksičkih igara, predstavlja prvi svjetski rekord mjeren elektronskim putem. Francuski biomehaničari i istrživači sporta koji su proučavali ljudske psihofizičke sposobnosti, smatraju da su atletičari u većini atletskih disciplina „utrošili" čak 99% ljudskih mogućnosti, a u nekima i 99.7% (Perišić, 2011). U periodu od 110 godina (1912-2022) postignuto 67 svjetskih rekorda, a rekord Donalda Lipinkota iz 1912. (10.6s) poboljšan je za „samo" jednu sekundu i sada iznosi 9.58s (Jusein Bolt). Poboljšanje rezultata u periodu 1968-2009. godine iznosi 0.37 s što je povećanje od 3.72%, u istom razdoblju svjetski rekord na 200 m revidiran je šest puta sa 19.83 s na 19.19 s što iznosi 3.33 % (Krzysztof i Mero, 2013). U sprinterskom trčanju za muškarce, na Svjetskom prvenstvu u Berlinu 2009. godine, Jusein Bolt je, oborivši dva svjetska rekorda, na 100 i 200m pomjerio „granicu sno-

moved the "dream border" at 100m and 200m, which has not been broken to this day. Based on the analysis of thousands of sprint races between 1920 and 2007, biologist Mark Denn, from Stanford University in California, determined that the result of 9.48s is the ultimate limit in men's 100m sprint (Perisic, 2011). After the race in Beijing, Glenn Mills, Bolt's coach, stated that Bolt could have achieved a time of 9.52s if he had not started to rejoice before crossing the finish line and thus slowed down the speed of movement he achieved by the 60th meter of the race, and Bolt stated to the Belgian media that his goal was to lower the world record for 100m from the current 9.58 to 9.40 seconds and he believed that this was the ultimate limit, which could no longer be broken (Perisic, 2011).

A sprint is a dynamic and explosive cyclic movement determined by an ability to accelerate, a size of maximum speed and an ability to maintain the speed in relation to an onset of fatigue, so many factors can affect a sprint result, whether they are of an internal nature - motivation, technique, readiness and fatigue, or external - wind direction and strength, altitude, temperature, texture and hardness of substrate (Nigg and Yeadon, 1987; Stafilidis and Arampatzis, 2007). At constant air pressure and temperature, air humidity shows little influence on the 100-meter race time, providing corrections below 0.01 s for the considered range, which is negligible, while corrections increase if the temperature varies at constant air humidity, but relatively little - 0.023 s (Mureika, 2006). Wind is one of the many forms of climatic conditions that can affect sports, and in athletics, wind aid is a benefit that an athlete receives during a race, which is recorded by a wind gauge (Zanca, 2019). Performance in the 100m sprint can be significantly aided by a strong tailwind, so the International Association of Athletics Federations (World athletics) has a limit of 2ms^{-1} for allowable tailwind when recognizing the 100m record, and experimental and statistical works on wind aid in sprinting suggest that a tailwind of +2.0 ms^{-1} reduces the result in a 10 s 100 m sprint by about 0.10 s (Mureika, 2001). At sea level, the corrections differ by about 0.02s, but increase for stronger winds and higher altitudes, while the difference between the maximum and minimum considered corrections is greater than 0.5s, implying that times running with "equal" winds can, in fact, significantly differentiate (Mureika, 2003). A high altitude competition venue is believed to improve sprint performance by reducing air density, which reduces the aerodynamic drag force acting on the athlete and thus allows the athlete to achieve a higher top speed (Ward-

va", koja do danas nije pomjerena. Na osnovu analize hiljada sprinterskih trka između 1920. i 2007. godine, biolog Mark Den, sa Univerziteta Stenford u Kaliforniji, utvrdio je da je rezultat 9.48s, krajnja granica u sprintu za muškarce na 100m (Perišić, 2011). Poslije trke u Pekingu, Glen Mils, Boltov trener, je izjavio da je Bolt mogao da ostvari vreme od 9.52s da nije počeo da se raduje prije polaska kroz cilj i tako usporio brzinu kretanja koju je ostvario do 60-tog metra trke, a Bolt je izjavio za belgijske medije da mu je cilj da svetski rekord na 100m spusti sa sadašnjih 9.58 na 9.40 sekundi i verovao je da je to krajnja granica, koja više neće moći da bude oborena (Perišić, 2011).

Sprint je dinamično i eksplozivno ciklično kretanje određeno sposobnošću akceleracije, veličinom maksimalne brzine i sposobnosti da se održi brzina u odnosu na početak zamora, pa mnogi faktor mogu uticati na rezultat u sprintu bilo da su unutrašnjeg karaktera – motivacija, tehnika, spremnost i umor, ili spoljašnjeg – smjer i jačina vjetra, nadmorska visina, temperatura, tekstura i tvrdoća podloge (Nigg i Yeadon, 1987; Stafilidis i Arampatzis, 2007). Pri konstantnom vazdušnom pritisku i temperaturi, vlažnost vazduha pokazuje mali uticaj na vrijeme trke na 100 metara, dajući korekcije ispod 0.01 s za razmatrani raspon što je zanemarivo, dok korekcije rastu ako temperatura varira pri konstantnoj vlažnosti vazduha ali relativno malo – 0.023 s (Mureika, 2006). Vjetar je jedan od mnogih oblika klimatskih uslova koji mogu uticati na sport, a u atletici, pomoć vjetra je dobrobit koju sportista dobija tokom trke, što bilježi mjerač vjetra (Zanca, 2019). Izvedba u sprintu na 100 metara može biti značajno potpomognuta jakim pratećim vjetrom, tako da Međunarodna asocijacija atletskih federacija (World athletics) ima ograničenje od 2 ms^{-1} za dozvoljeni pomoćni vjetar pri priznavanju rekorda na 100 metara a eksperimentalni i statistički radovi o pomoći vjetra u sprintu sugerišu da zadnji vjetar od +2.0 ms^{-1} smanjuje rezultat u sprintu od 10 s na 100 m za oko 0.10 s (Mureika, 2001). Na nivou mora, korekcije se razlikuju za oko 0.02s, ali se povećavaju za jači vjetar i veće nadmorske visine, dok je razlika između maksimalne i minimalne razmatrane korekcije veća od 0.5 s što implicira da se vremena koja se odvijaju sa „jednakim" vjetrom mogu, u stvari, značajno razlikovati (Mureika, 2003). Vjeruje se da mjesto za takmičenje na velikim nadmorskim visinama poboljšava performanse sprinta kroz smanjenje gustine zraka, što smanjuje aerodinamičku silu otpora koja deluje na sportistu i time omogućava sportisti da postigne veću maksimalnu brzinu (Ward-Smith, 1984). World athletics smatra „trčanje

Smith, 1984). World athletics considers "minimum altitude-assisted running" to be 1000 m above sea level and there is no limit to the altitude of the competition venue, although there is empirical evidence that sprint performance is significantly aided by higher altitude (Hollings, Hopkins & Hume, 2012; Matthews, 2015). Advantages that competitors achieve at high altitudes are diverse, which was confirmed by research conducted in Mexico City that showed that reduced wind resistance and the resistance of competitors' bodies in thin air enabled athletes to move more efficiently (Zanca, 2019). A wind of +1.8 ms^{-1} in Mexico City (2250 m) would give an advantage of about 0.29 s (Mureika, 2003). Ward-Smith (1984) found that men's 100m sprint performances at the 1968 Mexico City Olympics improved by 0.17s compared to performances at other Olympic Games, and Behncke (1997) calculated that performance improved by 0.17s. for men and 0.18s for women, but the accuracy of the results is questionable because the research did not correct race times for wind effects, used a mix of manual and electronic times, and Behncke did not take into account historical performance trends (Linthorne, 2016).

The goal of the research was to determine the connection between altitude and wind speed with the achieved results in the 100m running for men, which are categorized as world records (manually and electronically measured results) and to predict the results depending on altitude and wind speed, and to determine the best achieved times in years in which no world records were recorded and their connection with altitude and wind speed, and to determine the periods of stagnation of the results, in order to determine, after specifying those periods, whether the altitude of the cities where the records were achieved and the wind speed were possible causes of the stagnation measured during the achievement of the results, which would all help to create more optimal conditions for achieving a better result and setting a new record in the 100m running discipline.

Materials and Methods

In the research, methods of theoretical analysis were used, which was aimed at explaining the results achieved within the framework of achieving world record results in the men's 100m and the best running results in periods of stagnation in the achievement of world records on the same leg. Then, a descriptive method was used, which aimed to collect results from databases (https://worldathletics.org/records/all-time-toplists/sprints/100-metres/outdoor/men/senior) and to describe and explain connections between obtained results, as well as their rela-

uz pomoć minimalne visine" na nadmorskoj visini od 1000 m i ne postoji ograničenje za nadmorsku visinu mjesta takmičenja, iako postoje empirijski dokazi da su sprinterske performanse značajno potpomognute većom nadmorskom visinom (Hollings, Hopkins i Hume, 2012**;** Matthews, 2015)**.** Prednosti koje takmičari ostvaruju na velikim nadmorskim visinama raznoliki su, što je potvrđeno istraživanjem provedenim u Mexico Cityju koje je pokazalo da su smanjeni otpor vjetra i otpor tijela takmičara u razređenom vazduhu omogućili efikasnije kretanje sportista (Zanca, 2019). Vjetar od +1.8 ms^{-1} u Meksiko Sitiju (2250 m) bi dao prednost od oko 0.29 s (Mureika, 2003). Ward-Smith (1984) je otkrio da su muški sprinterski nastupi na 100 metara na Olimpijskim igrama u Meksiko Sitiju 1968. poboljšani za 0.17s u odnosu na nastupe na drugim Olimpijskim igrama, a Behncke (1997) je izračunao da su performanse poboljšane za 0.17s za muškarce i 0.18s za žene, ali je tačnost rezultata upitna jer istraživanja nisu korigovale vrijeme trke zbog uticaja vjetra, koristile su mješavinu ručnih i elektronskih vremena, a Behncke nije uzeo u obzir istorijski trend u performansama (Linthorne, 2016).

Cilj istraživanja bio je utvrditi povezanost nadmorske visine i brzine vjetra sa ostvarenim rezultatima u trčanju na 100m za muškarce koji su kategorisani kao svjetski rekordi (ručno i elektronski mjereni rezultati) i izvršiti predikciju rezultata u zavisnosti od nadmorske visine i brzine vjetra, te utvrditi najbolje ostvarena vremena u godinama u kojima nisu zabilježeni svjetski rekordi i njihovu povezanost sa nadmorskom visinom i brzinom vjetra, i utvrditi periode stagnacije rezultata, kako bi se nakon određivanja tih perioda utvrdilo da li su mogući uzroci stagnacije nadmorska visina gradova u kojima su rekordi postignuti i brzina vjetra izmjerena prilikom ostvarivanja rezultata, što bi sve pomoglo kreiranju optimalnijih uslova za ostvarivanje boljeg rezultata i postavljanje novog rekorda u disciplini trčanje na100m.

Metodologija

U istraživanju su korištene metode teorijske analize koja je bila usmerena na objašnjavanje rezultata postignutih u okviru ostvarivanja rezultata svjetskih rekorda na 100m muškarci i najboljih istrčanih rezultata u periodima stagnacije ostvarivanja svjetskih rekorda na istoj dionici. Zatim, je korištena deskriptivna metoda, koja je imala je za cilj prikupljanje rezulata iz baza podataka (https://worldathletics.org/records/all-time-toplists/sprints/100-metres/outdoor/men/senior) i da opiše i objasni veze između dobijenih rezultata, kao i njihove odno-

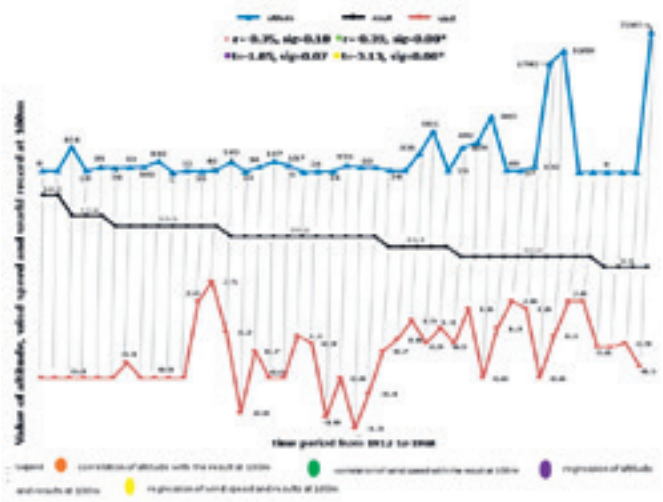
tionships. In this research, the results of the 100m world records measured by hand (43 results), the results of the 100m world records measured by electronic measurement (15 results) and the best results obtained during the stagnation period of achieving world records (the period from 1969 to 1982 - 15 results; the period from 1984 to 1987 - 4 results; the period from 2000 to 2004 - 5 results and the period from 2010 to 2023 - 14 results) were analyzed. The criterion variables in this research were the values of altitude (NV) and wind speed (VV) in the 100m races, while the predictor variable in this research was the results achieved in the 100m races. Statistical data processing was performed with the statistical program SPSS (version 20.0), and descriptive statistics, correlation analysis (linear relationship between two variables) and regression analysis (prediction of a variable (predictor) variable based on several independent (criterion) variables were performed.

Results

Table 1. *Descriptive statistics of manual measurement of world records at 100m*

	N	*M*	*S.d*
ALTITUDE / NV	43	257.81	51.45
WIND / VV	43	0.61	0.58
RES / REZ	43	10.16	0.17

Observing the average results of the achieved world records measured manually (table 1), it can be seen that the average world record was 10.16s, that the results were achieved at an average altitude of 257.81 m, and that the average wind speed was 0.61 ms^{-1}.



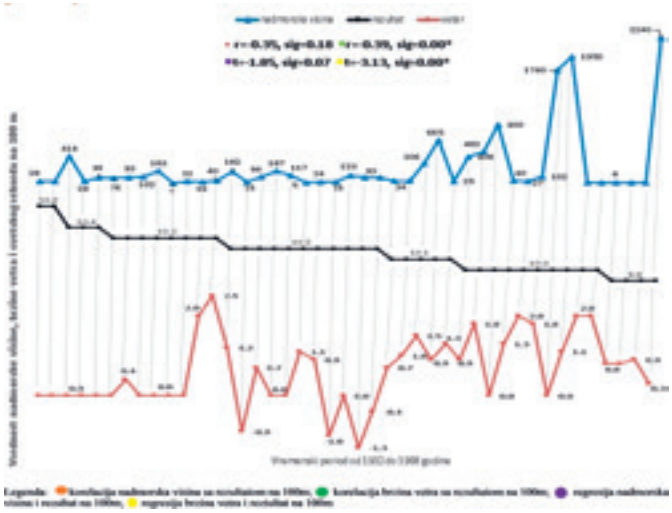
Graph 1. *Values of altitude, wind speed and world record at 100m in the period from 1912 to 1968 and their mutual relationship*

se. U ovom istraživanju su analizirani rezultati svjetskih rekorda na 100m mjerenih ručno (43 rezultata), rezultati svjetskih rekorda na 100m mjerenih elektronskim merenjem (15 rezultata) i najbolji rezultati istrčani u period stagnacije postizanja svjetskih rekorda (period od 1969. do 1982. - 15 rezultata; period od 1984. do 1987. - 4 rezultata; period od 2000. do 2004. - 5 rezultata i period od 2010. do 2023. - 14 rezultata). Kriterijske varijable u ovom istraživanju su bile vrednosti nadmorske visine (NV) i brzine vjetra (VV) na istrčanim trkama na 100m, dok je prediktorska varijabla u ovom istraživanju bila ostvareni rezultati u trkama na 100m. Statistička obrada podataka izvršena je statističkim programom SPSS (verzija 20.0), a provedene su deskriptivna statistika, korelaciona analiza (linearna veza između dvije promenljive) i regresiona analiza (predviđanje promenljive varijable (prediktorske) na osnovu više nezavisnih (kriterijskih) promenljivih).

Rezultati i diskusija

Tabela 1. *Deskriptivna statistika ručno merenje svjetski rekordi na 100m*

Posmatrajući prosečne rezultate ostvarenih svjetskih rekorda ručno mjerenih (tabela 1) uočava se da je prosječan svjetski rekord iznosio 10.16s, da su rezultati postignuti na prosječnoj nadmorskoj visini od 257.81 m, te da je prosječna brzina vjetra bila 0.61 ms^{-1}.



Grafikon 1. *Vrednosti nadmorske visine, brzine vjetra i svjetskog rekorda na 100m u periodu od 1912. do 1968. godine i njihov međusobni odnos*

By analyzing the correlation, i.e. the connection between the achieved results of the world records for the altitude where the values of the wind speed were run, the results shown in Graph 1 show that there is a statistically significant connection between the achieved results of the world records at 100m and the wind speed (r=-0.39. p=0.00*). It can be noticed that the negative sign correlation is shown, which means that if the wind speed is higher, the result is better and vice versa. The values of the results of the world records at 100m measured manually did not show a statistically significant relationship with the altitude. Graph 1 also shows the results of the prediction of world records at 100m based on altitude and wind speed. It is possible to predict the results based on the wind speed (p=0.00*), as shown by the correlation analysis. This means that the wind speed value is directly related to the 100m result values and is a significant factor that must be considered.

Analizom korelacije, odnosno povezanosti ostvarenih rezultata svjetskih rekorda nadmorske visine gdje su istrčani i vrednosti brzine vjetra rezultati prikazani u grafiku 1. govore da postoji statistički značajna povezanost ostvarenih rezultat svjetskih rekorda na 100m sa brzinom vjetra (r=-0.39. p=0.00*). Može se primjetiti da je pokazana korelacija negativnog predznaka što znači da ukoliko je brzina vjetra veća rezultat je bolji i obrnuto. Vrijednosti rezultata svjetskih rekorda na 100m mjerenih ručno nisu pokazali statistički značajnu povezanost sa nadmorskom visinom. Na grafiku 1. su, također, prikazani rezultati predikcije odnosno predviđanja rezultata svjetskih rekorda na 100m na osnovu nadmorske visine i brzine vjetra. Predviđanje rezultata moguće je ostvariti na osnovu brzine vjetra (p=0.00*) što je i pokazala korelaciona analiza. Ovo govori da je vrijednost brzina vjetra direktno povezana sa vrijednostima rezultata na 100m i značajan faktor koji se mora uzeti u obzir.

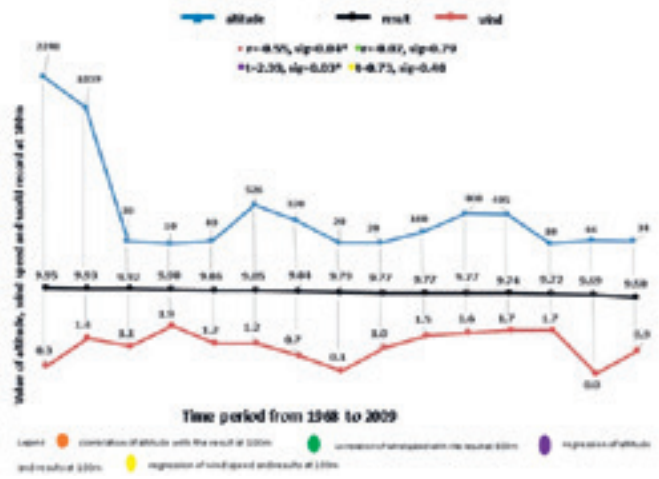
Table 2. *Descriptive statistics of electronical measurement of world records at 100m*

	N	*M*	*S.d*
ALTITUDE / NV	15	407.60	68.92
WIND / VV	15	1.08	0.59
RES / REZ	15	9.80	0.10

Tabela 2. *Deskriptivna statistika elektronsko merenje svjetski rekordi na 100m*

Observing the average results of achieved world records measured by electronic measurement in the period from 1968 to 2009 (table 2), it can be seen that in that period the average world record was 9.80s, that the results were achieved at an average altitude of 407.60 m, and that the average wind speed was 1.08 ms^{-1}.

Posmatrajući prosječne rezultate ostvarenih svjetskih rekorda mjerenih elektronskim mjerenjem u periodu od 1968. do 2009. godine (tabela 2) uočava se da je u tom razdoblju prosječan svjetski rekord iznosio 9.80s, da su rezultati postignuti na prosječnoj nadmorskoj visini od 407.60 m, te da je prosječna brzina vjetra bila 1.08 ms^{-1}.



Graph 2. *Values of altitude, wind speed and world record at 100m in the period from 1968 to 2009 and their mutual relationship*

Grafikon 2. *Vrijednosti nadmorske visine, brzine vjetra i svjetskog rekorda na 100m u periodu od 1968. do 2009. godine i njihov međusobni odnos*

Analyzing the correlation, i.e. the connection between the achieved results of world records and the altitude where they were run and the wind speed values, the results shown in Graph 2 show that there is a statistically significant correlation between the achieved results of world records at 100m and the altitude where they were run (r=0.55. p =0.04*). It can be noticed that the positive sign correlation is shown, which means that if the altitude is higher, the result is worse and vice versa. The values of the results of the world records at 100m measured by electronic measurement did not show a statistically significant connection with the wind speed that was used in those races.

The graph also shows the results of the prediction of world records at 100m based on altitude and wind speed. It is possible to predict the results based on the altitude (p=0.03) as shown by the correlation analysis, which means that the value of the altitude is directly related to the values of the results at 100m and is a significant factor that must be taken into account.

Analizom korelacije. odnosno povezanosti ostvarenih rezultata svetskih rekorda i nadmorske visine gdje su istrčani i vrijednosti brzine vjetra, rezultati prikazani u grafu 2. govore da postoji statistički značajna povezanost ostvarenih rezultat svjetskih rekorda na 100m sa nadmorskom visinom gdje su istrčani (r=0.55. p=0.04*). Može se primjetiti da je pokazana korelacija pozitivnog predznaka što govori da, ukoliko je nadmorska visina veća rezultat je lošiji i obrnuto. Vrednosti rezultata svjetskih rekorda na 100m mjerenih elektronskim mjerenje nisu pokazali statistički značajnu povezanost sa brzinom vjetra koja je izjerena na tim trkama. Na grafiku su, takođe, prikazani i rezultati predikcije odnosno predviđanja rezultata svjetskih rekorda na 100m na osnovu nadmorske visine i brzine vjetra. Predviđanje rezultata moguće je ostvariti na osnovu nadmorske visine (p=0.03) što je i pokazala korelaciona analiza, a to govori da je vrijednost nadmorske visine direktno povezana sa vrijednostima rezultata na 100m i značajan faktor koji se mora uzeti u obzir.

Table 3. *Descriptive statistics of electronic measurement of stagnation period from 1969 to 1982, from 1984 to 198, from 2000 to 2004 and from 2010 to 2023*

Tabela 3. *Deskriptivna statistika elektronsko mjerenje period stagnacije od 1969. do 1982, od 1984. do 1987, od 2000. do 2004. i od 2010. do 2023. godine*

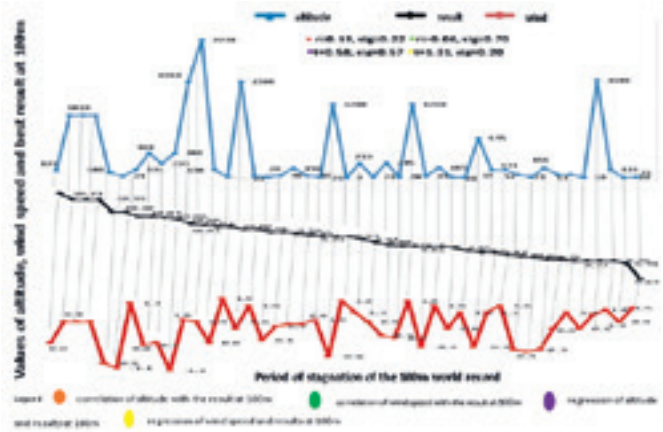
Period	ALTITUDE / NV			WIND / VV			RES / REZ		
	N	M	S.d	N	M	S.d	N	M	S.d
1969-2023*	45	336,41	54,77	45	0,66	0,21	45	9,91	0,13
1969-1982	15	613.92	73.58	15	0.21	0.08	15	10.06	0.07
1984-1987	4	56.00	6.67	4	1.10	0.34	4	9.95	0.02
2000-2004	5	145.60	27.93	5	0.58	0.37	5	9.87	0.04
2010-2023	14	181.64	40.83	14	0.87	0.72	14	9.77	0.05

**In the period from 1969 to 2023, there were also periods of stagnation lasting one or two years (1989-1990, 1992-1993, 1995, 1998-1999), a total of 7 results, which were not taken into consideration in individual analyzes because statistical analyzes do not recognize such a small sample, but are taken into consideration in the overall analysis.*

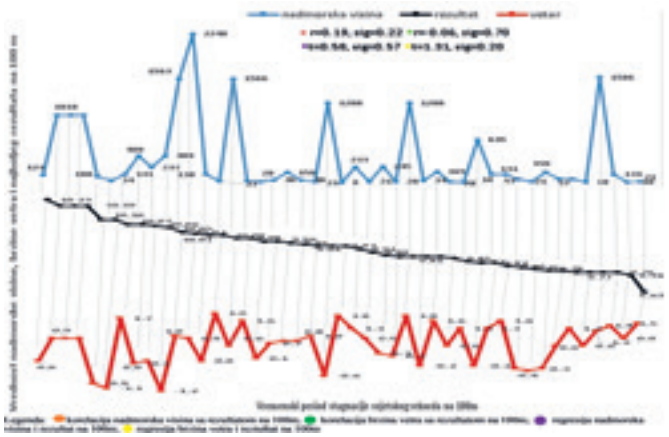
**U periodu od 1969 do 2023 bilo je i perioda stagnacije u trajanju od jednu ili dvije godine (1989-1990, 1992-1993, 1995, 1998-1999), ukupno 7 rezultata, koji nisu uzeti u razmatranje u pojedinačnim analizama jer statističke analize ne prepoznaju tako malobrojan uzorak, ali su uzeti u razmatranje u ukupnoj analizi.*

Looking at all the results (table 3) in the years when no world records were achieved at 100m (1969-2023), it can be seen that the average result is 9.91s, the average altitude is 336.41m, and the average wind speed is 0.66 ms^{-1}. Observing the average results of achieved world records by periods of stagnation (table 3), it can be seen that the best average result was in the period 2010-2023 and the worst in the period 1969-1982, that the highest average altitude was in the period 1969-1982, and the lowest in the period 1984-1987, and that the highest average wind speed was in the period 1984-1987 and the lowest in the period 1969-1982.

Posmatrajući sve rezultate (tabela 3) u godinama kada nisu postignuti svjetski rekordi na 100m (1969-2023) uočava se da je prosječan rezultat 9.91s, prosječna nadmorska visina 336.41 m, a prosječna brzina vetra 0.66 ms^{-1}. Posmatrajući prosječne rezultate ostvarenih svjetskih rekorda po periodima stagnacije (tabela 3) uočava se da je najbolji prosječan rezultat bio u periodu 2010-2023 a najlošiji u periodu 1969-1982, da je najveća prosječna nadmorska visina bila u periodu od 1969-1982, a najmanja u periodu 1984-1987, te da je najveća prosječna brzina vjetra bila u periodu 1984-1987 a najmanja u periodu 1969-1982.



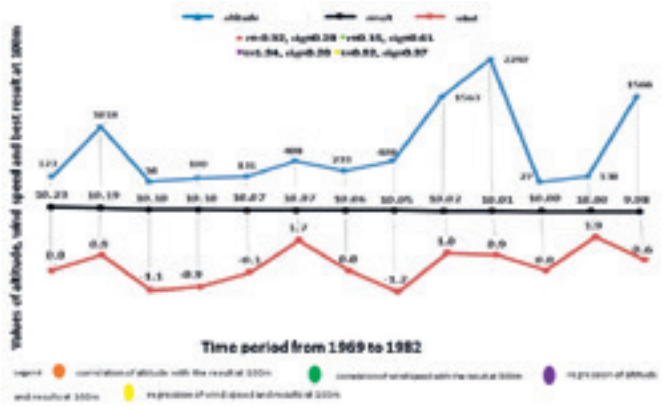
Graph 3. *Values of altitude, wind speed and the best result at 100m in the period since stagnation in total and their mutual relationship*



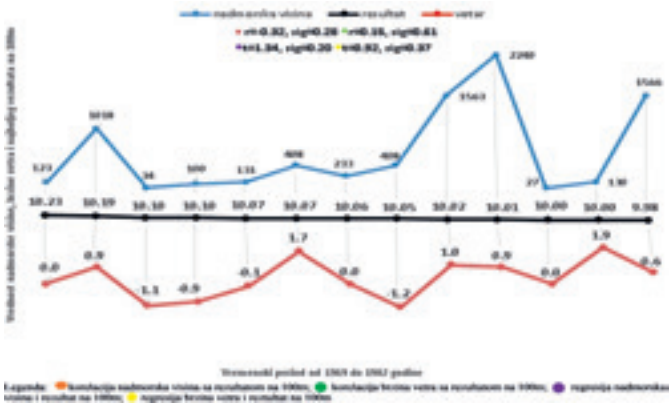
Grafikon 3. *Vrijednosti nadmorske visine, brzine vjetra i najboljeg rezultata na 100m u periodu od stagnacije ukupno i njihov međusobni odnos*

Analyzing the correlation, that is, the prediction of all results based on the values of altitude and wind speed in the period 1969-2023, no statistically significant correlations and predictions of results with the values of altitude and wind speed were observed (Graph 3).

