ISSN 1451-7485

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ISSN 1451-7485 eISSN 2337-0351

# SportMont

www.sportmont.ucg.ac.me

FEBRUARY 2024

VOL.22

NO.1

ISSN 1451-7485 eISSN 2337-0351
SportMont
www.sportmont.ucg.ac.me



## Index Coverage
Scopus; DOAJ; SCImago; SPORTDiscus; Index Copernicus; ERIH PLUS; Open Academic Journals Index; Google Scholar; Crossref; ROAD; SHERPA/RoMEO; NLM Catalog

## Prepress
**Milicko Ceranic**

## Print
**Art Grafika |** Niksic

## Print run
1000

ISSN 1451-7485 eISSN 2337-0351

**SPORT MONT**
International Scientific Journal

Vol. 22(2024), No.1 (1-175)

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**Full-text available free of charge at http://www.sportmont.ucg.ac.me/**

DOI 10.26773/smj.240201

ORIGINAL SCIENTIFIC PAPER

# Differences in the Quality of Life Relative to the Level of Cardiorespiratory Capacity of Primary School Students

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**Abstract**

As cardiorespiratory capacity is an important factor of an overall quality of life and a significant indicator of physical fitness, its development should begin from early childhood. The goal of the research is to determine the differences in the quality of life and cardiorespiratory abilities of primary education students. A total of 651 fourth-grade primary school students from the Republic of Croatia participated in the research. The average age of the subjects was 10.38±0.50 years, and the sample was divided in two subsamples according to gender, 316 girls (10.30±0.47 years) and 335 boys (10.34±0.49 years). Body height was measured with a portable altimeter, while body mass, body mass index – BMI, percentage of fat, level of obesity, and muscle mass were measured with a two-frequency body composition analyser (TANITA DC-360P). Waist circumference and hip circumference were measured with a centimeter tape, while the ratio of the waist and hip circumference (WHR index) was calculated based on their ratio. Cardiorespiratory capacity was assessed with a multi-stage 20m-running test (20MSRT Shuttle run test). For assessing the qualty of life, the researchers used a Croatian version of the KIDSCREEN-10 Questionnaire. The research results show a high mean value of the overall life quality assessment (4.33). The identification of individual differences between the researched groups demonstrated that students with a high level of cardiorespiratory capacity rate their quality of life significantly higher than students with a low or moderate cardiorespiratory capacity. According to the results, 41.01% of students have an unsatisfactory level of cardiorespiratory ability. There are statistically significant differences in morphological characteristics and cardiorespiraory capacity among the groups classified according to their level of cardiorespiratory capacity. Children with a higher level of cardiorespiratory capacity report a better quality of life and have better indeces of physical nutrition. Physical exercises used to boost the development of the cardiorespiratory capacity of children indirectly impact the prevention of obesity and can diminish other factors of cardiovascular risk.

***Keywords:*** *KIDSCREEN 10, quality of life, maximum oxygen uptake, 20 m Shuttle run test, students*

## Introduction

Health-related quality of life is a measure of impact of health or illness on everyday functions. It is greatly influenced by concerns, conditions, and aspirations of individuals, as well as the self-perceived health and well-being (Haraldstad et al., 2019). The World Health Organisation defined the health-related quality of life as a multidimensional and integrative construct consisting of physical, psychological, and social well-being and functioning (WHOQOL, 1993). Children's quality of life is as important as investing in the future of our society because children constitute an important social group and deserve a safe and healthy environment in which they grow up (Roca, 2023). It is necessary to raise awareness among young people regarding the importance and impact of doing physical activities and basic endurance sports, such as swimming and water polo (Marković & Milošević, 2023), useful for improving cardiorespiratory capacity. Children's quality of life has been conceptualised and studied for several decades, but

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with different approaches. Three main approaches include the health-related quality of life (HRQOL), social indicators, and subjective well-being (Wallander & Koot, 2016). Common aspects of the quality of  life include personal health (physical, mental, and spiritual), educational status, work environment, social status, wealth, sense of security, freedom, autonomy in decision-making, social belonging, and their physical environment (Ilić, Popović, Marković, Nemec, & Milosević, 2020; Teoli & Bhardwaj, 2023). Determinants of health quality include socio-demographic, environmental, and nutritional characteristics such as factors of nutrition and lifestyle (Pano et al., 2020). Physical exercise as a public health tool is based on its influence on physical health, including a positive influence on the prevention and control of diabetes type 2. There is an increasing interest in its impact on other aspects of health, such as mental and social health, and on the quality of life and an overall well-being (Heimer & Sporiš, 2016). The health-related quality of life encompasses the aspects of the overall quality of life that clearly impact physical and mental health. Nowadays, measuring the quality of life has become an important outcome in the evaluation of health interventions and treatments from clinical and epidemiological perspectives (Ravens-Sieberer et al., 2006).

Cardiorespiratory ability is linked to the health-related quality of life (Mišigoj-Duraković et al., 2018). Different factors impact the maximum oxygen uptake (VO2max). Over time, a downward trend in aerobic ability can be expected. It is assumed that these trends reflect temporal changes in body composition (increasing obesity), rather than a true drop of cardiorespiratory function over time  (Rowland, 2007). Maximum oxygen uptake (VO2 max) refers to the intensity of the aerobic process and indicates the maximum ability to transfer and use oxygen during exercising (Shete, Bute, & Deshmukh, 2014). Cardiorespiratory fitness in childhood considerably influences health in adulthood and offers a potential insight into the health status of the human population in the future (Ruiz et al., 2009). Cardiorespiratory fitness reflects an overall capacity of the physiological systems (cardiovascular, respiratory, metabolic, and neuromuscular) when performing a continued and dynamic physical exercise of large muscle groups at moderate to high intensity over long periods of time. The usefulness of the cardiorespiratory fitness is in the fact that it is one of the indicators of health index (Tomkinson, Lang, Blanchard, Léger & Tremblay, 2019). The American Heart Association states that cardiorespiratory fitness should be regularly assessed as the fifth clinical vital sign for predicting human health and lifespan, along with respiration, body temperature, pulse, and blood pressure (Ross et al., 2016). A higher value of cardiorespiratory fitness in childhood and adolescence is stronlgy linked to the current level of health, as well as to a great prediction for the future (Ortega et al., 2011). The research by Andersen et al. (2017) on a sample of 10-year-old Norwegian students found that improving the cardiorespiratory capacity greatly improves the quality of life of children. In the longitudinal study by Evaristo et al. (2019) it was concluded that the level of cardiorespiratory capacity decreased in children in two years, and therefore the quality of life decreased significantly. Basterfield, Burn, Galna, Karoblyte and Weston (2021), in a study on a sample of 432 subjects, found that additional physical activity of children during the day impacts the increase in cardiorespiratory capacity and the quality of their life. In addition, the existence of a significant connection between a high level of CRF and the quality of life of children and young people has been established in research (Marques, Mota, Gaspar, & de Matos, 2017; Pires-Júnior et al., 2018; Redondo-Tébar et al., 2019). Although there are studies that have addressed this topic, studies related to the population of children in Croatia are still lacking. Therefore, the goal of the research is to determine the differences in the quality of life and cardiorespiratory abilities of primary school students in Croatia.

## Methods

*Participants*

A sample of 651 fourth-grade primary school students in Croatia was used in this research. The average age was 10.38±0.50 years, and the sample was divided into two subsamples according to gender, 316 girls (10.30±0.7 years) and 335 boys (10.34±0.9 years). The research was conducted in the second term of the school year 2021/2022. All participants were completely healthy at the time of the research. Students with confirmed health problems were not included in the implementation of the research and, in agreement with the teachers, they were not granted consent to participate in the research. Students who provided a signed parental consent to participate in the research were included in the study. In each class, the research was conducted for the duration of two school hours of physical education, while students who did not perform one measurement were also excluded from the further procedure. The research was conducted in line with ethical principles set in the Code of Ethics of the University of Zagreb, The Code of Ethics in the Research Involving Children (Ajduković & Keresteš, 2020) and the study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of the University of Zagreb, Faculty of Teacher Education (Reg. No.:251-17-22-1, date of approval January 1st, 2022).

*Classification according to the Level of Cardiorespiratory Fitness*

Table 1 shows the results of the frequency analysis of the participants classified according to the level of cardiorespiratory fitness. The classification was carried out in line with the international norms (Tomnkinson et al., 2017). The participants classified under 40 centils were placed in the category low level of cardiorespiratory ability. The participants in the range 40-60 centils were categorised in the group of an average level of cardiorespiratory ability, whereas the participants in the range of 60-100 centils were ranked in the category of the high level of

**Table 1.** Results of the number of participants relative to gender and level of cardiorespiratory capacity

| | TOTAL | | BOYS | | GIRLS | |
|---|---|---|---|---|---|---|
| | No | % | No | % | No | % |
| Low level CRF | 267 | 41.01 | 168 | 50.15 | 99 | 31.33 |
| Average CRF | 176 | 27.04 | 60 | 17.91 | 116 | 36.71 |
| High level CRF | 208 | 31.95 | 107 | 31.94 | 101 | 31.96 |

Note CRF- Cardiorespiratory fitness

cardiorespiratory ability. The results show that out of the total sample, 41.01% of participants have an unsatisfactory level of cardiorespiratory ability. From gender perspective, 50.15% of boys have a very low level of this ability, the result which is much worse compared to 31.33% of girls.

*Anthropometric Characteristics*

Anthropometrical measurements were carried out in line with the International Biological Program (IBP) (Weiner & Lourie, 1969). Body height was measured with altimeter (Seca® 213, Hamburg, Germany), while body mass, body mass index – BMI, and fatty tissue (%) were measured with a two-frequency body composition analyser (TANITA DC-360P). Waist and hip circumferences were measured with a centimeter tape, and the ratio of the hip and waist circumference (WHR index) was calculated on the basis of their ratio.

*20 meters (20MSRT Shuttle run test)*

Cardiorespiraotory capacity was assessed by a multi-stage 20m running test (20MSRT Shuttle run test) where the speed of running starts at 8.5 km/h−1 and increases by 0.5 km/h−1 every minute. Every stage lasts about 60 seconds, and the sound signal interval dictates the duration of each interval (Leger & Lambert, 1982). Maximum oxygen uptake (VO2max, mL/kg/min) was calculated by using an equation VO2max = 31.025 + 3.238 (S) 2 3.248 (A) + 0.1536 (A 3 S), where S = speed in kilometers per hour at the end of the test and A = age expressed in years (Leger et al., 1988). This equation is suitable for boys and girls age 8-19 using an online calculator (Wood, 2019).

*Quality of life*

The participants' quality of life was determined by using a questionnaire for children and adolescents of age 8-18 (The KIDSCREEN Group Europe, 2006). For assessing the subjective health and well-being of adolescents the Croatian version of the quality of life questionnaire The KIDSCREEN-10 was used, which is shorter version of the KIDSCREEN-52 (Lorger, 2011). The questionnaire evaluates dimensions of physical and mental well-being, autonomy and parental relationships, peer and social support, and school environment. It consists of 10 questions in which the participants mark their level of agreement with the content of individual statements on a Likert-type scale of five levels, resulting in an overall score. The metric characteristics of the KIDSCREEN-10 are at a satisfactory level. The values of Cronbach alpha are 0.82, and coefficient test-retest 0.70 as a satisfactory result of the internal consistency of the questionnaire (Ravens-Sieberer et al., 2010).

*Statistical analyses*

In data processing, basic descriptive parameters were calculated for all researched variables: arithmetic mean, standard deviation, median, skewness, kurtosis, and frequency analysis. The significance of the differences between the subsamples according to cardiorespiratory capacity and the quality of life was tested by the univariate analysis of variance ANOVA. The statistical significance of the differences in morphological characteristics, quality of life, and aerobic capacity relative to gender was tested by the univariate analysis of variance (ANOVA). For variables that have a statistically significant F value, the Scheffe post hoc test was used to determine the differences between the arithmetic means of the groups in the further analysis. The statistical significance of the differences was tested at the significance level of p<0.05. Data processing was performed with the program STATISTICA version 14.0.0.15., TIBCO Software Inc.

## Results

The results in Table 2 show the descriptive parameters of all analysed variables. Due to the nature of the test on larger samples, asymmetry and skewness of the distributions were checked. The values are within the limits of -2 to +2 and with

**Table 2.** Descriptive indicators in morphological characteristics, cardiorespiratory capacity, and the quality of life of the fourth-grade boys and girls

| | **TOTAL N=651** | **BOYS N=335** | **GIRLS N=316** | | | |
|---|---|---|---|---|---|---|
| **Variables** | **M ± SD** | **M ± SD** | **M ± SD** | **Median** | **Skew** | **Kurt** |
| Body height (cm) | 147.92 ± 7.23 | 147.50 ± 6.85 | 148.37 ± 7.58 | 147.60 | 0.24 | 0.17 |
| Body mass (kg) | 41.03 ± 9.93 | 41.62 ± 10.42 | 40.40 ± 9.36 | 39.50 | 0.89 | 0.77 |
| Body fat (%) | 19.21 ± 7.57 | 17.88 ± 7.28 | 20.63 ± 7.62* | 18.20 | 0.55 | -0.29 |
| Body mass index (BMI) | 18.57 ± 3.45 | 18.93 ± 3.67* | 18.20 ± 3.15 | 17.90 | 0.95 | 0.68 |
| Waist circumference (cm) | 63.50 ± 8.88 | 65.33 ± 9.78* | 61.57 ± 7.35 | 61.00 | 1.22 | 1.72 |
| Hip circumference (cm) | 80.34 ± 8.58 | 80.98 ± 8.97* | 79.66 ± 8.10 | 79.00 | 0.58 | 0.07 |
| Waist and hip ratio (WHR) | 0.79 ± 0.05 | 0.80 ± 0.05* | 0.77 ± 0.05 | 0.79 | 0.37 | 1.73 |
| Health evaluation | 4.30 ± 0.74 | 4.30 ± 0.76 | 4.30 ± 0.72 | 4.00 | -0.80 | 0.08 |
| Physical form | 4.26 ± 0.84 | 4.33 ± 0.79* | 4.18 ± 0.89 | 4.00 | -1.16 | 1.31 |
| Energy level | 4.38 ± 0.75 | 4.38 ± 0.77 | 4.39 ± 0.72 | 5.00 | -1.22 | 1.61 |
| Total assessment of the quality of life | 4.33 ± 0.48 | 4.34 ± 0.46 | 4.33 ± 0.50 | 4.40 | -1.17 | 1,62 |
| Maximum oxygen uptake VO2max (mL/kg/min) | 45.16 ± 3.78 | 45.79 ± 4.33* | 44.50 ± 2.95 | 44.60 | 0.76 | 0.20 |
| Running distance-(m) | 487.28 ± 280.19 | 542.33 ± 323.72* | 428.92 ± 210.35 | 400.00 | 1.14 | 1.00 |

Note M=arithmetic mean; SD = standard deviation; Skewness =asymmetrical distribution; Kurtosis = tailedness of distribution; * significance at error level p < 0.05

the fulfilment of this criterion (Hair et al., 2010) the investigated variables were included in the parametric analysis. Differences relative to gender were determined by using the analysis of variance. Given the results of the total sample, it is evident that the students' average height is 147.92±7.23 centimetres and their average body weight is 41.03±9.93 kilograms. The result of the percentage of fat is 19.21%, while the values of the body mass index (BMI) are 18.57, which means that the participants are normally nourished. The analysis of the results of the morphological characteristics relative to gender shows that the differences between boys and girls can be identified in most variables. Girls have significantly higher results in fat percentage (20.63), while boys have significantly higher values of body mass index, waist and hip circumference and their ratio. No significant differences were observed in the variables that assess the quality of life, except in the dimension of physical form, where boys rate their form significantly higher than girls. In the field of cardiorespiratory fitness, boys have significantly higher results than girls in both measured variables.

According to the results of the analysis of variance (ANOVA), Table 3 clearly shows that there are statistically significant differences between the groups which are categorised by the level of the cardiorespiratory capacity. A post hoc analysis was carried out using the Scheffe test in the variables where statistical significance was confirmed by the analysis of variance. The results show that the participants belonging to the subsample with the low level of cardiorespiratory capacity have significantly poorer results in all variables. Similarly, significant differences were identified between the subsamples of average and high level of this capacity in variables assessing morphological characteristics and cardiorespiratory capacity. Moreover, a statistically significant difference was identified in the variable assessing the overall quality of life of primary school students. In the subsamples of average and low level of cardiorespiratory capacity, differences were found in all morphological characteristics and cardiorespiratory capacity.