Analiziranjem povezanosti, odnosno predikcije svih rezultata na osnovu vrednosti nadmorske visine i brzine vjetra u period 1969-2023., nije primećena statistički značajna povezanosti i predikcije rezultata sa vrednostima nadmorske visine i brzine vjetra (graf 3).



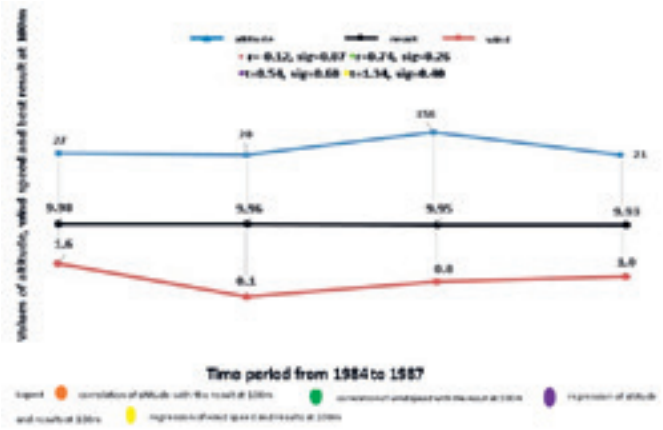
Graph 4. *Values of altitude, wind speed and best result at 100m in the period of stagnation from 1969 to 1982 and their mutual relationship*



Grafikon 4. *Vrednosti nadmorske visine, brzine vjetra i najboljeg rezultata na 100m u periodu od stagnacije 1969. do 1982. godine i njihov međusobni odnos*

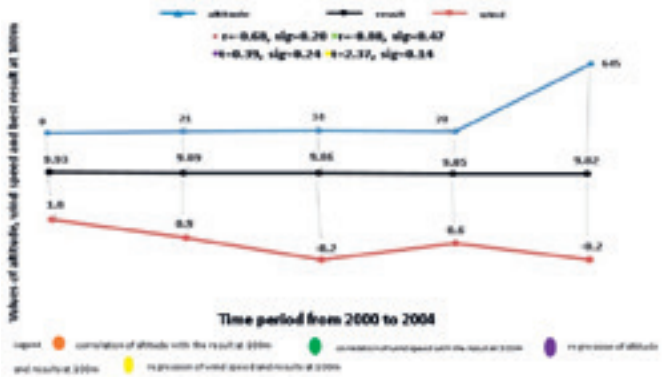
Observing the connection between the best results achieved at 100m in the period of stagnation (1969 to 1982) and the altitude where they were run and the wind speed values, the results shown in Graph 4 show that there is no statistically significant connection between the best results achieved in the period 1969-1982 with altitude where they were run (r=0.32, p=0.28) and wind speed (r=0.15, p=0.61). The graph also shows the results of the prediction of the best results at 100m in the period 1969-1982 based on altitude and wind speed. It is not possible to predict the results based on altitude (p=0.20), nor on the basis of wind speed (p=0.37).

Posmatrajući povezanosti ostvarenih najboljih rezultata na 100m u period stagnacije (1969 do 1982 godine) i nadmorske visine gdje su istrčani i vrednosti brzine vjetra, rezultati prikazani u grafikonu 4. govore da ne postoji statistički značajna povezanost ostvarenih najboljih rezultata u period 1969-1982. sa nadmorskom visinom gdje su istrčani (r=0.32. p=0.28) i brzinom vjetra (r=0.15. p=0.61). Na grafu su, takođe, prikazani i rezultati predikcije odnosno predviđanja najboljih rezultata na 100m u period 1969-1982. na osnovu nadmorske visine i brzine vjetra. Predviđanje rezultata nije moguće ostvariti na osnovu nadmorske visine (p=0.20), ni na osnovu vrednosti brzine vjetra (p=0.37).



Graph 5. *Values of altitude, wind speed and best result at 100m in the period of stagnation from 1984 to 1987 and their mutual relationship*

Observing the second period of stagnation of the world record at 100m (from 1984 to 1987), which is shown in Graph 5, no statistically significant correlation and prediction of the best results at 100m and altitude and wind speed were observed.



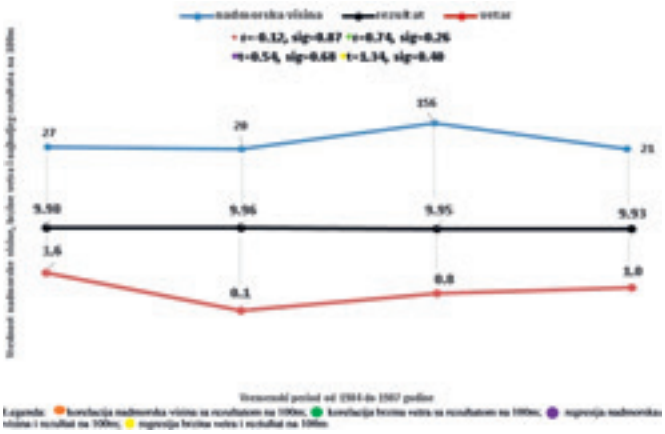
Graph 6. *Values of altitude, wind speed and best result at 100m in the period of stagnation from 2000 to 2004 and their mutual relationship*

Also, the third period of stagnation of the world record at 100m (from 2000 to 2004), which is shown in Graph 6, did not show a statistically significant correlation and prediction of the best results at 100m with altitude and wind speed.

In the fourth period of stagnation of the world record at 100m (from 2010 to 2023), no statistically significant correlation and prediction of the best results at 100m and the results of altitude and wind speed were observed (Graph 7).

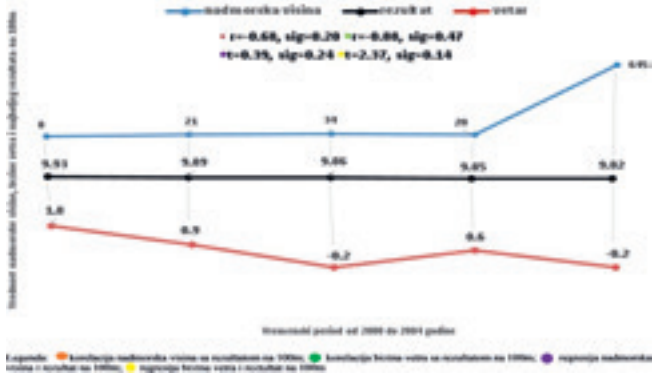
Discussion

After all the analyses, that is, by observing the results of recognized world records measured manually and electronically, it can be concluded that the wind speed had a



Grafikon 5. *Vrijednosti nadmorske visine, brzine vjetra i najboljeg rezultata na 100m u periodu od stagnacije 1984. do 1987. godine i njihov međusobni odnos*

Posmatrajući drugi period stagnacije svjetskog rekorda na 100m (od 1984. do 1987. godine) koji su prikazani u grafu 5. nije primećena statistički značajna korelacija i predikcija najboljih rezultata na 100m i nadmorske visine i brzine vjetra.



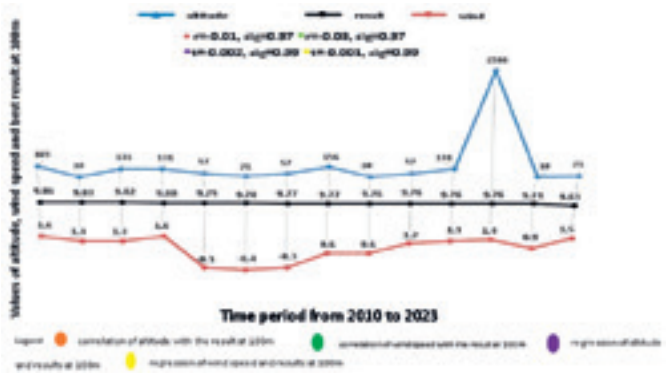
Grafikon 6. *Vrijednosti nadmorske visine, brzine vjetra i najboljeg rezultata na 100m u periodu od stagnacije 2000. do 2004. godine i njihov međusobni odnos*

Takođe, i treći period stagnacije svetskog rekorda na 100m (od 2000. do 2004. godine) koji je prikazan u grafu 6. nije pokazao statistički značajnu korelaciju i predikciju najboljih rezultata na 100m i nadmorske visine i brzine vjetra.

U četvrtom periodu stagnacije svjetskog rekorda na 100m (od 2010. do 2023. godine) nije primećena statistički značajna korelacija i predikcija najboljih rezultata na 100m i rezultata nadmorske visine i brzine vjetra (grafikon 7).

Diskusija

Nakon svih analiza, odnosno posmatranjem rezultata priznatih svjetskih rekorda mjerenih ručno i elektronski, može se zaključiti da je brzina vjetra imala pove-



Graph 7. *Values of altitude, wind speed and best result at 100m in the period of stagnation from 2010 to 2023 and their mutual relationship*

Grafikon 7. *Vrijednosti nadmorske visine, brzine vjetra i najboljeg rezultata na 100m u periodu od stagnacije 2010. do 2023. godine i njihov međusobni odnos*

connection and prediction in the achievement of the world record in the period from 1912 to 1968 when the results were measured manually (if the wind increased by 1 ms^{-1} the result would improve by 0.08 s), while the altitude value had a connection and prediction in the achievement of world records in the period from 1968 to 2009 when the results were recorded by electronic measurement (if the altitude increased by 1m the result would be improved by 0.00008 s). During the period of stagnation, the values of altitude and wind speed did not show a statistically significant connection or prediction, which might have been one of the reasons for this stagnation of the world record at 100m.

The development of the world record in athletics, and sports in general, has been influenced by several factors: enthusiasm of athletic (sports) experts (Bakov, 1961), evolution of technique (Stefanovic 1992b), development of athletic arenas (Skembler, 2007), improvement of sports equipment (Stefanovic, 2006), better training (Dik, 1980), pharmacological means of recovery (Dikic, 2007), financing (Mitrovic, Kantar, Rajkovic and Miletic, 2019), etc. The speed achieved in the sprint is determined by the processes of neuro-muscular regulation of movement, morphological characteristics, motor abilities and energy substrates (Mero, Komi and Gregor, 1992; Harland and Steele, 1997; Novacheck, 1998; Coh, Milanovic, Kampmiller, 2001; di Prampero , Fusi, Sepulcri, Morin, Belli and Antonutto, 2005), and is defined by step frequency and length (Delecluse, Ponnet and Diels, 1998; Brűggemann, Koszewski and Müller, 1999; Gajer, Thepaut-Mathieu & Lehenaff, 1999; Ferro, Rivera and Pagola, 2001), so the increase in step length is directly proportional to the decrease in step frequency (Mackala, 2007). Analyzing the progression of the world record at 100m, it can be concluded that in the period of 110 years (1912-2022) 67 world records were achieved, and Donald Lippincott's record from 1912 (10.6 s) was improved by "only" one second and now stands at 9.58 s (Ussain Bolt).

zanost i predikciju kod ostvarivanja svjetskog rekorda u periodu od 1912. do 1968. godine kada su rezultati mjereni ručno (ako se vjetar poveća za 1 ms^{-1} rezultat će se poboljšati za 0.08 sek), dok je vrednost nadmorske visine imala povezanost i predikciju u ostvarivanja svjetskih rekorda u period od 1968. do 2009. godine kada su rezultati bilježeni elektronskim mjerenjem (ukoliko se nadmorska visina poveća 1m rezultat će se poboljšati za 0.00008 sek). U period stagnacije vrijednosti nadmorske visine i brzine vjetra nisu pokazale statistički značajnu povezanost niti predikciju, što je možda jedan od razloga ove stagnacije svetskog rekorda na 100m.

Na razvoj svjetskog rekorda u atletici, i uopšte sportu, uticalo je više faktora: entuzijazam atletskih (sportskih) stručnjaka (Bakov, 1961) evolucija tehnike (Stefanović, 1992b), razvoj atletskih borilišta (Skembler, 2007), unapređenje sportske opreme (Stefanović, 2006), kvalitetniji trening (Dik, 1980), farmakološka sredstva oporavka (Dikić, 2007), finansiranje (Mitrović, Kantar, Rajković i Miletić, 2019), itd. Brzina postignuta u sprintu uslovljena je procesima neuro-mišićne regulacije kretanja, morfološkim karakteristikama, motoričkim sposobnostima i energetskim supstratima (Mero, Komi I Gregor, 1992; Harland i Steele, 1997; Novacheck, 1998; Čoh, Milanović, Kampmiller, 2001; di Prampero, Fusi, Sepulcri, Morin, Belli i Antonutto, 2005), a definisana je učestalošću i dužinom koraka (Delecluse, Ponnet i Diels, 1998; Brűggemann, Koszewski i Müller, 1999; Gajer, Thepaut-Mathieu i Lehenaff, 1999; Ferro, Rivera i Pagola, 2001), pa je povećanje dužine koraka izravno proporcionalno smanjenju frekvencije koraka (Mackala, 2007). Analizirajući progresiju svjetskog rekorda na 100m, može se zaključiti da je u periodu od 110 godina (1912-2022) postignuto 67 svjetskih rekorda, a rekord Donalda Lipinkota iz 1912. (10.6s) poboljšan je za „samo" jednu sekundu i sada iznosi 9.58s (Jusein Bolt). Trideset jedan

Thirty-one sprinters achieved one world record each, six achieved two world records each, four achieved three world records each, and three achieved four world records each.

About 75% of the Earth's land surface is at an altitude of less than 1000 m above sea level (Stacey and Davis, 2008), as is the vast majority of athletic competitions (Matthews, 2015). Sprint and jumping records were achieved in places above 1000 m - "aided by altitude" (Matthews, 2015). An altitude of 1000 m provides an advantage equivalent to a tailwind of 2 ms^{-1} (0.10 s), so the altitude of a competition venue should be taken into account when recognizing record-breaking performances in the 100 m sprint (Linthorne, 2016) . In the period 2000-2009, based on the performance of 56 elite male sprinters at major competitions, it was determined that the results achieved at an altitude above 1000 m above sea level were 0.05 s faster than those achieved in places below 1000 m above sea level and that the effect of the tailwind of 2 ms^{-1} in back improves the result by 0.08 s (Hollings, Hopkins and Hume, 2012), which indicates that the result in Mexico City (2250 m) should be given a time advantage of about 0.10 s (Linthorne, 2016). The analyzes of this research are not in accordance with those claims, because it was established that the world records were set at an average altitude of 407.60m, which is lower than 1000m, which would be worth investigating from the physiological basis of the body's functioning during sprint running, because, obviously, there are many factors that can be related to the result.

Explanation of the stagnation of the progress of world record results in the periods 1969-1982, 1984-1987, 2000-2004 and 2010-2023 should also be sought in the values of other climatic and other parameters. Also, potential factors that could affect the result and were not considered are: a time of year when a competition was held, differences in the time in which a sound of a starting gun travels to athletes from a starting gun, differences in sports shoes and the stiffness of a track, differences between athletes in the frontal area, effects of differences in air temperature, barometric pressure and humidity on aerodynamic resistance experienced by an athlete (Mureika, 2006) and an effect of temperature on generation of muscle power (Linthorne, 2016), because a fair system for recognizing record performances requires precise quantitative information about the effects of environmental conditions so that limits could be placed on the permissible range of conditions (Linthorne, 2016).

One of the problems with wind measurement in sprint running was observed at 200m, where there is a lack of wind data for the first half of the 200m race, because an anemometer measures wind speed of the last 85m of the race, but the question also arises as to whether wind speeds are constant

sprinter postigao je po jedan svjetski rekord, šestorica po dva svjetski rekord, četvorica po tri svjetski rekord, a trojica po četiri svjetska rekorda.

Oko 75% Zemljine kopnene površine nalazi se na nadmorskoj visini manjoj od 1000 m (Stacey i Davis, 2008), kao i velika većina atletskih takmičenja (Matthews, 2015). Rekordni u sprintu i skakanju postignuti su u mjestima iznad 1000 m- „potpomognute nadmorskom visinom" (Matthews, 2015). Nadmorska visina od 1000 m pruža prednost koja je ekvivalentna pomoćnom vjetru od 2 ms^{-1} (0,10 s), pa nadmorsku visinu mjesta takmičenja treba uzeti u obzir pri prepoznavanju rekordnih performansi u sprintu na 100 metara (Linthorne, 2016). U periodu 2000-2009. godina na osnovu nastupa 56 elitnih muških sprintera na velikim takmičenjima utvrđeno je da su rezultati postignuti na nadmorskoj visini iznad 1000 m bili 0.05s brži od onih postignutih u mjestima ispod 1000 m nadmorske visine i da efekat vjetra u leđa od 2 ms^{-1} u leđa poboljšava rezultat za 0.08 s (Hollings, Hopkins i Hume, 2012), što ukazuje da bi rezultat u u Mexico Cityju (2250 m) trebalo dati vremensku prednost od oko 0,10 s (Linthorne, 2016). Analize ovog istraživanja nisu u skladu sa tim tvrdnjama, jer je ustanovljeno da su svjetski rekordi postavljeni na prosječnoj nadmorskoj visini od 407.60m što je niža nadmorska visina od 1000m, što bi bilo vrijedno istražiti i sa fiziološke osnove funkcionisanja tijela prilikom sprinterskog trčanja, jer je očigledno da je mnogo faktora koji mogu biti povezani sa rezultatom.

Objašnjenje stagnacije napretka rezultata svjetskih rekorda u periodima 1969-1982, 1984-1987, 2000-2004. i 2010-2023. godine, takođe, treba tražiti u vrijednostima drugih klimatskih i ostalih parametara. Takođe, potencijalni faktori koji bi mogli uticati na rezultat a nisu razamatrani su: doba godine kada je takmičenje održano, razlike u vremenu u kojem zvuk startnog pištolja putuje do sportista iz startnog pištolja, razlike u sportskoj obući i krutosti staze, razlike među sportistima u frontalnom području, efekte razlika u temperaturi zraka, barometarskom pritisku i vlažnosti na aerodinamički otpor koji doživljava sportista (Mureika, 2006) i uticaj temperature na stvaranje mišićne snage (Linthorne, 2016), jer pravedan sistem priznavanja rekordnih performansi zahtjeva precizne kvantitativne informacije o efektima uslova sredine kako bi se mogla postaviti ograničenja na dozvoljeni opseg uslova (Linthorne, 2016).

Jedan od problema kod mjerenja vjetra kod sprinterskog trčanja uočen je na 200m gdje nedostatak podataka o vjetru za prvu polovinu trke na 200 m, jer vetromjer mjeri brzinu vjetra zadnjih 85 m trke, ali se postavlja pitanje

in the stadium, which questions the data on wind speed and its connection with the achieved result in the 100 m race (Mureika, 2003). The 100-meter sprint is the only discipline in which there is a reliable wind correction curve (Linthorne, 1994). Linthorne (2000) believes that the anemometer reading can only be accurate within ±0.9ms^{-1}. For the 100m races at the Olympics between 1964 and 2012, about 94% had wind readings between -2 and +2ms-^{1}, and only 4% were not eligible for the record because the wind was greater than +2ms^{-1} (Linthorne, 2016). In the 100m sprint, a tailwind of 2ms^{-1} produces a time advantage of about 0.10-0.12s over no-wind performance (Linthorne, 1994).

Applying mathematical models to calculate the time advantage of performing a 100m sprint in Mexico City gives an improvement in results of 0.05s (Dapena and Feltner, 1987), 0.08s (Mureika, 2001) and 0.10s (Behncke, 1997), but in Ward-Smith (1999) it is suggested that the predictions of mathematical models for sprinting should take into account a change in aerodynamic drag at a forward angle of a sprinter's body, as this is expected to affect sprinter's ability to generate forward propulsive force (which is only known with an accuracy of approx. 20%). The analyzes of this research are not in accordance with those claims, because it was established that the electronically measured world records were set at an average wind speed of 1.08, where no connection was established, so it is not possible to predict the results, while the connection of the wind with the manually measured results of the world records was shown, whereby a prediction can be made that with a wind speed of 1 ms^{-1} an improvement of the results of 0.08s can be expected. This, however, refers to a manually measured world records, while it cannot be claimed for electronically measured results. All of this points to the need for more detailed analyzes of as many factors as possible that can be related to the result in the 100m sprint, and that, in addition to mathematical models, it is necessary to analyze as many real factors and systems in which an athlete achieves the result with his/her performance.

Conclusion

Recent events related to the breaking of world records in athletics (broken world record in 400m, shot put, and pole vault) indicate that the limit of human capabilities has not yet been reached. The assumption is that the limits of records in athletics will still be moved, but much more slowly than before. The results of the research showed that until now the longest time distance between breaking two world records was 8 years, and the valid world record was achieved in 2009, thirteen and a half years ago, which indicates the fact that the world re-

i da li su brzine vjetra konstantne na stadionu što dovodi u pitanje i podatke o brzini vjetra i njenoj povezanosti sa postignutim rezultatom i u trci na 100 m (Mureika, 2003). Sprint na 100 metara je jedina disciplina u kojoj postoji pouzdana kriva korekcije vjetra (Linthorne,1994). Linthorne (2000) smatra da očitanje mjerača vjetra može biti tačno samo unutar ±0.9ms^{-1}. Za trke na 100 metara na Olimpijskim igrama između 1964. i 2012. godine, oko 94% je imalo očitavanje vjetra između 2 i +2 ms^{-1}, a samo 4% nije bilo kvalifikovano za rekord jer je vjetar bio veći od +2 ms^{-1} (Linthorne, 2016). U sprintu na 100 m pomoćni vjetar od 2 ms^{-1} proizvodi vremensku prednost od oko 0,10-0,12 s u odnosu na učinak bez vjetra (Linthorne, 1994). Primjena matematičkih modela za izračunavanje vremenske prednosti izvođenja sprinta na 100 metara u Mexico Cityju daje poboljšanje rezultata od 0.05 s (Dapena i Feltner,1987), 0.08s (Mureika, 2001) i 0.10s (Behncke, 1997), ali Ward-Smith (1999) sugeriše se da predviđanja matematičkih modela za sprint teba da uzmu u obzir promjenu aerodinamičkog otpora na ugao nagiba tijela sprintera prema naprijed, jer se očekuje da to utiče na sposobnost sprintera da generiše propulzivnu silu prema naprijed (što je poznato samo s preciznošću od oko 20%). Analize ovog istraživanja nisu u skladu sa tim tvrdnjama, jer je ustanovljeno da su elektronski mjereni svjetski rekordi postavljeni pri prosječnoj brzini vjetra od 1.08 pri čemu nije utvrđena povezanost pa se ne može izvršiti ni predikcija rezultata, dok se pokazala povezanost vjetra sa ručno mjerenim rezultatima svjetskih rekorda pri čemu se može izvršiti predikcija da se sa brzinom vjetra od 1 ms^{-1} može očekivati poboljšanje rezultata od 0.08s. To se, ipak odnosi na ručno mjeren svjetski rekord dok se ne može tvrditi za elektronski mjerene rezultate. Sve to ukazuje na potrebu detaljnijih analiza što većeg broja faktora koji mogu biti povezani sa rezultatom u sprintu na 100m, te da, i pored matematičkih modela, treba analizirati što više realnih faktora i sistema u kojima sportista svojom performansom ostvaruje rezultat.

Zaključak

poslednji događaji koji se odnose na obaranje svjetskih rekorda u atletici (oboreni svetski rekord na 400m, bacanju kugle, i skoku motkom) ukazuju da se još nije došlo do granice ljudskih mogućnosti. Pretpostavka je da će se granice rekorda u atletici još pomjerati, ali mnogo sporije nego do sada. Rezultati istraživanja su pokazali da je do sada najveća vremenska distanca između obaranja dva svjetska rekorda bila 8 godina, a važeći svjetski rekord postignut je 2009, prije trinaest i po godina, što ukazuje na činjenicu da će se svjetski rekord sve ređe

cords will be achieved less and less often. The conclusion reached by the analysis of the exhaustion of the men's 100m sprint record, when processed at a more profound level, leads to the opposite interpretation, which is reflected in the change of sports rules or a greater tolerance for mechanical aids, aggressive interventions on the human body, and all possible other options that will help to continue breaking the record ie. a projection of a false image of man's dominance over God, because "the show must go on". As health represents a kind of dynamic homeostasis, the assumption is that the future superior system of exercise and health will neither consider nor seriously encourage the phenomenon of records at any level, except in the sphere of interest.

In order to improve the results in the 100m sprint, it is necessary to include as many experts of all profiles as possible, whose actions would provide answers to the functioning of the human body in different environments and more complex systems in which it should deliver its performance to the maximum extent possible, because the observation of parts of the system through the data known to the wider scientific public, cannot give precise answers or instructions for achieving better results, and therefore not for improving world records.

i ređe postizati. Zaključak donešen analizom o iscrpljivanju rekorda u sprintu na 100m za muškarce, kada se obradi na dubljem nivou, vodi do suprotnog tumačenja, koje se ogleda u izmjeni sportskih pravila ili do veće tolerancije na mehanička pomagala, agresivne intervencije na ljudskom tijelu, i sve moguće druge opcije koje će pomoći da se nastavi obaranje rekorda tj. projekcija lažne slike dominacije čoveka nad bogom, jer „show must go on". Kako zdravlje predstavlja svojevrsnu dinamičku homeostazu, pretpostavka je da budući superiorni sistem vježbanja i zdravlja uopšte neće ni razmatrati, ni podsticati ozbiljno fenomen rekorda na bilo kojem nivou, sem u sferi zanimljivosti.

Kako bi se rezultati u sprintu na 100m poboljšavali, potrebno je uključiti što veći broj stručnjaka svih profila čije bi djelovanje dalo odgovore na funkcionisanje ljudskog tijela u različitim sredinama i kompleksnijim sistemima u kojima treba da svoju performansu izvede maksimalnim mogućnostima, jer posmatranje dijelova sistema kroz, široj naučnoj javnosti poznate podatke, ne mogu dati precizne odgovore niti upute za ostvarivanje boljih rezulatata, a samim tim ni za poboljšanje svjetskih rekorda.

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Analysis of Quantitative Changes in Morphological Characteristics of Young Volleyball Players Under the Influence of an Experimental Program

Analiza kvantitativnih promjena morfoloških karakteristika mladih odbojkašica pod uticajem eksperimentalnog programa

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Summary: *The study was conducted on a sample of 50 female respondents - girls from the Primary School "Sveti Sava" and the Primary School "Sutjeska" from Modriča, aged 10 to 12 years, who train volleyball in the Volleyball Club "Modriča - Novoprom" from Modriča, with the aim of determining partial and global quantitative changes in the applied morphological characteristics that occurred under the influence of a specially defined volleyball program lasting six months. The study used a set of 12 variables to assess morphological characteristics measured according to the instructions of the International Biological Program (IBP). To determine partial quantitative changes (differences) of the applied morphological characteristics, the results of the T test analysis were applied, and to determine quantitative changes (differences) of morphological characteristics at the global level, canonical discriminant analysis was applied. The results of the T test and canonical discriminant analysis show that under the influence of the programmed volleyball work for six months, statistically significant partial and global changes (differences) occurred in the space of morphological characteristics that can be attributed to the influence of the applied volleyball program, but changes in the biological growth and development of the subjects that are characteristic of the age group 10-12 years should not be ignored. The obtained results may be useful for coaches of younger volleyball selections in volleyball clubs and volleyball schools, and physical education teachers in quality programming of the training and teaching process with younger age categories of girls.*

Key words: *girls, canonical discriminant analysis, volleyball, changes, work program, T test.*

Sažetak: *Istraživanje je provedeno na uzorku 50 ispitanica - djevojčica JU OŠ „Sveti Sava" i JU OŠ „Sutjeska" iz Modriče, starosne dobi od 10 do 12 godina koje treniraju odbojku u OK „Modriča – Novoprom" iz Modriče s ciljem utvrđivanja parcijalnih i globalnih kvantitativnih promjena primijenjenih morfoloških karakteristika nastalih pod uticajem posebno definisanog programa odbojke u trajanju šest mjeseci. U istraživanju je primijenjen set od 12 varijabli za procjenu morfoloških karakteristika mjerenih prema uputama Internacionalnog Biološkog programa (IBP). Za utvrđivanje parcijalnih kvantitativnih promjena (razlika) primijenjenih morfoloških karakteristika primijenjeni su rezultati analize T testa a za utvrđivanje kvantitativnih promjena (razlika) morfoloških karakteristika na globalnom nivou primijenjena je kanonička diskriminativna analiza. Rezultati T testa i kanoničke diskriminativne analize pokazuju da je pod uticajem programiranog rada odbojke u trajanju šest mjeseci došlo do statistički značajnih parcijalnih i globalnih promjena (razlika) u prostoru morfoloških karakteristika koji se mogu pripisati uticaju primijenjenog programa odbojke ali se ne smiju zanemariti promjene biološkog rasta i razvoja ispitanica koje su karakteristične za uzrasnu dob 10 – 12 godina. Dobiveni rezultati mogu biti od koristi trenerima mlađih selekcija odbojkašica u odbojkaškim lubovima i školama odbojke, te profesorima tjelesnog odgoja u kvalitetnom programiranju trenažnog i nastavnog procesa sa mlađim uzrasnim kategorijama djevojčica.*

Ključne riječi: *globalne i parcijalne promjene, program rada, kanonička diskriminativna analiza,T test, učenici.*

Introduction

Morphological characteristics describe the body structure of a person based on a large number of anthropometric data. Morphological characteristics (anthropometric characteristics) are part of anthropological characteristics, and are defined as traits that are responsible for the dynamics of growth and development and the characteristics of the body structure to which they belong: bone growth in length, bone growth in width, muscle mass and subcutaneous fat tissue (Neljak et al., 2011). Taking into account the morphological characteristics of an individual child, it is possible to more easily assess the reason for success or failure in certain kinesiological activities.