**Table 3.** Results of ANOVA test and Scheffe post hoc test for determining the differences between the groups defined according to the level of cardiorespiratory capacity

| | Low level CRF | Average level CRF | High level CRF | Anova | |
|---|---|---|---|---|---|
| Variables | M±SD n=267 | M±SD n=176 | M±SD n=208 | F-test | p-value |
| Body height (cm) | 148.31 ± 7.49 | 147.89 ± 7.42 | 147.45 ± 6.69 | 0.83 | 0.44 |
| Body mass (kg) | 44.02 ± 11.17 | 40.70 ± 9.16*c | 37.47 ± 7.34 *a/b | 27.67 | 0.00 |
| Body fat (%) | 21.78 ± 8.00 | 19.67 ± 7.00*c | 15.53 ± 5.81*a/b | 46.00 | 0.00 |
| Body mass index (BMI) | 19.81 ± 3.90 | 18.44 ± 2.99*c | 17.10 ± 2.45*a/b | 40.79 | 0.00 |
| Waist circumference (cm) | 66.76 ± 10.37 | 62.73 ± 7.74*c | 59.97 ± 5.68*a/b | 39.21 | 0.00 |
| Hip circumference (cm) | 83.31 ± 9.30 | 80.27 ± 7.62*c | 76.59 ± 6.73*a/b | 40.13 | 0.00 |
| Waist and hip ratio (WHR) | 0.80 ± 0.06 | 0.78 ± 0.05*c | 0.78 ± 0.04*a | 8.48 | 0.00 |
| Health estimate | 4.14 ± 0.78 | 4.38 ± 0.73*c | 4.44 ± 0.66*a | 11.11 | 0.00 |
| Physical form | 4.10 ± 0.90 | 4.24 ± 0.87 | 4.47 ± 0.69*a/b | 11.68 | 0.00 |
| Energy level | 4.26 ± 0.83 | 4.41 ± 0.69 | 4.52 ± 0.66*a | 7.17 | 0.00 |
| Total quality of life assessment | 4.24 ± 0.51 | 4.32 ± 0.49 | 4.46 ± 0.39*a/b | 12.16 | 0.00 |
| Maximum oxygen uptake VO2max (mL/kg/min) | 42.05 ± 1.61 | 44.74 ± 1.36*c | 49.52 ± 2.85*a/b | 794.10 | 0.00 |
| Running distance -(m) | 264.64 ± 89.17 | 441.59 ± 97.87*c | 811.73 ± 238.17*a/b | 740.43 | 0.00 |

Note *statistical significance p<0.05; a=low level-high level; b= average level-high level; c= low level-average level; MEAN=arithmetic mean; SD = standard deviation; CRF- Cardiorespiratory fitness

## Discussion

In line with the set goal of the research, the researchers determined the presence of the statistically significant difference between the subgroups categorised relative to the level of cardiorespiratory capacity and the quality of life of the primary school students. By determining individual differences between the researched groups, it becomes evident that students who have a high level of cardiorespiratory capacity rate their quality of life significantly higher than students who have a low or average level of cardiorespiratory capacity. No significant differences were found between the groups of students who have a low or average level of cardiorespiratory capacity. Significant correlations between cardiorespiratory ability and the quality of life were obtained in a study by Evaristo et al. (2019). Improving cardiorespiratory ability is useful for improving the quality of life of children (Andersen et al., 2017). Many research studies show that cardiorespiratory capacity is associated with a higher quality of life of children and adolescents (Gu, Chang, & Solmon, 2016; Marques, Mota, Gaspar, & de Matos, 2017; Pires-Júnior et al., 2018). A higher level of cardiorespiratory capacity contributes to the healthy quality of life, while age has the opposite effect, namely, the quality of life in terms of health decreases with age (Marković et al., 2022). There is very little research that examined the differences between groups categorised according to the level of cardiorespiratory capacity with quality of life, which makes any comparisons difficult. Morales et al. (2013) obtained similar results as in our research, given that it was determined that boys and girls who have a higher level of cardiorespiratory capacity also have better physical well-being results. In girls with a higher cardiorespiratory capacity, a significant difference in the overall level of the quality of life was found. Children with better results in the dimension of physical well-being have significantly better results of cardiorespiratory capacity compared to those who reported a lower level of physical well-being which is an important segment of the quality of life (Pires-Júnior et al., 2018). A significant difference was found in body mass and body fat percentage. Students with an average level of cardiorespiratory capacity have a significantly lower body mass and fat percentage than students with a low level of cardiorespiratory capacity. Students with a high level of cardiorespiratory capacity have significantly lower body mass and body fat percentage than students with an average and low level. Students with a low level of cardiorespiratory capacity have significantly worse body mass index results compared to students with a higher level of aerobic capacity, while those with an average level have significantly lower body mass index results than students with a high level of cardiorespiratory capacity. Some research (Hermoso et al., 2019; Caamaño-Navarrete et al., 2021) found that children with normal physical nutrition have statistically better aerobic capacity results than those who belong to the obese or overweight groups. In the waist circumference and hip circumference variables, and their ratio, a statistically significant difference was found relative to the level of cardiorespiratory capacity. Students with a high level of cardiorespiratory capacity had significantly lower results in all three variables compared to students with average and low levels. Similar results were obtained in one research (Álvarez et al., 2020). A significant difference was also observed between students with an average and low levels, where students with an average level of cardiorespiratory capacity have significantly lower waist circumference, hip circumference, and waist-to-hip ratio results. In the research of Liu et al. (2022), it was found that children with better waist circumference achieved much better cardiorespiratory capacity results compared to those with worse waist circumference results. In our research, it was determined that boys have significantly better results in cardiorespiratory capacity than girls. The previous research showed that boys have significantly higher results than girls (Hamlin et al., 2014; Yang et al., 2019; Langer et al., 2020). In addition, our research confirmed a significant difference in the assessment of the physical form in favour of boys, but no difference was found in the overall assessment of the quality of life between the genders. Likewise, it was noted that boys have higher values of measures that assess body voluminousness and nutrition than girls. Boys have higher body mass index (BMI) values, but also waist and hip circumferences, which is very indicative for this age. A study (Živanović et al., 2018; Alvarez et al., 2020) showed that in both genders, the groups with a higher level of cardiorespiratory capacity had significantly lower values of waist circumference, waist and hip ratio, body mass index (BMI), and body fat percentage. The facts and conclusions of the previous research show that reducing obesity and increasing cardiorespiratory capacity contribute to a better quality of life. Children who have higher values of cardiorespiratory capacity report a better quality of life, but also have better indicators of physical nutrition. If young people continuously receive information about the importance of physical activity and proper nutrition, it is possible to encourage the development and maintenance of physical fitness and the adoption of a healthy lifestyle, thereby influencing the reduction of obesity as a dangerous health threat to the entire population.

The limitations of this research are found in measuring cardiorespiratory capacity which was carried out with a multi-stage 20 meter-running test (20MSRT Shuttle run test). Although this test is traditional in research involving children and has shown good metric characteristics, its assessment is based on field measurement and not on a direct measurement in the laboratory. Also, the limitation of this research may be the implementation of the 20-meter running test itself (20MSRT Shuttle run test) which is greatly influenced by motivation, giving rise to concerns that some results might be lower than the objective abilities of the research participants.

In the end, we can conclude that by raising the level of cardiorespiratory capacity in programmed and organised sports activities, it is possible to contribute to an increase in the quality of life of primary education students. This can certainly be an incentive to young people for a lifelong physical exercise, and cardiorespiratory capacity can be considered one of the factors influencing the quality of life from the aspect of health.

**Acknowledgments**
There are no acknowledgments.

**Conflict of Interest**
The author declares that there is no conflict of interest.

**Received:** 11 October 2023 | **Accepted:** 13 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240202

ORIGINAL SCIENTIFIC PAPER

# Associations between Sport Practice, Educational and Demographic Data in Sports Sciences Students in Salerno

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**Abstract**

The relationship between physical inactivity and students is a topic of growing interest, as lifestyle during academics can influence their general health and mental and physical well-being. The aim of the present study was to perform a survey on the sports habits of university students, to detect associations between physical practice, demographic and educational data. The sample consisted of 246 Sports Science students (age: 22.35±3.39 years) whom a survey, based on literature review and ISTAT survey, was administered via e-mail. Descriptive statistics were used to summarize data, while Chi-Square was performed to test the relationship between demographic, educational and physical practice data. Significant associations emerged between leisure-time physical practice and gender, personal beliefs and the arithmetic mean of the exams ($p<0.05$). Women predominantly practised fitness and dance, while men fitness and soccer. Men participated more in extracurricular activities than women. Most of the students who practised physical activity x 4/5 times a week had a grade average between 26-28, while those who practise it for 2/3 times a week also obtained grades between 28-30. Finally, most of those who considered physical activity important for daily life, did it in their free time. This study highlighted the importance of considering environmental, cultural, social, and spatial variables, variation in which can significantly affect the sports practice.

***Keywords:*** *physical practice, leisure time, study level, habits, health*

## Introduction

The relationship between physical inactivity and students is a topic of growing interest (Stavridou et al., 2020), as lifestyle during academics can influence their general health and mental and physical well-being. University students may spend long hours sitting during classroom lectures or during individual study (Castro et al., 2020). Sedentariness may increase due to the long study sessions required to prepare exams and projects, as well as the frequent use of electronic devices, such as laptops and tablets. Furthermore, the lack of active breaks during study sessions can exacerbate sedentariness (Lynch et al., 2022). The availability of time and resources affects participation in physical activity; infact, busy university students may find it difficult to integrate regular exercise into their daily routine (Arzu et al., 2006). Academic pressures and the workload of university students can often lead to a reduction in the time devoted to regular physical activity (Zhu et al., 2021). Therefore, the presence of sports facilities and physical activity programmes near the university campus may have an impact on students' physical activity adherence (Hsieh et al., 2013). Students living on university campuses may have access to on-site sports facilities, facilitating the inclusion of physical activity in their daily routine (Cradock et al., 2007); those who live off campus may face additional challenges in maintaining an active lifestyle. Physical inactivity among university students may vary depending on different demographic and educational factors (Kljajević et al., 2021). College students are typically young adults, and age may influence the level of physical activi-

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ty (Goje et al., 2014). In general, younger students may be more inclined to participate in physical activities than older students (Nowak et al., 2019). Gender differences may also influence the level of physical activity. Several studies (Carballo-Fazanes et al., 2020; Thomas et al., 2019) suggest that, in some cases, boys might be more involved in physical activities than girls during their university years. The socio-economic level of students may have an impact on the availability of resources and opportunities for physical activity (DiPietro et al., 2020). Students from families with a higher socio-economic level might have more access to sports facilities and fitness programmes (Dong et al., 2023). Finally, the choice of more demanding courses of study could influence the amount of time available for physical activity, but no evidence was found in the literature.

Excessive sedentariness and physical inactivity are two risk factors that lead to chronic and metabolic diseases, such as cardiovascular disease, type 2 diabetes etc. (Altavilla, 2016). Physical exercise during university is of paramount importance and offers a number of beneficial effects that go far beyond improving physical health. Exercise is correlated with better mental health: it reduces stress, anxiety and depression, promotes emotional well-being and can improve sleep quality (Wang & Boros, 2021). This contributes to improved ability to cope with academic challenges, as university students often face high levels of stress due to workload and deadlines. Physical activity can improve cognitive functions, including memory, attention and learning ability, which are particularly important during the university years to improve academic performance (Haverkamp et al., 2020).

The number of studies that focus on factors influencing the sport participation during Italian university is limited. One of the best known surveys that aims to detect the behaviour and habits regarding physical activity in the Italian population is carried out periodically by the National Institute of Statistics (ISTAT 2015; 2017; 2019). The problem is that the data collected concern the national territory, without taking into consideration the environmental, territorial, and cultural differences that significantly affect psychophysical and developmental levels (Raiola et al., 2018; Raiola, 2020). In fact, the same ISTAT data show that sports and physical activity are practiced in Italy with different rates depending on the main socio-demographic variables: gender, age, educational qualification, income, geographic location and other variables (Martelli & Porro, 2018). Therefore, the aim of the present study was to perform a survey on the sports habits of university students, to detect associations between physical practice, demographic and educational data. Our hypothesis is that several variables may hinder the choice to practice physical activity in own free time, and knowing them, it will be possible to find strategies to break them down.

## Methods

*Design and participants*

The study design was observational and associative. Participants were University students attending the Bachelor's Degree in Sports Science and Exercise or the Master's Degree in Sports Science and Technique (LM68) at University of Salerno. A total of 246 Sports Science students, 103 women (22.06±3.03 years), and 143 men (22.5±3.6 years), from University of Salerno answered the survey. Inclusion criteria were University students, sports science students, Italian residence. The study was conducted according to the guidelines of the Declaration of Helsinki. Informed consent was obtained from all participants. Data were treated anonymously.

*Data collection*

An ad-hoc survey, based on literature review and ISTAT (2015; 2017; 2019) reports, was prepared using Google Forms, which generated a link sent to representatives of the University of Salerno's Sports Science association, who sent it via social (WhatsApp, Telegram, Instagram and Facebook). The survey aimed to investigate demographic, educational and physical practice data. Item were 14, as follows in Table 1.

**Table 1.** Item of the questionnaire

| | |
|---|---|
| 1. | Gender |
| 2. | Ubication |
| 3. | What year of study are you in? |
| 4. | What is the arithmetic mean of your exams? |
| 5. | Do you have back exams? |
| 6. | How much time on average do you spend studying each day? |
| 7. | How effective do you think the course of study you are taking is in relation to your future expectations? |
| 8. | Do you currently practice physical activity? |
| 9. | How many times a week do you practice physical activity? |
| 10. | For how long? |
| 11. | What kind of physical activity do you practice regularly? |
| 12. | How important is physical activity to you? |
| 13. | How many people in your family (parents and siblings) exercise or have exercised regularly? |
| 14. | Have you ever practiced regularly extracurricular physical activity? |

*Statistical analysis*

Descriptive statistics were used to summarize the data into Mean [M] and standard deviation [SD] and frequencies/ percentages (F / %). A Chi-Square test ($X^2$) was performed (Aliberti et al., 2023) to test the associations between demographic, educational and physical practice data. Statistical significance was set at $P \leq 0.05$. Data analyses were performed using Statistical Package for Social Science software (IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY).

## Results

The majority (108/43.9%) came from Salerno. Students attended the 3rd of the degree course in Sports Science (101/41.1%); the arithmetic average was 26 - 28 / 30 (97/39.4%); they had no backlog of exams (177/72%); the average study time was 2-3 hours (87/35%) and 1-2 hours (65/25.6%). Seventy-nine percent (194) practiced physical activity during leisure time for 4/5 times a week (80/32.5%), or 2-3 times a week (73/29.7%), with an average duration of 1-2 hours per session (172/69.9%). Most considered physical activity important (106/43.1%), practicing mainly fitness (90/36.6%) and soccer (32/13.0%). 28.5% (70) have almost 2 people in their family who do physical activity regularly.

Significant associations were found between gender and arithmetic mean of exams ($X^2$=27.58; p<0.001), practice of extracurricular activities ($X^2$=6.92; p<0.10), average time of study ($X^2$=39.55; p<0.00), type of physical activity practiced ($X^2$=49.13; p<0.00). A detailed description in shown in Table 2.

**Table 2.** Relationships with gender

| | | Gender | | $X^2$; P |
|---|---|---|---|---|
| | | Women | Men | |
| What is the arithmetic mean of your exams? | 20-24 | 3 | 25 | 27.58; <.00 |
| | 24-26 | 25 | 50 | |
| | 26-28 | 44 | 53 | |
| | 28-30 | 30 | 15 | |
| Have you ever practiced regularly extracurricular physical activity? | No | 10 | 3 | 6.92; <.10 |
| | Yes | 93 | 140 | |
| How much time on average do you spend studying each day? | <1 hour | 7 | 24 | 39.55; <.00 |
| | 1-2 hours | 20 | 43 | |
| | 2-3 hours | 37 | 50 | |
| | 3-4 hours | 25 | 18 | |
| | > 4 hours | 14 | 8 | |
| What kind of physical activity do you practice regularly? | Non-practitioners | 26 | 26 | 49.13; <.00 |
| | Martial arts | 1 | 10 | |
| | Basket | 3 | 5 | |
| | Dance | 12 | 1 | |
| | Fitness | 45 | 45 | |

**Table 3.** Relationships with the degree course attended

| | | What year of study are you in? | | | | | $X^2$; P |
|---|---|---|---|---|---|---|---|
| | | 1st (Master's degree) | 2nd (Master's degree) | 1st (Bachelor's degree) | 2nd (Bachelor's degree) | 3rd (Backelor's degree) | |
| Do you have back exams? | No | 19 | 20 | 50 | 29 | 59 | 43.28; <.00 |
| | Yes | 0 | 10 | 1 | 16 | 42 | |
| What is the arithmetic mean of your exams? | 20-24 | 2 | 0 | 13 | 5 | 8 | 47.99; <.00 |
| | 24-26 | 3 | 3 | 15 | 14 | 40 | |
| | 26-28 | 10 | 13 | 12 | 18 | 44 | |
| | 28-30 | 4 | 14 | 10 | 8 | 9 | |
| How effective do you think the course of study you are taking is in relation to your future expectations? | <20 | 0 | 0 | 1 | 0 | 0 | 58.64; <.01 |
| | 1 | 0 | 0 | 0 | 0 | 1 | |
| | 2 | 0 | 1 | 0 | 0 | 3 | |
| | 3 | 0 | 1 | 0 | 1 | 5 | |
| | 4 | 0 | 2 | 0 | 2 | 5 | |
| | 5 | 2 | 2 | 1 | 0 | 10 | |
| | 6 | 3 | 4 | 5 | 4 | 19 | |
| | 7 | 7 | 6 | 8 | 15 | 29 | |
| | 8 | 7 | 5 | 23 | 12 | 17 | |
| | 9 | 0 | 4 | 4 | 7 | 4 | |
| | 10 | 0 | 1 | 10 | 4 | 5 | |

Significant associations were found between the degree course and back exams ($X^2$ =43.28; p<0.00), arithmetic mean of exams($X^2$ =47.99; p<0.00), perception on the effectiveness of the course of study ($X^2$ =58.64; p <0.01). A detailed description is shown in Table 3.

Significant associations were found between the arithmetic mean of exams and average study time ($X^2$ =34.08; p<0.02), degree program ($X^2$=27.91; p<0.03), gender ($X^2$ =47.99; p<0.00), frequency of physical practice ($X^2$ =27.58; p<0.00). A detailed description is shown in Table 4.

**Table 4.** Relationships with arithmetic mean of student exams

| | | What is the arithmetic mean of your exams? | | | | | $X^2$; P |
|---|---|---|---|---|---|---|---|
| | | 20-24 | 24-26 | 26-28 | 28-30 | <20 | |
| How much time on average do you spend studying each day? | Less than one hour | 8 | 12 | 10 | 1 | 0 | 34.08; <.02 |
| | 1-2 hours | 7 | 21 | 28 | 6 | 1 | |
| | 2-3 hours | 12 | 24 | 35 | 16 | 0 | |
| | 3-4 hours | 1 | 13 | 16 | 13 | 0 | |
| | >4 hours | 0 | 5 | 8 | 9 | 0 | |
| How many times a week do you practice physical activity? | Non-practitioner | 9 | 15 | 16 | 11 | 1 | 27.91; <.03 |
| | 1 a week | 0 | 0 | 1 | 0 | 0 | |
| | 2/3 times a week | 5 | 16 | 29 | 23 | 0 | |
| | 4/5 times a week | 11 | 26 | 35 | 8 | 0 | |
| | 6/7 times a week | 3 | 18 | 16 | 3 | 0 | |
| What year of study are you in? | | | | | | | 47.99; <.00 |
| Gender | | | | | | | 27.58; <.00 |

**Table 5.** Relationships with back exams

| | | Do you have back exams? | | |
|---|---|---|---|---|
| | | No | Yes | |
| How much time on average do you spend studying each day? | <1 hour | 14 | 17 | 19.19; <.00 |
| | 1-2 hours | 41 | 22 | |
| | 2-3 hours | 73 | 14 | |
| | 3-4 hours | 33 | 10 | |
| | > 4 hours | 16 | 6 | |
| What year of study are you in? | | | | 43.28; <.00 |

Significant associations were found between back exams and average study time ($X^2$ =19.19; p<0.00), degree program ($X^2$ =43.28; p<0.00). A detailed description is shown in Table 5.

Finally, there was a relationship between the importance of physical activity and physical practice ($X^2$= 60.00; p<0.00). A detailed description is shown in Table 6.

**Table 6.** Relationship with the importance of physical activity

| | | How important is physical activity to you? | | | | | | | | | $X^2$; P |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| Do you currently practice physical activity? | No | 1 | 1 | 1 | 3 | 5 | 12 | 16 | 4 | 9 | 60.00; <.00 |
| | Yes | 0 | 0 | 0 | 0 | 2 | 10 | 54 | 31 | 97 | |

## Discussion

The results showed significant associations between sports practice, educational and demographic data. The sample was predominantly made up of men (58.1%). Most of the participants resided in the province of Salerno (43.9%), followed by Naples (19.5%) and Avellino (12.6%). Most students attended the third year of the bachelor's degree program in Sports Sciences (41.1%), had an arithmetic mean ranging from 26 to 28 (39.4%) and 24 to 26 (30.5%). About 72% did not have any back exams, the average time of study ranged between 2 - 3 hours (35.4%) and considered the own study course to be quite effective in relation to their expectations. About 78.9% practiced physical activity 4/5 times a week (32.5%) and 2/3 times a week (29.7%) for about 1-2 hours (69.9%) per session. The predominant activity practiced was fitness (36.6%). About 43.1% placed the highest importance on physical activity. Ninety-four percent regularly engaged in extracurricular physical activity. In the family 28.5% had almost 2 people who regularly practiced physical activity while 21.5% had only one.

From Chi-Square analysis, a relationship between gender and the arithmetic mean of the exams, practice of extracurricular activities, average time of study, type of activity practiced, emerged. In fact, it seemed that females had a higher arithmetic mean than males and they studied more. This may be due to the fact that females used more successful strategies than males (Simsek & Balaban, 2010). According to Voyer & Voyer (2014) girls consistently earned better grades than boys. Twenty-nine percent of females had an average study ranging from 28 - 30 and 42.7% between 26 - 28 versus 10.5% and 37.1% of males, respectively. Most females studied between 2-3 hours per day (35.9%) as well as males (35.0%) but 24.3% of females studied 3 to more than 4 hours per day, compared to 12.6% of males. Males, on the other hand, were more physically active than women, in fact 30.8% of males practiced physical activity 4-5 times a week and 20.3% 6/7 times a week, compared to 35.0% and 10.7% of females, respectively. So, it could be that males preferred to spend more time to physical practice than to study (Peral-Suárez et al., 2020). Females of all ages were less active than their male peers (University of Exeter, 2009), even in the European Union (Eurobarometer, 2014). The average time for both was 1-2 hours per session. The activities predominantly performed by females were fitness (43.7%) and dance (11.7%), while males practiced mainly fitness (31.5%) and soccer (13.0%). According to Peral-Suárez et al. (2020) girls usually opted for individual sports with artistic connotations, while boys for team or contact sports.

Other relationships were found between the study course level and back exam, arithmetic mean of exams and perceptions about the effectiveness of the course of study. Master's degree students had a higher average than Bachelor's degree students. Those who make it to the Master's degree were motivated and this had a direct consequence on grades (Amabile, 2014). The vote in Master's degree is very important as it affects competitions (Raiola, 2012; 2013; 2017). Bachelor's degree students had more back exams than students in other years. Only one Master's degree student had back exams. In addition, back exams were associated with study time, in that those who studied for fewer hours had more back exams than those who studied for more hours. Most students from the first year of the Bachelor's degree experienced greater course effectiveness, compared to those from other years. Other relationships were found between arithmetic mean of exams and average study time, degree program, gender and training frequency. Those who spend more time studying had a higher arithmetic mean of exams. In addition, those who work out 2-3 times a week manage to have a high average, between 28 and 30, compared to those who work out several times a week, whose average starts to fall between 24 and 28. Finally, a relationship was found between perceptions about the importance of physical practice and physical practice itself. Those who practice physical activity perceived a greater importance regarding physical practice than those who did not practice it. Physical activity was considered very important by Sports Science students (Raiola, 2019abc). In fact, both practiced a lot of physical activity, although women slightly less. However, women studied for more hours than men and earned a better vote. It is important to investigate and disseminate information about a correct lifestyle (Altavilla, 2016) to prevent risks of various types, such as cardiovascular disease (Altavilla et al., 2018), type 2 diabetes (Salierno et al., 2021), to promote sports inclusion (D'Isanto, 2020; Di Domenico et al., 2022) and so on. Today, with the COVID-19 pandemic, things are changing (Raiola & Aliberti, 2021; Raiola et al., 2021) and therefore it would be interesting to investigate the consequences of the pandemic towards students and physical practice.

The study allowed us to highlight the differences found at the local level compared to surveys conducted on a national scale. This allows us to better understand the situation in our area to try to solve the problems and needs of citizens and students (D'Elia, 2019; 2020; D'Elia et al., 2018). However, this study has been addressed to a limited number of subjects and this has not allowed us to highlight territorial differences, since for most places the numbers are too low. Therefore, we postpone to future studies the possibility of expanding the target audience of the survey to make comparisons for each individual country. In any case, a number of significant associations were identified that may allow us to understand the relationship between study data, physical practice and gender.

## Conclusion

The majority of Sports Science students practice physical activity in their free time, preferring gym activities rather than sports activities, meeting World Health Organization guidelines. Several variables influence leisure-time physical activity, including gender, personal beliefs and the arithmetic mean of exams. Women predominantly practised fitness and dance, while men fitness and soccer. Men participated more in extracurricular activities than women. Most of the students who practised physical activity x 4/5 times a week had a grade average between 26-28, while those who practise it for 2/3 times a week also obtained grades between 28-30. Finally, most of those who considered physical activity important for daily life, did it in their free time. The main reason why we think that surveys should be carried out at the local level and not on a national scale is that in this way it is possible to observe fundamental variables, which have a significant impact on psychophysical and developmental levels. In this study, it was highlighted precisely how fundamental it is in a survey to take into account these environmental, cultural, social and territorial variables, since the variation of only one of these, even within the same territory, can determine significant differences, significantly affecting the result itself. Therefore, the survey is designed to address the needs of individual subjects, and conducting it at national level does not allow for specific information, which is crucial for effective intervention.

**Acknowledgments**
There are no acknowledgments.

**Conflict of Interest**
The author declares that there is no conflict of interest.

**Received:** 16 August 2023 | **Accepted:** 17 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240203

SportMont

ORIGINAL SCIENTIFIC PAPER

# Opportunities for the Development of Motor Skills through Music-Movement and Dance Activities of 9–10-Year-Old Pupils

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**Abstract**

The goal of the research was to determine the impact of an intervention program containing musical movement and dance activities on the level of pupils' physical abilities at the elementary level of education in physical and sport education classes. The object of the research consisted of Σ63 pupils, boys (n=30) aged 10.21±0.42 and girls (n=32) aged 10.32±0.37. The content of the movement program was selected means containing music and movement, dance activities and aerobics, which were implemented for 18 weeks, twice a week, 45 min during physical and sport education. In terms of data collection methods, standardized tests for physical education practice were used. Tests were used to assess the level of motor skills: sit-and-reach test, standing long jump, sit-ups in 30s, endurance shuttle run and shuttle run 4x10. The somatometry method was used. The effect of the implemented movement program was confirmed and significant positive changes in the level of the observed movement abilities were observed: the level of mobility in the joints of the trunk in boys (t=-8.471), girls (t=-9.357), explosive power of the lower limbs in boys (t=-14.459), girls (Z=-4.940), the dynamic and endurance power of the abdominal, hip and thigh muscles in boys (Z=-4.325), girls (t=-19.264), running speed in both boys (Z=-4.783), girls (t=7.095) with a large effect size, in endurance skills in both boys (Z=-4.828), girls, (Z=-5.028) also with a large effect size. Based on the results, the regular and purposeful physical activity of pupils in the school environment significantly influences the level of physical abilities, and thus physical fitness as one of the manifestations of health.

***Keywords:*** *aerobic, musical movement and dance activity, PE, physical abilities, primary school pupils*

## Introduction

Modern lifestyles and the absence of physical activity result in reduced physical fitness, musculoskeletal disorders, obesity, and the development of various non-infectious diseases carried into adulthood (Morano, Rutigliano, Rago, Pettoello-Mantovani, & Campanozzi, 2016; Di Maglie, 2017; Vukelja, Milanovic, & Salaj, 2022; Caron, Bernard, & Gadais, 2023). The persistence of risk factors during childhood, gives a prerequisite to prevent the development of cardiorespiratory and chronic disorders in adulthood (Ekelund et al., 2012; Negrea et al., 2021). On the other hand, an increase in the amount of physical activity in schoolchildren is directly related to many health benefits such as physical fitness, better bone structure (larger, stronger and firmer bone mass), and a more favourable body weight status (Physical Activity Guidelines Advisory Committee-PAGAC, 2018). New guidelines recommend at least 60 minutes of physical activity per day for children and adolescents (WHO, 2020). One option is to provide healthy lifestyle education for pupils at all levels of education (Gozhenko, Biryukov, Gozhenko, & Zukow, 2018; Diachenko-Bohun et al., 2019; Kashuba et al., 2020). Physical and sport education plays an essential role in the curriculum and is an essential part of the educational process for pupils. It should contribute to the prevention of sedentary lifestyle, ensure physical activity of pupils, act on the holistic formation of the personality of the young individual with the formation of lasting habits into adulthood in accordance with WHO recommenda-

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tions (Mantjes et al., 2012; Colella, 2016; Marttinen, Fredrick, & Silverman, 2018; D'Anna, Forte, & Gomez, 2019; Marinho, Neiva, Marques, Lopes, & Morais, 2022). To achieve the aforementioned goal of physical education, it is essential to offer pupils an attractive and varied content with the opportunity to experience success, which creates the basic prerequisite for seeking further activity. Studies point to the fact that fun and enjoyment in physical education (PE) classes can influence the development of positive attitudes towards physical activity (Silverman, 2017; Constantinides & Silverman, 2018). Based on the above, the authors recommend the educators to implement engaging movement programs in school physical education. Cvejić & Ostojić (2017) used the FITT program in their practice, whose main goal was to promote health and increase physical fitness. They recommended practicing in a developmental zone according to the students' abilities and preferences, with a constant increase in the load (intensity or duration) of physical activities. The above program is consistent with the study by Sallis et al. (2012), which means it is Health Optimizing PE or HOPE. The purpose of the FITT programme was to provide pupils with the knowledge, skills, abilities and attitudes that lead to lifelong activity. In relation to the above, it is recognised that pupils' activity alone, based on their interest in a varied movement programme, can lead to spontaneous engagement in the activities on offer, which in turn leads to the development of movement skills or physical fitness.

Such programmes for pupils should include a programme containing music, dance or aerobic activities. Their effectiveness is confirmed by some studies, which report that programs with applied aerobics have been confirmed to have positive effects on physical and mental health or the development of physical fitness for children (Gu, Chang, & Solmon, 2016; Cvejić, Buišić, Mitrović, & Ostojić, 2018). Independent studies of Kouli, Rokka, Mavridis, and Derri (2009), and Podrigalo, Iermakov, Alekseev, and Rovnaya (2016), and Rokka et al. (2019) highlight the popularity of aerobics and dance in physical and sport education classes, which lies in the non-competitive nature of the physical activity with the induction of a pleasant atmosphere in the group by means of a musical background. Some researchers have noted the development of body posture quality by dancing activities intervention (Gao, Zhang, & Stodden, 2013; Andrieieva et al., 2021; Kashuba et al., 2021; May et al., 2021). The following research confirm the effects of the mentioned means of physical education in different age categories. Mavridis et al. (2004) describe the positive effect of aerobic and dance program in physical education in 6-7 years old pupils on health-related abilities (cardiorespiratory fitness, strength, endurance, flexibility etc.), each to a different degree.

The purpose of the study (Kouli et al. 2009) was to evaluate the level of health-related fitness in 10 to 11 years old pupils. Afterwards, Aldemir, Ramazanoğlu, Çamlıgüney, and Kaya (2011) confirm the positive effect of dance activities in adolescents, Pantelić et al. (2019) confirmed the effect of an experimental dance program on children's motor coordination skills. The above-mentioned studies confirm the positive effects of the aerobics and dance program in school physical education for creating a suitable climate, motivating to physical activity, affecting the quality of body posture, increasing the level of physical fitness, or coordination abilities. Also, the movement abilities development in different age categories, but confirmation of the effect of musical movement and dance activities in 9-10 years old pupils is not sufficiently researched. The stated findings were the impetus for the creation of an attractive interventional musical movement and dance program for physical and sport education classes.

The goal of the research was to determine the impact of an intervention program containing musical movement and dance activities on the level of pupils' physical abilities at the elementary level of education in physical and sport education classes.

## Material and methods

*Participants*

In accordance with the goal, the research group included overall Σ n=62 pupils (n=30 boys and n=32 girls) of the town of Banská Bystrica, Slovak Republic, aged 9-10 years, i.e., pupils of early school age (included in I and II health group without impairments), willing to participate in research, with the consent of their parent's takers and of the school. Ethical approval was obtained from the ethical committee at the Matej Bel University, under project n. 1522/2022. Measurements were carried out in accordance with the ethical standards of the Declaration of Helsinki. Each participant voluntarily provided written informed consent before participating. The primary characteristic of the groups is presented in Table 1.

**Table 1.** Characteristics of the research object

| | Research object (n=62) | |
|---|---|---|
| Measured values | Boys (n=30) | Girls (n=32) |
| Age/years | 10.21±0.42 | 10.32±0.37 |
| Body weight/kg | 43.21±7.54 | 35.41±7.11 |
| Body height/cm | 145.37±6.54 | 138.1 ± 6.24 |
| BMI kg/m$^2$ | 20.45±2.21 | 18.57 ± 2.11 |

*Measurement organization*

The research has taken place in the academic year 2021/2022 at an elementary school in Banska Bystrica. After a thorough preparation of the research in order to achieve the aim, in February an input diagnostics (V1) of somatometric indicators and a diagnostics of body posture was carried out, which was evaluated by a standardized test used in school practice. Subsequently, an exercise program aimed at health promotion in relation to the correct posture of the pupils, was included in the teaching content of compulsory physical and sport education, twice a week for 45 minutes, for a period of 18 weeks, a total of 36 lessons. Each lesson of exercise program included music-implementing exercise and dance activities (Table 2), contained 10-minute warm-up, 25-minute main part and 5-minute Cool-Down. Every lesson included a 10 min warm up with stretching. The music was played at a soft rhythm 120-128 beats per minute (bpm). Main part included 30 min continuous musical-movement and dance activities, such as aerobic, dances, dance games, exercise on the wall bars, exercise on the over ball and stability ball, skipping rope games. The intensity of the main program was 60-75% of the maximum heart rate with a rhythm of 130-135 bpm in the first six weeks. After six weeks, from week seven to week eleven, the intensity was increased to 75-85% of the maximum heart rate (music 140-150 bpm). In the next seven weeks, the intensity of the program was variable, every other hour was reduced to 60-70% of the maximum heart rate and rest weeks was 75-85% of the maximum heart rate. In the last part of the lesson, the participants were given 5 min. cool down. It included muscular strength exercises with slow and relaxing rhythm music. The said program was inspired by following researches (Mavridis et al., 2004; Kouli et al., 2009; Andrieieva et al., 2021; Mischenko et al., 2023). The process of teaching was led by a qualified teacher with years of experience. Subsequently, output testing (V2) of the same indicators was performed.

**Table 2.** Timetable of the Movement program for 1 month (sample)

| Lesson | Warm-up (10min.) | Main Part (30 min.) | | Cool down (5min.) |
|---|---|---|---|---|
| | | A part | B part | |
| 1 | Warm-up | Stability ball | Dance games | stretching |
| 2 | Warm-up | Low Aerobic | Dance- modern | stretching |
| 3 | Warm-up | Stability ball | Dance- folk | stretching |
| 4 | Warm-up | Dance Aerobik | Dance - modern | stretching |
| 5 | Warm-up | Over ball | Rope Skipping | stretching |
| 6 | Warm-up | Exercise on the wall bars | Dance games | stretching |
| 7 | Warm-up | Skipping Rope games | Dance- folk | stretching |
| 8 | Warm-up | Low Aerobic | Dance Aerobik | stretching |
| Σ | 80min. | 240 min/month | | 40 min. |

*Measurement Taking*

In terms of data collection, somatometry was used, body height, body weight, BMI were collected (anthropometers and digital scales were used). The following tests were used to test physical abilities: sit-reach test, standing long jump, sit-ups test for 30 s, endurance shuttle run (Moravec et al., 1996) and 4x10 shuttle run (Čillík et al. 2013).

*Data Analyses*

In terms of data processing methods, the mathematical and statistical methods to process the collected data and to calculate basic descriptive statistics were used. Paired-Samples T Test was used to determine the significance of differences between input (pretest) and output (posttest) measurements in the studied variables. Cohen's d coefficient was used to calculate the effect size in the paired-samples t-test procedure, which was interpreted according to the minimum thresholds as follows: d=0.20 - small effect, d=0.50 - medium effect, d=0.80 - large effect (Cohen, 1988). In case of rejection of normality of data distribution by Shapiro-Wilk test, paired Wilcoxon signed rank test (Wilcoxon Signed Rank Test) was used to determine the significance of differences between input and output measurements. The effect size calculation for the Wilcoxon signed rank test procedure used the coefficient r (Corder - Foreman, 2009), which was interpreted according to the minimum thresholds as follows: r=0.10 - small effect, r=0.30 - medium effect, r=0.50 - large effect (Cohen, 1988). The probability of a Type I error was set at α=0.05 in all statistical analyses. Statistical analysis procedures were performed in accordance with the recommendations of the publication Pivovarnicek (2021) using IBM® SPSS® Statistics v28 and Microsoft® Office Excel 2016 software.

## Results

In the observed sample of primary school pupils, the effect of the designed movement programme on the level of movement abilities in boys (Table 3, Table 4) and separately in girls (Table 5, Table 6) was evaluated.