Volleyball as a sport, according to its structural characteristics, belongs to the group of polystructural acyclic sports. The dynamics with which volleyball actions are performed, especially in today's modern top sport, is extremely emphasized, with almost incredible moves of individuals that sometimes take place literally in a split second. The characteristics of volleyball are multiple and multidimensional, with some properties that simply must be above average if one wants to achieve top sports results (Janković and Sabljak, 2004).

Bonacin et al., (2008) point out that for the realization of volleyball demands of top sport in senior age, three preconditions are needed that must be achieved in order to reach that goal, and they are articulated as sports models. The first precondition is knowledge of the volleyball model, i.e. the characteristics of the game that is realized and the characteristics of the players who are part of such realization. The second precondition is knowledge of the transformation process that leads beginners of e.g. 7, 8 years old to top results. And the third precondition is the identification of potentially especially gifted children for volleyball, in accordance with their characteristics (Bonacin and Smajlović, 2005).

The main problem addressed in this paper relates to the determination of quantitative changes (differences) in morphological characteristics of volleyball players aged 10-12 years under the influence of a six-month volleyball program. Transformational processes that produce changes in the anthropological characteristics and abilities of athletes that strive for their greatest values include planning, programming, implementation and control of those processes in order to achieve a predetermined goal, which is reflected in the achievement of the highest levels of anthropological characteristics.

All anthropological characteristics and abilities at the beginning of the implementation of an experimental program are at a certain level of development, which is treated

Uvod

Odbojka kao sport po svojim strukturalnim karakteristikama pripada grupi polistrukturalnih acikličnih sportova. Dinamika kojim se odbojkaške akcije izvode, a posebno u današnjem modernom vrhunskom sportu, iznimno je naglašena, uz gotovo nevjerovatne poteze pojedinaca koji se ponekad odvijaju doslovno u djeliću sekunde. Karakteristike odbojke su višestruke i multidimenzionalne, uz neka svojstva koja naprosto moraju biti iznad prosječna ukoliko se želi postizati vrhunski sportski rezultat (Janković i Sabljak, 2004).

Bonacin i sar., (2008) ističu da su za realizaciju odbojkaških zahtjeva vrhunskog sporta u seniorskom uzrastu, potrebna tri preduslova koji se moraju ostvariti kako bi se taj domet i dostigao, a artikulišu se kao sportski modeli. Prvi preduslov je poznavanje modela odbojke, odnosno svojstva igre koja se realizuje i odlika igrača koji su dio takve realizacije. Drugi preduslov je poznavanje transformacionog procesa koji početnike uzrasta npr. 7, 8 godina dovodi do vrhunskih rezultata. I treći preduslov je identifikacija potencijalno posebno nadarene djece za odbojku, u skladu s njihovim odlikama (Bonacin i Smajlović, 2005).

Osnovni problem kojim se bavi ovaj rad odnosi se na utvrđivanje kvantitativnih promjena (razlika) morfoloških karakteristika odbojkašica uzrasne dobi 10-12 godina pod uticajem šestomjesečnog programa odbojke. Transformacioni procesi koji proizvode promjene antropoloških karakteristika i sposobnosti sportista koje teže njihovim najvećim vrijednostima obuhvataju planiranje, programiranje, provođenje i kontrolu tih procesa da bi se postigao unaprijed definisani cilj, koji se ogleda u postizanju najviših nivoa antropoloških obilježja.

Sve antropološke karakteristike i sposobnosti na početku realizacije nekog eksperimentalnog programa nalaze se na nekom nivou razvoja koji se tretira kao početni (inicijalni) nivo što predstavlja polaznu osnovu ili inicijalno stanje sportiste. Kada se utvrdi početni nivo osobina i sposobnosti na početku realizacije eksperimentalnog programa sa sportistom se ulazi u realizaciju programa u kojem su tačno definisani sljedeći elementi: opterećenje sa obimom i intenzitetom rada, trenažna sredstva, trenažne metode, oblici rada itd. Zbog toga u procesu trenažnog rada sa djecom i omladinom za razvoj pojedinih antropoloških obilježja (Srdić i sar., 2023) treba primjenjivati efikasne postupke u izboru sadržaja metoda rada, organizacionih oblika, intenziteta opterećenja i oporavka. Pozitivni efekti transformacionih procesa mogu se očekivati samo pod uslovom da je metodičko oblikovanje trenažnog rada prilagođeno

as the initial (initial) level, which represents the starting point or initial state of the athlete. When the initial level of characteristics and abilities is determined at the beginning of the implementation of the experimental program, the athlete enters the implementation of the program in which the following elements are precisely defined: workload with volume and intensity of work, training equipment, training methods, forms of work, etc. Therefore, in the process of training work with children and youth for the development of certain anthropological characteristics (Bala et al., 2018; Srdić et al., 2023), effective procedures should be applied in the selection of the content of work methods, organizational forms, intensity of load and recovery. Positive effects of transformation processes can be expected only on condition that the methodological design of training work is adapted to the individual abilities and characteristics of each individual (Sekulić and Metikoš, 2007).

By realizing the programmed contents conceived on the aforementioned basis and their realization over a certain period of time, it is realistic to expect changes in the level of initial abilities, characteristics and knowledge, which produce a new and better state (final state) compared to the initial state (initial state), provided that the programmed work was carried out according to plan.

With younger selections, changes occur during growth and maturation, especially during the development of physical abilities, sports technique and tactics, which plays a very important role in formation of habits and positive personality characteristics. According to Milanović (2010), body binding can influence the development of muscle mass and the reduction of subcutaneous fat tissue, while it is not possible to influence the longitudinal and transverse measurements of the skeleton.

When working with younger age categories of children, one should not be burdened with achieving premature sports results, but focus the training process more on improving specific abilities required for a specific branch of sport, adopting and mastering technique and game.

What should be the "guiding star" in working with younger age categories is that raising the necessary abilities, learning and perfecting the elements of the volleyball game are of primary importance, and the competition is what should come through the game (of secondary importance).

Methods

Sample of respondents

The study was conducted on a sample of 50 respondents - girls from the Primary School "Sveti Sava" and the Primary School "Sutjeska" from Modriča, aged 10 to

individualnim sposobnostima i osobinama svakog pojedinca (Sekulić i Metikoš, 2007).

Realizacijom programiranih sadržaja koncipiranih na navedenim osnovama i njihovom realizacijom kroz određeni vremenski period realno je očekivati promjene nivoa početnih sposobnosti, karakteristika i znanja, koje proizvode novo i kvalitetnije stanje (finalo stanje) u odnosu na početno (inicijalno stanje) pod uslovom da se programirani rad realizovao po planu.

Kod mlađih selekcija dešavaju se promjene tokom rasta i sazrijevanja, naročito tokom razvoja fizičkih sposobnosti, sportske tehinike i taktike, što ima veoma važnu ulogu u formiranju navika i pozitivnih karakteristika ličnosti. U radu sa mlađim uzrasnim kategorijama djece ne treba biti opterećen postizanjem preranih sportskih rezultata, već trenažni proces više usmjeriti na poboljšanje specifičnih sposobnosti potrebnih za konkretnu granu sporta, usvajanje i ovladavanje tehnikom i igrom.

Ono što treba biti „zvijezda vodilja" u radu sa mlađim uzrasnim kategorijama je da podizanje potrebnih sposobnosti, učenje i usavršavanje elemenata odbojkaške igre predstavljaju ono što je od primarnog značaja, a takmičenje je ono što što kroz igru treba da dođe (sekundarnog značaja).

Metode rada

Uzorak ispitanika

Istraživanje je provedeno na uzorku od 50 ispitanica - djevojčice JUOŠ „Sveti Sava" i JUOŠ „Sutjeska" iz Modriče, starosne dobi od 10 do 12 godina koje treniraju odbojku u OK „Modriča – Novoprom" iz Modriče. Po pitanju validnosti uzorka nije bilo nikakvih posebnih ograničenja izuzev osim što su djevojčice uključene u ovaj uzorak u trenutku testiranja i mjerenja, kao i provedbe programa rada morale biti zdrave i u cjelosti proći planirani trenažni program.

Uzorak varijabli

Za procjenu morfoloških karakteristika primijenjen je set od 12 morfoloških mjera koje relativno dobro pokrivaju istraživani prostor (Kurelić i sar. 1975; Mikić, 1999). Kod izbora varijabli vodilo se računa da budu prilagođene uzrasnoj dobi ispitanica.

12 years old, who train volleyball at the OK "Modriča - Novoprom" from Modriča. There were no special restrictions regarding the validity of the sample, except that the girls included in this sample had to be healthy at the time of testing and measurement, as well as the implementation of the work program, and had to fully complete the planned training program.

Sample variables

A set of 12 morphological measures was used to assess morphological characteristics, which relatively well covered the studied area (Kurelic et al. 1975). When choosing variables, care was taken to ensure that they were adapted to the age of the subjects.

Results

Analysis of partial quantitative changes in morphological characteristics

Table 1 shows the results of the analysis of the T test results of 12 morphological characteristics, in which the arithmetic mean values and T test values for all applied variables for the assessment of morphological characteristics are presented. Based on the presented arithmetic mean values (Mean) of the applied morphological characteristics at the initial and final measurement, i.e. Before and after the implementation of a six-month volleyball program and based on the significance of transformation changes (p) tested by the T test for dependent variables, changes can be seen in measures for assessing the longitudinal dimensionality of the body (body height ATJVIS .058; arm length .000; leg length .007) and in measures for assessing the transverse dimensionality of the body (hand diameter ADIJZŠ .000; ankle diameter joint ADIJSZ .004 and knee joint diameter ADIJKO .005).

Further analysis of the significance of the changes (p) tested (T-test) shows that all measures of morphological characteristics that achieved a certain increase in the final measurement in the values of arithmetic means (Mean) achieved the corresponding coefficient of statistical significance (p). Variables of morphological characteristics tested by T-test that achieved their corresponding coefficient of statistical significance (p), thus show that there were statistically significant differences in those variables change.

The results of the T test show that out of the 12 applied morphological variables, there were significant changes in 6 variables, namely the variables for assessing the longitudinal and transverse dimensionality of the body, which are strongly influenced by the genetic code and are a product of the growth and development of the girls' organism. No

Rezultati

Analiza parcijanih kvantitativnih promjena morfoločkih karakteristika

U tabeli 1 prikazani su rezultati analize rezultata T testa morfoloških karakteristika u kojoj su przentirane vrijednosti aritmetičkih sredina i vrijednosti T testa za sve primijenjene varijable za procjenu morfoloških karakteristika. Na osnovu prezentiranih vrijednosti aritmetičkih sredina (Mean) na inicijalnom i finalnom mjerenju tj. prije i poslije realizacije šestomjesečnog programiranog rada odbojke i na osnovu značajnosti transformacionih promjena (p) testiranih T testom može se vidjeti da je primijenjeni program odbojke proizveo statistički značajne parcijalne promjene u svim testovima za procjenu longitudinalne dimenzionalnosti tijela (tjelesna visina ATJVIS .058; dužina ruku .000; dužina nogu .007). Takođe, statistički značajne promjene utvrđene su kod mjera za procjenu transverzalne dimenzionalnosti tijela (dijametar šake ADIJZŠ .000; dijametar skočnog zgloba ADIJSZ .004 i dijametar zgloba koljena ADIJKO .005). Na ivici statističke značajnosti nalazi se i varijabla tjelesne težine ATJTEŽ .061.

Daljom analizom značajnosti promjena (p) testiranih (T-testom) može se vidjeti da su svi testovi morfoloških karakteristika koji su postigli određeni porast u finalnom mjerenju tj. na kraju realizacije programa u vrijednostima aritmetičkih sredina (Mean) postigli su pripadajući im koeficijent statističke značajnosti (p). Varijable morfoloških karakteristika testirane T-testom koje su postigle pripadajući im koeficijent statističke značajnosti (p), time pokazuju da je u tim varijablama došlo do statistički značajnih parcijalnih promjena.

Na osnovu dobijenih rezultata T testa može se konstatovati da program rada odbojke proizveo parcijalne kvantitativne promjene u većem broju varijabli za procjenu morfoloških karakteristika.

Kod antropometrijskih mjera za procjenu cirkularne dimenzionalnosti tijela i kod kožnih nabora nisu utvrđene statistički značajne parcijalne promjene (razlike) što predstavlja iznenađenje.

Table 1. *Analysis of partial quantitative changes in morphological characteristics tested by the T test*

Tabela 1. *Analiza parcijalnih kvantitativnih promjena morfoloških karakteristika testiranih T testom*

	Wilks' Lambda	F	df1	df2	Sig
Anthropometry body height / ATJVIS	.965	.3672	1	102	.058
Anthropometry arm length / ADUŽRU	.860	16.560	1	102	.000
Anthropometry leg length / ADUŽNO	.932	7.453	1	102	.007
Anthropometry ankle joint diameter / ADIJSZ	.981	1.966	1	102	.004
Anthropometry knee diameter / ADIJKO	.975	2.663	1	102	.005
Anthropometry wrist joint diameter / ADIJZŠ	.800	25.456	1	102	.000
Anthropometry body weight / ATJTEŽ	.970	3.112	1	102	.061
Anthropometry chest circumference / ASROGK	.991	.956	1	102	.330
Anthropometry abdominal circumference / AOBTRB	.998	.166	1	102	.685
Anthropometry triceps skinfold / ANATRI	.999	.077	1	102	.782
Anthropometry calf skinfold / ANAPOT	.999	.104	1	102	.748
Anthropometry skinfold of the back / ANALEĐ	.995	.542	1	102	.463

statistically significant changes (differences) were found in the variables for evaluating the circular dimensionality of the body and skin folds, which is a surprise in this research considering the minor influence of genetic inheritance. Skin folds are less influenced by genetic inheritance, i.e. growth hormone (K = .50), which provides a greater possibility of their change under the influence of well-programmed kinesiology activities. On the transformation of circular dimensionality, as well as skin folds, programmed work can affect positive changes depending on the training contents and training operators of which it is composed, as well as the duration of the experimental treatment.

Analysis of global quantitative changes in morphological characteristics

To determine global quantitative changes (global quantitative effects of change) in morphological characteristics, canonical discriminant analysis was applied in this study. The criterion for the discriminant strength of the applied variables was the so-called Wilks' Lambda. The determination of the statistical significance of each discriminant variable was performed based on the Bartlett Chi-square test. Significant discriminant variables were used for interpretation and explained a certain percentage of the common variance.

The tables also show standardized discriminant coefficients as well as normalized coefficients of participation of morphological variables in the formation of significant discriminant functions of central groups on significant discriminant functions.

Box's test (table 2) in the initial and final measurements determined that there are statistically significant differences (Sig. .000) in the covariances of the analyzed matrices.

Analiza globalnih kvantitativnih promjena morfoločkih karakteristika

Za utvrđivanje globalnih kvantitativnih promjena (globalni kvantitativni efekti promjena) morfoloških karakteristika u ovom istraživanju primijenjena je kanonička diskiriminativna analiza. Kriterij za diskriminativnu jačinu primijenjenih varijabli bio je tzv. Wilksova Lambda. Određivanje statističke značajnosti svake diskriminativne varijable vršeno je na osnovu Bartletovog Hi-kvadrat testa. Za interpretaciju korištene su značajne diskriminativne varijable i one objašnjavaju određeni procenat zajedničke varijanse.

U tabelama su prikazani i standardizovani diskriminativni koeficijenti kao i normirani koeficijenti učešća morfoloških varijabli u formiranju značajnih diskriminativnih funkcija centralnih grupa na značajnim diskriminativnim funkcijama.

Boxovim testom (tabela 2) u inicijalnom i finalnom mjerenju utvrđeno je da postoje statistički značajne razlike (Sig. .000), u kovarijansama analiziranih matrica.

Table 2. *Box's test of statistical significance of changes in morphological characteristics*

Tabela 2. *Boxov test statističke značajnosti promjena morfoloških karakteristika*

	Rank	Log Determinant
Initially / Inicijalno	12	19.080
Final / Finalno	12	33.953
Pooled within-groups	12	32.215

Test Results

Box's M		581.285
F	Approx.	6.527
	df1	78
	df2	32854.097
	Sig.	.000

Based on the results presented in Table (3), the differences between the initial and final measurements in the quantitative effects of the volleyball program in the space of morphological characteristics of young volleyball players were analyzed. Table 3 shows the significance of the isolated discriminant function. The results obtained indicate that the discriminative power of morphological tests, as shown by the Wilks' Lambda test, is very high (.644), which indicates that the differences between the initial and final measurements of the subjects are statistically significant at the (Sig. .000) level.

The canonical correlation coefficient indicates that .597% of the significance of the canonical function is explained, or rather, the discriminative function, which shows us in what correlation the set of applied data on the basis of which we performed discriminative analysis and the results in the discriminative function are. The explained correlation coefficient for the entire set of morphological variables has a high value (Chi-square = 42.25).

Na osnovu rezultata prezentiranih u tabeli (3) analizirane su razlike između inicijalnog i finalnog mjerenja u kvantitativnim efektima programa odbojke u prostoru morfoloških karakteristika mladih odbojkašica. U tabeli 3 prikazana je značajnost izolovane diskriminativne funkcije. Dobiveni rezultati ukazuju da je diskriminativna jačina morfoloških testova prikazana testom Wilks' Lambda vrlo visoka (.644), što ukazuje da su razlike između inicijalnog i finalnog mjerenja ispitanica statistički značajne na nivou (Sig. .000).

Koeficijent kanoničke korelacije (Canonical Correlation) ukazuje da je .597% objašnjena značajnost kanoničke funkcije, odnosno diskriminativnost funkcije što nam ukazuje u kojoj su korelaciji skup primijenjenih podataka na osnovu kojih smo vršili diskriminativnu analizu i rezultati u diskriminativnoj funkciji. Objašnjeni koeficijent korelacije na cijeli set morfoloških varijabli ima visoku vrijednosti (Chi-square = 42,25).

Table 3. *Significance of the isolated discriminative function of morphological characteristics*

Tabela 3. *Značajnost izolovane diskriminativne funkcije morofloških karakteristika*

Fukction	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.553[a]	100.0	100.0	.597

Wilks' Lambda

Test of Functions (s)	Wilks' Lambda	Chi- square	df	Sig.
1	.644	42.253	12	.000

Legend: Eigenvalue-squares *of discrimination coefficients, Canonical R-coefficient of canonical correlation, Wilks Lambda-values of Bartlett's test, Chi-square-significance of the relationships investigated space, df-degrees of freedom*

Legenda: Eigenvalue-kvadrati *koeficijenata diskriminacije, Canonical R-koeficijent kanoničke korelacije, Wilks Lambda-vrijednsoti Bartletovog testa, Chi-square-značajnost veza istraživanih prostora, df-stepeni slobode*

In order to verify the effectiveness of the applied volleyball program, twelve morphological measures

Da bi se provjerila efikasnost primijenjenog programa odbojke izmjereno je na početku i na kraju

were measured at the beginning and end of the program, which are assumed to be good measures of the investigated morphological space.

An overview of the results shown in table 4 shows that the greatest contribution to the discriminative function is made by anthropometric measures for assessing the longitudinal dimensionality of the body (arm length, body height) and transverse dimensions of the body (hand diameter, knee diameter and ankle diameter).

programa dvanaest morfoloških mjera za koje se pretpostavlja da su dobra mjera istraživanog morfološkog prostora.

Pregledom rezultata prikazanih u tabeli 4 vidi se da najveći doprinos diskriminativnoj funkciji imaju antropometrijske mjere za procjenu longitudinalne dimenzionalnosti tijela (dužina ruku, tjelesna visina) i transverzalne dimenzionalnosti tijela (dijametar šake, dijametar koljena i dijametar skočnog zgloba).

Table 4. *Matrix of standardized coefficients of discriminative analysis of morphological characteristics*

Tabela 4. *Matrica standardizovanih koeficijenata diskriminativne analize morfoloških karakteristika*

	Funkcion 1
Anthropometry body height / ATJVIS	-.923
Anthropometry arm length / ADUŽRU	1.088
Anthropometry leg length / ADUŽNO	-.018
Anthropometry ankle joint diameter / ADIJSZ	.257
Anthropometry knee diameter / ADIJKO	.327
Anthropometry wrist joint diameter / ADIJZŠ	.715
Anthropometry body weight / ATJTEŽ	.143
Anthropometry chest circumference / ASROGK	.042
Anthropometry abdominal circumference / AOBTRB	-.279
Anthropometry triceps skinfold / ANATRI	-.103
Anthropometry calf skinfold / ANAPOT	-.392
Anthropometry skinfold of the back / ANALEĐ	.165

Table 5 shows the factor structure of the isolated discriminative function. The results presented in Table 5 indicate that the greatest contribution to the discriminative function, i.e. the difference between the initial and final measurement of the morphological characteristics of the subjects, is the diameter of the wrist joint (ADIJZŠ .672). In addition, the variables arm length (ADUŽRU ,542), leg length (ADUŽNO ,364), body height (ATJVIS ,255),

U tabeli 5 prikazana je faktorska struktura izolovane diskriminativne funkcije. Prikazani rezultati u tabeli 4 ukazuju da najveći doprinos diskriminativnoj funkciji tj. razlici između inicijalnog i finalnog mjerenja morfoloških karakteristika ispitanica ima dijametar zgloba šake (ADIJŠA .672). Pored nje s nešto nižim vrijednostima u diskriminaciji učestvuju varijable dužina ruku (ADUŽRU ,542), dužina nogu (ADUŽNO ,364), tjelesna

Table 5. *Matrix of the structure of the isolated discriminative function of morphological characteristics*

Tabela 5. *Matrica strukture izolovane diskriminativne funkcije morfoloških karakteristika*

	Funkcion 1
Anthropometry wrist joint diameter / ADIJZŠ	.672
Anthropometry arm length / ADUŽRU	.542
Anthropometry leg length / ADUŽNO	.364
Anthropometry body height / ATJVIS	255
Anthropometry body weight / ATJTEŽ	.235
Anthropometry knee diameter / ADIJKO	.217
Anthropometry ankle joint diameter / ADIJSZ	.197
Anthropometry chest circumference / ASROGK	.130
Anthropometry skinfold of the back / ANALEĐ	.098
Anthropometry abdominal circumference / AOBTRB	.054
Anthropometry calf skinfold / ANAPOT	-.043
Anthropometry triceps skinfold / ANATRI	.037

body weight (ATJTEŽ ,235) and knee diameter (ADIJKO ,217) participate in the discrimination with slightly lower values. The other measured morphological variables did not significantly participate in the discrimination of the initial from the final measurement in the space of morphological characteristics.

Based on standardized centroids, the effects of a six-month volleyball program on the morphological characteristics of female participants who train in volleyball are observed in terms of the increase in longitudinal and transverse body dimensions. The position of the centroids of the initial and final measurements show that in this sample of respondents there are significant differences in morphological characteristics at the two measurements.

visina (ATJVIS ,255), tjelesna težina (ATJTEŽ ,235) i dijametar koljena (ADIJKO , 217). Ostale mjerene morfološke varijable nisu značajno učestvovale u diskriminaciji inicijalnog od finalnog mjerenja u prostoru morfoloških karakteristika.

Na osnovu standardizovanih centroida uočavaju se efekti djelovanja šestomjesečnog programa odbojke na morfološke karakteristike ispitanica koje treniraju odbojku u smislu prirasta lodgitudinalne i transverzalne dimenzionalnosti tijela. Položaj centroida inicijalnog i finalnog mjerenja pokazuju kako u ovom uzorku ispitanica postoje značajne razlike u morfološkim karakteristikama na dva mjerenja.

Table 6. *Centroid positions*

	Function / **Funkcija *1***
Initially / Inicijalno	-,736
Final / Finalno	,736

Tabela 6. *Položaji centroida*

Discussion

Knowing the structure of morphological characteristics is of great importance because it allows for an objective picture of the state of physical development of children and youth, monitoring the course of growth and development by comparing data from measurements conducted at appropriate intervals, and timely directing the child towards sports disciplines in which, given their morphological characteristics, they could achieve optimal results. According to Kosinac (2011), who deals with morphological and motor measurements through the method of collecting data on the child's physique and maturation, on the basis of which body dimensions are determined and judged, the four-dimensional model of morphological characteristics (Momirović et al., 1975) has been accepted as dimensions that can be directly measured and reliably describe the morphological status of a person, namely: longitudinal dimensionality of the skeleton, transverse dimensionality of the skeleton, circular dimensionality of the skeleton and subcutaneous fat tissue.

Programmed training activities in the form of experimental programs can produce certain transformational changes in certain anthropological features of the participants of such treatments to a greater or lesser extent, provided that the programmed activities represent optimal stimuli that are well adapted to the age characteristics and individual abilities and characteristics of each individual. The effects of such experimental programs that are applied are visible in the level of quantitative and qualitative

Diskusija

Programirane trenažne aktivnosti u vidu eksperimentalnih programa mogu proizvesti željene transformacione promjene antropološkog statusa učesnika takvih tretmana pod uslovom da programirane aktivnosti predstavljaju optimalne stimulanse koji su dobro prilagođeni uzrasnim karakteristikama i individualnim sposobnostima i osobinama svakog pojedinca. Efekti takvih eksperimentalnih programa koji se primjenjuju vidljivi su u nivou kvantitatitvnih i kvalitativnih promjena određenih segmenata antropološkog prostora.

Dosadašnja istraživanja problema transformacionih procesa uglavnom su se bavila utvrđivanjem efekata posebno programiranih kinezioloških aktivnosti u smislu kvantitativnih i kvalitativnih promjena određenih antropoloških karakteristika i sposobnosti subjekata koji se podvrgavaju takvim programima (Pejčić, 2001; Bajrić i sar., 2011, 2013, 2014; Šmigalović i sar., 2012; Malijević, 2012; Srdić i sar., 2021; Galić i sar., 2022, 2024). Pejčić (2001) u svom istraživanju konstatuje da svaka dobro programirana fizička aktivnost značajno utiče na promjene kako motoričkih sposobnoati tako i na promjene morfoloških odlika. Bajrić i sar. (2012) su na uzorku od 73 učenika uzrasta 13-14 godina OŠ „Tojšići" utvrđivali efekte četvoromjesečnog programa dodatne nastave na promjenu bazičnih i situaciono-motoričkih sposobnosti. Autori su konstatovali da je precizno definisani program vježbanja iz odbojke sa svojim operatorima, povoljno je djelovao na razvoj motorič-

changes in certain segments of the anthropological space.

The subject of research in this paper is the impact of a specially defined experimental volleyball program lasting six months, with the application of the content of technical elements of the volleyball game without a ball and with a ball, on changes in the morphological characteristics of girls aged 10-12 years. The purpose of this research was to determine whether positive changes in the morphological characteristics of the treated sample of test subjects could be achieved by applying the proposed experimental volleyball program.

The analysis of the results of the T test shows that in the period of six months in which the experimental volleyball program was implemented, there were significant changes in the variables for assessing the longitudinal and transverse dimensionality of the body, but not in the variables for assessing the circular dimensionality of the skeleton and skin folds. Similar results were obtained using canonical discriminant analysis. The results of the canonical discriminant analysis show that the discriminative power of the morphological tests shown by the Wilks' Lambda test is high (.644), which indicates that the differences between the initial and final measurements of the subjects statistically significant at the (Sig. .000) level. The biggest contribution to the discriminative function, i.e. the difference between the initial and final measurement of the morphological characteristics of the test subjects is the variable of the transverse dimensionality of the skeleton (diameter of the hand joint), and next to it, with slightly lower values, they participate in the discrimination variables of longitudinal dimensionality of the skeleton (length of arms, length of legs and height). The variables for evaluating the circular dimensionality of the skeleton and skin folds did not significantly participate in the discrimination of the initial from the final measurement in the area of morphological characteristics in the treated subjects.

Based on the obtained results of the T test and discriminant analysis, it can be concluded that the changes in the mentioned dimensions of the morphological status of the girls included in the experimental volleyball work program are not a surprise, because it is known that the longitudinal and transverse measurements of the skeleton cannot be influenced by physical exercise due to the high coefficient of the hereditary factor (Milanović, 2010). Therefore, the changes in the variables for assessing the longitudinal and transverse dimensionality of the skeleton that were determined in this study were more due to the growth and development of the girls' organism, and less or not at all due to the influence of the experimental volleyball program.

kih i situaciono-motoričkih sposobnosti učenika uzrasta 13-14 godina te je izazvao proces homogenizacije i reorganizacije funkcija koje su odgovorne za uspješne rezultate u testovima motoričkih i situacono-motoričkih sposobnosti. Doprinos globalnim kvantitativnim promjenama pored korištenih operatora u okviru programa može se pripisati i drugim trenažnim sadržajima koji su korišteni u procesu rada u vremenskom intervalu između inicijalnog i finalnog mjerenja. Srdić i sar. (2021) su utvrđivali efekte sadržaja dodatne nastave na promjene motoričkih sposobnosti učenika i utvrdili da je pod uticajem programskih sadržaja dodatne nastave došlo do značajnih promjena motoričkih sposobnosti kod tretiranog uzorka ispitanika. Galić i sar. (2024) su na uzorku 88 djevojčica-košarkašica uzrasta 13-15 godina utvrđivali kvantitativne promjene motoričkih sposobnosti nastalih pod uticajem tromjesečnog programiranog rada. Dobiveni rezultati ukazuju da je pod uticajem programiranog rada došlo do statistički značajnih globalnih promjena u prostoru motoričkih sposobnosti u smislu poboljšanja repetitivne snage, koordinacije i okretnosti. Nićin i Stijepić (2008) ističu da je za tjelesni razvoj djece mlađeg školskog uzrasta između 9. i 11. godine, povoljan odnos tjelesne visine i tjelesne težine kod dječaka i djevojčica. Autri smatraju da u ovom uzrastu vjerovatno zbog te činjenice ne postoje značajne razlike između dječaka i djevojčica u osnovnim morfološkim odlikama. U organizmu se dešavaju nešto manje promjene, a količina mišićne mase znatno manje zaostaje u odnosu na težinu tijela. Srdić (2012) je u svom istraživanju utvrđivao efekte eksperimentalnog programa kod juniora u plesu. Na osnovu dobivenih rezultata autor je utvrdio statistički značajne kvalitativne i kvantitativne promjene tretiranih antropoloških obilježja kod juniora u plesu.

Upravo je ovo istraživanje imalo za cilj da se utvrde efekti posebno definisanog eksperimentalnog programa odbojke na promjene morfoloških karakteristika mladih odbojkašica u vidu kvantitativnih promjena na parcijalnom i globalnom nivou.

Na osnovu dobivenih rezultata može se konstatovati da je primijenjeni program odbojke povoljno djelovao na tretirane morfološke odlike, u prvom redu na priraštaj dijametra zgloba šake i dužine nogu i ruku, a zatim i na prirast tjelesne visine i tjelesne težine. Zbog toga bi trebalo transformacioni trenažni proces sa mladim odbojkašicama usmjeriti na prirast morfoloških karakteristika u skladu sa njihovim karakteristikama u pojedinim fazama razvoja.

Na osnovu prethodno navedenog može se kon-

No statistically significant changes (differences) were found in the variables for evaluating the circular dimensionality of the body and skin folds, which is a surprise in this research. Many previous studies confirm that circular dimensions, and especially subcutaneous fat tissue, are variable and less reliable measures than longitudinal and transverse dimensions for assessing the morphological status of subjects. Malacko (1985) points out that morphological characteristics are influenced by genetic and environmental factors, but that the influence of genetic factors is not the same on all morphological characteristics. The author also points out that the innateness coefficient for the longitudinal dimensionality of the skeleton is the highest and is about 98%, for voluminousness 90%, and for adipose tissue 50%. Đurašković (2001) points out that it is possible to achieve a greater impact on the reduction of skin folds, which depends on the scope and intensity of kinesiological activity, considering the lesser impact of the genetic code, i.e. growth hormone (K = .50). The same author indicates that positive changes occur under the influence of physical exercise. It multiplies muscle cells are activated, the number of capillaries increases, circulation improves, and fat tissue disappears from the muscles.

Essentially, experimental training programs can affect the transformation of the circular dimensionality of the skeleton and skin folds depending on the content and means that the specific program includes, as well as the duration of the experimental treatment. Malina, Bouchard, & Bar-Or, (2004) conclude in their research that special exercise programs do not produce positive effects on the longitudinal dimensionality factor of the skeleton, unlike the circular dimensionality factor of the skeleton and subcutaneous fat tissue.

Similar results on the positive impact of the experimental program on changes in morphological characteristics are presented in their research by Bala et al. (2018).

The obtained results point to the conclusion that the changes in the examined morphological characteristics of the female volleyball players who represented the sample of respondents in this study are primarily caused by the influence of growth factors and biological maturation, and partly by the influence of the experimental volleyball program. Morphological characteristics have a high genetic dependence and the influence of the experimental program is negligible, with the exception of body weight and subcutaneous fat tissue, where changes under the influence of the experimental program are possible.

The results of this research are similar to the results obtained by many researchers who have treated the problem of changes in morphological characteristics under the

statovati da su dobijene parcijalne i globalne kvantitativne promjene morfoloških odlika kod tretiranog uzorka ispitanica posljedica primijenjenog eksperimentalnog programa koji je realizovan u vremenskom periodu od šest mjeseci.

Mnoga istraživanja (Stojiljković i sar., 2010; Hrgetić i sar., 2016; Špirtović i sar., 2021; Bajrić i Adžemović, 2023) bavila su se utvrđivanjem efekata eksperimentalnih programa na promjenu sastava tijela kod vježbača i rekreativaca. Špirtović i sar. (2021) su utvrđivali efekte programiranog rada na promjene kompozicije tijela ispitanica rekreativnog vježbanja. Na osnovu dobivenih rezultata autori konstatuju da je programirani rad proizveo statistički značajne promjene u tjelesnoj kompoziciji rekreativnih vježbača a promjene su u prvom redu nastale u tjelesnoji mišićnoj masi kao i procentu masnog tkiva. Bajrić i Adžemović (2023) su na uzorku od 44 vježbača rekreativaca (27 ženskih i 17 muških) starosti od 25 do 40 godina, izvršili istraživanje s ciljem utvrđivanja efekata tromjesečnog Hard Body programa vježbanja na promjene tjelesne kompozicije. Primjenom analize rezultata T testa autori konstatuju da je tromjesečni Hard Body program vježbanja proizveo statistički značajne razlike u sastavu tijela vježbača žena i muškaraca, rekreativaca, odnosno da postoji razlika u tjelesnoj težini i kod muških i ženskih rekreativaca, obimu struka, postotku mišićnog tkiva i dnevnom unosu kalorija kod ženskih vježbača, rekreativaca, zatim postotku masnog tkiva, body mass indexu i postotku vode kod muških vježbača, rekreativaca. Autori na kraju konstatuju da je kvalitet života i životna putanja najveća borba koju vodimo sami sa sobom, ali kada je savladamo, koraci koje pravimo su laganiji i uspijevamo da vidimo dalje od drugih.

Zaključak

Osnovni cilj istraživanja bio je da se utvrde kvantitativne promjene morfoloških karakteristika mladih odbojkašica koje su činile uzorak ovog istraživanja na parcijalnom i globalnom nivou. U tu svrhu na uzorku od 50 ispitanica mladih odbojkašica primijenjen je set od dvanaest morfoloških varijabli koje hipotetski pripadaju odgovarajućim dimenzijama longitudinalnog, transferzalnog, cirkularnog prostora i varijabli za procjenu potkožnog masnog tkiva. Za utvrđivanje efekata šestomjesečnog programa rada odbojke koji se odražava na kvantitativne promjene morfoloških karakteristika mladih odbojkašica na parcijalnom i globalnom nivou primijenjeni su rezultati t testa za zavisne uzorke i kanonička diskriminativna analiza.

influence of programmed work, either in the teaching or training process (Bala, 1981; Babin et al., 1999; Pejčić, 2001; Zrnzević, 2007; Nićin and Stijepić, 2008; Srdić, 2012; Zrnzević and Zrnzević, J., 2015; Bala et al., 2018; Mitrović et al., 2021; Galić et al., 2022).

In his research, Pejčić (2001) states that any well-programmed physical activity significantly affects changes in both motor skills and morphological characteristics. Nićin and Stijepić (2008) point out that for the physical development of children of younger school age between 9 and 11 years, the ratio of body height and body weight in boys and girls is favorable. The authors believe that at this age, probably due to this fact, there are no significant differences between boys and girls in basic morphological characteristics. Slightly smaller changes occur in the organism, and the amount of muscle mass lags significantly less in relation to body weight. Srdić (2012) in his research determined the effects of an experimental program in juniors in dance. Based on the results obtained, the author determined statistically significant quantitative and qualitative changes in the treated anthropological characteristics in juniors in dance.

Also, some studies (Stojiljković et al., 2010; Hrgetić et al., 2016; Špirtović et al., 2021; Bajrić and Adžemović, 2023) have investigated the effects of experimental programs on changes in body composition in exercisers and recreational exercisers. Špirtović et al. (2021) have determined the effects of programmed work on changes in body composition of recreational exercisers. Based on the results obtained, the authors conclude that programmed work produced statistically significant changes in the body composition of recreational exercisers, and the changes primarily occurred in body muscle mass and the percentage of fat tissue. Bajrić and Adžemović (2023) conducted research on a sample of 44 recreational exercisers (27 female and 17 male) aged 25 to 40 years with the aim of determining the effects of a three-month Hard Body exercise program on changes in body composition. By applying the analysis of the results of the T test, the authors state that the three-month Hard Body exercise program produced statistically significant differences in the body composition of female and male exercisers, recreationists, that is, there is a difference in body weight in both male and female recreationists, waist circumference, percentage of muscle tissue and daily calorie intake in female exercisers, recreationists, then the percentage of fat tissue, body mass index and percentage of water in male exercisers and recreationists.

Analiza rezultata T testa pokazuje da je šestomjesečni program rada odbojke proizveo parcijalne kvantitativne promjene u sedam od ukupno dvanaest varijabli za procjenu morfoloških karakteristika. Najznačajnije parcijalne promjene su se desile kod varijabli za procjenu longitudinalne i trasverzalne dimenzionalnosti tijela. Iznenađenje predstavlja podatak da parcijalne promjene nisu utvrđene kod varijabli za procjenu kod kožnih nabora.

Rezultati kanoničke diskriminativne analize pokazuju da je došlo do značajnih promjena morfoloških karakteristika ispitanica na globalnom nivou a najveći doprinos diskriminativnoj funkciji tj. razlici između inicijalnog i finalnog mjerenja morfoloških karakteristika ispitanica ima dijametar zgloba šake (ADIJŠA .672). Pored nje s nešto nižim vrijednostima u diskriminaciji učestvuju varijable dužina ruku (ADUŽRU ,542), dužina nogu (ADUŽNO ,364), tjelesna visina (ATJVIS ,255), tjelesna težina (ATJTEŽ ,235) i dijametar koljena (ADIJKO , 217). Ostale mjerene morfološke varijable nisu značajno učestvovale u diskriminaciji inicijalnog od finalnog mjerenja u prostoru morfoloških karakteristika.

Generalno, dobiveni rezultati pokazuju da je definisani program odbojke u trajanju šest mjeseci proizveo značajne kvantitativne promjene morfoloških karakteristika mladih odbojkašica kako na parcijalnom tako i na globalnom nivou. Ovakvi rezultati upućuju na činjenicu da eksperimentalni programi mogu proizvesti značajne željene promjene antropološkog statusa ispitanika ali mora biti strukuriran tako da programirane aktivnosti predstavljaju optimalne stimulanse koji su dobro prilagođeni uzrasnim karakteristikama i individualnim sposobnostima i osobinama svakog pojedinca. Dobiveni rezultati se odnose na tretirani uzorak ispitanica a za generalizaciju rezultata potrebno je izvršiti veći broj istraživanja koji bi podrazumijeva ovaj ili sličan uzorak i veći broj ispitanica.

Rezultati istraživanja mogu predstavljati dobru osnovu i poticaj drugim istraživačima za istraživanje i definisanje strukture morfološkog prostora i utvrđivanje mogućih odnosa morfoloških karakteristika sa drugim dimenzijama antropološkog prostora kod odbojkašica različite uzrasne dobi. Svakako da bi takvi rezultati mogli doprinijeti boljoj selekciji i kvalitetnijem planiranju i programiranju trenažnog rada sa mladim odbojkašicama uvažavajući osobenosti morfoloških karakteristika za svaku uzrasnu dob ispitanica.

Conclusion

The main goal of the research was to determine whether and to what extent positive changes (at partial and global levels) in the morphological characteristics of female volleyball players aged 10-12 years can be achieved by applying a specially defined experimental volleyball program. For this purpose, a set of twelve morphological variables was applied to a sample of 50 young female volleyball players, which hypothetically belong to the corresponding dimensions of the longitudinal, transferal, circular space and variables for assessing subcutaneous fat tissue. To determine the effects of the six-month volleyball program on quantitative changes in the morphological characteristics of young female volleyball players at partial and global levels, the results of the T test for dependent samples and canonical discriminant analysis were applied.

Based on the analysis of the differences in the arithmetic means (Mean) of the results of the applied morphological characteristics at the beginning and at the end of the experimental program, the significance of the changes was tested by the T-test for dependent samples and partial quantitative changes were analyzed for each applied variable. The results of the T test show that changes were achieved in the measures for assessing the longitudinal and transverse dimensionality of the body. The surprise is the fact that changes were not determined in the variables for assessing circular dimensionality and skin folds.

As the results of the T test show, the results of the canonical discriminant analysis show that significant changes in the morphological characteristics of the subjects occurred at the global level, and the greatest contribution to the discriminant function, i.e. the difference between the initial and final measurement of the morphological characteristics of the test subjects is the variable of the transverse dimensionality of the skeleton (the diameter of the hand joint, and next to it, with slightly lower values, the variables participate in the discrimination longitudinal dimensions of the skeleton (arm length, leg length and body height). The variables of the circular dimensionality of the skeleton and skin folds did not participate in the discrimination of the initial from the final measurement in the space of morphological characteristics.

Based on the results obtained and the results of previous research, we can conclude that the changes in the examined morphological characteristics of female volleyball players are primarily caused by the influence of growth factors and biological maturation, and partly by the influence of the experimental volleyball program. Given that morphological characteristics have a high genetic conditionality, the influence of experimental programs is negligible, with the exception of subcutaneous fat tissue, where changes are possible provided that the content of the program, operators, load and training methods are well selected and adapted to the age categories of the subjects. Therefore, a lot of knowledge and experience are needed, and above all, good programming of training work, adequate load and knowledge of the age characteristics and abilities of the participants undergoing experimental programs. Even the best concept will not significantly affect the efficiency of training work if the training content, training operators, forms of training work, training methods are not modernized and the volume and intensity of the load is not adjusted. For these reasons, it is necessary to monitor and control the achieved effects of experimental programs, the achievement of the desired results, as well as the necessary corrections of such training programs.

The results of the research can represent a good basis and incentive for other researchers to research and define the structure of morphological space and determine possible relationships of morphological characteristics with other dimensions of anthropological space in volleyball players of different ages. The results of such research could contribute to better selection and better planning and programming of training work with young volleyball players, taking into account the characteristics of morphological characteristics for each age group of the respondents.

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The effects of the COVID-19 pandemic on college students' physical activity and nutrition

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Abstract: *Nutrition plays a crucial role in sports. Diet has an important role in human health, especially when the nutritional needs have to be adjusted for different sports. The aim of this study was to find how did COVID-19 impact nutrition and physical activity among students of AAB college. A survey was conducted among students of AAB College from 12-30 April 2023. The survey link was spread to students using Email. Questionnaire included questions regarding: height, weight, physical activity, nutrition, food supplements, during COVID-19 and after COVID-19. A total of 296 students completed the questionnaire, consisting of 211 females and 85 males. Economics had the highest number of students (22.3%) and Mass Communication had the lowest (2.4%); the statistical test (Chi-square) shows a significant difference between the fields. Wilcoxon signed-rank test indicates a significant difference, there is a notable difference in BMI between during COVID-19 and after COVID-19. Consumption of meat and cereals changed significantly during and after COVID-19 ($\chi^2 = 9.33$, $p = 0.003$), $\chi^2 = 20.06$, $p = 0.000$. Consumption of fruits, vegetables, dairy products, and foods high in fat, sugar, and salt did not change significantly. Physical activity levels during and after COVID-19 also showed a significant change ($\chi^2 = 4.96$, $p = 0.033$), indicating that some students started exercising again. Consumption of meat and cereals changed significantly during and after COVID-19 and the importance of wellbeing (nutrition, physical activity) can be used as an incentive to maintain an active lifestyle and healthy food consumption.*

Keywords: *Sports, Health, Nutritional needs, Differences.*

Abbreviations: *Body mass Index (BMI), Noncommunicable diseases (NCDs), World Health Organization (WHO), Coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).*

Introduction

Diet has an important role in human health, especially when the nutritional needs have to be adjusted for different sports. Nutrition plays a crucial role in sports. The importance of an active lifestyle and healthy nutritional food habits, was shown significantly more during the COVID-19 pandemic. The immune system is activated by an active lifestyle, whereas it is suppressed by obesity and related disorders-this information emphasized the significance of maintaining an active lifestyle during this time (Khoramipour et al., 2021).

Regular exercise enhances quality of life, mental health and well-being; helps in prevention and treatment of noncommunicable diseases (NCDs), hypertension, overweight, and obesity (Global action plan on physical activity 2018–2030). World Health Organization (WHO) recommends that adults between the ages of 18 and 64 engage in at least per week (150 minutes of moderate-intensity physical activity, 75 minutes of vigorous-intensity physical activity or a relevant combination of moderate- and vigorous-intensity physical activity); this is the minimum amount of physical activity required to maintain adequate health and fitness (Lippi et al., 2020). Health is closely linked to nutrition. Evidence currently available shows that a person's immune system and susceptibility to disease are significantly impacted by their diet (Naja & Hamadeh, 2020). Immune system support requires proper nutrition-a healthy diet regulates immune homeostasis (Mentella et al., 2022). Minerals (zinc and selenium) and vitamins (A, C, D, E, and B complex) are found in diets rich in fruits and vegetables-these nutrients are crucial immune system modulators (de Faria Coelho-Ravagnani et al., 2020). Water, antioxidants, and fiber found in fruits and vegetables help prevent weight gain, diabetes, and hypertension-some of the major risk factors for COVID-19 problems (de Faria Coelho-Ravagnani et al., 2020). Fruits and vegetables' effectiveness to reduce disease may be partially attributed to their high flavonoid and antioxidant/anti-inflammatory contents (Khoramipour et al., 2021).

Healthy eating practices encourage health and the prevention of disease, whereas unhealthy eating practices affect metabolism and lead to health deterioration (Özen et al., 2021). Nutrition recommendations were given on the limitation of salt, sugar, and alcohol, the recommended daily intake of water was six to ten glasses (Detopoulou et al., 2022); eating homemade healthy balanced diet (Rafique, 2022), avoiding irregular snacking (Naja & Hamadeh, 2020). The lockdown could change weight-gain related health behaviors (Parekh & Deierlein, 2020). Adults are classified as obese if their body mass index (BMI) is greater than 30 kg/m² (Safaei et al., 2021). Sedentary behavior and unhealthy lifestyles grew as a result of COVID-19, particularly in the midst of youths *(*Akter et al., 2022). Students do not take enough care of their health or healthy lifestyle, neglecting physical activity and healthy eating, but giving more priority to the obligations in the faculty as well as entertainment (Myrtaj, Pireva, & Mikić, 2023). The impact of this physical inactivity is likely to have consequences in many areas such as: health and social care, mental well-being of people, education, etc. (Rexhepi, Pireva, Vehapi, & Gashi, 2020). In some research there was noticed the increase in Physical activity during the COVID-19 pandemic, compared to physical activity before the pandemic. A large part of research participants (85.5%) stated they liked online teaching of PE, while 80.1% stated that online teaching helped them stay physically active (Antekolović & Kovačić, 2020). Regular physical exercise has significant impact on human body and is important factor of enhancing immune system, which enables faster recovery and easier dealing with symptoms of COVID-19 (Šebić, Suhonić, Kovačević, Čović, Bajramović, 2023). During the pandemic time the negative impact of e-sports as a phenomenological phenomenon for children's health, their psychological and physical development has been proven (Milić, 2020).

The objective of this study was to investigate the impact of COVID-19 on nutrition and physical activity among students at AAB College. Specifically, the study aimed to assess how the duration of the pandemic and the associated public health measures—such as isolation and movement restrictions—affected students' behavioral patterns. Additionally, the study sought to examine how these behavioral changes influenced physical activity levels and body mass index (BMI) across different student groups, stratified by faculty.

Material and Methods

A survey was conducted among students of AAB College from 12-30 April, 2023. The survey link was spread to students using Email. Nutrition approach test questionnaire: For the online survey the Nutritional Habits Questionnaire was used. The questionnaire was prepared by (Altun et all. 2021). The questions proved validity of the researches which have been done on the subject before have been used. Basic informational questions involved: gender, age, and the field of study. Questionnaire included questions regarding: height, weight, physical activity, nutrition, food supplements, during COVID-19 and after COVID-19. Questions during the COVID-19 period and after COVID-19 period contained: The current body weight? Did the body weight have any significant variation during the COVID-19 pandemic compared to the period prior to the pandemic? How frequently per day do you consume meals? Which food categories are most predominant in your diet? Do you use nutritional supplements? Which types of nutritional supplements do you use? Are you physically active? Type of physical activity? How many times per week do you engage in physical activity? The duration of your physical activity session? Where do you exercise?

The tested hypotheses were: Did eating habits during COVID-19 period became unhealthier, so the students BMI increased? What are the differences during and after COVID-19 at students in: frequency of consuming meals, food categories in diet, nutritional supplements, physical activity (type, duration, place). The collected data were analyzed with SPSS 25.0 software (SPSS, Chicago, IL, USA). The non-parametric statistics used for the data analyses are Chi-square test and Wilcoxon signed-rank test.

Results

A total of 296 students completed the questionnaire, consisting of 211 females and 85 males. The majority number of students were in the (>23) age group. Economics had the highest number of students (22.3%) and Mass Communication had the lowest (2.4%); the statistical test () shows a significant difference between the fields. Among students 86.5% were at the Bachelor level (256), and 13.5% were at the Master level (40). With COVID-19 were infected 52.7% of students (156) and 47.3% of students (140) were not; the Chi-square test ($\chi^2 = 0.865$, $p = 0.352$) indicates no significant difference. Wilcoxon signed-rank test indicates a significant difference, ($Z= 6.675$, $P=0.000$*) there is a notable difference in BMI between during COVID-19 and after COVID-19.

Table 1. *Descriptive statistics and Ch-square of the study participants (n = 296)*

Variables		Frequency (N)	Percentages (%)	Distribution differences
Gender	Female	211	71.3	χ^2 (1. N = 296) = 53.635. P = 0.000*
	Male	85	28.7	
Age	>23	233	78.7	χ^2 (3. N = 296) = 460.73. P = 0.000*
	24-30	37	12.5	
	31-36	12	4.1	
	37+	14	4.7	
Study field	Physical Education and Sports	24	8.1	χ^2 (9. N = 296) = 88.730. P = 0.000*
	Social Sciences	38	12.8	
	Economics	66	22.3	
	Psychology	44	14.9	
	Mass Communication	7	2.4	
	Public Administration	24	8.1	
	Computer Science	35	11.8	
	Law	23	7.8	
	Health Sciences	11	3.7	
	English Language	24	8.1	
Study level	Bachelor	256	86.5	χ^2 (1. N = 296) = 157.622. P = 0.000*
	Master	40	13.5	
Participants infected with COVID -19	Yes	156	52.7	χ^2 (1. N = 296) = 0.865. P = 0.352
	No	140	47.3	

The significant difference was found between the students according to age, gender, study field and study level but there was no significant difference according to the infection with Covid 19 virus ($p < 0.05$).

Table 2. *Chi-square test and Wilcoxon signed-rank test for BMI*

Variables	Metrics and changes before vs. after	Statistical Test Results	P-Value
COVID-19 & BMI	22.42 ± 3.83 23.12 ± 3.52	Z (296) = -6.675	P=0.000*
COVID-19 & Meals	Mean Rank = 1.49 Mean Rank = 1.51	χ^2 (296) = 0.117	P = 0.732
COVID-19 & Supplements	23 (No → Yes) 78 (Yes → No)	χ^2 (1. 296) = 29.95	P =0.000*
Vitamin C & COVID-19	Mean Rank = 36.29 Mean Rank = 23.5	Z (134) = -5.589	P=0.000*
Vitamin D & COVID-19	Mean Rank = 30.40 Mean Rank = 27.55	Z (134) = -0.455.	P=0.649
Multivitamin & COVID-19	Mean Rank = 28.78 Mean Rank = 26.26	Z (134) = -2.813	P=0.005*
Omega 3 & COVID-19	Mean Rank = 18.83 Mean Rank = 19.45	Z (134) = -2.464	P=0.014*
Creatine & COVID-19	Mean Rank = 5.25 Mean Rank = 6.43	Z (134) = -1.089	P=0.276
Protein Powder & COVID-19	Mean Rank = 7.64 Mean Rank = 9.95	Z (134) = -1.137	P=0.256

Fruit and Vegetables & COVID-19	21 (No → Yes) 17 (Yes → No)	χ^2 (1. 296) = 0.421	P = 0.627
Dairy products & COVID-19	32 (No → Yes) 28 (Yes → No)	χ^2 (1. 296) = 0.267	P = 0.699
Meat products & COVID-19	46 (No → Yes) 21 (Yes → No)	χ^2 (1. 296) = 9.33	P =0.003*
Cereals & COVID-19	55 (No → Yes) 17 (Yes → No)	χ^2 (1. 296) = 20.06	P =0.000*
High sugar foods & COVID-19	30 (No → Yes) 41 (Yes → No)	χ^2 (1. 296) = 1.704	P = 0.235
High salt foods & COVID-19	25 (No → Yes) 32 (Yes → No)	χ^2 (1. 296) = 0.86.	P = 0.427
High fat foods & COVID-19	23 (No → Yes) 29 (Yes → No)	χ^2 (1. 296) = 0.692	P = 0.488

The significant difference was found between the students in the BMI index, supplements intake, multivitamins, omega 3, usage of meat productions and cereals. In other components there was not significant differences at the level of significance ($p < 0.05$).

Table 3. *The effect of COVID-19 on students` physical activity (n = 296)*

Variables	Metrics and changes before vs. after	Statistical Test Results	P-Value
Physical Activity & COVID-19 (before & during)	0 (No → Yes) 66 (Yes → No)	χ^2 (1. 296) = 66	P = 0.000*
COVID-19 & Physical Activity (during & after)	55 (No → Yes) 34 (Yes → No)	χ^2 (1. 296) = 4.96	P = 0.033*
COVID-19 & Exercise Frequency	Mean Rank = 1.48 Mean Rank = 1.52	χ^2 (1. 79) = 0.36	P = 0.549
COVID-19 & Exercise Duration	Mean Rank = 1.43 Mean Rank = 1.57	χ^2 (1. 79) = 4.172	P = 0.041*
COVID-19 & Exercise Location	32 (Home → Gym) 0 (Gym → Home)	χ^2 (1. 79) = 32	P = 0.000*

The significant difference was on the level of student's activity before and during covid, physical activity during and after covid. Exercise duration and Exercise location. There was not significant difference at the Exercise frequency ($p < 0.05$).

Discussion

The aim of this study was to investigate the impact of COVID-19 on nutrition and physical activity among students at AAB College. Specifically, the study aimed to assess how the duration of the pandemic and the associated public health measures—such as isolation and movement restrictions—affected students' behavioral patterns. Additionally, the study sought to examine how these behavioral changes influenced physical activity levels and body mass index (BMI) across different student groups, stratified by faculty.

There was no significant difference in number of meals consumed during COVID-19 and after COVID-19. Supplement use changed during and after COVID-19: there were no notable changes in the use of vitamin D, creatine, or protein powder, there were notable changes in the usage of vitamin C, multivitamins, and omega 3. Consumption of meat and cereals changed significantly during and after COVID-19. Consumption of fruits, vegetables, dairy products, and foods high in fat, sugar, and salt did not change significantly. Physical activity levels before and after COVID-19 changed significantly ($\chi^2 = 66$, $p = 0.000$), many students stopped physical activity during COVID-19. Physical activity levels during and after COVID-19 also showed a significant change ($\chi^2 = 4.96$, $p = 0.033$), indicating that some students started exercising again. Exercise duration ($\chi^2 = 4.172$, $p = 0.041$) and physical activity ($\chi^2 = 4.96$, $p = 0.033$) increased significantly during and after COVID-19. Exercise frequency did not change significantly ($\chi^2 = 0.36$, $p = 0.549$). After COVID-19, there was a noticeable return to gym workouts from at-home workouts.