**Table 3.** Comparison of the input and output measurements in boys

| | | | X | SD | Median | Mode | Min | Max |
|---|---|---|---|---|---|---|---|---|
| SR | $V_1$ | (cm) | 16.6 | 6.2 | 16 | 16 | 4 | 30 |
| | $V_2$ | (cm) | 20.5 | 5.04 | 21 | 17 | 11 | 31 |
| SLJ | $V_1$ | (cm) | 139.8 | 28.5 | 138 | 115 | 89 | 200 |
| | $V_2$ | (cm) | 153.2 | 27.5 | 151 | 128 | 100 | 215 |
| SU | $V_1$ | (n) | 18 | 7.7 | 17 | 17 | 6 | 36 |
| | $V_2$ | (n) | 23.1 | 6 | 22 | 21 | 10 | 37 |
| 4x10 | $V_1$ | (s) | 13.5 | 1.6 | 13 | 11.9 | 11.3 | 17.1 |
| | $V_2$ | (s) | 13 | 1.6 | 12.6 | 11 | 11 | 16.7 |
| ESR | $V_1$ | (n) | 35.7 | 15 | 34 | 33 | 9 | 76 |
| | $V_2$ | (n) | 40 | 15 | 38 | 41 | 15 | 77 |

SR – sit-and-reach; SLJ- standing long jump; SU- sit-ups; 4x10 the shuttle run; ESR- endurance shuttle run; SD- standard deviation; X- arithmetical mean; $V_1$ – input, $V_2$ – output

**Table 4.** Statistical significance of differences after movement program intervention in boys

| | Test statistics | | | |
|---|---|---|---|---|
| | Z-value | t-value | p- value | Effect size |
| SR | - | t=-8.471 | p<0.05 | d=1.55** |
| SLJ | - | t=-14.459 | p<0.05 | d=2.64** |
| SU | Z=-4.325 | - | p<0.05 | r=0.56* |
| 4x10 | Z=-4.783 | - | p<0.05 | r=0.62* |
| ESR | Z=-4.828 | - | p<0.05 | r=0.62* |

* Wilcoxon Signed Rank Test ** Paired-Samples T Test

**Table 5.** Comparison of the input and output measurements in girls

| | | | X | SD | Median | Mode | Min | Max |
|---|---|---|---|---|---|---|---|---|
| SR | $V_1$ | (cm) | 21 | 6 | 21 | 22 | 5 | 33 |
| | $V_2$ | (cm) | 27.3 | 3.9 | 28 | 31 | 17.5 | 34 |
| SLJ | $V_1$ | (cm) | 139 | 23.8 | 134 | 115 | 103 | 186 |
| | $V_2$ | (cm) | 151.2 | 22.2 | 141.5 | 141 | 119 | 191 |
| SU | $V_1$ | (n) | 17.7 | 6.3 | 17 | 17 | 4 | 30 |
| | $V_2$ | (n) | 21.9 | 5.8 | 22.5 | 17 | 10 | 34 |
| 4x10 | $V_1$ | (s) | 13.3 | 1.3 | 13.2 | 12.9 | 11.2 | 16.4 |
| | $V_2$ | (s) | 13 | 1.2 | 12.9 | 11 | 11 | 16 |
| ESR | $V_1$ | (n) | 29.3 | 12.9 | 28 | 28 | 7 | 65 |
| | $V_2$ | (n) | 33.8 | 12.4 | 32 | 24 | 13 | 67 |

SR – sit-and-reach; SLJ- standing long jump; SU- sit-ups; 4x10 the shuttle run; ESR- endurance shuttle run; SD- standard deviacion; X- arithmetical mean; $V_1$ – input, $V_2$ – output

**Table 6.** Statistical significance of differences after movement program intervention in girls

| | Test statistics | | | |
|---|---|---|---|---|
| | Z-value | t-value | p- value | Effect size |
| SR | - | t=-9.357 | p<0.05 | d=1.65** |
| SLJ | Z=-4.940 | - | p<0.05 | r=0.62* |
| SU | - | t=-19.264 | p<0.05 | d=3.41** |
| 4x10 | - | t=7.095 | p<0.05 | d=1.25** |
| ESR | Z=-5.028 | - | p<0.05 | r=0.63* |

* Wilcoxon Signed Rank Test ** Paired-Samples T Test

Sit and reach test. Boys demonstrated a lower level of trunk joint mobility despite an average progression of 3.9 cm, which was confirmed as significant (t=-8.471, p<0.05,). In girls, a significant improvement of 6.3 cm in the result of the given test (t=-9.357, p<0.05) was observed. Differences in the level of joint mobility were demonstrated in the entire study set with a large effect size (d=1.55; d=1.65).

Comparing the input and output values of the measurement in standing long jump test, a significant difference in boys (t=-14.459, p<0.05) was found, when there was an increase in power output by an average of 13.4 cm. At the same time, the increase was higher than in girls, when girls achieved an increase in the level of explosive power of the lower limbs by an average of 12.2 cm, which also proved to be statistically significant (Z=-4.940, p<0.05). Based on the influence of the movement program, the object of the research achieved changes in the level of explosive strength of the lower limbs with a large effect (d=2.64; r=0.62).

In sit-ups test the higher mean values were found in boys, when 5.1 more repetitions were recorded in the output testing, which was shown as a significant improvement (Z =-4.325, p<0.05). In girls, about 4.2 repetitions better performance in sit-ups test was recorded, which also proved to be significant due to the intervention (t=-19.264, p<0.05). At the same time, a large effect of the achieved changes in the level of strength of the abdominal, hip and thigh muscles for the whole group (r=0.56; d=3.41) was noticed.

In the shuttle run 4x10 test, the mean values for girls and boys were almost equal. In the input testing, boys and girls achieved a time of 13.5 s and 13.3 s, respectively. After the influence of the exercise program, an average value of 13 s from both genders was observed, so it can be considered the differences in the level of running speed to be significant in both boys (Z=-4.783, p<0.05) and girls (t=7.095, p<0.05) with a large effect (r=0.62; d=1.25).

In Endurance shuttle run test, boys performed at a higher level, as a significant improvement of 4.3 sections (Z=-4.828, p<0.05) was observed in the output testing as well as 4.5 sections in girls, confirming a significant improvement (Z=-5.028, p<0.05) with a large effect size (r=0.62, r=0.63).

## Discussion

This study investigated the effect of an intervention movement program containing music and dance activities on the development of motor performance in 9-10-year-old children. By comparing the acquired data of physical development (body weight, body height, BMI) of the monitored group with the reference standards Sedláček and Cihová (2009), it was found that the groups of girls and boys fall into the average category of Slovak population.

Looking at actual findings, but also the findings of other studies, it can be concluded that the level of movement abilities of 10-year-old pupils in Slovakia is constantly decreasing. By comparing the actual findings with studies by Moravec et al. (1996), Čillík et al. (2015), Mandzák and Slováková (2018) and Lupo et al. (2022). The level of joint mobility of the school population as measured by the Sit and Reach test has a decreasing trend. In Moravec et al. (1996), the average performance for boys in Slovakia was 18.4 cm, and currently, it is recorded as 16.6 cm, which is also in agreement with Čillík et al. (2015). In comparison with the research of Lupo et al. (2022), which investigated the movement performance of students from Turin, it was found that actual research sample performed worse in input testing in terms of joint mobility for both boys and girls. However, after the targeted intervention, the observed population exceeded all the above averages, indicating that a program containing music and dance activities significantly influences the development of joint mobility, as was expected. In girls, the changes in the level of joint mobility of the Slovak population are less pronounced. In comparison, in Moravec et al. (1996) the recorded average value of the seated forward bend was 21.89 cm, in Čillík et al. (2015) at the level of 20.62 cm and the current study shows similar results, namely 21 cm. However, the observed girls were able to significantly increase the level of joint mobility due to the influence of the designed movement program.

The level of explosive strength of the lower limbs was determined by the standing long jump test. In boys, the average level of 139.8 cm was measured. A continuous decline in performance was recorded, while compared to Čillík et al. (2015), boys achieved an average value of 151.93 cm and Mandzák and Slováková (2018), when an average value of 146.7 cm was recorded. In girls, the average value of the parameter was currently 139 cm compared to the value of 144.06 cm recorded in Čillík et al. (2015) and the value of 145.2 cm, recorded in Mandzák and Slováková (2018). Again, a decline in performance was noticed, but due to the impact of the movement intervention program, a significant positive change was achieved in both, boys (153.2 cm) and girls (151.2 cm). An interesting finding is that, compared to the research of Lupo et al. (2022), who investigated the explosive strength of the lower limbs of the Turin pupils with the same test, current findings confirm higher performance for both, boys and girls in present pupils in the input testing.

Chronologically decreasing levels were also observed in the dynamic abdominal muscle strength parameter, as measured by the sit-ups test. While the results of Čillík et al. (2015) are known at the level of 19.75 in boys and 17.86 in girls, currently an average value of 18 in boys and 17.7 in girls was found. However, after the intervention, a significant improvement in the level of abdominal muscle strength skills was observed, namely boys improved by an average of 5.1 (23.1) and girls by 4.2 (21.9) repetitions per 30 s.

Pupils in Čillík et al. (2015) performed at a similar level in speed abilities as it was found in the current testing. In that year, boys and girls achieved an average time in the shuttle run of 12.8 s and 13.34 s, respectively. Currently, values at an average level of 13.5 s for boys and 13.3 s for girls were recorded. Through intentional intervention, an improvement of 0.5 s for boys and 0.3 s for girls was achieved.

The children's current level of endurance ability found indicates approximately the same level of performance that was measured in the research of Čillík et al. (2015). In the endurance shuttle run test, the actual boys achieved an average of 35.7 runs, compared to 37.08 in the aforementioned study. For girls, the current number of runs at 29.3 was measured, while in Čillík et al. (2015) it was 29.51. After the implementation of the movement program, an improvement was observed to a level of 40 crossing runs for boys and 33.8 for girls. Based on the above results, it can be concluded that the movement program, with the content of music and dance activities has a positive effect on the motor performance of the observed children.

During the application of the movement program, with the content of music and dance activities, an increased interest in physical activity associated with joy was found, which corresponds to the findings of Kouli et al. (2009), and Mischenko et al., (2023). The positive progress of movement abilities due to the influence of dance and aerobic activities in pupils of younger school age is also in accordance with other studies. For example, Kouli et al. (2009), specify an improvement in the strength/endurance of the abdominal muscles, flexibility of the muscles of the back and of the hip and an improvement in the strength of the hands. Effects of the FITT program on physical activity and health-related fitness in primary school age pupils (Cvejič & Ostojic, 2017) significantly contributed to the improvement of aerobic fitness, muscular fitness and partially flexibility. Velickovska, Gontarev, and Popovski (2022) researched the effects of innovative tandem hours on physical education on motor capacity of pupils in elementary school level. Experimental group achieved better results in motor tests: dynamometer 50 on the palm, standing long jump, sit-ups for 30 seconds and shuttle run 4x10 m. The findings of this study are consistent with the results obtained by Aldemir et al. (2011) in children of similar age, confirming a positive effect of dance activities on flexibility, coordination, dynamic balance, jump performance, agility, acceleration, and speed. Similar results were also reported by Mavridis et al. (2004) and Pantelić et al. (2019), albeit with slightly younger children. The key element that led to the improvement in the experimental group is stated to be the correct planning, organisation and implementation of the lessons, i.e. the correct and optimal choice of the type, duration, intensity and frequency of physical exercises.

Moreover, such programs contribute to pupils' cognitive and emotional development and significantly ameliorate kinetic skills (Ferdowsi et al., 2010; Kriventsova et al., 2017).

The strength of the study is the fact that the results obtained are unique, as there are few studies that present the use of music-movement and dance activity in physical education for 9-10 years old pupils. Another advantage is the easy implementing a movement program into the teaching process at low cost.

Limitation of the study is the absence of a control group to determine the effect of the program and to generalize the conclusions.

## Conclusions

This study was able to demonstrate the effect of a movement intervention program, containing music-movement, dance and aerobic activities, on the development of children's movement performance.

The effect of the implemented movement program and significant positive changes in the level of the observed movement abilities was confirmed: Boys demonstrated a higher level of trunk joint mobility with an average progression of 3.9 cm, which was confirmed as significant. In girls, was observed a significant improvement of 6.3 cm in the result of the given test). In explosive lower limb strength was found a significant improvement in boys, when there was an increase in power output by an average of 13.4 cm. The increase was higher than in girls, when girls achieved an increase by an average of 12.2 cm, which also proved to be statistically significant. In dynamic and endurance strength of the abdominal, hip and thigh muscles, higher mean values were found in boys (+5.1 repetitions) and girls (+4.2 repetitions). After the influence of the movement program, decreasing of the speed abilities was observed. The improvement in the level of running speed was significant in both boys and girls. In endurance abilities a significant improvement was observed. In boys about 4.3 sections in the output testing as well as 4.5 sections in girls, confirming a significant improvement.

Based on the findings, a relevant conclusion can be stated that regular and purposeful physical activity of pupils in the school environment significantly affects the level of movement ability and, therefore, physical fitness as one of the manifestations of health.

**Acknowledgement**

The article was supported by KEGA grant no. Project Nr. 025UMB-4/2021 2021 Creation of multimedia Tool Focused on Health of Pupils in Primary Education

**Conflicts of interest**

The authors declare that there is no conflict of interest.

**Received:** 16 June 2023 | **Accepted:** 08 November 2023 | **Published:** 01 February 2024

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DOI 10.26773/smj.240204

ORIGINAL RESEARCH

# Effects of Non-Compliance with the Protocol on InBody 770 in Students of Different Training

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**Abstract**

The research aimed to investigate whether alterations in the measurement protocol, accounting for dehydration, resulted in variations in body composition parameters among participants with different weekly training frequencies. The sample consited of ninety healthy participants categorized into three subgroups; the first group (n=28, body height 172.13±9.12 cm, body weight 67.05±11.38 kg) included students with low levels of weekly PA, the second group (n=35, body height 172.93±7.76 cm, body weight 67.53±9.06 kg) consisted of students whith medium level of PA, and the third group (n=27, body height 175.87±9.27 cm, body weight 71.14±11.58 kg) comprised students with high weekly training frequencies. Using the body composition analyzer, InBody770, various morphological characteristics were measured, including Body Height (BH), Body Weight (BW), Body Mass Index (BMI), Percent Body Fat (PBF%), Body Fat Mass (BFMkg), Fat Free Mass (FFM), Total Body Water (TBW), Intracellular Water (ICW), Extracellular Water (ECW), Proteins (PROT), Minerals (MNRL), Soft Lean Mass (SLM), Skeletal Muscle Mass (SMM), Waist-Hip Ratio (WHR), Visceral Fat Level (VFL), Visceral Fat Area (VFA), and Obesity Degree (OD). It can be detected that there is generally no significant difference between the initial and final measurements within the variables describing body composition. Additionally, when analyzing the effect size on the overall sample, it was found to be insignificant in almost all variables, except for the following parameters: Body Fat Mass (ES=.28); Body Mass Index (ES=.21); Percent Body Fat (ES=.21); Visceral Fat Level (ES=.24); Visceral Fat Area (ES=.26); Obesity Degree (ES=.22). The results of this study, following the water intake treatment, revealed a notable overall difference in body composition parameters. However, upon closer examination by group, it becomes evident that a statistically significant difference is particularly pronounced in individuals with a high exercise frequency (Group III), indicating their body's efficient capacity for rapid water absorption into various body composition parameters. These findings underscore the critical importance of adhering to the prescribed protocol when diagnosing body composition using the InBody 770 device, particularly among highly trained individuals..

***Keywords:*** *body composition, bioelectrical impedance, In Body 770 protocol, dehydration, measurement protocol alterations*

## Introduction

The method of bioelectric impedance analysis (BIA), as exemplified by the InBody 770, is a widely utilized approach for evaluating body composition due to its accessibility, non-invasive nature, and rapid results generation (Bosy-Westphal et al., 2008; Finn et al., 2015; McLester, Nickerson, Kliszczewicz, & McLester, 2018). This technique involves measuring the body's resistance to low-frequency electrical currents passed through contact points, such as the hands and feet (Esco et al., 2015). By employing an algorithm that takes into account physical characteristics like height, age, gender, and weight, this analysis aims to generate various parameters for assessing participants' body composition (Bosy-Westphal et al., 2008). Prior to the introduction of multi-frequency BIA, numerous studies conducted reliability tests comparing single-frequency BIA to reference instruments employing a similar methodology. Some

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studies found a concurrence of results (Goldfield, Cloutier, Mallory, & Prud'Homme, 2006; Jebb et al., 2007; Thomson, Brinkworth, Buckley, Noakes, & Clifton, 2007), while others reported disparities between BIA and reference methods (Frisard, Greenway, & DeLany, 2005). In recent years, advancements in technology have expanded bioelectrical impedance analysis to encompass the utilization of multiple frequencies and impedance measurements, thereby enhancing the precision and reliability of body composition assessments (Quiterio et al., 2009; Lee et al., 2018). Multi-frequency BIA devices, such as the InBody 770, represent high-tech instruments developed for the assessment of segmental and total body composition (Ramírez-Vélez et al., 2018; Schoenfeld et al., 2020).

The author of one of the studies suggests that multi-frequency devices can be less subject to errors caused by redistribution of total body water to extracellular and intracellular water and that they represent a more superior method of assessment of total body composition (Moon, 2013). It is well-established that exercise can lead to fluctuations in total body water (TBW), potentially introducing methodological errors in various body composition categories that rely on a constant relationship between lean mass variables (FFM) (Clark, Kuta, & Sullivan, 1994). Variations in the density and composition of FFM, including water, minerals, proteins, and other constituents, between athletes and non-athletes are associated with corresponding methodological errors (Modlesky et al., 1996; Prior et al., 2001). Taking into account that electrical impulse travels through body water, hidratation may influence the validity and reliability of the results. Dehydration is a well-known factor that influences BIA measurement since it increases the body's electrical resistence and it can also lead to changes in FFM (Kyle et al., 2004). There is an insufficient body of research which are based on differences in body composition after the protocol of testing on bioelectrical impedance is changed. Also, it raises the question of whether altering the measurement protocol affects body composition parameters in individuals with varying levels of physical activity.

In line with the aforementioned objectives, the research aimed to investigate whether alterations in the measurement protocol, accounting for dehydration, resulted in variations in body composition parameters among participants with different weekly training frequencies.

## Metods

*Subjects*

In this experimental research, the participant pool consisted of undergraduate students from the Faculty of Sports and Physical Education at the University of Nis. The study included a total of 90 healthy participants, encompassing both genders, with the following characteristics: an average height of 173.56±8.70 cm, an average weight of 68.47±10.63 kg, and an average BMI of 22.59±1.95 kg/m². Out of these participants, 61 were male, and 29 were female, with an age range of 18 to 24 years and an average age of 20.33±1.50 years. The participants were categorized into three subgroups based on their weekly engagement in organized physical activities. The primary criterion for this categorization was the frequency of weekly physical activity as determined by a pre-testing survey. The first subgroup (EGL: n=28, body height 172.13±9.12 cm, body weight 67.05±11.38 kg) included students with low levels of weekly physical activity, ranging from physical inactivity (no recreational physical activities) to a maximum of three training sessions per week. The second subgroup (EGM: n=35, body height 172.93±7.76 cm, body weight 67.53±9.06 kg) consisted of students who engaged in physical activity four to five times per week in addition to their regular academic studies. Lastly, the third subgroup (EGH: n=27, body height 175.87±9.27 cm, body weight 71.14±11.58 kg) comprised students who, alongside their regular studies, participated in six to ten training sessions per week. The participants in this experimental research willingly volunteered to take part and had no health issues or contraindications such as chronic illnesses, mobility limitations, cardiovascular problems, or respiratory conditions. The Ethics Committee of the Faculty of Sports and Physical Education at the University of Nis confirmed (decision number: 04- 542/2; date: 27.04.2023) that this experimental research adhered to all ethical standards governing scientific studies involving human participants, following the guidelines outlined in the Helsinki Declaration (World Medical Association, 2011).

*Procedures*

The research aimed to measure various morphological characteristics, including Body Height (BH), Body Weight (BW), Body Mass Index (BMI), Percent Body Fat (PBF%), Body Fat Mass (BFMkg), Fat Free Mass (FFM), Total Body Water (TBW), Intracellular Water (ICW), Extracellular Water (ECW), Proteins (PROT), Minerals (MNRL), Soft Lean Mass (SLM), Skeletal Muscle Mass (SMM), Waist-Hip Ratio (WHR), Visceral Fat Level (VFL), Visceral Fat Area (VFA), and Obesity Degree (OD). These measurements were conducted using a professional body composition analyzer, the InBody770 (Body Composition Analyzer – InBody770, InBody Co., Ltd., Chungcheongnam-do, Korea), which has been verified for its reliability with 95% accuracy (McLester, Nickerson, Kliszczewicz & McLester, in print). Body Height was measured with a Martin anthropometer with an accuracy of 0.1 cm, and Body Mass Index (BMI) was calculated using the standard procedure, dividing body weight in kilograms by the square of body height in meters (BMI=BW(kg)/BH(m²)).