According to the study by Zahri et al. (2022) students' intakes of dietary supplements and micronutrients in-

creased during the COVID-19 pandemic compared to their pre-pandemic intakes; most commonly students consumed vitamins. In the study of Altun et al. (2022) students of sports faculty made better choices for nourishment- due to the fact that they participate in sports and receive nutritional education, leading to higher nutrition scores than students from other faculty.

In the study of Jalal et al. (2021) poor physical exercise and a sedentary lifestyle were linked to the students' elevated BMI; half of the students held their BMI constant during lockdown. The period of COVID-19 had an impact on nutritional consumption, dietary choices, physical activity, lifestyle behaviors- which impacted body weight and general health in the short and long term (Antwi et al., 2021). Of the approximately 900 persons in the United States whose data were collected, 44% self-reported having made a beneficial dietary change (Jaeger et al., 2021). The lessons during COVID-19: the importance of wellbeing (nutrition, physical activity) can be used as an incentive to maintain an active lifestyle and healthy food consumption.

Conclusion

Consumption of meat and cereals changed significantly during and after COVID-19 Consumption of fruits, vegetables, dairy products, and foods high in fat, sugar, and salt did not change significantly. Wilcoxon signed-rank test indicates a significant difference, there is a notable difference in BMI between during COVID-19 and after COVID-19. Physical activity levels during and after COVID-19 also showed a significant change ($\chi^2 = 4.96$, $p = 0.033$), indicating that some students started exercising again. The lessons during COVID-19: the importance of wellbeing (nutrition, physical activity) can be used as an incentive to maintain an active lifestyle and healthy food consumption.

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Paper review
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Aerobic Physical Exercise and BMI Values in Students With Overweight

Aerobno fizičko vežbanje i vrednosti BMI kod učenika sa viškom kilograma

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Abstract: *The modern lifestyle and insufficient physical activity are an increasing problem among the younger generation. The question arises as to how the educational system can influence the resolution of this issue. One way is to introduce additional physical exercise classes within the regular curriculum or to improve the program of organized physical exercise with students. This study analyzed three individual studies that dealt with the impact of organized aerobic physical exercise on BMI values and body fat percentage in adolescent students. In this meta-analysis, standardized mean differences and relative risk with 95% confidence intervals were calculated using random effects. The combined value of the standardized mean difference calculated from the random effects model is 0.32 (95% CI; -2.74; 3.38). The combined RR value from the random effects model is 0.34 (-1.15; 1.83). The RR is not statistically significantly different from one (p=0.6527). No statistically significant difference was observed between students who, in addition to the regular classes, participated in organized aerobic physical exercise aimed at regulating excess weight. Due to the small number of participants, it is not possible to generalize the conclusion in this study.*

Keywords: *Aerobic physical exercise, Students, Primary school, BMI, Overweight.*

Sažetak: *Savremeni način života i nedovoljno fizičke aktivnosti sve češće postaju problem mlađeg naraštaja. Postavlja se pitanje na koji način vaspitno-obrazovni sistem može uticati na rešavanje navedenog problema. Jedan od načina jeste da se u okviru redovne nastave uvedu dodatni časovi fizičkog vežbanja ili da se unapredi program organizovanog fizičkog vežbanja sa učenicima. Ova studija je izvršila analizu tri individualne studije koje su se bavile uticajem organizovanog aerobnog fizičkog vežbanja na vrednosti BMI i procenta masnog tkiva učenika adolescentne dobi. U ovoj meta-analizi standardizovane srednje razlike i relativni rizik sa 95% intervala poverenja prikupljene su iz slučajnih efekata. Objedinjena vrednost standardizovane razlike aritmetičkih sredina izračunata je iz modela slučajnih efekata i iznosi 0,32 (95% CI; -2,74; 3,38). Objedinjena vrednost RR iz modela slučajnih efekata iznosi 0,34 (-1,15; 1,83). RR nije statistički značajno različit od jedinice (p=0,6527). Nije uočena statistički značajna razlika između učenika koji su pored redovne nastave imali organizovano aerobno fizičko vežbanje radi regulisanja viška kilograma. U ovom radu nije moguće generalizovati zaključak zbog malog broja ispitanika.*

Ključne reči: *fizička aktivnost, vaspitno-obrazovni sistem, BMI*

Introduction

Excess body weight can represent one of the risk factors for the development of cardiovascular diseases in children and adolescents (Toriola & Monyeki, 2012; Tremblay & Williams, 2003). The development of chronic diseases and spinal deformities, as well as the onset of sedentary behavior, can be attributed to the unhealthy lifestyle inherent to by modern times. Due to the uncontrolled use of technological devices, children lose interest in daily physical activity. On the other hand, insufficient movement contributes to the development of excess body weight, which can negatively affect the quality of life during the growth

Uvod

Prekomerna telesna masa može da predstavlja jedan od rizika za razvoj kardiovaskularnih bolesti kod dece i adolescenata (Toriola & Monyeki, 2012; Tremblay & Williams, 2003). Razvoj hroničnih bolesti i deformiteta kičme, kao i razvoj sedentarnosti može se pripisati nepravilnom načinu života koji nudi savremeno doba. Nekontrolisanom upotrebom tehnoloških sredstava deca gube interesovanje za svakodnevnu fizičku aktivnost, dok nedovoljno kretanja utiče na pojavu prekomerne telesne mase, koje može imati negativnog uticaja na kvalitet života tokom perioda odrastanja. Smatra se da deca

period. It is believed that children with excess weight have a low level of physical fitness (Toriola & Monyeki, 2012; Pahkala et al., 2013; Ng M. et al., 2014). Changing lifestyle and developing healthier habits can positively influence the regulation of body weight (Bull et al., 2020).

In order to have a positive impact of continuous physical activity on reducing obesity during adolescent growth, it is important to motivate students to participate in all forms of physical exercise (Martin et al., 2018). The World Health Organization recommends continuous moderate to vigorous physical activity for children and youth lasting 60 minutes throughout the day (Bull et al., 2020; Davis et al., 2009). The problem arises from adolescents' insufficient interest in sports and recreation. A large number of adolescents are unable to meet even the minimum recommendation of the World Health Organization (Martin et al., 2018). Besides the duration of the activity, the manner of exercising also has a significant impact. The same holds for high intensity that can negatively affect the motivation of obese children to participate in PE classes (PE classes), (Deforche et al., 2011).

It is obvious that the problem of hypokinesia in school-aged children is becoming increasingly significant. Many studies have investigated how physical exercise should be organized, how to motivate students to participate in PE classes, and how organized physical exercise programs affect the morphological status of students. This paper covers the period of adolescence, during which there are rapid changes in the body, as well as the occurrence of obesity due to students' insufficient physical activity. The problem of obesity has become a societal phenomenon that many authors are addressing today. Additionally, there has been a recent increase in obesity among young people (Han et al., 2000). However, differences in the degree of obesity are observed among students of different ages, with older students being more prone to weight gain, as well as male students (Kim et al., 2008). It is known that continuous physical activity of light to moderate intensity, at least three times a week, positively affects the quality of life (Lipnowski et al., 2012). Authors note that an organized physical exercise program with physically inactive students who are overweight generally leads to improvements in physical fitness, regulation of BMI, and reduction of body fat. Furthermore, organized training can positively influence the maintenance or increase of muscle and bone mass (Kwan, 2001; Back & Ji, 2015).

Numerous authors who have investigated the effects of organized physical exercise on reducing body weight and fat tissue claim that time spent at school is the best period for physical activity, as children spend most of

sa viškom kilograma imaju nizak nivo fizičke kondicije (Toriola & Monyeki, 2012; Pahkala et al., 2013; Ng M. et al., 2014). Promenom načina života i razvojem zdravijih navika može se pozitivno uticati na regulisanje telesne mase (Bull et al., 2020).

Da bi kontinuirana fizička aktivnost imala pozitivan uticaj na smanjenje gojaznosti tokom odrastanja adolescenata, važna je motivacija učenika radi učešća u svim vidovima fizičkog vežbanja (Martin et al., 2018). Svetska zdravstvena organizacija preporučuje za decu i mlade kontinuirano fizičko vežbanje umerenog do visokog intenziteta u trajanju od 60 minuta u toku dana (Bull et al., 2020; Davis et al., 2009). Problem postaje nedovoljna zainteresovanost adolescenata za sport i rekreaciju. Veliki broj adolescenata ne može da zadovolji ni preporučeni minimum Svetske zdravstvene organizacije (Martin et al., 2018). Osim trajanja opterećenja značajan uticaj ima i način vežbanja. Visok intenzitet može imati negativan uticaj na motivaciju gojazne dece za učešće u nastavi fizičkog vaspitanja (Deforche et al., 2011).

Očigledno je da problem hipokinezije u dečijem školskom uzrastu postaje sve veći. Mnoge studije su istraživale na koji način je potrebno organizovati fizičko vežbanje, motivisati učenike za učešće u nastavi fizičkog vaspitanja, kao i na koji način program organizovanog fizičkog vežbanja utiče na morfološki status učenika. U ovom radu obuhvaćen je period adolescencije u kome dolazi do burnih promena u organizmu, kao i pojava gojaznosti usled nedovoljne fizičke aktivnosti učenika. Problem gojaznosti postaje fenomen u društvu kojim se danas bave mnogi autori. Takođe, u poslednje vreme je sve veći porast gojaznosti među mladima (Han et al., 2000). Međutim, uočava se razlika u stepenu gojaznosti među učenicima različite životne dobi, pa su tako stariji učenici podložniji povećanju telesne mase, kao i učenici muškog pola (Kim et al., 2008). Poznato je da kontinuirana fizička aktivnost lakog do umerenog intenziteta, najmanje tri puta nedeljno, pozitivno utiče na kvalitet života (Lipnowski et al., 2012). Autori navode da organizovani program fizičkog vežbanja sa fizički neaktivnim učenicima koji imaju višak kilograma uglavnom dovodi do poboljšanja fizičke kondicije, regulacije BMI, kao i smanjenja telesne masti u organizmu. Takođe, organizovani trening će pozitivno uticati na održavanje ili povećanje mišićne i koštane mase (Kwan, 2001; Back & Ji, 2015).

Brojni autori koji su istraživali problem koji se tiče efektata organizovanog fizičkog vežbanja na smanjenje telesne mase i masnog tkiva, navode da je boravak u školi najbolje vreme za fizičko vežbanje jer deca najviše vremena provode u školskom okruženju (Gray et al., 2016).

their time in a school environment (Gray et al., 2016). The quantitative presentation of the impact of this research problem is best demonstrated by selecting relevant scientific studies and calculating the effect size through meta-analysis. This paper deals with a systematic review of the impact of organized and systematically guided continuous aerobic physical exercise on BMI values and the percentage of body fat in overweight students. This meta-analysis may highlight the importance of organized aerobic physical exercise for adolescents in terms of regulating body weight. Due to the small number of participants, the research problem in this paper cannot be generalized to the population of adolescent students. Future research should include a larger number of studies and a greater number of participants in order to achieve more reliable results.

Methods

Search Method

The literature search and selection of references were conducted in accordance with the rules and recommendations for systematic reviews and meta-analyses (PRISMA) (Moher et al., 2009). A systematic review of the scientific literature and the selection of individual studies based on clearly defined selection criteria was followed by an analysis of the selected individual studies. The selection of scientific studies was carried out using two bibliographic databases ("PubMed" and "Mlibrary"). The following keywords were used during the search: "Physical Education," "High School," "Running," "BMI," as well as a defined publication type referring to randomized clinical trials (RCT), with no time limitation, and exclusively in the English language.

Literature Selection

A detailed presentation of the selected individual studies is shown in the Flow Diagram (Figure 1). The following studies were excluded from this meta-analysis: those with duplicate titles, inappropriate design, method of physical exercise, research outcomes, as well as studies with an inappropriate research problem. For this meta-analysis, RCT scientific studies that met the established criteria (method of physical exercise, participants, primary outcomes, and research problem) were selected. Additionally, only studies that had two measurements (pretest and posttest) were chosen, thus allowing an investigation of how organized aerobic physical exercise influenced the measured outcomes.

Kvantitativni prikaz uticaja navedenog problema istraživanja najbolje se prikazuje odabirom relevantnih naučnih studija i izračunavanjem veličine efekta kroz meta-analizu. U ovom radu kroz sistematski pregled prikazan je uticaj organizovanog i planski vođenog kontinuiranog aerobnog fizičkog vežbanja na vrednosti BMI i procenat masnog tkiva učenika koji imaju višak kilograma. Ova meta-analiza može da ukaže na značaj organizovanog aerobnog fizičkog vežbanja sa adolescentima na regulaciju telesne mase. Zbog malog broja ispitanika istraživani problem ovog rada se ne može generalizovati na populaciju učenika adolescentne dobi. Buduća istraživanja bi trebala da uvrste mnogo veći broj studija, kao i veći broj ispitanika kako bi rezultat bio pouzdaniji.

Metode

Metod pretraživanja

Pretraživanje literature i odabir referenci realizovan je u skladu sa pravilima i preporukama za sistematske preglede i meta-analize (PRISMA) (Moher et al., 2009). Pored sistematskog pregleda naučne literature i izbora pojedinačnih studija, prema jasno definisanim kriterijumima za odabir, izvršena je analiza odabranih individualnih studija. Selekcija naučnih studija izvršena je korišćenjem dve bibliografske baze podataka („PubMed" i „Mlibrary"). Prilikom pretrage korišćene su sledeće ključne reči: „Physical Education", „High School", „Running", „BMI", kao i definisan tip publikacije koji se odnosio na randomizovane kliničke studije (RCT), bez vremenskog ograničenja i koje su isključivo na engleskom jeziku.

Izbor literature

Detaljan prikaz izabranih individualnih studija predstavljen je u Dijagramu toka (Slika 1). Iz ove meta-analize isključene su sledeće studije: sa dupliranim naslovima, neodgovarajućim dizajnom, načinom fizičkog vežbanja, ishodima istraživanja, kao i studije sa neodgovarajućim problemom istraživanja. Za ovu meta–analizu izdvojene su RCT naučne studije koje ispunjavaju postavljene kriterijume (način fizičkog vežbanja, ispitanici, primarni ishodi i problem istraživanja). Takođe, izabrane su samo one studije koje su imale dva merenja (pretetst i posttest), a samim tim i mogućnost da se istraži na koji način je organizovano aerobno fizičko vežbanje imalo uticaja na merene ishode.

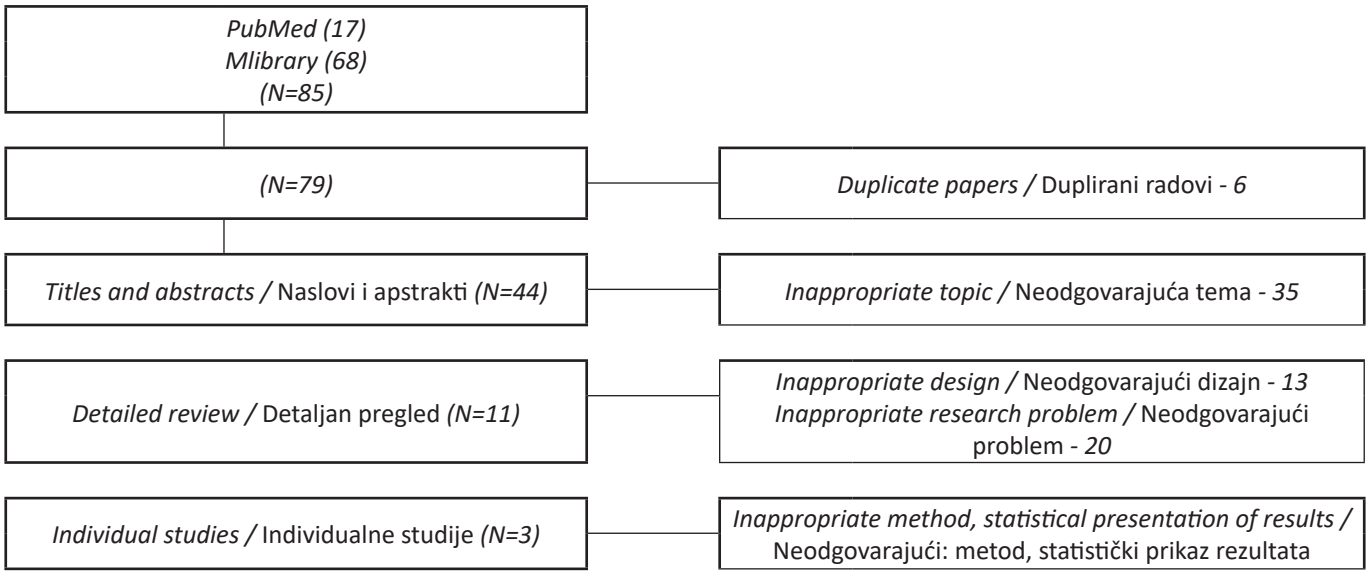


Figure 1. *Flow diagram of the systematic review of individual studies*

Slika 1. *Prikaz sistematskog pregleda individualnih studija Dijagram toka*

Participants

The criterion for selecting participants was the school age of children who were in the prepubertal or pubertal period. In the individual studies of this meta-analysis, students aged between 8 and 16 years. The students were randomized into two research groups. Many students were overweight and had not been sufficiently physically active in the past six months. In the experimental group, students participated in organized aerobic physical exercise in addition to regular PE classes, while the control group attended only the regular physical education lessons.

Organized Physical Exercise

The significance of this meta-analysis lies in presenting the impact of organized aerobic physical exercise on the measured outcomes (BMI and body fat percentage). Therefore, the main criterion for selecting studies was the type of physical exercise, that represents aerobic physical activity (running or other aerobic physical activities). In addition to running or aerobic exercises, strength exercises are also described in the individual studies as an integral part of the program (a more detailed description is provided in the individual studies: Back, 2015; Meng, 2022; Zuo, 2023). The organized aerobic physical exercise program was conducted at school by physical education teachers and/or trainers.

The organized aerobic physical exercise implemented in the individual studies of this meta-analysis can be summarized and described as follows: The first part of the program consisted of a 5-10 minute warm-up. The main part of the program involved aerobic physical exercise consisting

Ispitanici

Kriterijum za izbor ispitanika odnosio se na školski uzrast dece koja su u periodu predpuberteta ili puberteta. U individualnim studijama ove meta-analize učenici su imali od 8 do 16 godina. Učenici su randomizovani u dve istraživačke grupe. Mnogi učenici su imali višak kilograma i nisu bili dovoljno fizički aktivni u poslednjih šest meseci. U eksperimentalnoj grupi učenici su pored redovne nastave fizičkog vaspitanja učestvovali i u organizovanom aerobnom fizičkom vežbanju, dok je kontrolna grupa pohađala samo redovne časove fizičkog vaspitanja.

Organizovano fizičko vežbanje

Značaj ove meta-analize ogleda se u prikazu uticaja organizovanog aerobnog fizičkog vežbanja na merene ishode (BMI i procenat masnog tkiva). Stoga, glavni kriterijum za odabir studija bio je način fizičkog vežbanja koji predstavlja aerobnu fizičku aktivnost (trčanje ili druge aerobne fizičke aktivnosti). Pored trčanja ili aerobnih vežbi u individualnim studijama se opisuju i vežbe snage kao sastavni deo programa (detaljniji opis je dat u individualnim studijama: Back,2015; Meng, 2022; Zuo, 2023). Program organizovanog aerobnog fizičkog vežbanja je realizovan u školi od strane nastavnika fizičkog vaspitanja i/ili trenera.

Organizovano aerobno fizičko vežbanje koje je realizovano u individualnim studijama ove meta-analize može se objediniti i prikazati kroz sledeći opis: U prvom delu programa realizovano je zagrevanje u trajanju od 5 do 10 minuta. U glavnom delu programa realizovano je aerobno fizičko vežbanje kroz: specifičan program 108

of a specific program 108 – Bae, training on an athletic track running with changes in intensity and rest pauses between sets, and continuous running for 30 minutes at moderate intensity with a gradual increase in load. At the end of each organized aerobic physical exercise program, a cool-down and muscle stretching was performed.

Apart from PE classes, the students were not involved in other extracurricular sports activities. Both groups of participants regularly attended PE classes. Parental consent was obtained for participation in the individual study research.

Outcome Measurement

The primary outcome measures in this study were the total BMI value and the percentage of body fat in overweight students. Outcome values were measured before and after the experimental program of organized aerobic physical exercise. BMI was calculated using the formula BMI = kg/m², while the percentage of body fat was calculated using a body composition scale. All measured values were recorded in the teacher's work log.

Data Extraction and Risk of Bias

The reliability of a meta-analysis can depend on the assessment of risk, as well as a bias in the individual studies selected. The quality assessment of the data in this meta-analysis was performed by two independent authors (D.G. and V.Z.). In cases of disagreement during the analysis of the extracted data, the final decision was resolved through discussion between the reviewer and a third author (K.B.). Table 1 presents the extracted data included in the analysis.

Data Analysis

The unit of measurement in this meta-analysis was the individual scientific study. The pooling of results was performed by determining the relative risk (RR) and calculating the standardized mean differences from a total of three studies. Additionally, an analysis of the study heterogeneity and publication bias was conducted. The obtained results were tested at a statistical significance level (alpha level) of 0.05. Data analysis was performed in the R programming language and environment using the "metafor" and "meta" packages (Viechtbauer, 2010; Schwarzer et al., 2015).

Results

The standardized mean of all measured outcomes was calculated from three studies. The total number of participants in both groups was 93 students. Funnel plots for all measured outcomes were symmetrical (BMI at

– Bae, trening na atletskoj stazi – trčanje sa promenom intenziteta i pauzama odmora između serija i istrajno trčanje u trajanju od 30 minuta umerenog intenziteta sa postepenim povećanjem opterećenja. Na kraju svakog programa organizovanog aerobnog fizičkog vežbanja realizovano je istrčavanje i istezanje mišića.

Osim nastave fizičkog vaspitanja učenici nisu bili uključeni u druge vannastavne sportske aktivnosti. Obe grupe ispitanika su redovno pohađale nastavu fizičkog vaspitanja. Za učestvovanje u istraživanjima individualnih studija autori su dobili saglasnost roditelja.

Merenje ishoda

Primarni ishodi merenja u ovoj studiji bili su ukupna vrednost BMI i procenat masnog tkiva kod učenika sa viškom kilograma. Vrednosti ishoda mereni su pre i nakon eksperimentalnog programa organizovanog aerobnog fizičkog vežbanja. BMI je izračunat korišćenjem formule BMI=kg/m², dok je procenat masnog tkiva izračunat uz pomoć vage za merenje kompozicije tela. Sve izmerene vrednosti beležene su u dnevnik rada nastavnika.

Ekstrakcija podataka i rizik od pristrasnosti

Pouzdanost meta-analize može da zavisi od procene rizika, kao i od pristrasnosti u izabranim pojedinačnim studijama. Procenu kvaliteta podataka u ovoj meta-analizi izvršila su dva nezavisna autora (D.G. i V.Z.). Ukoliko je došlo do neslaganja prilikom analize izdvojenih podataka, konačna odluka se rešavala diskusijom između recenzenta i trećeg autora (K.B.). U Tabeli 1. prikazani su izdvojeni podaci uključeni u analizu.

Analiza podataka

Jedinicu mere u ovoj meta-analizi predstavljala je individualna naučna studija. Objedinjavanje rezultata izvršeno je određivanjem relativnog rizika (RR) i utvrđivanjem standardizovanih razlika aritmetičkih sredina iz ukupno tri studije. Takođe, izvršena je analiza heterogenosti studija, kao i publikaciona pristrasnost. Dobijeni rezultati analize su testirani na nivou statističke značajnosti (alfa nivo) od 0,05. Analiza podataka je izvršena u R programskom jeziku i okruženju korišćenjem paketa „metafor" i „meta" (Viechtbauer, 2010; Schwarzer et al., 2015).

Rezultati

Standardizovana aritmetička sredina svih merenih ishoda izračunata je iz tri studije. Ukupan broj ispitanika u obe grupe iznosio je 93 učenika. Za sve merene ishode levkasti dijagrami su bili simetrični (BMI u prvom mere-

first measurement p=0.0043; BMI at second measurement p=0.0001; Body fat percentage at first measurement p=0.0009; Body fat percentage at second measurement p=0.0009). No publication bias was observed in the individual studies.

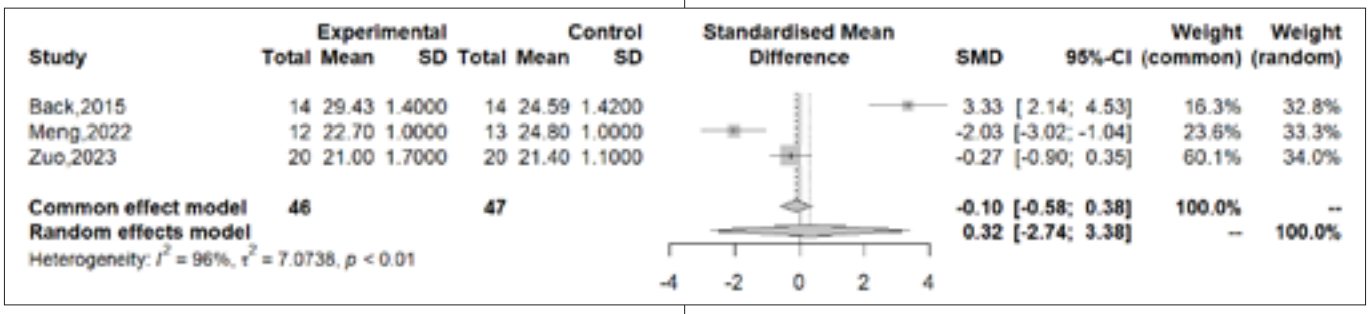
The combined standardized mean difference for BMI values at the first measurement, calculated using a random-effects model, was 0.81 (95% CI; -0.24; 1.86). Physically active and insufficiently active students did not differ statistically significantly regarding BMI at the first measurement (p=0.1293). High heterogeneity among studies was observed. The data were statistically significantly heterogeneous (p<0.01; I^2=82%; τ^2=0.6973). The combined relative risk (RR) value from the random-effects model for body fat percentage at the first measurement was 0.90 (-0.46; 2.26). RR was not statistically significantly different from 1 (p=0.1941). The difference in body fat percentage at the first measurement between physically active and sedentary students was 10%.

The combined standardized mean difference for BMI values at the second measurement, calculated using a random-effects model, was 0.32 (95% CI; -2.74; 3.38). Physically active and insufficiently active students did not differ statistically significantly regarding BMI at the second measurement (p=0.8362). High heterogeneity among studies was observed. The data were statistically significantly heterogeneous (p<0.01; I^2=96%; τ^2=7.0738) (Graph 1).

nju p=0,0043; BMI u drugom merenju p=0,0001; Procenat telesne masti u prvom merenju p=0,0009 i Procenat telesne masti u drugom merenju p=0,0009). U individualnim studijama nije uočena publikaciona pristrasnost.

Objedinjena vrednost standardizovane razlike aritmetičkih sredina za vrednosti BMI u prvom merenju izračunata je iz modela slučajnih efekata i iznosi 0,81 (95% CI; -0,24; 1,86). Fizički aktivni i nedovoljno fizički aktivni učenici se ne razlikuju statistički značajno u odnosu na BMI u prvom merenju (p=0,1293). Uočena je visoka heterogenost studija. Podaci su statistički značajno heterogeni (p<0,01; I2=82%; τ2=0,6973). Objedinjena vrednost RR iz modela slučajnih efekata za vrednosti procenta masti u prvom merenju iznosi 0,90 (-0,46; 2,26). RR nije statistički značajno različit od jedinice (p=0,1941). Razlika u vrednosti procenta masti u prvom merenju između fizički aktivnih i sedentarnih učenika iznosti 10%.

Objedinjena vrednost standardizovane razlike aritmetičkih sredina za vrednosti BMI u drugom merenju izračunata je iz modela slučajnih efekata i iznosi 0,32 (95% CI; -2,74; 3,38). Fizički aktivni i nedovoljno fizički aktivni učenici se ne razlikuju statistički značajno u odnosu na BMI u drugom merenju (p=0.8362). Uočena je visoka heterogenost studija. Podaci su statistički značajno heterogeni (p<0,01; I2=96%; τ2=7,0738) (Grafikon 1).