*Description of the Experiment*

The tests for all the participants in this experimental research were performed during October, 2020 in the Hall of the Centre for Multidisciplinary Research of the Faculty of Sports and Physical Education in Nis, from 8-10 am in order to avoid daily variations of measurements. The air temperature in the Hall during testing ranged from 22°C to 26°C. Testing in this study was conducted according to previously established protocols, which implied that: participants had to be of normal nutrition (BMI=18-25 kg/m²); participants did not have a chronic illness and were not consuming medications as prescribed therapy for the treatment of any type of illness; female participants should not be menstruating; participants should not eat or drink 8 hours before testing (no food and drink from 00:00 to 8:00); participants had to empty their bladder before testing; participants, due to the testing requirements, had to be barefoot and wear only their bathing suits.

The testing process was carried out by experienced experts and it was divided into four phase. Body height measurement of the participants was done in the first phase while the values were recorded on the previously prepared research protocol list. The second phase involved the body composition assessment (the initial measurement) using a professional body composition analyser of brand InBody770. After receiving the report on the analysis of the subject's body composition, the participants, according to the protocol of the third phase of the testing, consumed liquid in the form of a bottled natural non-carbonated mineral water „Aqua viva", nutritional value of water: Calcium ($Ca^{2+}$): 88.09 mg/lit; Magnesium ($Mg^{2+}$): 44.96 mg/lit; Calium ($K^+$): 2.01 mg/lit; Natrium ($Na^+$): 9.17 mg/lit; Bicarbonates ($HCO_3$): 305 mg/lit; Sulfates ($SO_4^{2-}$): 17.77 mg/lit; Chlorine ($Cl^-$): 13.51 mg/lit; Dry residue: 329 mg/lit). In the fourth phase of the testing, a repeated analysis of the subjects' body composition (the final measurement) was conducted 30 minutes after the consumption of the liquid. During the final phase of testing, after collecting all the results of the variables which were tested, the statistical data processing was done.

*Statistical Analysis*

All data obtained will be represented by descriptive statistical parameters, including the average value (mean), standard deviation (SD), minimum result (min), and maximum result (max). The Kolmogorov–Smirnov test was used to assess the

**Table 1.** Descriptive results of body composition parametres and results of ANOVA analysis between the groups

| Variables | Initial (Mean±SD) | Final (Mean±SD) | Initial I group | Final I group | Initial II group | Final II group | Initial III group | Final III group | Initial p | Final p |
|---|---|---|---|---|---|---|---|---|---|---|
| Body Height (cm) | 173.56 ± 8.70 | | 172.13 ± 9.12 | | 172.93 ± 7.76 | | 175.87 ± 9.27 | | | |
| Body Weight (kg) | 68.47 ± 10.63 | 69.75 ± 11.41 | 67.05 ± 11.38 | 69.13 ± 12.75 | 67.53 ± 9.06 | 71.01 ± 10.61 | 71.14 ± 11.58 | 68.75 ± 11.24 | .29 | .70 |
| Total Body Water (L) | 41.84 ± 8.07 | 41.93 ± 8.39 | 40.19 ± 8.20 | 41.61 ± 8.87 | 41.08 ± 7.17 | 42.46 ± 7.88 | 44.55 ± 8.63 | 41.57 ± 8.80 | .10 | .89 |
| Intracellular Water (L) | 26.30 ± 5.17 | 26.33 ± 5.36 | 25.24 ± 5.23 | 26.12 ± 5.66 | 25.77 ± 4.60 | 26.68 ± 5.06 | 28.07 ± 5.52 | 26.09 ± 5.60 | .09 | .87 |
| Extracellular Water (L) | 15.55 ± 2.91 | 15.60 ± 3.04 | 14.95 ± 2.98 | 15.49 ± 3.22 | 15.31 ± 2.59 | 15.79 ± 2.83 | 16.48 ± 3.12 | 15.49 ± 3.22 | .12 | .90 |
| Protein | 11.36 ± 2.24 | 11.37 ± 2.31 | 10.90 ± 2.27 | 11.29 ± 2.44 | 11.13 ± 2.00 | 11.53 ± 2.18 | 12.13 ± 2.38 | 11.26 ± 2.42 | .09 | .88 |
| Minerals | 3.97 ± 0.75 | 3.99 ± .80 | 3.81 ± .77 | 3.99 ± .86 | 3.85 ± .62 | 4.02 ± .75 | 4.28 ± .83 | 3.94 ± .81 | .03* | .93 |
| Body Fat Mass (kg) | 11.28 ± 3.66 | 12.45 ± 4.65 | 12.15 ± 3.88 | 12.24 ± 4.47 | 11.45 ± 3.82 | 12.99 ± 5.36 | 10.17 ± 3.01 | 11.96 ± 3.86 | .12 | .67 |
| Soft Lean Mass (kg) | 53.89 ± 10.44 | 54.00 ± 10.84 | 51.74 ± 10.61 | 53.59 ± 11.47 | 52.89 ± 9.28 | 54.69 ± 10.20 | 57.41 ± 11.15 | 53.52 ± 11.34 | .10 | .89 |
| Fat Free Mass (kg) | 57.18 ± 11.04 | 57.30 ± 11.49 | 54.91 ± 11.22 | 56.89 ± 12.17 | 56.08 ± 9.77 | 58.01 ± 10.80 | 60.97 ± 11.82 | 56.79 ± 12.01 | .09 | .90 |
| Skeletal Muscle Mass (kg) | 32.29 ± 6.75 | 32.33 ± 6.99 | 30.93 ± 6.84 | 32.05 ± 7.37 | 31.61 ± 6.01 | 32.80 ± 6.59 | 34.59 ± 7.20 | 32.02 ± 7.31 | .09 | .88 |
| Body Mass Index | 22.59 ± 1.95 | 23.03 ± 2.30 | 22.49 ± 2.17 | 22.86 ± 2.22 | 22.49 ± 1.86 | 23.25 ± 2.52 | 22.82 ± 1.86 | 22.91 ± 2.13 | .76 | .76 |
| Percent Body Fat (%) | 16.84 ± 5.89 | 18.15 ± 6.65 | 18.40 ± 6.02 | 17.99 ± 6.09 | 17.26 ± 6.21 | 18.48 ± 7.36 | 14.66 ± 4.80 | 17.90 ± 6.45 | .05* | .93 |
| Waist-Hip Ratio | .85 ± .05 | .85 ± .05 | .86 ± .06 | .86 ± .06 | .85 ± .05 | .86 ± .04 | .83 ± .04 | .85 ± .04 | .16 | .80 |
| Visceral Fat Level | 4.09 ± 1.88 | 4.61 ± 2.37 | 4.43 ± 1.95 | 4.61 ± 2.30 | 4.23 ± 1.99 | 4.83 ± 2.72 | 3.56 ± 1.58 | 4.33 ± 1.98 | .19 | .72 |
| Visceral Fat Area | 45.72 ± 18.63 | 51.30 ± 23.25 | 49.45 ± 19.39 | 50.85 ± 22.38 | 47.17 ± 19.56 | 53.85 ± 27.15 | 39.97 ± 15.68 | 48.45 ± 18.66 | .14 | .66 |
| Obesity Degree | 103.42 ± 8.44 | 105.46 ± 10.12 | 103.14 ± 9.39 | 104.68 ± 9.46 | 103.00 ± 8.31 | 106.37 ± 11.49 | 104.26 ± 7.81 | 105.07 ± 9.14 | .82 | .78 |

Note Mean – arithmetic mean; SD - standard deviation; p - significance coefficient; * - denotes statistical significance of $p<0.05$.

normal distribution of the results. A t-test was employed to determine the differences between the initial and final measurements for each individual group, along with the inclusion of an effect size (ES) for each independent variable, following the methodology of Hopkins, Marshall, Batterham, & Hanin (2009). The ES was estimated using Cohen's d effect size. The criteria for determining the magnitude of the effect were as follows: <0.20 trivial (t); 0.20-0.50 small (s); 0.50-0.80 moderate (m); 0.80-1.3 large (l); and >1.3 very large (vl) (Cohen, 1988). Additionally, univariate analysis of variance (ANOVA) was utilized to identify differences between the groups of participants. A significance level of 0.05 (p<0.05) was applied to assess the statistical significance of differences in results between the initial and final measurements, as well as differences among groups. Data analysis was conducted using the statistical package SPSS (IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.)

## Results

Based on the ANOVA analysis (Table 1), it was determined that there were no differences between the subgroups of participants in the initial measurement, except for the variables of Minerals (p=0.03) and Body Fat Percentage (p=0.05). While, there were no significant differences among the subgroups of participants in the final measurement.

Based on the results presented in Table 2, which illustrates the differences between the initial and final measurement within the variables describing the body composition, it can be detected that there is not a statistically generally significant difference between the initial and final measurement of the participants Additionally, when analyzing the effect size on the overall sample, it was found to be insignificant in almost all variables, except for the following parameters: Body Fat Mass (kg) (ES=.28); Body Mass Index (ES=.21); Percent Body Fat (ES=.21); Visceral Fat Level (ES=.24); Visceral Fat Area (ES=.26); Obesity Degree (ES=.22). Here the effect was low.

In the first group of participants, the results of the T-test of repeated measurements showed no statistically significant differences between the initial and final measurements in any variables. However, when analyzing the effect size, only the 'Minerals' variable showed a small effect (ES=.22), while all other variables had trivial (insignificant) effects. For participants in the second group, who trained four to five times per week, the T-test did not detect statistically significant differences between the initial and final measurements. Nevertheless, the effect size analysis revealed small effects in variables such as Weight of the respondent (ES=.35), Minerals (ES=.25), Body Fat Mass (kg) (ES=.33), Body Mass Index (ES=.34), Waist-Hip Ratio (ES=.22), Visceral Fat Level (ES=.25), Visceral Fat Area (ES=.28), and Obesity Degree (ES=.34), while other variables exhibited trivial effects.In the third group of participants, the T-test results indicated statistically significant differences in the following variables: Body Fat Mass (kg) (p=.04), Percent Body Fat (p=.05), and Visceral Fat Area (p=.04). The effect size analysis in this group demonstrated small effects in nearly all variables, except for Body Mass Index (ES=.05) and Obesity Degree (ES=.10), where the effect was trivial.

**Table 2.** Differences of body composition parameters following the application of the experimental treatment for every subsample and generally (t-test)

| Variables | General | | I group | | II group | | III group | |
|---|---|---|---|---|---|---|---|---|
| | p | ES (95% CI) | p | ES (95% CI) | p | ES (95% CI) | p | ES (95% CI) |
| Weight (kg) | .46 | .12 (.12 to .12)T | .54 | .17 (.18 to .17)T | .12 | .35 (.38 to .35)S | .52 | .21 (.21 to .21)S |
| Total Body Water | .95 | .01 (.01 to .01)T | .53 | .17 (.17 to .17)T | .43 | .18 (.19 to .18)T | .30 | .34 (.35 to .34)S |
| Intracellular Water | .97 | .01 (.01 to .01)T | .55 | .16 (.17 to .16)T | .42 | .19 (.20 to .19)T | .28 | .36 (.36 to .36)S |
| Extracellular Water | .91 | .02 (.02 to .02)T | .50 | .17 (.18 to .17)T | .45 | .18 (.19 to .18)T | .34 | .31 (.32 to .31)S |
| Protein | .97 | .00 (.00 to .00)T | .54 | .16 (.17 to .16)T | .42 | .19 (.20 to .19)T | .27 | .36 (.37 to .36)S |
| Minerals | .87 | .03 (.03 to .03)T | .40 | .22 (.23 to .22)S | .31 | .25 (.27 to .25)S | .22 | .41 (.41 to .41)S |
| Body Fat Mass (kg) | .05* | .28 (.32 to .28)S | .93 | .02 (.02 to .02)T | .18 | .33 (.40 to .33)S | .04* | .52 (.59 to .52)M |
| Soft Lean Mass (kg) | .95 | .01 (.01 to .01)T | .53 | .17 (.17 to .17)T | .42 | .18 (.19 to .18)T | .29 | .35 (.35 to .35)S |
| Fat Free Mass (kg) | .95 | .01 (.01 to .01)T | .52 | .17 (.18 to .17)T | .42 | .19 (.20 to .19)T | .29 | .35 (.35 to .35)S |
| Skeletal Muscle Mass (kg) | .97 | .01 (.01 to .01)T | .56 | .16 (.16 to .16)T | .41 | .19 (.20 to .19)T | .28 | .35 (.36 to .35)S |
| Body Mass Index | .18 | .21 (.23 to .21)S | .57 | .17 (.17 to .17)T | .15 | .34 (.41 to .34)S | .87 | .05 (.05 to .05)T |
| Percent Body Fat | .15 | .21 (.22 to .21)S | .77 | .07 (.07 to .07)T | .47 | .18 (.20 to .18)T | .05* | .57 (.68 to .57)M |
| Waist-Hip Ratio | .46 | .00 (.00 to .00)T | .98 | .00 (.00 to .00)T | .87 | .22 (.20 to .22)S | .19 | .50 (.50 to .50)S |
| Visceral Fat Level | .08 | .24 (.28 to .24)S | .74 | .08 (.09 to .08)T | .30 | .25 (.30 to .25)S | .07 | .43 (.49 to .43)S |
| Visceral Fat Area | .06 | .26 (.30 to .26)S | .79 | .07 (.07 to .07)T | .24 | .28 (.34 to .28)S | .04* | .49 (.54 to .49)S |
| Obesity Degree | .15 | .22 (.24 to .22)S | .58 | .16 (.16 to .16)T | .16 | .34 (.41 to .34)S | .71 | .10 (.10 to .10)T |

Note p - significance coefficient; ES - Cohen's d effect size (<0.20 trivial (t); 0.20-0.50 small (s); 0.50-0.80 moderate (m); 0.80-1.3 large (l); and >1.3 very large (vl)); * - denotes statistical significance of p<0.05.

## Discussion

According to a goal of this research, differences in certain parametres of body composition were determined. These differences arose due to variations in participant hydration levels, which resulted from non-compliance with the prescribed protocol, across individuals with different weekly training frequencies.

According to the World Health Organization (WHO) in

2020 (World Health Organization, 2020), individuals in the specified age group should engage in aerobic physical activities for 150-300 minutes per week at a moderate intensity level, or at least 75-150 minutes of vigorous aerobic exercise. Alternatively, they can engage in an equivalent combination of moderate and vigorous activities throughout the week. To gain additional health benefits, one can increase the duration of these activities and incorporate muscle-strengthening exercises for all major muscle groups on two or more days per week. However, it's important to avoid excessive exercise, as intense physical activity can lead to oxidative stress, which can be particularly harmful to lymphatic tissues, as it is a natural byproduct of oxidative metabolic processes during exercise (Nunes-Silva & Freitas-Lima, 2015; Salim, 2016; Estruel-Amades et al., 2019). Moderate exercise has been found to increase levels of reactive oxygen species (ROS) while also enhancing the body's antioxidant defense mechanisms, which contributes to maintaining a healthy oxidative status (He et al., 2016). It also plays a role in activating the immune system (Dröge, 2002). However, engaging in intense exercise can lead to a significant increase in ROS production, surpassing the body's antioxidant capacity and resulting in oxidative stress (Neubauer et al., 2010). Several studies have demonstrated excessive ROS production during strenuous exercise, particularly among athletes (Lee, Kim, Lim, Kim, & Kang, 2015; Vezzoli et al., 2016; Thirupathi & Pinho, 2018). This heightened ROS production during intense exercise can have various effects, including potential muscle damage and a subsequent reduction in muscle performance (Thirupathi & Pinho, 2018). Given the aforementioned facts, it can be concluded that the first group participating in the research engages in university activities and 0-3 training sessions per week while maintaining a balance between ROS and antioxidants in their body. For the second group, it cannot be claimed with certainty, but it is highly probable (considering their frequency of training - 4-5 times per week, and university activities) that an imbalance exists, leaning toward the generation of ROS, indicating oxidative stress. In the third group, they train 6-10 times per week alongside regular activities at the university. There is no balance between ROS and antioxidants; that is, it is directed towards the creation of ROS which overcomes antioxidants – an oxidative stress.

These conclusions find support in the data presented in Table 2, which demonstrates a small level of effect for most variables (except for BMI and OD) when assessed using the BIA method for the third group of participants. Similarly, the second group shows a small effect level for most variables (except for PBF, Protein, TBW, ICW, and ECW). In contrast, the first group of participants only exhibits such results for the mineral variable. Upon comparing the values from Table 2 for the second and third groups of participants, it becomes apparent that all variables related to lipids (except PBF in the second group) show a small effect level. This observation supports the hypothesis of increased ROS production relative to antioxidants in these two groups of participants, indicating oxidative stress. Specifically, heightened oxidative stress can disrupt adipocyte differentiation and contribute to dysfunction in adipose tissue (Murdolo et al., 2013).

BMI serves as an anthropometric method to assess generalized obesity and offers the most accurate prediction of total fat tissue value, with an error margin of up to 11% (Kvist, Chowdhury, Grangard, Tylen, & Sjostrom, 1988). Additionally, it's crucial to note the substantial correlation between WHR and the ratio of cross-sectional area VFL (Visceral Fat Level) and subcutaneous fat tissue. A higher WHR is indicative of a greater proportion of intra-abdominal fat (Ashwell, Cole, & Dixon, 1985).