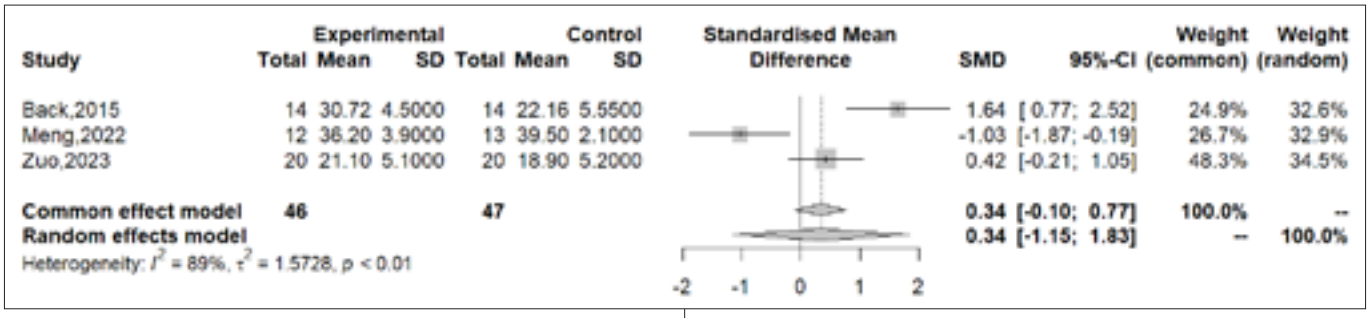


Graph 1. *Display of individual results and the combined value of the standardized mean difference of BMI at the second measurement*

Grafikon 1. *Prikaz individualnih rezultata i objedinjena vrednost standardizovane razlike aritmetičkih sredina BMI u drugom merenju*

The combined RR value for body fat percentage at the second measurement, calculated using a random-effects model, is 0.34 (-1.15; 1.83). The RR is not statistically significantly different from one (p=0.6527). The difference in body fat percentage at the second measurement between physically active and sedentary students is 66% (Graph 2).

Objedinjena vrednost RR za vrednosti procenta masti u drugom merenju izračunata je iz modela slučajnih efekata iznosi 0,34 (-1,15; 1,83). RR nije statistički značajno različit od jedinice (p=0,6527). Razlika u vrednosti procenta masti u drugom merenju između fizički aktivnih i sedentarnih učenika iznosti 66% (Grafikon 2).



***Graph 2**. Display of individual results and combined RR value for body fat percentage at the second measurement*

***Grafikon 2.** Prikaz individualnih rezultata i objedinjena vrednost RR za vrednost telesne masti u drugom merenju*

Research limitations

The main problem in this study can be attributed to the meta-analysis of a small number of individual studies that met the established selection criteria. No statistically significant differences were found for the measured outcomes in this study. Most studies related to research results were based on a single measurement. Additionally, many studies included students of different ages, as well as male students. None of the studies assessed the prior level of students' physical activity. In some studies, the average daily caloric intake, which was higher than the recommended values, was controlled (Meng et al., 2022; Zuo et al., 2023). Future research should revise this study and include in the meta-analysis only individual studies that cover a clearly defined age group of students of both sexes, provide a detailed and clear description of the aerobic physical exercise program, and include pretest and posttest measurements. The research groups should be identical in selection, meaning that both groups of participants should have a similar BMI level, so as to demonstrate the effect of the organized aerobic physical exercise program. Besides the method and type of physical exercise, intensity also plays a significant role. The inconsistency of the physical exercise programs applied in the individual studies certainly influenced the final measurement outcomes in this meta-analysis.

Discussion

This paper presents a meta-analysis of data describing the impact of organized aerobic physical exercise on the measured values of BMI and body fat percentage in overweight students. It is not possible to generalize the obtained results or draw definite conclusions, as the research was conducted on a small number of studies. The following factors influenced this issue: the type of experimental physical exercise program, the sample of participants, the primary outcome measures, the methodology, and the statistical data processing. During the

Nedostaci istraživanja

Glavni problem u ovom istraživanju može se pripisati meta-analizi malog broja individualnih studija koje su zadovoljile postavljene kriterijume za odabir. U ovoj studiji nisu dobijene statistički značajne razlike za merene ishode. Većina studija se odnosila na rezultate istraživanja prikazanih na osnovu jednog merenja. Takođe, u mnoge studije uvršteni su učenici različite starosne dobi, kao i učenici muškog pola. Ni u jednom radu nije utvrđivan prethodni nivo fizičke aktivnosti učenika. U pojedinim studijama vršena je kontrola prosečne vrednosti dnevnog kalorijskog unosa koji je bio veći od preporučenih vrednosti (Meng et al., 2022; Zuo et al., 2023). Buduća istraživanja bi trebalo da izvrše reviziju ovog istraživanja i u meta-analizu uključe isključivo individualne studije koje obuhvataju jasno definisanu uzrast učenika oba pola, detaljan i jasan opis programa aerobnog fizičkog vežbanja, kao i istraživanja sa pretestom i posttestom. Istraživačke grupe bi trebalo da su identične po odabiru, odnosno da obe grupe ispitanika imaju podjednak nivo BMI kako bi se mogao prikazati uticaj organizovanog programa aerobnog fizičkog vežbanja. Pored načina i vrste fizičkog vežbanja, veliku ulogu igra i intenzitet. Neujednačenost primenjenih programa fizičkog vežbanja individualnih studija sigurno je imala uticaja na konačan ishod merenja u ovoj meta-analizi.

Diskusija

U ovom radu izvršena je meta-analiza podataka koji opisuju uticaj organizovanog aerobnog fizičkog vežbanja na merene vrednosti BMI i procenta masnog tkiva kod učenika sa viškom kilograma. U radu nije moguće uopštavati dobijene rezultate i doneti konačne zaključke, jer je istraživanje realizovano na malom broju studija. Na navedeni problem su uticale sledeće stavke: vrsta eksperimentalnog programa fizičkog vežbanja, uzorak ispitanika, primarni ishodi merenja, metod rada, kao i statistička obrada podataka. Prilikom pregledanja naučnih studija

review of scientific studies, it was observed that some authors conducted their research exclusively with boys, and that the ages of students in these studies varied. Additionally, there is an inconsistency in the experimental programs related to the form of organized aerobic physical exercise programs on which the data analysis and the final result of the effect size calculation were based. For this reason, it was difficult to select studies that would meet the criteria set for this meta-analysis. The analysis of the selected individual studies did not yield statistically significant results, but it did show a positive effect of organized aerobic physical exercise on regulating students' body weight. The individual studies are described further in the text.

In the first individual study (Back & Ji, 2015), a program (108 – Bae) suitable for sedentary individuals with excessive body weight was implemented. Compared to other studies, this research shows positive results in reducing BMI values, body fat percentage, and visceral fat. The limitation of this study lies in the analysis of a smaller number of students, solely males. Furthermore, the conclusion regarding the quality and effectiveness of the organized physical exercise 108 – Bae is questioned, as the study results obtained in this research are compared with the results from studies conducted on women and older adult dancers (Lee, 2008; Seo et al., 2008; Kim, 2004). Compared to the students in the control group who had normal BMI values, the experimental group experienced a positive impact due to continuous aerobic physical exercise, and a reduction in BMI and body fat percentage. The authors state that the 108 – Bae program positively affects the development of physical abilities and is suitable for all ages. In this study, the program lasted 12 weeks (4 times per week) with participants (N=28) aged 16 years.

In the second individual study (Meng et al., 2022), the authors presented data on the average daily caloric intake, which could have influenced the research outcome. The study did not find statistically significant differences in results between the two groups of participants: the experimental group that exercised at high intensity (HIT) and the control group (CON), which did not engage in additional physical exercise except regular PE classes. This study shows that, although there is no significant difference in the results of body mass and body fat percentage after intense and moderate physical exercise, there is a significantly more efficient use of time, with exercise duration reduced from 30 minutes to as little as 11 minutes. The study analyzed three groups of students, one of which exercised at moderate intensity (MICT).

uočeno je da je jedan broj autora sproveo svoja istraživanja isključivo sa dečacima, kao i da je uzrast učenika u studijama bio različit. Takođe, uočava se neujednačenost eksperimentalnog programa u vidu organizovanog programa aerobnog fizičkog vežbanja na kome se zasniva analiza podataka i konačan rezultat kroz dobijanje veličine efekta. Iz tog razloga, bilo je teško izvršiti selekciju studija koje bi zadovoljile postavljene kriterijume ove meta-analize. Analiza izdvojenih individualnih studija nije dala statistički značajne rezultate, ali je pokazala pozitivan uticaj organizovanog aerobnog fizičkog vežbanja na regulaciju telesne mase učenika. Dalje u tekstu su opisane individualne studije.

U prvoj individualnoj studiji (Back, & Ji, 2015) realizovan je program (108 – Bae) koji je prigodan za sedentarne osobe sa prekomernom telesnom masom. U poređenju sa ostalim istraživanjima, ova studija pokazuje pozitivne rezultate na smanjenju vrednosti BMI, procenta telesne masti i visceralne masti. Nedostatak ove studije ogleda se u analizi manjeg broja učenika i to isključivo muškog pola. Takođe, dovodi se u pitanje zaključak o kvalitetu i efikasnosti organizovanog fizičkog vežbanja 108 – Bae, jer se rezultati studije dobijene u ovom istraživanju porede sa rezultatima studija u kojima su istraživanja vršena sa ženama, kao i plesačima starije životne dobi (Lee, 2008; Seo et al., 2008; Kim, 2004). U poređenju sa učenicima u kontrolnoj grupi koji su imali normalne vrednosti BMI, u eksperimentalnoj grupi je došlo do pozitivnog uticaja usled kontinuiranog aerobnog fizičkog vežbanja i smanjenja vrednosti BMI i procenta masnog tkiva u organizmu. Autori navodi da program 108 – Bae pozitivno utiče i na razvoj fizičkih sposobnosti, kao i da je pogodan za sve uzraste. U ovoj studiji program je trajao 12 nedelja (4 puta nedeljno) sa ispitanicima (N=28) uzrasta 16 godina.

U drugoj individualnoj studiji (Meng et al., 2022) autori su prikazali podatke prosečne vrednosti dnevnog kalorijskog unosa koji bi mogli imati uticaja na ishod istraživanja. U studiji nisu uočene statistički značajne razlike u rezultatima između dve grupe ispitanika, odnosno između eksperimentalne grupe koja je vežbala visokim intenzitetom (HIT) i kontrolne grupe (CON) koja nije imala dodatno fizičko vežbanje osim redovnih časova nastave fizičkog vaspitanja. Ova studija pokazuje, da iako ne postoji značajna razlika u rezultatima nakon intenzivnog i umerenog fizičkog vežbanja na vrednosti telesne mase i procenta masnog tkiva, postoji značajno efikasnija potrošnja vremena koje je sa 30 minuta vežbanja smanjeno na čak 11 minuta. U studiji su analizirane tri grupe učenika od kojih je jedna grupa vežbala umere-

Additionally, shorter exercise duration positively affects motivation to exercise and is less demanding for school-age children. Therefore, this type of physical exercise is easier to implement during PE classes (Millard et al., 2018). An increase in body mass was observed in the control group, which may indicate insufficient load during regular PE classes. In this study, the program lasted 12 weeks (3 times per week) with participants (N=25) aged 11 years.

In the third individual study (Zuo et al., 2023), which investigated organized aerobic physical exercise in students performing high-intensity running and those engaged in moderate-intensity running, no significant difference was observed between the groups in muscle mass percentage. However, high-intensity physical exercise proved more useful for the analysis of body composition, body fat percentage, and cardiorespiratory function. The study reports average daily caloric intake values. The organized physical exercise program, which included a 50-meter running test, showed a positive effect on leg muscle strength. However, no major differences between the groups were observed, which can be explained by the continuous aerobic physical exercise performed by participants in both groups. It can be considered that the effect of reducing body weight and body fat percentage, and consequently increasing muscle mass, is directly related to the type and method of physical exercise. In this study, the program lasted 8 weeks (3 times per week) with participants (N=40) aged 8 years.

A review of the existing literature reveals there is a problem with standardized research methods regarding the mentioned issue. One meta-analysis that addressed this problem included students aged from 6 up to 18 years in its research. Additionally, inconsistent physical exercise programs due to the application of different intensities lead to results in individual studies that are difficult to compare later (Guerra et al., 2013). Therefore, this meta-analysis can be considered significant due to the clearly defined criteria for selecting individual studies, which influenced the effect size outcome. Although a very small number of studies were included in this meta-analysis, the obtained results indicate the possibility of a positive impact of organized aerobic physical exercise on the measured research outcomes. This research may highlight the need for studies with a larger number of participants so that the investigated problem can be generalized to the population of prepubertal and pubertal students.

nim intenzitetom (MICT). Takođe, kraće trajanje vežbanja pozitivno utiče na motivaciju za vežbanjem i manje je zahtevno za decu školskog uzrasta. Stoga, takav vid fizičkog vežbanja je lakše realizovati tokom nastave fizičkog vaspitanja (Millard et al., 2018). U kontrolnoj grupi uočava se povećanje vrednosti telesne mase što može da ukaže na nedovoljno opterećenje u okviru redovne nastave fizičkog vaspitanja. U ovoj studiji program je trajao 12 nedelja (3 puta nedeljno) sa ispitanicima (N=25) koji su imali 11 godina.

U trećoj individualnoj studiji (Zuo et al., 2023) u kojoj je istraživano organizovano aerobno fizičko vežbanje sa učenicima koji su primenjivali visok intenzitet trčanja i učenicima koji su primenjivali umeren intenzitet trčanja, uočeno je da nema značajne razlike između grupa u procentu mišićne mase. Ipak, fizičko vežbanje visokim intenzitetom pokazalo se uspešnijim pri analizi sastava telesne mase, procenta masnog tkiva i kardiorespiratorne funkcije. U studiji se navode prosečne vrednosti dnevnog kalorijskog unosa. Program organizovanog fizičkog vežbanja koji je obuhvatio test trčanja na 50 m pokazao je pozitivan efekat na snagu mišića nogu. Međutim, nisu uočene veće razlike između grupa što se može objasniti kontinuiranim aerobnim fizičkim vežbanjem ispitanika u obe grupe. Može se smatrati da je efekat smanjenja telesne mase i procenta masnog tkiva, a samim tim i povećanje mišićne mase u direktnoj vezi sa vrstom i načinom fizičkog vežbanja. U ovoj studiji program je trajao 8 nedelja (3 puta nedeljno) sa ispitanicima (N=40) koji su imali 8 godina.

Dosadašnjim pregledom istražene literature uočava se da postoji problem sa ujednačenim metodama istraživanja pomenutog problema. Jedna od meta-analiza, koja se bavila istraživanjem navedenog problema, navodi da je u svoje istraživanje uvrstila učenike od 6 do čak, 18 godina. Takođe, neujednačeni programi fizičkog vežbanja usled primene različitog intenziteta dovode do rezultata u pojedinačnim studijama koji se kasnije teško mogu porediti (Guerra et al., 2013). Stoga, ova meta-analiza se može smatrati značajnom zbog jasno definisanog kriterijuma za odabir individualnih studija koje je imalo uticaj na rezultat veličine efekta. Iako je u ovu meta-analizu uvršten veoma mali broj studija, dobijeni rezultati ukazuju na mogućnost pozitivnog uticaja organizovanog aerobnog fizičkog vežbanja na merene ishode istraživanja. Ovo istraživanje može da ukase na potrebu da se izvrše istraživanja sa većim brojem ispitanika kako bi se istraživani problem mogao generalizovati na populaciju učenika predpubertetskog i pubertetskog doba.

Conclusion

This meta-analysis examined three individual studies that analyzed organized aerobic physical exercise of students who were insufficiently physically active and overweight. Based on the small number of studies, it is not possible to obtain a reliable effect size result wherefrom a generalized conclusion could be drawn. However, although the study results did not show a statistically significant difference between the measured outcomes (BMI and body fat percentage), differences between groups were observed in individual studies. It is necessary to analyze data from a much larger number of studies, as well as with a greater number of participants who can be compared by age, gender, level of physical fitness, and BMI values.

Zaključak

Ovom meta-analizom izvršena je analiza tri individualne studije koje su izvršile analizu organizovanog aerobnog fizičkog vežbanja sa učenicima koji nisu dovoljno fizički aktivni i imaju i višak kilograma. Na osnovu malog broja studija nije moguće dobiti pouzdan rezultat veličine efekta na osnovu kog bi se zaključak mogao generalizovati. Međutim, iako rezultati studija nisu pokazali statističku značajnu razliku između merenih ishoda (BMI i procenat masnog tkiva), u pojedinačnim studijama uočene su razlike između grupa. Neophodno je izvršiti analizu podataka na mnogo većem broju studija, kao i sa većim brojem ispitanika koji se mogu porediti po: uzrastu, polu, nivou fizičke sposobnosti, kao i vrednostima BMI.

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Pregledni rad

Use of AI Technology Training on Motor Parameters: Systematic review

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Abstract: *The aim of this systematic review was to examine the use of AI training technology on motor performance. The research was conducted according to the PRISMA guidelines, using the PICOS framework for study selection, and the search included relevant databases such as PubMed, Web of Science, Scopus, MEDLINE, ERIC and Google Scholar. The final analysis included 16 studies that met strict methodological relevance criteria, and quality was assessed using the PEDro scale. Analysis of the included studies indicates that the most effective programs lasted between 5 and 8 weeks, with a frequency of at least three training sessions per week, while more significant effects were observed with interventions that included personalized feedback and adaptive algorithms. AI systems have shown the potential to improve strength, flexibility, coordination and other motor parameters, providing precise, individualized feedback. Although the results are promising, the variable methodological quality and heterogeneity of the technologies used indicate the need for further research in real-world sports conditions.*

Keywords: *Artificial intelligence, Physical training, Motor fitness, Exercise, Digital coaching, Robotics.*

Introduction

Wearable technology, such as electronic devices with wireless communication such as clothing on the body, equipment or accessories containing sensors for monitoring physiological and motor functions, is increasingly on the rise (Ometov et al., 2021). The value of 40.65 billion dollars in 2020 is an indicator of the attractiveness of this technology, with an expected growth of 13.8% by 2028 (Svertoka et al., 2021). A wide range of applications in the fields of sports medicine and training as well as low costs are just some of the benefits.

The emergence and development of AI technology has led to significant changes in the sports context. Wearable devices allow for precise measurement of parameters, optimization of training, and better insight into conditions such as heart rate, blood pressure, body temperature, EEG, ECG, as well as movement speed and acceleration (Altini et al., 2021; de Zambotti et al., 2019). For example, the Oura ring has proven to be a very reliable tool for sleep monitoring, while smartwatches such as the Apple Watch, through the Apple Health app, participate in the Apple Heart and Movement Study and the Apple Hearing Study (Turakhia et al., 2019).

The amount of data generated by these devices and processed using artificial intelligence (AI) has proven to be very effective and applicable. Russell and Norvig defined artificial intelligence as the design and construction of intelligent agents that receive instructions from the environment and take actions that affect that same environment (Helm et al., 2020). Machine learning in sports practice allows the system to "learn" and absorb knowledge from data in order to improve athlete performance (Estava et al., 2019). It has proven very effective as learning has already been applied in medical sciences in diagnostics as well as in disease monitoring (Vandevoorde et al., 2022).

In the fields of sports medicine, the most common application of sensors is for injury prevention, risk assessment, performance optimization and motor skills improvement, and if there is huge potential, there is still a lack of concise works that connect artificial intelligence and wearable technology in sports practice.

In addition, AI systems that function as digital assistants in motor learning are increasingly being used, using algorithms to recognize patterns in movements and analyze complex biomechanical parameters (Vandevoorde et al., 2022). These systems, when connected to wearable devices and sensors, enable advanced forms of individualization of training, as well as the identification of potential errors in the performance of motor tasks (Chidambaram et al.,

2022). In the teaching context, the implementation of AI technology contributes to more efficient learning and more precise execution of exercises, which is especially important in higher education sports education (Fu, 2020). Also, digital sports applications driven by artificial intelligence offer users the possibility of continuous progress monitoring, automated feedback and injury risk prediction, which further contribute to the optimization of training (Bodemer, 2023; Hajder et al., 2025). However, this technology requires additional research to address all the challenges and ethical dilemmas that accompany its increasingly intensive application (Bodemer, 2023).

The aim of the research is to examine the use of AI training technology on motor performance.

Method

For research purposes, PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) were applied.

Literature search strategy

An electronic search was conducted in multiple scientific databases, including PubMed, Web of Science, Scopus, MEDLINE, ERIC, and Google Scholar, as well as in relevant grey literature related to the application of artificial intelligence in the context of physical exercise and motor fitness. Recent papers published between 2020 and 2025 were analyzed.

The keyword combination used for the search included the phrases: “artificial intelligence” AND “physical training” OR “motor fitness” OR “exercise” AND “digital coaching” NOT “robotics”, with the use of logical operators to narrow the search scope. Specific keywords included: AI fitness coaching, motor skill improvement, digital personal trainer, intelligent feedback systems, and automated posture correction.

Only papers published in English were considered. Conference abstracts, preprints, and papers that had not passed the peer review process were excluded from the analysis in order to preserve scientific relevance and methodological consistency.

Titles and abstracts of papers were first screened for relevance, after which studies that met the previously defined inclusion criteria underwent a detailed content analysis. When necessary, the authors consulted with each other about the inclusion of certain studies in the research.

Criteria for inclusion and exclusion of studies

To ensure objectivity in the selection of papers, three authors (BB, Đ.H., RP) independently assessed the studies according to predefined criteria, using the PICOS framework (Population, Intervention, Comparators, Outcomes and Study Design). Only papers that:

- have as their topic the application of AI technologies in the context of physical exercise or motor fitness,
- contain clearly described interventions aimed at improving motor fitness,
- use measurable indicators of progress,
- papers published in peer-reviewed scientific journals

Papers that focus exclusively on passive technologies (e.g., robotic assistance without a training component) were excluded, as were studies that did not include human subjects or did not have clearly defined methodological approaches.

A total of 16 studies that met all of the above criteria were included in the analysis. The PICOS model was used in this paper to systematically define the inclusion and exclusion criteria for studies, thus ensuring methodological clarity and consistency in the selection of relevant studies. This approach allows for precise structuring of the population, interventions, comparators, outcomes, and study design within the analysis of the impact of AI technologies on motor fitness.

Table 1. *The inclusion and exclusion criteria used according to the PICOS model*

PICOS category	Inclusion criteria	Exclusion criteria
P (Population)	People of both sexes, regardless of age, level of physical activity or health status; including recreational users, athletes, students and clinical groups.	People with serious health conditions or injuries that prevent them from performing physical activity.
And (Intervention)	Studies that used AI technologies in training – including virtual assistants, chatbot trainers, algorithms for posture correction, program personalization, and fatigue management; measurements performed through sensors, video analysis, and applications.	Studies that did not use any form of artificial intelligence; works that relied solely on self-reported physical activity without objective verification; interventions that did not have a physical component.
C (Comparators)	Studies comparing an experimental group (AI intervention) with a control group or other digital training modalities (e.g. classic online training vs. AI training).	Comparisons between unrelated sports or populations (e.g., soccer players vs. handball players); studies without a clear comparator.
About (Outcomes)	Changes in motor fitness: coordination, strength, flexibility, balance, precision; posture correction; increased physical activity; motivation; positive effects on mental health.	Studies that did not perform or report specific intervention outcomes; imprecise or incomplete outcomes.
With (Study design)	Randomized and non-randomized controlled studies; experimental and quasi-experimental research; research published in English or Serbian in peer-reviewed journals between 2010 and 2024.	Duplicates; conference abstracts; case reports with <5 participants per group; review papers; preprint versions; studies outside the given timeframe or in languages other than Serbian or English.

Study selection and assessment of methodological quality

Screening and data extraction were performed by three authors (BB, Đ.H., RP) in accordance with the previously described search strategy. EndNote was used for reference management, while Mendeley Reference Manager (version 2.111.0, Copyright © 2024 Elsevier Ltd., Barcelona, Spain) was used for duplicate detection. The quality of the included studies was critically assessed, with systematic identification of potential limitations such as: small sample sizes, limited application of AI tools, as well as differences in the type of technology used and measurement instruments. Given the pronounced heterogeneity among the studies, a qualitative approach was applied to analyze their characteristics, while meta-analysis was not feasible.

The study used a descriptive method, and the methodological quality of the selected papers was independently assessed by three researchers using the PEDro scale (Physiotherapy Evidence Database), which contains 11 assessment criteria. Each criterion was scored binary (1 = met, 0 = not met). Studies that achieved 6 or more points were rated as high-quality, those with 4 to 5 points as medium quality, while studies with less than 4 points were classified as low quality.

Results

Literature search

The process of data collection, analysis, and study elimination is shown in Figure 1. An initial search of the selected databases identified 417 potential studies. After removing duplicates, reviewing titles and abstracts, and applying the defined exclusion criteria, 47 studies were included in the analysis. A more detailed assessment of eligibility further excluded some of the studies, reducing the total number of studies meeting the predefined inclusion criteria to 16. The final number of included studies forms the basis for this systematic review, and the complete selection and analysis procedure is shown in Figure 1.

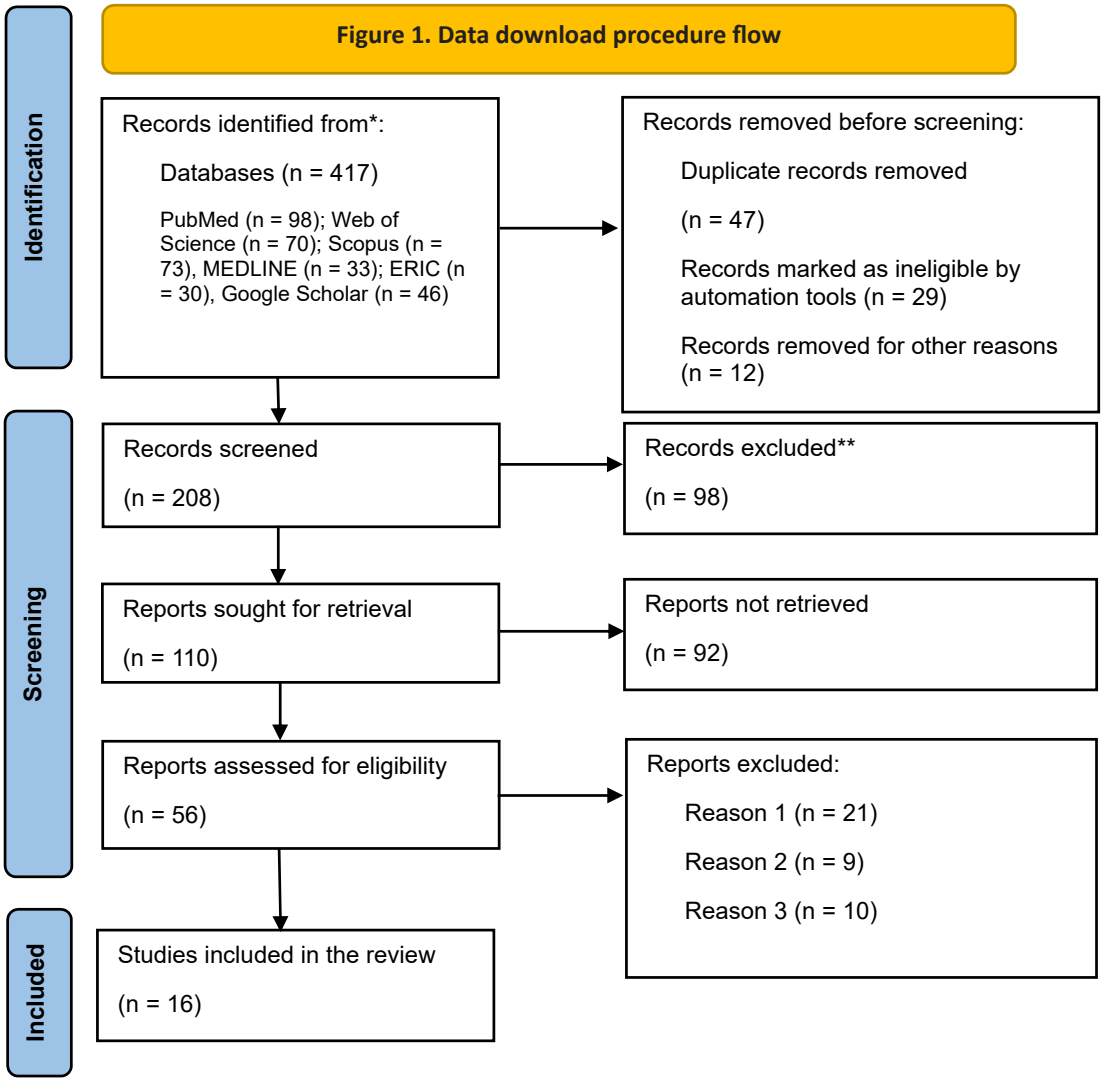

Figure 1. *PRISMA flow diagram, process for collecting studies for systematic review*

Study characteristics

A total of 16 studies investigating the use of artificial intelligence (AI) in the context of physical activity and health were analyzed, with a total of 85,321 respondents. The smallest number of participants was recorded in the study by Jörke et al. (2024), with only 16 participants, while the largest number of participants was included in the study by Chiam et al. (2024), which included 84,764 people. The number of respondents was not emphasized in the works (Chen & Yang, 2020; Choi et al., 2025; Delgoshaei et al., 2025; Kim et al., 2023). The AI methods used are diverse and include conversational agents (PlanFitting – Shin et al., 2023; GPTCoach – Jörke et al., 2024), interactive systems based on LLM and wearable devices (PhysioLLM – Fang et al., 2024), AI for posture correction through video analysis (Pose Trainer – Chen & Yang, 2020; HALE – Lee et al., 2023), as well as systems for personalized health and physical activity (BalanceUP chatbot – Ulrich et al., 2024; AI voice assistants – Hassoon et al., 2021). Deep learning methods have also been used, such as CNN-LSTM for functional movements (Pathak et al., 2022), as well as MediaPipe for shape recognition (Kim et al., 2023).