The BIA (Bioelectrical Impedance Analysis) method employed for measurements in this study offers the advantage of being radiation-free, making it suitable for assessing body composition in various participants (Kyle et al., 2004; Mourtzakis et al., 2008). However, it has limitations in terms of specificity and accuracy because it relies on the differences in electrical resistance between fat and lean-fat-free components of the body. Recent efforts to estimate intra-abdominal fat and WHR using BIA have shown significant correlations with precise recording techniques like computerized tomography (CT scan) (Nagai et al., 2008; Shoji et al., 2008). Nevertheless, it's important to interpret these results cautiously since they are based on the measurement of fat-free tissue, while BIA calculates total fat mass by subtracting lean mass from body weight. Additionally, the hydration status can impact the measurement of lean tissue, which, in turn, may affect the accuracy of fat measurement (Shuster, Patlas, Pinthus, & Mourtzakis, 2012). The limited effect observed in the mineral variable for all three groups of participants (Table 2) can be attributed to dehydration, as evidenced by the statistically significant difference between participant subgroups in the initial measurement analyzed using the ANOVA method (Table 1), which was not present in the final measurement after the described fluid intake. Water and electrolytes are important components of 'interiour ambience' of a body. It surrounds almost all cells through which different metabolites and gasses pass through in all directions (Sobotka, Allison, & Stanga, 2008). Disorders of water and electrolyte balance in the body can negatively affect both cellular and systemic function in the body thus, one should consume an adequate liquid 24 hours prior to exercising Convertino et al. (1996) or, at least, a few hours before exercising (Sawka et al., 2007). Every shortage of liquid before exercising can potentially endanger thermoregulation during the following exercising, especially if there is no an adequate liquid substitution (Convertino et al., 1996). Some studies have indicated that water intake and maintaining a proper water-electrolyte balance in the body can have significant implications for weight and body composition management (Laja García et al., 2019). Indicators such as decreased urination and loss of body mass, are more reliable indicators of dehydration than thirst (Maughan, Leiper, & Shirreffs, 1997). Research results Marta Milla-Tobarra et al. (2016) show an inverse relationship among water (in ml/kg of body weight) and BMI, BFM, FFM, waist circumference and other clinical parameters in children and young people. Essentially, increase of sympathetic activity (skeletal muscles, fat tissue, heart, lungs, metabolism, mental activity, etc.) induced by consuming water is an important and not widely known component of daily energy consumption (Vij & Joshi, 2014).

The strength of the study lies in the fact that it is one of the rare studies that have explored the impact of different InBody protocols on the body composition of students. Additionally, it should be emphasized that the study was conducted on a large sample size and with a comprehensive set of body composition variables.

However, like any study, this one has certain limitations. One of the limitations is related to the assessment of physical activity levels, which relied on sports activity frequency. Hence, a recommendation for future research is to incorporate an objective assessment of PA using accelerometers or include an evaluation of students' physical fitness levels, forming subgroups accordingly. Additionally, it is essential to segregate male and female participants and conduct separate subgroup analyses.

## Conclusion

The results of this study, following the water intake treatment, revealed a certain difference in body composition parameters. However, upon closer examination by group, it becomes evident that a statistically significant difference is particularly pronounced in individuals with a high exercise frequency (Group III), indicating their body's efficient capacity for rapid water absorption into various body composition parameters. Additionally, it is apparent that the parameters exhibiting statistically significant increases include measures related to fat, minerals, and bodily fluids. These findings underscore the critical importance of adhering to the prescribed protocol when diagnosing body composition using the InBody 770 device, particularly among highly trained individuals.

**Acknowledgments**
There are no acknowledgments.

**Conflict of Interest**
The author declares that there is no conflict of interest.

**Received:** 05 November 2023 | **Accepted:** 17 December 2023 | **Published:** 01 February 2024

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DOI 10.26773/smj.240205

ORIGINAL SCIENTIFIC PAPER

# The Impact of the Soccer Training Season on the Body Composition and Physical Performances of Young Soccer Players

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**Abstract**

The purpose of this research was to prove the effectiveness of a soccer training program during a macrocycle (preparation and competition season) on the body composition and physical performances of young players. The research was conducted with a sample of 24 soccer players in two age groups: U15 (n=12) and U17 (n=12). The initial testing took place prior to the start of the preseason, whereas the final testing was performed after four months of training. The results prove that the soccer training program for the U15 age range causes important significant differences in the isokinetic force: peak torque flexion and peak torque extension. No significant changes were seen in body composition (body height/mass and muscle and fat mass) or vertical jump (Squat Jump - SJ, Counter-Movement Jump - CMJ, Maximal Counter-Movement Jump - CMJmax). The results also prove that the U17 soccer training program causes important statistical differences in muscle mass, fat mass, SJ, CMJ, CMJmax, and peak torque flexion, but there were no statistically significant changes in peak torque extension or body height/mass of the U17 soccer players. This research shows that the sensitive phase for relevant improvements in explosive force occurs after the age of 15 years, a period that is characterized by the dramatic development of muscle mass.

***Keywords:*** *association football, training programs, anthropometry, jumping, strength*

## Introduction

Training programs for young soccer players are designed to stimulate optimal body development in terms of its composition and physical performances relevant to soccer's game-play (Sermaxhaj et al., 2022). Nowadays, modern soccer requires players with a perfect technical level, developed tactical thinking, and physical training to be able to cope with game-play difficulties. Fulfilling these prerequisites requires planning precise training processes with scientific support and continuous assessment knowledge during the growth and development period (Huijgen et al., 2014).

Soccer is a sport that is characterized by many different and complex dynamic kinesiology activities characterized by a large number of cyclic and acyclic movements (Gardasevic, Bjelica, & Vasiljevic, 2016; Matin & Sæther, 2017). If they wish to identify game play's success determinants, they need to understand that simply knowing its movements is not enough. Yet, they also need to study the impact of soccer training on the development of body composition and physical performance during growth and the biological development phases in young soccer players. A five-year study monitoring morphological characteristics and physical performance changes over puberty found that the highest body height and mass increases occur at 13.8±0.8 yrs, when height and mass change per year peak at 9.7±1.5 cm·yr-1 and 8.4±3 kg·yr-1, respectively (Philippaerts et al., 2006). Even explosive power, speed, agility, and anaerobic endurance development peaks occur at the highest heights of age (Philippaerts et al., 2006). Bodily

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structure changes should cope with the specific sport's ability to make body development healthy (Popovic et al., 2013; Gontarev et al., 2016). Currently available technology allows obtaining accurate sportsman's bodily structure data (total, lean, and fat body and segments' mass). Such data quick detection allows matching together sound bodily structure, development, and specific sport training. Body composition assessment needs to be longitudinal to support the search for adequate methods and procedures for effective soccer player selection (Sermaxhaj et al., 2022). Another study showed how a training program for soccer players can significantly improve body composition in terms of overall (-1.6 kg) and fat mass (-2.8 kg) (Melchiorri et al., 2000). Skeleton longitudinal dimensionality showed an increase over age (from U13 to U19). Body composition was found to differ in soccer players with two years of training experience (U11, U13, and U15) compared with boys not playing soccer (Vänttinen et al., 2011). Also, at the young soccer players U13, it is confirmed that regular training increases lean mass by 1.15 kg, or 1.81%, and body fat reduction by 0.77 kg, or 3.1 (Sermaxhaj, 2019).

During a soccer match, a player carries out 1400–1600 activities (runs, dribbles, jumps, kicks, headers, tackles, etc.). 700–800 of these activity changes consists of changes of direction and/or speed, and only 11% of the total traveled distance is run at high speed, which is therefore relevant for the match result (Williams & Reilly, 2005). Strength and vertical jump ability are acknowledged determinants of many soccer fundamentals (Ferrete et al., 2014; Lehnert et al., 2014). Namely, explosive force development over knee flexion and/or extension is the determinant of effective runs and jumps (Newman et al., 2004). Isokinetic contraction is a kind of exercise in which one contracts some muscles maximally against a resistance provided by the isokinetic dynamometer that allows movement at a fixed speed (i.e., "iso-kinetic") around a fixed range of motion (Padulo et al., 2013a). That is a common exercise testing and training modality. Isokinetic contraction can be both concentric and eccentric and around many different specific joints (Padulo et al., 2013a). Peak torque, an absolute value, is the greatest amount of force that a muscle can develop. That can be assessed for both a single repetition (1-repeat maximum isotonic strength test) and a multiple-repetition set (Kowalski, 2003).

Hammami et al. (2013) found that a soccer-training season provided balanced improvements in both anthropometric (body height, mass, and fat) and performance variables (Yo-Yo Intermittent Recovery Test Level 1, counter-movement-jump, squat-jump, five-jump-test, and 10-m and 30-m sprints) in young players. Together with body height, mass, (lower) fat, and (relatively higher), viz., being born in the first six months of the year (Rađa et al., 2018), age, speed, maximum oxygen consumption, agility, and shooting precision make teenagers more likely to be selected as soccer players (Gil et al., 2007; Sermaxhaj et al., 2015). A speed, agility, and quickness training program were shown to improve sprints, jumps, and agility performances in young soccer players (Jovanovic et al., 2011; Sermaxhaj, 2017). Training them is meant to improve their body composition and physical performance and to prevent injuries.

An optimal training program for body composition and physical performance improvement needs specific periodization. That is made up of three phases: preparation, competition, and transitions. Each coach's main task is to ensure that his or her players achieve a satisfactory sporting condition over the preparation and maintain that condition over the competition season. A satisfactory sports condition is a state where players' physical, technical, and tactic skills allow the team optimal match performance. From a longer perspective, an optimal training program is a systematic, multi-year activity. Although football training may impact body composition and physical performance, based on previous research, it is unclear what the effects of football training are on young players aged 15 to 17. The aim of the present study was to assess the impact of soccer training on young (U15 and U17) players' body composition and physical performance over the preparation and competition seasons. The hypothesis was that they hypothesized that 1) age-specific training programs designed following expert advice cause different effects on body composition and physical performance of different-age young soccer players' groups (U15 and U17), and 2) the best effects, in terms of bodily and performance improvement, are achieved in the older age group (U17).

## Materials and Methods

*Participants*

Two different age groups of young soccer players from the Football Club Ramiz Sadiku of Prishtina participated in this research: a group of U15 players (U15, n=12), and a group of U17 players (U17, n=12). The average age of the players in the initial measurements were; U15 (14.0±0.4 years) and U17 (15.6±0.4 years). Players were involved for 16 weeks in the regular soccer training sessions in preparation and during the competition period. Before participating in the study, participants underwent a medical checkup at the sports medicine center in Prishtina. Check-up cleared all participants for participating in the study. Furthermore, all participants were informed about the purpose and procedures of testing and provided written consent to participate in this study. In accordance with the Declaration of Helsinki, the local university ethics committee approved the study (Universe College Ethics Committee; Prof. Jeton Havolli; protocol number: FCP 11/10/2016-2), and participants were informed of its goals and procedures and signed a written consent.

Measurements were taken in the sports performance laboratory of the Sports College of the University of Prishtina. Pre-tests took place before the 1st of August, the season's beginning, and post-tests took place four months later, within November's end, the macrocycle's end.

*Procedures and measures*

The first were body height and composition (total, lean, and fat mass) measured sequentially with a Martin anthropometer and a specific analyzer (InBody 720, InBody, Seoul, Korea).

After that, players started with a 12-min freely chosen speed-running warm-up. Then, they performed squat jump (SJ), countermovement jump (CMJ), maximal countermovement jump (CMJmax; Bosco et al., 1983; Philippaerts et al., 2006), and knee isokinetic flexion and extension peak torques (Lehnert et al., 2014).

*Jumping performance*

SJ is a vertical jump from a static crouched position without previous downward countermovement. Knees bend down to 90°, the body is upright, and hands remain in contact with hips. Players were asked to jump as high as possible, starting from such a position (Padulo et al., 2013b; Gheller et al., 2015). CMJ is a vertical jump with a previous downward countermovement. Jump begins in an upright posture with hands remaining in contact with hips and body center of mass lowering until knees become about 90° bent before the final vertical push. Players were asked to jump as high as possible in the above way. CMJmax is a vertical jump. The only difference with respect to CMJ is that hands are free to enhance momentum. All vertical jump tests were performed on a tenziometric system (Powertimer 300, Newtest Oy, Tyrnävä, Finland). The system used in this study consisted of a controlling computer and a high-sensor-density 84x95 cm mat (Balciunas et al., 2006; Enoksen et al., 2009). Jump height was calculated using the equation h=t2×1.22625, where h is the jump height in meters and t is the time in the air of the jump in seconds (Bosco et al., 1983).

*Knee flexion and extension*

The dominant leg's knee flexors and extensors' isokinetic strength was measured with an isokinetic dynamometer (Biodex System 4, Biodex Medical Systems, New York, USA). Knee isokinetic flexion and extension peak torques were measured at 120°/s in the seated position and 100° hip angle. Players were asked to randomly flex and extend their dominant knee with maximal force three times (Stastny et al., 2018). The strongest repetition was chosen for further analysis. Considering the short exercise duration (<1 sec) and to minimize any fatigue effect, a 1-min passive recovery between two same-type repetitions and a 2-min passive recovery between the two repetition types were allowed for the players. During testing, players were provided with concurrent visual feedback as an isokinetic strength curve on a dynamometer monitor (Vico et al., 2013).

*Training program*

During the season's first macrocycle, participants trained three times per week (48 sessions in total) and played three friendly and 11 tournament matches. Training was designed following literature and relevant bodies' recommendations (Bisanz & Gerisch, 2008). Both age groups' training programs were based on four components: conditional (CO), technical (TE), tactic (TA), and mental component (ME). All components were managed by Union of European Football Associations-certified trainers.

Both age groups' weekly cycles were designed as functions of the programs' components. In the first training session (on the week's beginning), TE prevailed; in the second training session (on the week's middle), CO prevailed; in the third training session (on the week's end), TA prevailed; and friendly and tournament matches took place on weekends. Training sessions were made up of a general and specific warm-up (20–25 min), a main part (40–50 min), and a cool-down (10-min running recovery). The main content of the program is shown in Table 1.

**Table 1.** Training schedule season's first macrocycle

| Soccer players U15 | Soccer players U17 |
|---|---|
| 4 week pre-season period and 12 week season period | 4 week pre-season period and 12 week season period |
| Target: training to build the game | Target: focused on achieving results |
| TE - Technical (training to improve the technical approach to the game) | TE -Technical (situational techniques - application of technical elements during the game), |
| CO - Conditioning (development of coordination, basic endurance, speed and strength), | CO - Conditioning (development of fast force, coordination, speed and specific endurance), |
| TA - Tactical (learning individual and group tactical elements to improve the soccer game). | TA - Tactical (collective tactics in the game system—training for the soccer game). |
| ME - Mental (socializing, motivation, communication and confidence). | ME - Mental (motivation, courage, striving to win and team spirit). |

*Statistical analysis*

Statistical analysis was performed with SPSS 21.0 (IBM, Armonk, USA). The Shapiro-Francia test was first used to assess normal data distribution. For both U15 and U17, it was calculated pre- and post-training means and standard deviations (SD) of body composition (body height, total lean, and fat mass) and physical performance variables (SJ, CMJ, and CMJmax heights, and knee isokinetic flexion and extension peak torques). Differences between initial and final measurements were assessed for both groups using a analysis of ANOVA. The level of significance was 0.05.

## Results

Table 2 shows the values of body composition variables before and after training U15. ANOVA results showed that the training program made positive changes but was statistically insignificant on the body composition variables of U15 players.

**Table 2.** U15 pre- and post-training body composition variables values

| Variable | U15-pre (Mean±SD) | U15-post (Mean±SD) | F | p |
|---|---|---|---|---|
| Body height (cm) | 169±9.6 | 171.3±9.6 | 0.279 | 0.603 |
| Body mass (kg) | 52.3±8.9 | 54.3±9.1 | 0.109 | 0.745 |
| Lean mass (%) | 50.52±2.23 | 50.86±1.88 | 0.162 | 0.691 |
| Fat mass (%) | 8.46±3.96 | 8.24±3.07 | 0.022 | 0.885 |

Note: Mean=arithmetic mean, SD=Standard Deviation, F=F score, p=p value

Table 3 shows the values of the physical performance U15 variables before and after the training. ANOVA results showed that the training session affected positively physical performances, but positive significant changes were achieved only in the isokinetic force of knee flexor peak torques (p=0.007) and extensor peak torques (p=0.014). Hypothetically, it can be concluded that the non-improvement of jumping force (SJ, CJM, and CJMmax) was preceded by insufficient muscle development in relation to height during this period.

**Table 3.** U15 pre- and post-training physical performance variables values

| Variable | U15-pre (Mean±SD) | U15-post (Mean±SD) | F | p |
|---|---|---|---|---|
| Squat jump (cm) | 28.3±5.9 | 29.9±4.8 | 0.555 | 0.464 |
| Countermovement jump (cm) | 32.5±5.1 | 33.2±5.2 | 0.119 | 0.733 |
| Max. countermovement jump (cm) | 38.4±4.9 | 38.7±5.2 | 0.024 | 0.878 |
| Flexion peak torque (Nm) | 68.54±16.5 | 93.90±24.80 | 8.716 | 0.007** |
| Extension peak torque (Nm) | 72.67±21.2 | 94.40±18.60 | 7.123 | 0.014* |

Note: Mean=arithmetic mean, SD=Standard Deviation, F=F score, p=p value, bold=significant values

Table 4 shows the values of body composition U17 variables before and after training. ANOVA results showed that the training session affected all body composition variables, but significant changes were achieved in muscle mass with an increment p=0.024 and a decrease of fat mass, p=0.048.

Table 5 shows the values of physical performance U17 variables before and after training. ANOVA results showed that the training program had a positive effect on physical performances, but statistically significant changes were achieved on the jumping force variables SJ (p=0.026), CJM (p=0.46), CJMmax (p=0.011) and isokinetic force of knee flexor peak torques (p=0.004).

**Table 4.** U17 pre- and post-training body composition variables values

| Variable | U17-pre (Mean±SD) | U17-post (Mean±SD) | F | p |
|---|---|---|---|---|
| Body height (cm) | 175.7±6.4 | 177.1±6.5 | 1.292 | 0.268 |
| Body mass (kg) | 61.1±10.2 | 62.2±8.8 | 0.293 | 0.594 |
| Lean mass (%) | 49.50±3.92 | 52.58±1.96 | 5.919 | 0.024* |
| Fat mass (%) | 9.13±3.03 | 6.94±2.79 | 3.370 | 0.048* |

Note: Mean=arithmetic mean, SD=Standard Deviation, F=F score, p=p value, bold=significant values

**Table 5.** U17 pre- and post-training physical performance variables values

| Variable | U17-pre (M±SD) | U17-post (M±SD) | F | p |
|---|---|---|---|---|
| Squat jump (cm) | 31.4±4.8 | 35.5±3.5 | 5.670 | 0.026* |
| Countermovement jump (cm) | 34.9±3.6 | 37.7±3.5 | 3.739 | 0.046* |
| Max. countermovement jump (cm) | 38.3±3.7 | 43.3±5.1 | 7.621 | 0.011* |
| Flexion peak torque (Nm) | 76.60±28.80 | 115.40±29.90 | 10.437 | 0.004** |
| Extension peak torque (Nm) | 109.30±30.10 | 120.20±30.30 | 0.788 | 0.384 |

Note: Mean=arithmetic mean, SD=Standard Deviation, F=F score, p=p value, bold=significant values

## Discussion

This research was performed on soccer players of two age groups (U15 and U17) in a relevant phase of biological growth, which is characterized by important shaping of body composition and an increase in physical performance (Philippaerts et al., 2006). Through training sessions, it is intended to optimize muscular mass and fat mass, especially during the growth and development phase (Melchiorri et al., 2000; Helgerud et al., 2001).