Table 2. *A systematic review of the papers included in the research*

Author(s)	Year	Population / Sample	AI / Application	Key findings	AI training performance	Limitations
Shin et al.	2023	18 participants	PlanFitting (conversational AI for workout planning)	It allows users to create and customize weekly exercise plans through natural language, taking into account personal circumstances and goals.	↑	Small sample size; focus on one type of exercise
Chiam et al.	2024	84,764 participants	AI platform for digital health promotion	Increase daily physical activity by 6.17% and weekly moderate to intense activity by 7.61% through personalized daily incentives.	↑	The need for data sharing between clubs for more efficient analysis
Fang et al.	2024	24 Fitbit users	PhysioLLM (interactive health data analysis system)	Integrating physiological data from wearable devices to provide personalized insights and goals, focusing on improving sleep quality.	≠	Small sample size; focus on sleep quality
Chen & Yang	2020	/	Pose Trainer (posture correction app)	Detects user posture during exercise and provides personalized recommendations to improve form and reduce the risk of injury.	↑	Limited to four exercise types; requires a computer with a GPU
Lee et al.	2023	20 women	Home Alone Exercise (HALE)	An application that uses AI to analyze videos of users exercising and provide feedback for posture correction.	↑	Small sample size; focus on one type of exercise
Zhu et al.	2021	53 users	Physical activity app with AI personalization	Using AI to personalize social comparison goals, which can increase users' motivation and physical activity.	↑	Further research is needed to confirm the findings
Jörke et al.	2024	16 participants	GPTCoach (chatbot coach)	Uses motivational interviewing and a personalized approach to encourage physical activity	↑	Small sample size; short-term intervention
Choi et al.	2025	/	LLMOps-based system	Automated exercise analysis and personalized recommendations for users in social healthcare	≠	No empirical data on effectiveness
Ulrich et al.	2024	198 participants	BalanceUP chatbot	Improving mental well-being and reducing somatic symptoms in people with frequent headaches	≠	Specific target group; self-assessment
Kim & Park	2024	51 participants	Mobile app for coaching (with nurse support)	Improving a healthy lifestyle and body composition	↑	Limited to a specific clinical population
Hassoon et al.	2021	42 participants	AI voice assistant and AI text coach	Increase in step count and physical activity compared to the control group	↑	A small sample; short follow-up period
Delgoshaei et al.	2025	/	AI systems for inclusion in physical activities	AI can facilitate the inclusion of people with disabilities in physical activities through personalization and real-time assistance	≠	Lack of empirical data

Jaiswal et al.	2023	60 students	Virtual AI tutor for fine motor skills	Significant improvement in accuracy and speed in learning fine motor skills (e.g. writing) using AI assistants	↑	Experimental setting, short intervention time
Kim et al.	2023	/	Learnable Physics AI for form correction	The AI system uses MediaPipe to recognize movements and provides real-time correction tips, reducing the risk of injury	↑	Limited to simulated conditions; further validation required
Pathak et al.	2022	40 participants	CNN-LSTM system for FMS tests	Automatic assessment of functional movements using AI, with high accuracy compared to physiotherapists	↑	Limited number of moves; limited generalization
Ma et al.	2024	35 athletes	AI fatigue management system (IMU + ML)	Real-time AI-powered endurance and fatigue tracking during training, with the ability to adjust load	↑	Smaller sample size; specificity for the sports population

Legend: *AI – artificial intelligence; CNN – Convolutional Neural Network; LSTM – Long Short-Term Memory; FMS – Functional Movement Screen; IMU – Inertial Measurement Unit; ML – Machine Learning; ↑ - positive effects of using the AI training system; ≠ - lack of data to evaluate the quality of the AI training system.*

Methodological assessment of the quality of the included studies

The methodological quality of the included studies was assessed using the PEDro scale (Physiotherapy Evidence Database). Of the sixteen (n = 16) studies, four were rated as moderate quality, while the remaining studies were classified as low methodological quality, mainly due to the lack of randomization, blinding, and empirical data. The analysis was conducted in accordance with the PRISMA guidelines. Both longitudinal and cross-sectional studies addressing the effects of applying artificial intelligence (AI) in training and planning physical activity were included.

Table 3.PEDro *scale for assessing methodological relevance and quality of studies*

Reference	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Shin et al. (2023)	+	-	-	-	-	-	-	-	-	+	+	**3**
Chiam et al. (2024)	+	+	-	+	-	-	-	+	-	+	+	6
Fang et al. (2024)	+	-	-	-	-	-	-	-	-	+	+	**3**
Chen & Yang (2020)	+	-	-	-	-	-	-	-	-	+	+	**3**
Lee et al. (2023)	+	-	-	-	-	-	-	-	-	+	+	**3**
Zhu et al. (2021)	+	+	-	+	-	-	-	-	-	+	+	**5**
Jörke et al. (2024)	+	-	-	-	-	-	-	-	-	+	+	**3**
Choi et al. (2025)	+	-	-	-	-	-	-	-	-	-	+	**2**
Ulrich et al. (2024)	+	-	-	-	-	-	-	-	-	+	+	**3**
Kim & Park (2024)	+	+	-	+	-	-	-	-	-	+	+	**5**
Hassoon et al. (2021)	+	-	-	+	-	-	-	-	-	+	+	**4**
Delgoshaei et al. (2025)	+	-	-	-	-	-	-	-	-	-	+	**2**
Jaiswal et al. (2023)	+	+	-	+	-	-	-	-	-	+	+	**5**
Kim et al. (2023)	+	-	-	-	-	-	-	-	-	+	+	**3**
Pathak et al. (2022)	+	+	-	+	-	-	-	-	-	+	+	**5**
Ma et al. (2024)	+	+	-	+	-	-	-	-	-	+	+	**5**

Legend: *+ indicates one point; - indicates no point; (1) Eligibility criteria; (2) Radomization; (3) Concealment of allocation; (4) Between-group homogeneity; (5) Blinded of subjects; (6) Blinded trainers; (7) Blinded testers; (8) Dropout rate < 15%; (9) Intention-to-treat; (10) Statistical be-tween-group comparisons; (11) Point and variability estimates; (12) total scores.*

Discussion

The application of artificial intelligence (AI) in sports training brings numerous benefits that can improve athlete performance. The results presented in this systematic review indicate that AI is increasingly integrated into various aspects of sports, from biomechanical analysis of movements, through load planning, to performance prediction and injury prevention. One of the most important findings from the included studies is the ability of AI systems to analyze large amounts of data in real time and provide feedback that is specific, personalized and immediately applicable. According to research conducted by Connolly et al. (2021), the use of machine learning to assess biomechanical parameters during running allowed for timely correction of technique, which resulted in a reduction in the risk of injury.

The work of Lamas, et al. (2022) highlights that the application of AI learning can predict athlete fatigue by analyzing movement patterns and physiological signals. This can help coaches optimally adjust loads to prevent overtraining. However, an important challenge is the need for high-quality and reliable data, as well as ethical standards regarding athlete privacy. Despite the obvious advantages, most of the included studies show limited applicability in real-world training conditions. Many studies (Taylor et al., 2020; Li et al., 2021) were experimental in nature and conducted in controlled conditions, which makes it difficult to generalize the results. Additional research is needed to test the effectiveness of AI systems in long-term and complex sports environments.

PEDro's analysis of study quality indicates variable methodological quality of research, with only some meeting the criteria. This further highlights the need for standardization of methods for evaluating AI systems in sport.

Recent studies have explored the effects of AI-based technologies on motor fitness and physical education. AI-generated calisthenics training programs have shown improvements in flexibility and muscular endurance, although human-made programs were superior in some areas (Masagca, 2024). AI-guided assistance systems integrating motor learning principles, machine learning algorithms, and sensor technologies offer potential for motor skill training in real-world environments (Vandevoorde et al., 2022). Chatbot-generated personalized fitness regimens have demonstrated promise in strength and conditioning applications, although further research is needed (Bays et al., 2024). In college physical education, AI applications such as Intelligent Computer-Aided Instruction, wearable devices, and motion capture systems have enhanced precision and efficacy (Mao & Chen, 2024). AI algorithms have shown superior performance in identifying sports movement features and human body detection compared to traditional methods, reducing errors by 36.69% (Mao & Chen, 2024). These findings suggest AI's potential to revolutionize motor fitness training and physical education.

The application of artificial intelligence (AI) in modern sports training shows the potential to transform the way in which the development of motor skills and the optimization of physical preparation are approached. The most effective AI trainings are based on a combination of personalization, real-time feedback and analysis of large amounts of data, which allows a high level of precision in determining the load, technique and progression. Chatbot assistants such as FitBot, based on NLP models, have shown the ability to generate programs for the development of strength and endurance that are comparable to those created by experts, especially in the context of recreational training (Bays et al., 2024). AI systems that include machine learning and wearable devices enable biomechanical analysis of movements, which accurately detect technical errors and potential risks of injury (Connolly et al., 2021).

In terms of intensity, most AI-guided workouts favor medium to high loads (60–85% 1RM), especially in the development of muscle strength and hypertrophy. At the same time, flexibility, coordination, and endurance are developed through AI routines that use higher repetitions and carefully controlled movements at lower intensities (Masagca, 2024). The integration of sensors and movement pattern recognition algorithms allows for continuous performance monitoring, while reinforcement learning models learn from feedback and adapt training according to changes in the athlete's physiological response (Lamas et al., 2022).

Vandevoorde, et al. (2022) point out that AI-assisted systems that incorporate motor learning principles can effectively improve technique in real-world sports environments, which is of particular importance for the development of coordination and agility. Also, studies in the context of physical education at universities show that the application of AI systems such as wearable devices, ICAT (Intelligent Computer-Aided Training), and movement tracking systems significantly increase the accuracy of performance and motivation of students (Mao & Chen, 2024). It is especially important to emphasize that AI can be an effective tool for personalizing training based on physiological and biomechanical parameters, thus ensuring optimal progression and prevention of overtraining.

The implementation of AI technology in sport still faces challenges such as ethical issues related to data privacy

and the need for standardization of evaluation methods. However, a growing body of evidence suggests that AI will play a key role in the future of sports coaching, with the potential to enhance motor skill development through a high level of personalization and adaptation.

Study limitations

The systematic review provides significant insights into the potential of AI applications in the field of training, however, a number of limitations have also been identified. First, most of the included studies have a small number of participants, which limits statistical power and the possibility of generalizing the results. Second, the application of AI technologies has in many cases been tested in controlled conditions, rather than in real training situations, which calls into question their validity. Third, a large number of studies were assessed as having low methodological quality according to the PEDro scale, with a lack of randomization and blinding methods. Another issue is the pronounced heterogeneity of the AI systems, interventions and measurement instruments used, which makes it difficult to compare results across studies.

Conclusion

Based on the results of the systematic review, it can be concluded that artificial intelligence has significant potential for improving motor skills in physical exercise and sports training. AI systems enable personalization of training, precise biomechanical analysis of movements, automated technique correction and improved user motivation. Analysis of the included studies indicates that the most effective programs lasted between 5 and 8 weeks, with a frequency of at least three training sessions per week, while more significant effects were recorded in experimental programs that included personalized feedback and adaptive algorithms. However, current research is still not sufficiently uniform or methodologically precise to draw definitive conclusions about the long-term effect of these technologies. Further empirical research with larger samples and realistic protocols is needed to confirm the effectiveness of AI systems and enable their wider application in sports and physical education.

Conflict Of Interest

No potential conflict of interest relevant to this article was re-reported.

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Prevalence of Obesity in Younger School-Age Students

Prevalencija gojaznosti učenika mlađeg školskog uzrasta

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Summary: *The primary goal of this research is to objectively determine the actual state of nutrition in younger school-aged students, of both sexes, from four primary schools in the Odžaci municipality of the Republic of Serbia. The sample of respondents consisted of younger school age students from four primary schools from the area of the Odžaci municipality (R. Serbia). The total sample of respondents consisted of 93 students of both sexes, of which 42 were boys and 51 were girls. For research needs, basic anthropometric measurements, body height and body weight were applied, and the body mass index (BMI) was calculated based on the aforementioned. The BMI was used for the purpose of assessing the nutrition of respondents - students in individual groups.*

All collected data was processed using descriptive and comparative statistics. The arithmetic mean, standard deviation, maximum and minimum measurement values were calculated from the descriptive statistics area, while the t test of independent samples was used from the comparative statistics area.

The research results show that the prevalence of obesity among younger school age students is 19.4%, while another 16.1% of students are at risk of obesity. Boys and girls did not differ significantly in BMI. Respondents - older students on average have higher BMI values than younger students, but obesity was not found to be more prevalent in any of the examined age groups.

The obtained results enable the design of strategies for further research on younger school age children, for the purpose of monitoring growth and development, as well as the possibility of determining certain standards of psychophysical preparedness of children for going to school, successful school attendance and inclusion in various physical activity programs.

Keywords: *antopometric measurements, obesity, younger school age, gender, age.*

Sažetak: *Osnovni cilj ovog istraživanja jeste da se transverzalnim presjekom na objektivan način utvrdi stvarno stanje uhranjenosti učenika mlađeg školskog uzrasta oba pola iz četiri osnovne škole sa prostora opštine Odžaci u Republici Srbiji. Uzorak ispitanika činili su učenici mlažeg školskog doba iz četiri osnovne škole sa prostora opštine Odžaci (R. Srbija). Ukupan uzorak ispitanika činilo je 93 učenika oba pola, od čega je 42 dečaka i 51 devojčica. Za potrebe istraživanja primenjene su osnovne antropometrijske mere, telesna visina i telesna težina a na osnovu njih izračunat je Indeks telesne mase (ITM). Indeks telesne mase korišten je u svrhu procenjivanja uhranjenosti ispitanika – učenika pojedinim grupama.*

Svi prikupljeni podaci obrađeni su postupcima deskriptivne i komparativne statistike. Iz prostora deskriptivne statistike izračunata je aritmetička sredina, standardna devijacija, maksimalne i minimalne vrednosti merenja, dok je iz prostora komparativne statistike korišćen t test nezavisnih uzoraka.

Rezultati istraživanja pokazuju da prevalenca gojaznosti kod učenika mlađeg školskog uzrasta iznosi 19,4%, a da rizik od gojaznosti ima još 16,1% učenika. Dečaci i devojčice se nisu značajno razlikovali u indeksu telesne mase. Ispitanici - učenici starije uzrasne dobi u proseku imaju veće vrednosti indekas telesne mase od učenika mlađe uzrasne dobi, ali se gojaznost nije ustanovila kao zastupljenija u nekoj od ispitivanih uzrasnih grupa.

Dobiveni rezultati omogućuju osmišljavanje strategija u daljnjim istraživanjima dece mlađeg školskog uzrasta, u svrhu praćenja rasta i razvoja kao i mogućnost utvrđivanja određenih standarda psihofizičke pripremljenosti dece za odlazak u školu, uspješno pohađanje škole i uključivanje u različite programe fizičkih aktivnosti.

Ključne reči*: antopometrijske mere, gojaznost, mlađi školski uzrast, pol, starosna dob.*

Introduction

We are a witness to the constant growth in childhood obesity which has reached epidemic proportions (Delaš

Uvod

Svedoci smo kako je dečja gojaznost u stalnom porastu i poprima epidemijske razmere (Delaš i sar.,

et al., 2008). The majority of authors believe that it is the result of excessive food intake, a sedentary lifestyle and psychological factors, that is, unhealthy lifestyle habits that are a consequence of the modern lifestyle (Delmas et all, 2007, Basaldua & Chiquete, 2008).

Obesity in children is classified as primary and secondary obesity. Primary (idiopathic, exogenous, nutritional obesity) is the most common cause of obesity in childhood and adolescence. Less than 5% of the causes of childhood obesity is secondary obesity, associated with genetic factors, endocrine disorders, and lesions of the central nervous system (Greenberg & Obin, 2006).

It can be said that the prevalence of obesity among children in Serbia is in line with the data obtained in foreign research, which states that around 20-25% of children are actually obese or suffer from excessive nutrition (Lobstein & Frelut, 2003; Milanović and Radisavljević Janjić, 2015). It is estimated that there are around 150 million obese children in the world today (Wang & Lobstein, 2006). However, what is even more worrying is that this trend is constantly increasing (Shields, 2009).

Critical periods for the development of obesity have been identified in different school ages according to gender, so that in the lower grades of primary school, students are more vulnerable compared to the population of female students, while female students are more vulnerable in higher grades of primary school (Đokić, Međedović and Smiljanić, 2011).

Regular physical activity is of great importance for the proper growth and development of children (Strong et al. 2005), which clearly mitigates many of the health risks associated with being overweight or obese (Blair & Brodney, 1999).

At a younger age, regular physical activity of a directed, systematically guided or unstructured nature, has a positive effect on the child's physical development during the later period of life (Malina & Bouchard, 1991). Moreover, regular physical activity at an early age has a direct and indirect positive effect on health status in adulthood (Twisk, Kemper & VanMenchelen, 2000).

Today, there are ever more sports schools on the global level, which aim to engage children from the earliest age in order to prevent obesity and the occurrence of physical deformities, influence the proper growth and development of children, as well as their sports and technical achievements (Stević et al., 2018).

It is at this age that many children begin to develop a love for a particular sport and begin to train, considering that there are children who belong to the group of children with excessive body weight and obesity.

2008). Većina autora smatra kako je to rezultat prekomernog unosa hrane, sedentarnog načina života i psiholoških faktora, dakle ne zdravih životnih navika koje su posledica savremenog načina života (Delmas et all, 2007., Basaldua & Chiquete, 2008).

Gojaznost kod dece se klasifikuje kao primarna i sekundarna gojaznost. Primarna (idiopatska, egzogena, nutritivna gojaznost) je najčešći uzrok gojaznosti u detinjstvu i adolescenciji. Manje od 5% uzroka gojaznosti u detinjstvu je sekundarna gojaznost, povezana sa genetskim faktorom, endokrinim poremećajima kao i lezijama centralnog nervnog sistema (Greenberg & Obin, 2006).

Može se reći da je prevelanca gojaznosti kod dece u Srbiji u skladu i sa podacima koji se dobijaju u inostranim istraživanjima, u kojima se govori o tome da je oko 20-25% dece zapravo gojazno ili pati od prekomerne uhranjenosti (Lobstein & Frelut, 2003; Milanović i Radisavljević Janjić, 2015). Procenjuje se da danas u svetu ima oko 150 miliona gojazne dece (Wang & Lobstein, 2006). Međutim, ono što je još više zabrinjavajuće jeste da je taj trend konstantno u porastu (Shields, 2009).

Kritični periodi za razvoj gojaznosti su identifikovani u različitom školskom uzrastu prema polu, tako da su u nižim razredima osnovne škole ugroženiji učenici u odnosu na populaciju učenica, dok su učenice ugrožene u višim razredima osnovne škole (Đokić, Međedović i Smiljanić, 2011).

Redovna fizička aktivnost je od velikog značaja za pravilan rast i razvoj dece (Strong et al. 2005), jasno ublažava mnoge zdravstvene rizike povezane sa prekomernom težinom ili gojaznošću (Blair & Brodney, 1999).

Redovna fizička aktivnost, usmerenog, sistematski vođenog ili nestrukturiranog karaktera, u mlađem životnom dobu, pozitivno se odražava na fizički razvoj deteta u kasnijem periodu njegovog života (Malina & Bouchard, 1991). Štaviše, redovna fizička aktivnost u ranom dobu ima direktan i indirektan pozitivan uticaj na zdravstveni status u odraslom dobu (Twisk, Kemper & VanMenchelen, 2000).

Danas su u svetu sve više zastupljene školice sporta, koje imaju za cilj angažovanje dece od najranijeg uzrasta, kako bi se preventivno delovalo na gojaznost i nastanak telesnih deformiteta, uticalo na pravilan rast i razvoj dece kao i na sportsko-tehnička postignuća (Stević i sar., 2018).

Dosta dece u ovom uzrastu počinje da razvija ljubav prema određenom sportu i počinju da treniraju s

Bearing in mind the importance of sports school for the proper growth and development of preschool and younger school age children, the Sports Association of the Odžaci municipality in Serbia launched a project for the establishment and operation of a sports school for younger school age students (Board of Education Decision No. 1-1309/2016 of September 13, 2016), which was financed by the local community. The mission behind the establishment of the sports school was to improve the physical growth and development of children and to improve the overall anthropological status of children. Special attention at the sports school is dedicated to the prevention and correction of body deformities, obesity and improving the general health of children.

Research Method

Sample of respondents

The total sample of respondents consisted of 93 respondents of both sexes - students of lower grades from the following primary schools: Public Institution Bora Stanković Primary School in Karavukovo, Public Institution Ratko Pavlović Ćićko Primary School in Ratkovo, Public Institution Vuk Karadžić Primary School in Deronje, and Public Institution Nestor Žučni Primary School in Lalić.

Structure of respondents:

According to gender: 42 boys (45.2%) and 51 girls (54.8%).

According to the place of primary school attendance: Primary School Karavukovo: 16 students (M=9; F=7), 41 students (44%) Primary School Ratkovo: 41 students (M=12; F=29), Primary School Deronje: 20 students (M=9; F=11) and Primary School Lalić 16 students (M=11; F=5).

According to grades: I grade=30 students (M=13; F=17), II grade=14 (M=4; F=10), III grade=26 (M=10, F=16), IV grade=23 (M=14; F=9).

Consent for conducting the research was obtained from the parents of the tested children. The research was conducted during the month of October of the 2016/2017 school year, at the beginning of the implementation of the sports school program.

Sample variables

Children who underwent testing had their body height (ATEVIS) and body mass (ATEMAS) measured. We used a *Seca 217* medical altimeter to measure body height, while an *Omron BF 511* digital scale was used to measure body mass.

Body Mass Index (BMI) is a height-weight indicator of an individual's nutrition and is a valid measure of

obzirom da ima dece koja pripadaju grupi dece sa prekomernom telesnom masom i gojaznošću.

Imajući u vidu značaj školice sporta za pravilan rast i razvoj dece predškolskog i mlađeg školskog uzrasta Sportski savez opštine Odžaci u Srbiji pokrenuo je Projekat za osnivanje i rad školice sporta za učenike mlađeg školskog uzrasta (Odluka UO broj 1-1309/2016 od 13.09.2016. godine) koji je finansiran sredstvima lokalne zajednice. Misija osnivanja školice sporta je unapređenje telesnog rasta i razvoja dece i poboljšanje celokupnog antropološkog statusa dece. Posebna pažnja rada školice sporta usmerena je na prevenciju i korekciju telesnih deformacija, gojaznosti i poboljšanje opšteg zdravlja dece.

Metod istraživanja

Uzorak ispitanika

Ukupan uzorak ispitanika činilo je 93 ispitanika oba pola – učenika nižih razreda iz sljedećih osnovnih škola: JUOŠ „Bora Stanković" u Karavukovu, JUOŠ „Ratko Pavlović Ćićko" u Ratkovu, JUOŠ „Vuk Karadžić" u Deronjama i JUOŠ „Nestor Žučni" u Laliću.

Struktura ispitanika:

Prema polu: 42 dečaka (45,2%) i 51 devojčica (54,8%).

Prema mestu pohađanja osnovne škole: JUOŠ Karavukovo: 16 učenika (M=9; Ž=7), 41 učenik (44%) JUOŠ Ratkovo: 41 učenik (M=12; Ž=29), JUOŠ Deronje: 20 učenika (M=9; Ž=11) i JUOŠ Lalići 16 učenika (M=11; Ž=5).

Prema razredima: I razred=30 učenika (M=13; Ž=17), II razred=14 (M=4; Ž=10), III razred=26 (M=10, Ž=16), IV razred=23 (M=14; Ž=9).

Saglasnost za sprovođenje istraživanja je dobijena od starne roditelja ispitivane dece. Istraživanje je sprovedeno u mesecu oktobru školske 2016/2017 godine na početku realizacije programa školice sporta.

Uzorak varijabli

Deci koja su podvrgnuta testiranju merene su telesna visina (ATEVIS) i telesna masa (ATEMAS). Za merenje telesne visine koristili smo medicinski visinomer *Seca 217*, dok je za merenje telesne mase korišćena digitalna vaga *Omron BF 511*.

Indeks telesne mase ITM (eng. Body Mass Index: BMI) predstavlja visinsko-težinski pokazatelj uhranjenosti pojedinca i validna je mera gojaznosti kako kod odraslih, tako i kod dece. Izračunava se kada težinu tela u kilogramima podelimo sa kvadratom visine u metrima

obesity in both adults and children. It is calculated when an individual's body weight in kilograms is divided by the square of their height in meters: BMI=BM [kg]/TV^2 [m^2] (Ostojić and Đorđić, 2013:133).

The choice of BMI to measure the level of obesity among children is supported by the International Obesity Task Force.

According to the criteria of the Centers for Disease Control and Prevention (CDC), 2000, BMI can be categorized into four broad groups: undernourished (below the 5th percentile), normal nutrition (from the 5th to the 84th percentile), obesity risk (from the 85th to the 94th percentile) and obesity (above the 95th percentile). This distribution of nutrition in relation to BMI in children of early primary school age was also used in this research.

Data processing methods

All collected data was processed using descriptive and comparative statistics. From the space of descriptive statistics, the arithmetic mean (MEAN), standard deviation (St. Dev.), the maximum value of the measurement (Max), and the minimum value of the measurement (Min), was calculated in order to gain insight into the distribution of variables and the frequency of representation of obese younger school age children.

From the area of comparative statistics, the t test of independent samples and one-factor analysis of variance were used to determine the differences in BMI between the two groups of respondents (boys and girls) with regard to gender and age. Determination of differences was performed at the level of statistical significance Sig<0.05.

The SPSS for Windows 20.0 application statistics program for personal computers was used for all calculations.

Results and Discussion

The younger school age period (7 to 11 years) represents the first phase of slowed growth. It has been proven that the increase in body height is relatively slow, and the annual increase in height is relatively uniform until the end of this period. Growth in height is accompanied by a corresponding increase in body mass. During this period, children grow approximately five centimeters per year, gaining an average of two to three kilograms in body weight (Medved, 1987).

Table 1 shows the basic statistical parameters for all applied anthropometric measures of respondents-younger school age students, shown by sub-samples with regard to age and grade. Looking at the obtained results (Table 1), it can be seen that the average height of ten-year-old students (IV grade) is 144.73+/-6.48 cm, body

pojedinca: ITM=TM [kg]/TV^2 [m^2] (Ostojić i Đorđić, 2013:133).

Izbor ITM za merenje nivoa gojaznosti među decom podržava Međunarodna radna grupa za gojaznost (International Obesity Task Force).

Prema kriterijumima Centra za kontrolu bolesti i prevenciju (Centers for Disease Control and Prevention, 2000), indeks telesne mase se može kategorizovati u četiri široke grupe: neuhranjensot (ispod 5. percentila), normalna uhranjenost (od 5 do 84. percentila), rizik od gojaznosti (od 85 do 94. percentila) i gojaznost (iznad 95. percentila). Ovakva raspodela uhranjenosti u odnosu na indeks telesne mase kod dece ranog osnovnoškolskog uzrasta je korišćena i u ovom istraživanju.

Metode obrade podataka

Svi prikupljeni podaci obrađeni su postupcima deskriptivne i komparativne statistike. Iz prostora deskriptivne statistike izračunata je i utvrđena aritmetička sredina (MEAN), standardna devijacija (St. Dev.), maksimalna vrednost merenja (Max) i minimalna vrednost merenja (Min), kako bi se stekao uvid u distribuciju varijabli i frekvenciju zastupljenosti gojazne dece mlađeškolskog uzrasta.

Iz prostora komparativne statistike korišćen t test nezavisnih uzoraka i jednofaktorska analiza varijanse, kako bi se utvrdile razlike u indeksu telesne mase između dve grupe ispitanika (učenika i učenica) s obzirom na pol i uzrasnu dob. Utvrđivanje razlika izvršeno je na nivou statističke značajnosti Sig<0,05.

Za sva izračunavanja koristio se aplikacioni statistički program za personalne računare SPSS for Windows 20.0.

Rezultati i diskusija

Period mlađeg školskog uzrasta (7 do 11 godina), predstavlja prvu fazu usporenog rasta. Dokazano je da je porast visine tela relativno usporen, a godišnji priraštaj visine relativno ujednačen do pred kraj ovog perioda. Priraštaj u visinu praćen je odgovarajućim priraštajem u masi tela. U ovom periodu deca okvirno, godišnje porastu oko pet cantimetara, u masi tela dobijaju prosečno dva do tri kilograma (Medved, 1987).