This research in U15 showed that a three-times per week over a four-month macrocycle training program increased significantly both flexion (+25.36 Nm, +37%) and extension (+21.73 Nm, +30%) peak torques without any changes to either body composition variables or vertical jump performances. The results of this study show that the training program made positive changes but was statistically insignificant for the body composition variables of U15 players. The results of this study are consistent with the research of other authors (Philippaerts et al., 2006; Sperlich et al., 2011). Another study indicates that football practice in young U10 and U12 football players produces benefits in body composition and physical fitness (Wong et al., 2010; Thaheri et al., 2014; Sermaxhaj, 2019; Martin et al., 2023).

Based on the results of this research and several other studies, it is proposed that individual training sessions with the purpose of achieving positive changes between muscle mass and fat mass are the best approach. This shows that the sensitive phase for improvement of jumping force is not at this age. Similar results were proven in another research (Sperlich et al., 2011).

This research was performed on U17 soccer players as well, but with a different training program and results. Regarding the effect of training programs on U17 soccer players, the results of this research have shown a sensitive increase in muscle mass (+3.08%, -6%) and a reduction in fat mass (-2,19%, -24%). Results of this research confirm that the increment in body weight is a result of the increase in muscle mass percentage and the decrease in subcutaneous fat mass percentage in total value, which is normal when considered that the balance between body height and weight begins in the U17 category. The obtained results show that the muscle mass increase and fat mass decrease are a product of the regular 4-month training program and the intensive growth and development of soccer players U17 muscles. Similar results were achieved by other researchers (Melchiorri et al., 2000; Vänttinen et al., 2011). There was no statistical impact proven by the soccer training program on the physical composition of senior-aged teams (Campos et al., 2013). This shows that soccer training is more effective in the development of body composition. This shows us that soccer training is more effective in the development of body composition at the age of puberty.

Regarding physical performance variables, significant increases in squat (+4.1 cm, +13%), countermovement (+2.8 cm, +8%), and maximal countermovement (+5.0 cm, +13%) jump heights and knee flexion peak torque (+38.8 Nm, +51%) were assessed without any change to knee extension peak torque. Therefore, it can be conclude that the reasons behind the positive changes in physical performances (jumping and isokinetic force) are the content of the training program and muscle mass increment. Although a number of studies have focused on the changes in isokinetic strength of knee flexors and extensors after a training program applied during the season (Gioftsidou et al., 2008; Brito et al., 2010; Sermaxhaj et al., 2018), results also indicate that peak torque values of knee flexors and extensors varied differently in trained youth soccer players depending on muscle group (Lehnert et al., 2014).

In U17, body composition variables improved along with physical performance variables.In addition, this study did not consider biological maturity status (Tanner, 1962).

Seeing the limits of this study, we suggest research with a larger sample and with a control group, as well as researching not the general impact of the sports program but the separate impact of conditional preparation (CO), technical (TE), tactical (TA), and mental preparation (ME). This would enable more specific conclusions regarding the preparation of football players of young ages.

## Conclusion

This research showed that growth phase sensitivity for relevant explosive force improvements occurs after the age of 15 years, a time marked by a concurrent muscle mass increase. It is suggested that with age groups U15 and U17, in addition to regular training, it might be effective to perform very carefully specific explosive force training to maximize such body composition and physical performance changes in young soccer players. This research further contributes to describing the different body compositions of young players as they age. The bodily and performance spurts described are due to both soccer training and puberty. These research results may prompt further studies on the relationships between training, body composition, and physical performance in youth.

**Acknowledgments**

The authors wish to thank all the players who volunteered in this study, their coaches Ardian Haliti and Triumf Sinani from Football Club Ramiz Sadiku, and professors Abedin Bahtiri and Jeton Havolli from University College. No external financial support has been received. The authors declare no conflicts of interest, financial or otherwise.

**Conflict of Interest**

The author declares that there is no conflict of interest.

**Received:** 10 May 2023 | **Accepted:** 13 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240206

SportMont

ORIGINAL SCIENTIFIC PAPER

# Differences in Trunk Muscle Strength (Lateral Flexor Group) between Male and Female Athletes

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**Abstract**

The strength of the lateral flexor muscles in the trunk is necessary for maintaining stability in the rib cage, spinal column, and preventing a higher number of injuries, while also enhancing overall trunk muscle strength. This study, conducted in a transversal manner, aimed to identify gender-based differences in the strength of trunk lateral flexor muscles among university athletes in the younger senior age group. The study involved 46 athletes from the University of Novi Sad, comprising 25 male participants (height =181.27±6.28 cm; weight =78.31±12.14 kg; BMI =23.78±3.13 kg/m2; mean age =23.75±0.30) and 21 female participants (height =168.19±5.48 cm; weight = 3.72±5.94 kg; BMI =22.53±7.78 kg/m2; mean age =23.68±0.22). The results of the independent t-test revealed no statistically significant differences between the two gender groups based on dimorphic characteristics (p>0.05) in the assessment of trunk lateral flexor muscle strength. It is essential to consider other aspects of the locomotor system specific to each sport and discipline to effectively prevent injuries during training and decrease the overall injury rate.

***Keywords:*** *trunk stabilizers, university athletes, strength*

## Introduction

Impaired body posture during the execution of specific movements can stem from muscle imbalances (Kopecky, 2004). These imbalances typically manifest in two primary groups of skeletal muscles situated at the front and back of the body. The first group consists of tonic muscles—also referred to as monoarticular, local, postural, or antigravitational muscles—primarily responsible for maintaining static body positions through isometric contractions. In contrast, the second group consists of phasic, multiarticular muscles. These muscles, depending on their subgroup (stabilizers/actuators), regulate the stabilizing and dynamic functions of the locomotor apparatus through isotonic contractions (Richardson et al., 2004; Kendall et al., 2005; Abernethy et al., 2013). This category includes the trunk's lateroflexor muscles. The synchronized collaboration of these two muscle groups ensures a secure transfer of load from the chest to the pelvis. This, in turn, stabilizes the spinal column segments and alleviates forces acting on the lumbar spine during various functional activities (Richardson et al., 2004; McGill, 2015).

The lateroflexors play a crucial role in maintaining trunk stability (Kibler et al., 2006). This involves the ability to control the position and movement of the trunk, facilitating optimal production, transfer, and control of force and movement throughout the integrated kinetic chain activities. According to Reed, Ford, Myer, and Hewett (2012), trunk stability can be observed in maintaining control during the application of trunk strength, indicating the interplay between stability and strength. These authors argue that the strength of the trunk muscles is defined by their capacity to generate and endure force. Due to their central location in nearly all functional kinetic chains, the trunk muscles, particularly the lateroflexors, bear the responsibility of ensuring stability for the spinal column and pelvis. They also contribute significantly to the generation and transfer of force from larger body parts to smaller ones, providing proximal stability for distal mobility (McGill, 2002; McGill, 2004; Kibler et al., 2006; Kato et al., 2018).

Tonic muscles include deep abdominal and dorsal muscles, including m. multifidus, m. transversus abdominis, mm. inter-

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spinalis, mm. intertransversarii, m. semispinalis, the posterior part of m. obliquus internus abdominis, the middle fibers of m. quadratus lumborum, the central part of m. erector spinae, the diaphragm, and the muscles located at the bottom of the pelvis. This group of muscles plays a crucial role in stabilizing and controlling the position of joints or segments in the spinal column. Through their active engagement, they prevent local movements of specific spinal segments and ensure stability in all three planes of the entire spinal column (Richardson et al. 2004; Reeve & Dilley, 2009; McGill, 2015). On the other hand, phasic, multi-articular actuators comprise muscles responsible for actively moving joints, unrelated to anti-gravitational postural activity. This muscle group includes the thoracic part of m. erector spinae, m. rectus abdominis, the anterior part of m. obliquus internus abdominis, m. obliquus externus abdominis, the outer part of m. quadratus lumborum, m. psoas major, m. tensor fasciae latae, m. rectus femoris, and m. adductor longus (Bullock-Saxton et al., 2000; McGill 2015).

While stability in the strength of both front and back trunk muscles, as well as lateroflexor muscles on the left and right sides of the body, is expected, age-related changes in life modules suggest probable indications of maturation, adaptation, or morphological alterations throughout one's lifetime. Gender differences, evident across all levels, including the top two superfactors of physical activity and gender, have been noted (Masahiro et al., 2022). During the growth process, muscles and ligaments may struggle to keep pace with bone growth, resulting in muscle imbalances and gender disparities (Purcell, 2009). Additionally, gender differences extend to spinal kinematics and core stability (Masahiro, Yoshitaka & Nobuhiro, 2022; Masahiro et al., 2022).

There are several procedures available for testing the strength of the trunk's lateroflexor muscles. The most commonly used diagnostic method is the "side and prone bridge" (McGill, 2002; McGill, 2004; Andrade et al., 2012; Pareira et al., 2014; Shamsi et al., 2016; Freidrich et al., 2017). Given the absence of studies addressing gender differences in the strength of the trunk lateroflexors, this study aims to assess the status of the lateroflexors, with a primary focus on strength, among university athletes.

## Method

The conducted study falls under the category of cross-sectional empirical research and is classified as applied, confirmatory research. The field method was employed, emphasizing a moderate degree of control. Data collection involved anthropometric methods and muscle endurance testing methods. The obtained results were then interpreted in the context of previous studies through theoretical analysis. The data underwent processing using suitable statistical procedures, enabling valid conclusions to be drawn about the examined phenomena.

### *Participants*

The study involved a sample of 46 younger senior athletes from the University of Novi Sad, consisting of 25 male participants (height =181.27±6.28 cm; weight =78.31±12.14 kg; BMI =23.78±3.13 kg/m2; age =23.75±0.30) and 21 female participants (height =168.19±5.48 cm; weight =63.72±5.94 kg; BMI =22.53±1.78 kg/m2; age =23.68±0.22). During the assessment of trunk lateroflexor muscle strength, all participants were in good health and were capable of engaging in training and competition, free from injuries.

### *Procedures*

In assessing morphological characteristics, variables were selected following the recommendations of the International Biological Program - IBP (Weiner & Lourie, 1969). The research incorporated the measurement of anthropometric characteristics, including: Body height (cm), and Body weight (kg). From these measurements, the Body Mass Index (BMI) was calculated (kg/m2).

The Martin anthropometer was utilized for measuring body height, and a digital decimal scale was used for measuring body weight.

### *Measurements*

The study incorporated the utilization of standardized motor tests to assess trunk lateral flexor strength: Cylinder left (s), Cylinder right (s) (Hennes, 2018), test of isometric endurance of the lateral flexor muscles of the left trunk - left side bridge measured in seconds, and test of isometric endurance of the lateral flexor muscles of the right side of the body - right side bridge (McGill, Childs, & Liebenson, 1999) measured in seconds.

All measurements took place at the "Scolio Centar" in Novi Sad during 2021. The measurement conditions ensured a well-lit and ventilated room, featuring a secure, flat surface and sufficient space for efficient work with all required equipment. Trained evaluators conducted the measurements, adhering consistently to standard protocols. To minimize the impact of daily variation in measured indicators, anthropometric measurements and muscle endurance measurements were carried out on the same day for each participant. The measurement process spanned several days to encompass all participants.

### *Cylinder left and right*

The subject was positioned on the left or right knee, with the other leg being abducted to the side (hands on hips) depending on the desired side of the trunk and lateral flexor muscles being tested. The subject then performed a bend to the left side while maintaining a corrected posture. At that point, the center of gravity was shifted to the left side. The leg on the T-side was placed on a stool or Swedish box frame to the side. Beginners place the leg to the side without raising it to a height of 40 cm, but in this study, since the subjects are athletes, the leg was raised on the Swedish box. The arm on the left side of the trunk was placed on the lumbar prominence, and the opposite arm was placed on the prominent hip bone (LHT). The spine was elongated while breathing normally. The subject maintained the position. The tester had to pay attention to the correction of the neck and the basic tension of the muscles.

The purpose of the test is to evaluate the strength of the trunk lateral flexor muscles, with time measured in seconds, and the maximum duration of the test set at 5 minutes (300 s). The test was conducted three times, and the best result from each trial was considered for both the left and right sides of the trunk (Hennes, 2018).

### *Test of Isometric Endurance of Trunk Lateral Flexor Muscles - Side Bridge, Left and Right*

This test involves the examinee assuming a side position, supported on their elbow, with legs extended and the "upper" leg slightly forward. The body must maintain a straight and active position without joint flexion, particularly in the hip joint (considering this in the examinee's procedure). The free hand is placed next to the body. The examinee is allowed a practice attempt before the actual measurement. Upon taking the starting position, the stopwatch is initiated, and the duration the examinee maintains the position is measured. The test concludes when the examinee touches the floor with their hip, disrupting the prescribed body position, prompting the cessation of the test, and stopping the timer. Time is recorded in seconds. This test evaluates the endurance of the trunk lateral flexors (McGill et al., 1999). It is separately performed for both the left and right side of the trunk (McGill et al., 1999).

*Statistics*

The statistical analysis of the data involved calculating basic descriptive statistics, including mean (M), standard deviation (SD), minimum (MIN), and maximum (MAX) values of the measurement results. Additionally, the coefficient of determination (R2 - %) was calculated to clarify differences between subgroups. The normality of variable distribution was assessed using the Shapiro-Wilk test for small samples. An independent sample t-test was applied to determine differences between groups of subjects. All data processing was conducted using the IBM SPSS 26 software package (Statistical Package for the Social Sciences), with a significance level set at $p<0.05$.

## Results

Based on the average values presented in Table 1, a notable heterogeneity of results is observed in all four variables for both groups of subjects. The predominant unevenness is noticeable in the strength of the left and right side muscles of the trunk within both subject groups. The Shapiro-Wilk coefficient values, as indicated in Table 1, suggest normality in the distribution for all four analyzed motor variables (SW $p>0.05$) within both sub-samples.

**Table 1.** Descriptive statistics of the torso lateral flexor variables based on gender

| Variable | Male athletes (N=25) | | | Female athletes (N=21) | | |
|---|---|---|---|---|---|---|
| | AM±S | CV | SWp | AM±S | CV | SWp |
| Left cylinder (s) | 162.67±41.88 | 25.74 | 0.66 | 202.16±89.33 | 44.19 | 0.15 |
| Right cylinder (s) | 158.50±50.88 | 32.10 | 0.06 | 184.49±89.83 | 48.69 | 0.23 |
| Left side bridge (s) | 89.03±27.48 | 30.87 | 0.33 | 82.41±21.48 | 26.06 | 0.70 |
| Right side bridge (s) | 92.05±27.21 | 29.56 | 0.47 | 82.63±22.62 | 27.38 | 0.31 |

Note N - number of participants; M - male athletes; F - female athletes; AM - arithmetic mean; S - standard deviation; CV - coefficient of variation; SWp - level of statistical significance of Shapiro-Wilk coefficient.

The results of the independent samples t-test reveal no statistically significant differences between male and female athletes from the University of Novi Sad concerning the variables measuring the strength of the trunk lateral flexors ($p>0.05$). Although certain differences in means were found, such as in the cylinder left and cylinder right variables favoring female athletes, and in the left side bridge and right side bridge variables favoring male athletes, these differences did not reach statistical significance (Table 2). A more detailed exploration of these differences is illustrated in Graph 1.

**Table 2.** Differences by gender in variables for strength assessment of trunk lateral flexor muscles

| Variable | Male atheletes (N=25) | | Female athletes (N=21) | | t | p |
|---|---|---|---|---|---|---|
| | AM | S | AM | S | | |
| Left cylinder (s) | 162.67 | 41.88 | 202.16 | 89.33 | -1.86 | 0.08 |
| Right cylinder (s) | 158.50 | 50.88 | 184.49 | 89.33 | -1.18 | 0.25 |
| Left side bridge (s) | 89.03 | 27.48 | 82.41 | 21.48 | 0.90 | 0.38 |
| Right side bridge (s) | 92.05 | 27.21 | 82.63 | 22.62 | 1.26 | 0.21 |

Note t - value of the independent t-test, p - level of statistical significance of the t-test.

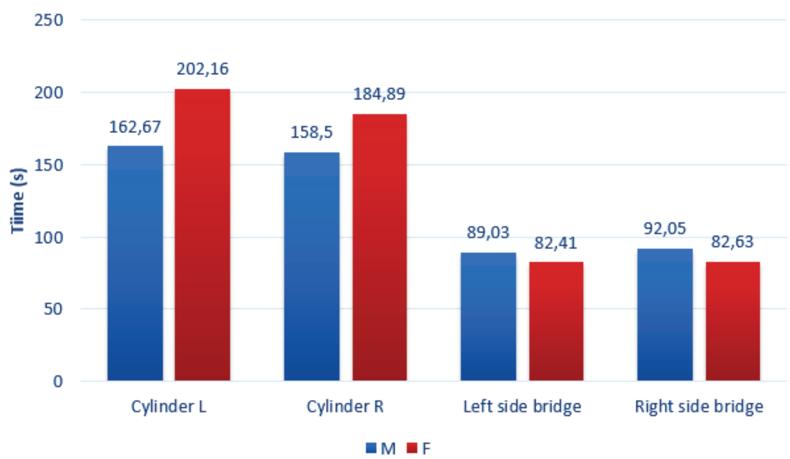


FIGURE 1. Graphic representation of the analysis of the average values of the trunk lateral flexors based on gender

## Discussion

The aim of the study was to explore gender-based differences in the strength of trunk lateral flexor muscles among university athletes. The research involved 46 subjects, university athletes, with a mean age of 23.72±0.29. This group comprised 25 male athletes (mean age =23.75±0.30; mean height =181.27±6.28 cm; mean weight =78.31±12.14 kg; mean BMI =23.78±3.13 kg/m2) and 21 female athletes (mean age =23.68±0.22; mean height =168.19±5.48 cm; mean weight =63.72±5.94 kg; mean BMI =22.53±7.78 kg/m2).

The results indicate that there are no statistically significant differences in the strength of the trunk lateral flexor muscles between male and female athletes at the University of Novi Sad, as assessed by standardized tests (Side bridge left and right and Cylinder left and right) with p>0.05. Despite female athletes displaying higher average values in the Cylinder left and Cylinder right tests compared to their male counterparts, these differences did not reach statistical significance. It appears that the strength of the central trunk muscles, as well as all associated soft tissues (including joint and fibrous structures, cartilage, ligaments, tendons, muscles, and fascia) with a proximal extension originating from the axial skeleton, is at a very similar level in both male and female athletes. The active engagement in maintaining stability during the Cylinder left and Right tests suggests a slightly greater strength in the m. multifidus (lumbar), m. erector spinae, m quadratus lumborum, external oblique, m. oblique externus abdominis, internal oblique muscle of the abdomen (m. oblique internus abdominis), rectus abdominis muscle (m. rectus abdominis), transverse abdominal muscle (m. transversus abdominis), m. psoas major, and pelvic floor muscles in female athletes (Corbin et al., 2004; Gonçalves et al., 2018).