U tabeli 1 prikazani su osnovni statistički parametri za sve primenjene antropometrijske mere ispitanika-učenika mlađeg školskog uzrasta prikazanih po subuzorcima s obzirom na uzrasnu dob i razred koji pohađaju. Uvidom u dobivene rezultate (tabela 1) može se videti da je prosečna vrednost telesne visine učenika desetogodišnjaka (IV razred) 144,73+/-6,48 cm, telesne težine 42,81+/-

weight is 42.81+/-14.88 kg, and BMI is 20.17+/-5.89 kg/m2. The average height of nine-year-old students (III grade) is 137.76+/-5.30 cm, body weight 34.15+/-7.95 kg, and BMI 17.86+/-3.11 kg/m2. The average height of eight-year-old students (II grade) is 136.07+/-4.92 cm, body weight 34.06+/-6.45 kg, and BMI 18.28+/-3.01 kg/m2. The average height of seven-year-old students (I grade) is 128.93+/-5.03 cm, body weight 28.10+/-4.04 kg, and BMI 16.88+/-2.16 kg/m2. Observing the sample of respondents in total, it is visible that the average value of body height is 136.38+/-8.07 cm, body weight 34.40+/-10.60 kg, and BMI 18.19+/-3.92 kg/m2.

Based on the results presented in Table 1, an increase in the average values of body height (ATEVIS), weight (ATETEŽ) and standard deviation (St.dev.) of the respondents is visible with the age of the respondents. The values of standard deviation (St. Dev.) show that the value of the measured parameters is the smallest in the seven-year-old respondents and the largest in the ten-year-old respondents, which is not surprising given that it is during this period that children enter a new phase of development.

Table 1. *Basic statistical parameters for anthropometric measurements of subjects according to age (grade)*

Age-grade / **Uzrasna dob-razred**		***Min***	***Max***	***MEAN***	***St. Dev.***
10 years (IV grade) / 10 god. (IV raz.)	ATEVIS	128	154	144.73	6.48
	ARETEŽ	22.6	92.9	42.81	14.88
	BMI	13.20	40.74	20.17	5.89
9 years (III grade) / 9 god. (III raz)	ATEVIS	129	152	137.76	5.30
	ATETEŽ	23.7	56.1	34.15	7.95
	BMI	13.90	24.28	17.86	3.11
8 years (II grade) / 8 god. (II raz.)	ATEVIS	128	143	136.07	4.92
	ATETEŽ	24.5	45.9	34.06	6.45
	BMI	14.30	22.60	18.28	3.01
7 years (I grade) / 7 god. (I raz.)	ATEVIS	120	140	128.93	5.03
	ATETEŽ	20.20	37.70	28.10	4.04
	BMI	13.40	21.60	16.88	2.16
Total / Ukupno	ATEVIS	120	154	136.38	8.07
	ATETEŽ	20.20	92.90	34.40	10.60
	BMI	13.20	40.74	18.19	3.92

In children, the BMI value is compared with centile curves. A BMI between the 90-97th centile indicates overweight, and a BMI above the 97th centile is considered obesity. The value of BMI is recommended as an objective diagnostic criterion of obesity in children and adolescents. The WHO Child Growth Standards (WHO) recommends the z-value of the BMI for

14,88 kg, a indeks telesne mase 20,17+/-5,89 kg/m2. Prosečna vrednost telesne visine učenika devetogodišnjaka (III razred) iznosi 137,76+/-5,30 cm, telesne težine 34,15+/-7,95 kg, a indeks telesne mase 17,86+/-3,11 kg/m2. Prosečna vrednost telesne visine učenika osmogodišnjaka (II razred) iznosi 136,07+/-4,92 cm, telesne težine 34,06+/-6,45 kg, a indeks telesne mase 18,28+/-3,01 kg/m2. Kod učenika uzrasne dobi od sedam godina (I razred) prosečna vrednost telesne visine iznosi 128,93+/-5,03 cm, telesne težine 28,10+/-4,04 kg, a indeks telesne mase 16,88+/-2,16 kg/m2. Posmatrajući uzorak ispitanika u totalu vidljivo je da prosečna vrednost telesne visine iznosi 136,38+/-8,07 cm, telesne težine 34,40+/-10,60 kg, a indeks telesne mase 18,19+/-3,92 kg/m2.

Na osnovu rezultata prikazanih u Tabeli 1 vidljivo je povećanje prosečnih vrednosti telesne visine (ATEVIS), težine (ATETEŽ) i standardne devijacije (St.dev.) ispitanika sa uzrasnom dobi ispitanika. Vrednosti standardne devijacije (St. Dev.) pokazuju da je najmanja raspršenost vrednost merenih parametara kod ispitanika od sedam godina a najveća kod ispitanika od deset godina što ne predstavlja iznenađenje obzirom da upravo u ovom periodu deca ulaze u novu fazu razvoja.

Tabela 1. *Osnovni statistički parametri antropometrijskih mera ispitaniak prema uzrastu (razredu)*

Kod djece vrijednost ITM-a se uspoređuje sa centilnim krivuljama. ITM između 90-97 centila ukazuje na prekomjernu težinu, a ukoliko je ITM iznad 97 centila govori se o pretilosti. Vrijednost ITM-a preporučuje se kao objektivni djagnostički kriterij pretilosti u dječijoj i adolescentnoj dobi. WHO Child Growth Standards (SZO) kao dijagnostički kriterij pretilosti preporučuje z-vrijednost indeksa tjelesne

length/height as a diagnostic criterion for obesity: a z-value of +1 SD (standard deviation) indicates a risk of overnutrition, a z-value of +2SD indicates overweight, a z-value of +3SD indicates obesity, and the values of the 85th and 95th percentiles of BMI for age and gender have been highlighted. There are several anthropometric procedures for assessing the degree of obesity.

For newborns and infants, the simplest way is to weigh and measure the length (height) of the child and record an increase in height and weight. One of the possibilities for younger children (preschool and school age) is also the possibility of weighing and comparing body mass with reference values for age or height.

For older children and adolescents, there are several anthropometric methods and measurement procedures, starting with the measurement of skin folds or measuring the circumference of the extremities in certain places, all the way to modern measurement procedures involving an analysis of the bioelectrical resistance of the body (Bioelectrical Impedance Analysis m - BIA).

The BMI is most often used to diagnose obesity in adults, and it represents the standard recommended by the WHO, the World Obesity Federation and the CDC.

Based on insight into the BMI values, the treated sample of respondents - students, can be grouped into one of four categories based on the standard tables of the CDC, which view the BMI in the context of the child's age, *i.e.*, in the context of the already described correction for age and gender on the standardized BMI score. According to this distribution, the treated sample of respondents can be classified into groups as shown in Table 2.

Table 2. *Categorization of respondents - students in relation to BMI*

Respondent category / **Kategorija ispitanika**	***Number of respondents /*** **Broj ispitanika**	***Percentage of respondents /*** **Procenat ispitanika**
Malnutrition / Neuhranjenost	6	6.5%
Normal nutrition / Normalna uhranjenost	54	58%
Risk of obesity / Rizik od gojaznosti	15	16.1%
Obesity / Gojaznost	18	19.4%

Based on the analysis of the results shown in Table 3, it can be concluded that 54 (58%) of the students - respondents have a normal body weight. The risk of obesity was recorded in 15 (16.1%) respondents - students, while the group of obese respondents - students was at 18 (19.4%). In addition, the table in question shows that 6 (6.5%) respondents - students belong to the category of malnourished.

mase za dužinu/visinu: z-vrijednost od +1 SD (standardnu devijaciju) označava rizik preuhranjenosti, z-vrijednost od +2SD označava prekomjernu tjelesnu masu, z-vrijednost od +3SD označava pretilost, a istaknute su i vrijednosti 85. i 95. centile ITM-a za uzrast i pol. Za procjenu stepena pretilosti postoji nekoliko antropometrijskih postupaka.

Za novorođenčad i dojenčad najjednostavniji način je vaganje i mjerenje dužine (visine) djeteta i bilježenje prirasta u visini i masi djeteta. Jedna od mogućnosti za malu djecu (predškolska i školska djeca) je i mogućnost vaganja i poređenje tjelesne mase s referentnim vrijednostima za uzrasnu dob ili za tjelesnu visinu.

Za stariju djecu i adolescente postoji više antropometrijskih metoda i postupaka mjerenja, počev od mjerenja kožnih nabora ili mjerenja obima ekstremiteta na određenim mjestima, pa sve do savremenih mjernih postupaka mjerenja analizom bioelektričnog otpora tijela (Bioelectrical Impedance Analysis m – BIA).

Za dijagnostiku pretilosti odraslih najčešće se koristi Indeks tjelesne mase IMT (engl. Body Mass Index – BMI), koji predstavlja standard koji preporučuju Svjetska zdravstvena organizacija (WHO), Svjetska federacija za pretilost i Američki centar za kontrolu i prevenciju bolesti (CDC).

Na osnovu uvida u vrednosti indeksa telesne mase, tretirani uzorak ispitanika - učenici mogu se grupisati u jednu od 4 kategorije na osnovu standardnih tabela Američkog centra za kontrolu bolesti i prevenciju (CDC), koje indeks telesne mase posmatraju u kontekstu uzrasta deteta, odnosno u kontekstu već opisane korekcije za starost i pol na standardizovanom skoru indeksa telesne mase. Prema ovoj raspodeli tretirani uzorak ispitanika ovog istraživanja može se razvrstati u grupe kao što je prikazano u tabeli 2.

Tabela 2. *Kategorizacija ispitanika - učenika u odnosu na indeks telesne mase (ITM)*

Na osnovu analize rezultata prikazanih u tabeli 3 može se konstatovati da normalnu telesnu težinu ima 54 (58%) učenika – ispitanika. Rizik od gojaznosti zabeležen je kod 15 (16,1%) ispitanika - učenika, dok grupu gojaznih ispitanika – učenika čini njih 18 (19,4%). Takođe, iz date tabele je vidljivo da 6 (6,5%) ispitanika – učenika pripada kategoriji neuhranjenih.

The state of nutrition of school children in the Republic of Croatia, between the ages of 7 and 14 and conducted during the period from 2000 to 2005, shows that 23% of the respondents included in the survey had increased body weight, while 7.2% were obese (HZJZ, 2007). Applying the anthropometric index of body mass for height according to HZJZ, 11.9% of subjects had excessive body mass and 6.9% of subjects were obese during the same period.

In their research, Antonić et al. (2004) indicate an increased risk for developing obesity in children aged 7 to 15 in Croatia, 11.2% of boys and 9.8% of girls, while 5.7% of boys and 5.4% of girls are obese.

Abazović et al. (2016) conducted research with the aim of determining the obesity status of children in primary schools in Sarajevo Canton/Federation of Bosnia and Herzegovina. The sample of respondents consisted of 33,200 children of both sexes, primary school students, of which 16,240 were girls and 16,960 were boys. Based on the obtained results, the authors state that out of the total number of students included in this research, as many as 39.6% (13,159) are obese. Based on the results, the authors conclude that every other child in Sarajevo Canton/ Federation of Bosnia and Herzegovina has a nutritional disorder (49.3%), which is a worrying situation. It was determined that 55.5% of children have a normal body mass, while 44.5% of children have an increased or decreased BMI. Out of the total 44.5% of children, or 822 children, found to have a deviation from the normal body weight, 19.46% (8.7% of the total sample) were undernourished, 26.16% (11.65% of the total sample) were moderately malnourished, 27.01% (12% of the total sample) were overweight and 27.37% (12.2% of the total sample) were obese. The authors point out that such studies should be done every year in order to systemically monitor the state of nutrition and the trend in the development of obesity in children and, in this regard, create an adequate strategy to fight obesity.

Čolakhodžić et al. (2017) conducted a study on a sample of 1,800 respondents, primary school students of both sexes in the City of Mostar, who participated in a regular systematic review in 2016 with the aim of determining physical growth and development, and the state of nutrition of students. The obtained results showed that 36.4% of students are overweight or obese. Almost every other child (43.9%) has a nutritional disorder, which is worrying and alarming.

As part of a research project entitled "Prevalence of overweight and obesity in children aged 6 to 9 years", Ljubojević et al. (2020) conducted research on a sample of 2,039 male students attending nine primary schools in

Stanje uhranjenosti školske dece u Republici Hrvatskoj u uzrastu od 7 do 14 godina u periodu od 2000. do 2005. godine, pokazuju da je povećanu telesnu masu imalo je 23% ispitanika obuhvaćenih ispitivanjem, dok je 7,2% bilo pretilih (HZJZ, 2007). Primenjujući antropometrijski indeks telesne mase za visinu prema HZJZ-u, u istom periodu je bilo 11,9% ispitanika s prekomernom telesnom masom i 6,9% pretile dece.

Antonić i sar. (2004) u svom istraživanju ukazuju na povećani rizik za razvoj pretilosti dece u uzrastu od 7 do 15 godina u Hrvatskoj, ima 11,2% dečaka i 9,8% devojčica, dok je pretilo 5,7% dečaka i 5,4% devojčica.

Abazović i sar. (2016) izvršili su istraživanje s ciljem utvrđivanja stanja pretilosti dece u osnovnim školama Kantona Sarajevo/Federacije Bosne I Hercegovine. Uzorak ispitanika činilo je 33.200 dece oba pola, učenika osnovnih škola, od čega je 16.240 devojčica i 16.960 dečaka. Na osnovu dobijenih rezultata autori konstatuju da je od ukupnog broja učenika obuhvaćenih ovim istraživanjem, čak 39,6% (13.159) pretilo. Autori na osnovu rezultata zaključuju da svako drugo dete u Kantonu Sarajevo/Federacije BiH ima poremećaj uhranjenosti (49,3%), što predstavlja stanje koje zabrinjava. Utvrđeno je da 55,5% dece ima normalnu telesnu masu, a 44,5% dece ima povećan ili umanjen indeks telesne mase. Od ukupnih 44,5% dece ili njih 822 kod kojih je utvrđeno odstupanje od normalne telesne mase, njih 19,46% (8,7% ukupnog uzorka) je pothranjeno, 26,16% (11,65% ukupnog uzorka) je umereno pothranjeno, 27,01% (12% ukupnog uzorka) ima prekomernu telesnu masu i 27,37% (12,2% ukupnog uzorka) je pretilo. Autori ističu da bi ovakve studije trebalo raditi svake godine kako bi se sistemski moglo pratiti stanje uhranjenosti i trend razvoja pretilosti dece te s tim u vezi kreirati adekvatnu strategiju borbe protiv pretilosti.

Čolakhodžić i sar. (2017) su na uzorku 1800 ispitanika koji su činili učenici osnovnih škola oba pola u Gradu Mostaru, a koji su učestvovali u redovnom sistematskom pregledu u toku 2016. godine, izvršili istraživanje s ciljem utvrđivanja telesnog rasta i razvoja, te stanje uhranjenosti učenika. Dobijeni rezultati su pokazali da 36,4% učenika ima prekomernu telesnu težinu ili je pretilo. Gotovo svako drugo dete (43,9%) ima poremećaj uhranjenosti, što je zabrinjavajuće i alarmantno.

Ljubojević i sar. (2020) su u sklopu projektnog istraživanja pod nazivom „Prevalencija prekomerne težine i gojaznosti dece od 6 do 9 godina", izvršili istraživanje na uzorku od 2039 učenika muškog pola u devet osnovnih škola grada Banja Luka. Kod ispitanika su merene

the city of Banja Luka. The subjects' height and weight were measured, with BMI calculated based on those two measurements. The obtained results indicate that 9.26% of the tested primary school children in Banja Luka are overweight, and 5.37% are obese. Overall prevalence of overweight and obesity among Banja Luka children amounts to almost 15%, which is not a small percentage. The authors point out that the overall prevalence of overweight and obesity among children of primary school age in the city of Banja Luka is somewhat lower compared to the results of a similar sample in other European countries (available: http://www.euro.who.int). However, what is worrying is the increasing trend of overweight and obesity with age.

The aforementioned research results show that the increase in obesity in the child population is increasing compared to the results of previous studies (Gajić, 1993; Kisić Tepavčević et al., 2008).

According to data from the International Obesity Task Force for 2005, over the last ten years Serbia has been at the very top of countries experiencing a sudden increase in the prevalence of obesity in children (Wang & Lobstein, 2006).

Determining differences in BMI values in relation to gender

To determine the differences in the values of the BMI in relation to gender, an analysis of the t test results for independent samples was applied. Based on the obtained t test results shown in Table 3, it can be concluded that there is no significant difference in BMI values be-

telesna visina i telesna težina, a na osnovu te dve mere izračunat je Index telesne mase. Dobijeni rezultati ukazuju da od ukupnog broja testirane dece osnovnih škola u Banja Luci prekomernu težinu ima 9,26% testirane djece, a 5,37% je gojazno. Ukupna prevalencija prekomerne telesne težine i gojaznosti banjalučke dece iznosi skoro 15% što nije mali procenat. Autori ističu da je ukupna prevalencija prekomerne težine i gojaznosti dece osnovnoškolskog uzrasta grada Banja Luke u poređenju sa rezultatima sličnog uzorka u drugim evropskim zemljama nešto niža (dostupno: http://www.euro.who.int). Međutim, ono što zabrinjava jeste trend porasta prekomerne telesne težine i gojaznosti sa godinama.

Rezultati navedenih istraživanja pokazuju da je porast gojaznosti u dečijoj populaciji u porastu u odnosu na rezultate predhodnih studija (Gajić, 1993; Kisić Tepavčević i sar., 2008).

Prema podacima Međunarodne radne grupe za gojaznost (International Obesity Task Force) za 2005. godinu, Srbija se nalazi u samom vrhu zemalja s naglim povećanjem prevalencije gojaznosti kod dece u poslednjih deset godina (Wang & Lobstein, 2006).

Utvrđivanje razlika u vrednostima indeksa telesne mase (ITM) u odnosu na pol

Za utvrđivanje razlika u vrednostima indeksa telesne mase (ITM) u odnosu na pol primenjena je analiza rezultata t testa za nezavisne uzorke. Na osnovu dobijenih rezultata t testa prikazanih u Tabeli 3 može da se zaključi da ne postoji značajna razlika u vrednostima ITM

Table 3. *Differences in BMI values in relation to the gender of the respondents*

Tabela 3. *Razlike u vrednostima ITM u odnosu na pol ispitanika*

	MEAN	***T***	***P***
IV grade - 10 years / **IV raz. - 10 godina**			
Male / Muški *(N=14)*	21.32 ± 6.45	1.183	0.250
Female / Ženski *(N=9)*	18.37 ± 4.68		
III grade - 9 years / **III raz. - 9 godina**			
Male / Muški *(N=10)*	18.19 ± 2.94	0.412	0.684
Female / Ženski *(N=16)*	17.66 ± 3.29		
II grade - 8 years / **II raz. - 8 godina**			
Male / Muški *(N=4)*	16.47 ± 1.51	-2.000	0.070
Female / Ženski *(N=10)*	19.01 ± 3.21		
I grade - 7 years / **I raz. - 7 godina**			
Male / Muški *(N=13)*	16.66 ± 2.18	-0.519	0.608
Female / Ženski *(N=17)*	17.08 ± 2.19		
Entire sample / **Celokupan uzorak**			
Male / Muški *(N=42)*	18.56 ± 4.59	0.822	0.413
Female / Ženski *(N=51)*	17.88 ± 3.27		

**Statistical significance at the 0.05 level*

**Statistička značajnost na nivou od 0,05*

tween boys and girls, for the total sample as well as for each age group of children separately.

The results, that there are no statistically significant differences in morphological variables by gender, coincide with the research of domestic (Nićin and Stjepić, 2008; Krsmanović B., Batez and Krsmanović T., 2011) and foreign authors (Basaldua & Chiquete, 2008).

Abazović et al. (2016) conducted research on a sample of 33,200 primary school age children, of which 16,240 were girls and 16,960 were boys, with the aim of determining differences in nutrition (obesity) of children with regard to gender. The authors state that obesity is more present in boys compared to girls, *i.e.*, out of 16,960 boys, 7,451 or 43.9% of them had increased body weight or were obese, while out of a total of 16,240 girls, 5,798 or 35.2% had an increased body weight or were obese.

Determining differences in BMI values in relation to age

One-factor analysis of variance (ANOVA) was used to determine differences in BMI values in relation to the age of the subjects. Based on the ANOVA results presented in Table 4, it can be concluded that there is a statistically significant difference in the values of the BMI in relation to the age of the subjects (p=0.023).

Table 4. *Differences in BMI values in relation to the age of the respondents*

	MEAN	F	P
10 years / godina	20.17 ± 5.89	3.330	0.023*
9 years / godina	17.86 ± 3.11		
8 years / godina	18.28 ± 3.01		
7 years / godina	16.88 ± 2.16		

**Statistical significance at the 0.05 level*

The post hoc test (Table 5) was applied with the aim of determining the existence of differences between the subsamples of respondents with regard to age. Based on the results of the post hoc test, a statistically significant difference was found between ten-year-olds and seven-year-olds (p=0.013), where older subjects have significantly higher BMI values.

Obesity in younger school age children is a problem that reached epidemic proportions at the end of the 20th century. Due to such a situation, it is very important to identify children who are at risk for obesity, mainly because this problem can negatively affect both the physical health and the psychological well-being of students.

u odnosu na dečake i devojčice za ukupan uzorak kao i za svaki uzrast dece posebno.

Rezultati da ne postoje statistički značajne razlike u morfološkim varijablama po polu se poklapaju sa istraživanjima domaćih (Nićin i Stjepić, 2008; Krsmanović B., Batez i Krsmanović T., 2011) i stranih autora (Basaldua & Chiquete, 2008).

Abazović i sar. (2016) su na uzorku od 33.200 dece oba pola, učenika osnovnih škola, od čega je 16.240 devojčica i 16.960 dečaka s ciljem utvrđivanja razlika uhranjenosti (pretilosti) dece s obzirom na pol. Autori konstatuju da je pretilost više prisutna kod dečaka u odnosu na devojčice, odnosno od 16.960 dječaka, njih 7.451 ili 43,9% ima povećanu tjelesnu masu ili je pretilo, dok od ukupno 16.240 djevojčica, njih 5.798 ili 35,2% ima povećanu tjelesnu masu ili je pretilo.

Utvrđivanje razlika u vrednostima indeksa telesne mase (ITM) u odnosu na uzrasnu dob

Za utvrđivanje razlika u vrednostima indeksa telesne mase (ITM) u odnosu na uzrasnu dob ispitanika primenjena je jednofaktorska analiza varijanse (ANOVA). Na osnovu rezultata jednofaktorske analize varijanse (ANOVA) prikazanih u Tabeli 4 može se konstatovati da postoji statistički značajna razlika u vrednostima indeksa telesne mase (ITM) u odnosu na uzrasnu dob ispitanika (p=0,023).

Tabela 4. *Razlike u vrednostima ITM u odnosu na starosnu dob ispitanika*

**Statistička značajnost na nivou od 0,05*

Post hoc test (Tabela 5) je primenjen sa ciljem da se utvrdi postojanje razlika između subuzoraka ispitanika s obzirom na uzrasnu dob. Na osnovu rezultata post hoc testa statistički značajna razlika utvrđena je između desetogodišnjaka i sedmogodišnjaka (p=0,013) gde stariji ispitanici imaju značajnije više vrednosti indeksa telesne mase (ITM).

Gojaznost kod dece mlađeg školskog uzrasta predstavlja problem koji je poprimio epidemijske razmere još krajem XX veka. Usled takve situacije, veoma je važno identifikovati decu koja su pod rizikom za gojaznost, najviše iz razlogašto ovaj problem može negativno da se odrazi kako na fizičko zdravlje, tako i na psihološko bla-

Table 5. *Post hoc test to examine differences between individual groups*

Age of the respondents / **Uzrasna dob ispitanika**	***p***
7 - 8 years / godina	0.666
7 -9 years / godina	0.769
7 - 10 years / godina	0.013*
8 -9 years / godina	0.987
8 - 10 years / godina	0.458
9 - 10 years / godina	0.152

**Statistical significance at the 0.05 level*

Tabela 5. *Post hoc test za ispitivanje razlika između pojedinačnih grupa*

**Statistička značajnost na nivou od 0.05*

These research findings indicate that older male and female students, although not obese to a significant degree, tend to increase their BMI, which may indicate a potential trend of obesity at older ages. In this regard, it should be emphasized that almost 20% of younger school-aged students who participated in this research were recognized as obese, and the trend may increase considering that positive attitudes towards exercise and physical education classes decrease as the child progresses through schooling.

Previous research has shown that the BMI increases from birth to the first year of life, then decreases until the preschool period, after which it shows an increase again until the end of primary education (Demerath et al., 2006). In addition, previous research results have clearly shown that a higher BMI is evident with an increase in the age of children, as well as that there is an ever-increasing number of children who have excessive nutrition or can be characterized as obese.

Conclusion

Our research results show that one third of the treated respondents - younger school age students were recognized as obese or at risk of developing obesity, 15 (16.1%) of the respondents belong to the risk group of obesity and 18 (19.4%) of the respondents are obese. The obtained results point to a significant number of obese or at-risk obese younger school age students, which is why it is necessary to take timely preventive measures in order to prevent obesity and its negative consequences for children's health.

The danger of the consequences of obesity is constantly present because previous studies have shown a decrease in children's physical activity, and a decline in interest and positive attitudes towards physical exercise as the child progresses through schooling. That is why it is extremely important to increase participation in physical activities as children age, through various sports school programs, as a form of additional training in addgostanje učenika. Nalazi ovog istraživanja ukazali su da stariji učenici i učenice, iako nisu gojazni u značajnom stepenu, imaju tendenciju porasta indeksa telesne mase (ITM), što može ukazati na potencijalni trend javljanja gojaznosti na starijim uzrastima. S tim u vezi, potrebno naglasiti i da je skoro 20% učenika mlađeg školskog uzrasta u ovom istraživanju bilo prepoznato kao gojazno, a trend se može uvećavati s obzirom na to da pozitivni stavovi prema vežbanju i nastavi fizičkog vaspitanja opadaju kako dete napreduje kroz školovanje.

Dosadašnja istraživanja su pokazala da indeks telesne mase (ITM) raste od rođenja do prve godine života, a zatim opada do predškolskog perioda, nakon čega opet ispoljava rast do kraja osnovnog obrazovanja (Demerath et al., 2006). Takođe, rezultati dosadašnjih istraživanja ne dvosmislenopokazuju da je sa uzrastom dece evidentan veći indeks telesne mase (ITM), kao i da sve više dece ima prekomernu uhranjenost ili se može okarakterisati kao gojazno.

Zaključak

Rezultati istraživanja pokazuju da jedna trećina tretiranih ispitanika – učenika mlađeg školskog uzrasta je je prepoznato kao gojazno ili predstavlja rizik za nastanak gojaznosti (15 (16,1%) ispitanika pripada rizičnoj grupi od nastanka gojaznosti a 18 (19,4%) ispitanika je gojazno). Dobiveni rezultati upozoravaju na izražen broj gojaznih ili rizično gojaznih učenika mlađeg školskog uzrasta zbog čega je neophodno preduzimanje preventivnih mera kako bi se gojaznost i njene negativne posledice za zdravlje dece prevenirale na vreme.

Opasnost posledica gojaznosti je stalno prisutna jer su dosadašnja istraživanja pokazala na smanjenu fizičku aktivnost dece i opadanje interesa i pozitivnih stavova prema fizičkom vežbanju kako dete napreduje kroz školovanje. Zbog toga je izuzetno važno sa uzrastom dece povećati njihovo učešće u fizičkim aktivnosima, pored redovne nastave fizičkog i zdravstvenog vaspitanja i kroz različite programe školice sporta kao vid dodatnog

dition to regular physical and health education classes. The greatest transformation under the influence of exogenous factors (the process of sports training) is possible in fatty tissue, the coefficient of innateness is 0.50 (Mikić, 2000:102).

In order to regularly monitor the growth and development of school children and, therefore, monitor the level of nutrition, it is important to take appropriate measures such as training teachers to systematically monitor the growth and development of children through regular physical education classes.

For more effective implementation of preventive programs, greater cooperation is needed not only from children and their parents, but also from teachers and physical education teachers, in order to ensure the conditions for the proper growth and development of students, with the aim of eliminating obesity as a problem that affects the school population in the Republic of Serbia.

treninga. Najveća transformacija pod uticajem egzogenih faktora (procesom sportskog treninga) moguća je kod masnog tkiva, koeficijent urođenosti 0,50 (Mikić, 2000:102).

Kako bi se redovno pratio rast i razvoj kod školske dece a samim tim i pratio i stepen uhranjenosti, važno je preduzeti odgovorajuće mere kao što su obuka učitelja i nastavnika za sistematsko praćenje rasta i razvoja dece kroz redovnu nastavu fizičkog vaspitanja.

Za efikasnije sprovođenje preventivnih programa potrebna je veća saradnja ne samo dece, već i njihovih roditelja, ali i učitelja i nastavnika fizičkog vaspitanja, kako bi se sa sigurnošću mogli obezbediti uslovi za pravilan rast i razvoj učenika, u cilju eliminisanja gojaznosti kao problema koji pogađa školsku populaciju u Republici Srbiji.

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