It is reasonable to consider that the previous training period (training level) and likely the state of movement functionality may influence subjects of different sexes, even with a similar level of strength in lateral flexors among athletes. The study acknowledges a limitation in not ranking athletes based on the degree (level) of competition, such as international athletes, state-level athletes, or athletes of lower ranks of competition, due to the small-sized but appropriate sample. In future research on this issue, it is essential to give more attention to the ranking of athletes irrespective of gender and subsequently assess the strength of the trunk lateroflexors.

The comparable muscle strength observed among younger senior athletes in the mentioned body regions, as evidenced by the mentioned tests, could be attributed to the heightened role of fusimotor fibers. Fusimotor fibers, activated during the excitation of cross-striated muscles, are known to concurrently intensify the activity of sensory fibers within the neuromuscular spindle. This phenomenon is believed to arise from the contraction of intrafusal fibers. It is conceivable that fusimotor neurons are maximally engaged throughout the multi-year training processes undergone by both groups of younger athletes. In deliberate, targeted movements with precise definitions, such as the testing examples mentioned involving specific positions, fusimotor neurons likely do not precede but rather follow, building upon alpha motor activity, albeit with a minor, negligible delay (Galeano et al., 2000). It can be hypothesized that innervations (load levels causing overload, stimuli) during training sessions within this group of individuals in the training process prevent intrafusal fiber relaxation during contraction, thereby facilitating better motor control of movements.

If they wouldn't have been activated in time, the neuromuscular spindles as motion sensors would have remained inactive. Similar intramuscular coordination of movement could have been crucial for similar results in analyzed variables among university athletes in the tested sample. It should be particularly emphasized that muscle strength is determined by intramuscular coordination (Zatsiorsky & Kraemer, 2009). The more complex the movement is, the greater the activity of muscle fibers and their mutual cooperation is required, as demonstrated when performing the Side bridge left or right and the Cylinder left and Cylinder right test. Athletes in the training process can better coordinate the activation of fibers in individual muscles (Suchomel et al., 2018), which is the result of good neural adaptation, and therefore, the results are probably similar among the tested groups of athletes.

The average body height could potentially explain the moderately better results of female athletes in the variables Cylinder left and Cylinder right, given their shorter average height. Biomechanical considerations, particularly the length of lower extremities, influencing the lower center of gravity in female athletes, might contribute to the comparatively better average results in favor of this group (Purcell, 2009; Butler et al., 2014). Conversely, in the variable side bridge, male athletes exhibited superior average results. In the side bridge variable, endurance in a static regime played a crucial role, with the center of gravity being a less significant factor in this segment. Studies suggest that isometric strength training in both men and women leads to less fatigue and results in superior strength for specific joint angles compared to dynamic strength training. This type of training has shown to be beneficial for dynamic sports-related performance, such as running and jumping (Lum & Barbosa, 2019). It can be presumed that this form of training was incorporated by some athletes, leading to a discernible difference in the exertion of strength in the trunk lateral flexors. This training method is designed to circumvent excessive fatigue while still promoting positive neuromuscular adaptations. It aims at enhancing strength, particularly in biomechanically challenging joint positions during specific movements. This type of training is beneficial for improving specific movements relevant to sports that primarily involve isometric contractions, especially when athletes are restricted in movement due to injuries.

The importance of core muscles, often referred to as trunk or central core muscles, in stabilizing and generating force across various sports activities is gaining increased recognition (Kibler et al., 2006; Wirth et al., 2016). Muscular strength, in this context, is essentially a static ability that can be best understood as the pre-programmed integration of local, single-joint muscles and multi-joint muscles. This integration aims to provide stability and facilitate movement (Myers, Poletti, & Butler, 2017). The stability of trunk muscles, or their strength, appears to be quite similar among university athletes from Novi Sad. This similarity may contribute to proximal stability, distal mobility, a semblance of distal force creation, and the generation of interactive moments that drive and safeguard distal joints in both groups of subjects.

Postural control is a sophisticated mechanism that relies on receiving, processing, and responding to afferent signals from the visual, somatosensory, and vestibular systems. These systems register changes in the body's center of gravity based on internal oscillations and the effects of external loads. Each system contributes to effective postural control by providing specific information about body posture to the central nervous system. The somatosensory system, which includes muscle and joint receptors and mechanoceptors, offers proprioceptive information about the body's position in space (Mahdieh et al., 2020). An observed difference in the analyzed variables, specifically Cylinder left and Cylinder right, favored female individuals, while the other two variables, Side bridge left and Side bridge right, on average, demonstrated better results for male subjects. It's important to note that one muscle stabilizer of trunk movement (trunk core) and four core actuator muscles (m. rectus abdominis, m. obliquus externus abdominis, m. erector spinae, and m. quadratus lumborum) participate in the lateral flexion of the trunk. However, six individual muscles and muscle groups are involved in core muscles and are not directly engaged in lateral flexion. Considering the above, it can be observed that the coordinated contraction of all stabilizers and global executors of trunk movements facilitated optimal spinal stabilization in both groups of subjects, with minor observable differences in average values in both applied tests.

The strength of the trunk lateroflexor muscles and the overall balance with core muscles play a crucial role in preventing sports injuries and enhancing sports performance (Rivera, 2016; Kuniki et al., 2022). Robust trunk lateroflexor muscles contribute to efficiency in various sports (Behm et al., 2010; Barbado et al., 2016; Correia et al., 2016). It is widely believed that a correlation exists between the maximum muscular force of the trunk (core) muscles and the muscular endurance of lateroflexors, directly influencing athletic performance at a higher level (Sharma & Yadav, 2020). Conversely, weak core muscles, including the cylinder muscles, can potentially lead to health issues (Davidek, Andel & Kobesova, 2018). It's crucial to highlight that weak core muscles have a negative impact on athletic performance. Additionally, insufficient trunk lateroflexor muscles may contribute to the development of incorrect movement patterns, impaired postural control, and consequently, an increased risk of injury (Davidek et al., 2018).

The results of this study exhibit notable similarities to those of Escamilla et al. (2016), who highlighted a comparable level of strength in the rectus abdominis muscle, as well as both the external and internal oblique muscles of the trunk in male and female subjects. Specifically, the strength of the external oblique abdominal muscles was significantly greater in athletes during the Side bridge test, where the strength of these muscles becomes more evident (Escamilla et al., 2016). This is attributed to maintaining a longer lever arm for work, particularly in the upper body, as the lever extends with lateral flexion in the form of the side bridge position. In comparison to bringing the side position (left or right) in a half-squat position, and the side bridge position (board) on the knees (test of isometric contraction of trunk muscles), greater strength is required for these muscles. In this context, male athletes demonstrated dominance in this area.

Nevertheless, differences in the strength expression of the lateral flexor muscles on the left and right sides of the trunk have been confirmed. Such favoritism toward one or more muscle structures over another can result in muscle imbalances and their interrelated dysfunction, a phenomenon supported by prior research (Cresswell et al., 1994; Wilke et al., 1995; Norris, 2000). Participants of both genders exhibited higher average values in the test for the left cylinder and the right side bridge, with the distinction being more pronounced in male athletes compared to their female counterparts. The study's limitation lies in the small number of respondents, restricted solely to athletes. In future research of this nature, it is recommended to monitor the state of musculature over an extended period, such as during training.

In general, it can be concluded that the level of strength in the trunk lateral flexor muscles is similar among University of Novi Sad athletes, with certain minor differences in muscle strength observed between the left and right sides of the body. The condition of the trunk muscles, crucial for overall postural stability, significantly impacts the maximum functional abilities of athletes. Enhanced strength in the lateroflexors contributes to better injury prevention and more efficient training optimization.

Having information on the level of core muscle strength in young athletes can lead to improved injury prevention, enhanced training optimization, and, consequently, better sports results in the future.

**Acknowledgments**
There are no acknowledgments.

**Conflict of Interest**
The author declares that there is no conflict of interest.

**Received:** 30 November 2023 | **Accepted:** 14 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240207

ORIGINAL SCIENTIFIC PAPER

# Digital-Based E-module in Tennis Learning for Undergraduate Students in Sports Education

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**Abstract**

Although many studies have examined the use of e-modules for physical education at school and university levels, very few explore the development of digital-based e-modules in tennis learning. This research aims to develop a digital-based e-module in tennis learning for undergraduate sports education students. It was conducted using the Research and Development (R&D) design by adopting the Plomp model. The model consists of preliminary research, prototyping, and assessment phases. This research invited 12 experts, consisting of 4 material experts, 4 language experts, and 4 media experts. The experts were professors and lecturers with profound expertise in their respective fields. This research also involved 35 sports education undergraduate students taking tennis courses, consisted of males (n=25) and females (n=10). The instrument was a Likert scale questionnaire. Validity testing was measured using Aiken's V validity coefficient. The reliability was calculated using Intraclass Correlation Coefficients (ICC), while product practicality was analyzed using percentages. The results show that the average product validity before and after revision was 0.790 (medium) and 0.904 (high), while the average reliability was 0.754 (high). In terms of practicality, the average was 89.71, which means the product is very practical. In conclusion, digital-based e-modules in tennis learning can be used for undergraduate sports education students. This research is expected to facilitate undergraduate sports education students, lecturers, and tennis practitioners to overcome limitations in teaching tennis. Future research is needed to test the product's effectiveness by conducting an experimental design and comparing it with other groups.

***Keywords:*** *content validity, instruments, technology, higher education*

## Introduction

Tennis is one of the practical courses for undergraduate students in sports education. This sport is intermittent, characterized by repeated high intensity (e.g., acceleration, deceleration, change of direction, and stroke). It requires physical fitness components like speed, agility, muscle strength, and cardiovascular fitness (Fernandez-Fernandez, Sanz, Sarabia, & Moya, 2016).

The development of tennis learning in universities is universal. In general, the learning course focuses on developing students' understanding of the basic knowledge of tennis, such as characteristics, basic skills, and basic hitting methods. Because this knowledge is fundamental, teaching staffs need to increase students' interest and enthusiasm to learn it (Wang, 2021). One of the strategies is utilizing technology in teaching because various applications of technological intelligence have changed traditional ways of teaching (Elbamby, Perfecto, Bennis, & Doppler, 2018). Although technology has been gradually integrated into the learning course, it does not mean that the roles of the teaching staff have been replaced (Freeman et al., 2016). Instead, their tasks in teaching activities have shifted from traditional to designing materials, creating innovations, and helping and motivating students (Berg & Vance, 2016), as exemplified in e-modules (Komikesari et al., 2020).

An e-module is an information and communication technology-based module. Such an interactive module offers convenience in giving display, images, audio, video, animation,

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and feedback through formative tests and quizzes (Voithofer, 2005). This type of feedback will make it easier for students to study independently according to their respective abilities (Alnedral, Ihsan, Mario, Aldani, & Sari, 2023). Additionally, the ever-evolving and changing education system (from face-to-face learning to online platforms) has made it an important aspect for a long time (Blaine, 2019).

Previous studies have examined the role of technology in achieving successful learning for physical education at school (Handayani, Myori, Yulifri, Komaini, & Mario, 2023) and university levels (Alnedral et al., 2023; Born, Nguyen, Grambow, Meffert, & Vogt, 2021; Wang, 2021). For example, Born et al. (2018) integrated tennis teaching videos into a classroom. This integration has been shown to be effective in improving forehand and backhand techniques in college students. Wang (2021) also reported that the Android-based online tennis teaching information platform was also proven to be effective for use with college students. Similar results were also provided by Chen, Yang, & Xie (2022), who designed a multimedia teaching system for tennis using 5G-enabled internet technology. In Indonesia, the Android-based TennBasTech application was designed and developed by Mulya et al. (2021) to teach tennis to athletes aged 10 to 11 years.

In this regard, the application of digital-based e-modules has also been investigated by previous studies (Alnedral et al., 2023). However, these studies focus on learning Tarung Derajat martial arts at the basic level. The results show that e-modules can be used by sports students to achieve effective self-defense learning. Then, Handayani et al. (2023) also developed Android-based gymnastics learning media, which has proven effective in improving handstand skills in junior high school students. To our knowledge, very few studies have examined the development of digital-based e-modules in tennis instruction for undergraduate sports education students.

Therefore, this research aims to develop a digital-based e-module in tennis learning for undergraduate students in sports education. This research is very important because the use of multimedia technology can speed up the reform of tennis teaching, changing it from traditional teaching to a more interactive way. Hence, the teaching theory, form, and quality can be effectively improved (Li, He, Liu, & Yu, 2017). This research is aimed at overcoming limitations in tennis learning, both for undergraduate sports education students, lecturers and tennis practitioners.

## Methods

### *Study design*

This research was conducted with the R&D design. It adopted the design from Plomp and Nieveen (2013). The research would develop and evaluate a digital-based e-module in tennis learning for undergraduate sports education students.

### *Participant*

A total of 12 experts participated in this research, consisting of 4 material experts, 4 language experts, and 4 media experts. The experts were professors and lecturers who had expertise in their respective fields. Then, this research also involved 35 sports education undergraduate students from the Faculty of Sports Science, Universitas Negeri Padang, Indonesia. Participants were students taking tennis courses, consisting of males (n=25) and females (n=10) (Table 1). This research was carried out with the approval of the Institute for Research and Community Service at Universitas Negeri Padang, Indonesia (contract number: 803/UN35.13/LT/2021).

**Table 1.** Characteristics of participants

| Characteristics | Sex | |
|---|---|---|
| | Male (n=25) | Female (n=10) |
| Age | 21.27 ± 1.03 | 20.94 ± 0.96 |
| Weight | 65.33 ± 4.51 | 62.35 ± 3.52 |
| Height | 169.52 ± 2.36 | 165.28 ± 2.03 |
| BMI | 22.73 ± 1.17 | 22.82 ± 1.12 |

### *Procedures and instruments*

This research went through several procedures: preliminary research, prototyping, and assessment phases (Plomp & Nieveen, 2013). Preliminary research is the initial stage, which consists of student analysis, learning planning analysis, learning objectives, learning mechanisms, curriculum analysis, and material analysis. The prototyping stage is the product design stage in the form of a digital-based e-module in tennis learning. In this phase, the research has started making an e-module cover, foreword and table of contents, instructions for using the e-module, learning materials (initial introduction to learning tennis, forehand learning, backhand learning, service learning, and volleyball learning), learning videos, quizzes, assignments, evaluations, and reference lists (Figures 1.a and 1.b).

The prototyping phase began with making a cover for the e-module. The cover was designed to include one of the national tennis players from the province of West Sumatra, Indonesia. Meanwhile, images and interactive media were also presented in a more interesting way and were adapted to the material studied at each meeting. The material was adapted to the basic materials in learning tennis for undergraduate sports education students (learning implementation plan). Then, the technical explanation was presented as best as possible and refers to the ease with which students can learn theoretically and practically, both in groups and independently.

Following that, the e-module has an instruction menu where users can learn how to use the media, both online and offline. Each material was available in pdf format. Additionally, learning videos that explained how to perform tennis techniques were available in the video menu. The assignment menu and quizzes were done in a Google form containing instructions and uploaded by students in a format containing the student identification number.

The first material in the e-module was “an initial introduction to learning tennis”. This activity aims to maintain focus on the ball, practice target accuracy, and develop coordination (eyes, hands, and feet). The second material was “forehand learning”. Forehand learning in this e-module shows how the ball is hit with a forehand method, using either the right or left hand (can be done horizontally or with a spin). This material can be done according to the alternatives given by the lecturer. Following that, the third material was "backhand learning". The execution of the backhand consists of a ready position, backswing, forward swing, and follow-up movement. It was the next material was "service learning". The execution of the serve presented consists of ready position, swing, contact with the ball, follow-up movement, and grip. Then, the fifth material was "volley learning". The main aim of volleying is to speed up the return of the ball to the opponent's playing area by cutting off the speed of the incoming ball.

Then, the products that have been designed were assessed by experts, who independently reviewed and evaluated the relevance of the content. Meanwhile, the practicality of the product involved undergraduate sports education students who have used digital-based e-modules in learning tennis for one semester (± 4 months). This instrument is presented in Table 2.

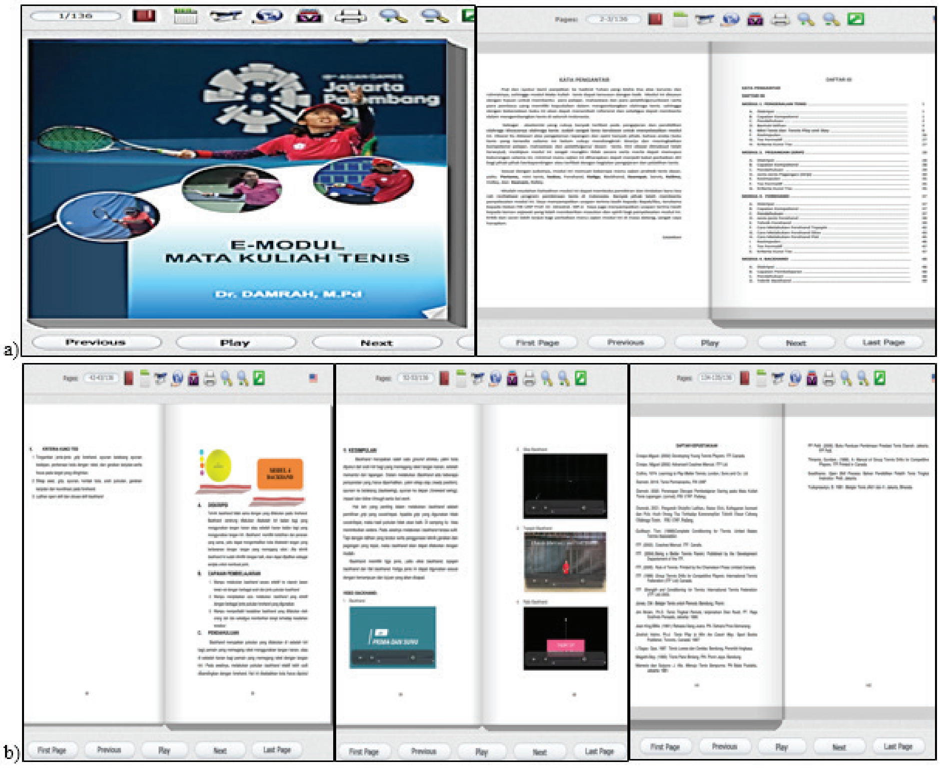


FIGURE 1. a) Cover, foreword, and table of contents; b) Learning materials, learning videos, and reference list

**Table 2.** Research instruments

| Aspect | Assessment items |
|---|---|
| Material experts (n=4) | The suitability of the title on the e-module. |
| | Introduction in e-module. |
| | Suitability of the material with the learning objectives (learning plan) |
| | E-modules are arranged systematically. |
| | The presentation of material in the e-module is arranged in a complete and easy-to-understand manner. |
| | E-modules are equipped with clear examples. |
| | The material presented in the e-module is adjusted to the needs of students (analytical skills). |
| | E-module contains supporting theories. |
| | E-module contains theories that do not conflict with social and moral values. |
| | The explanation in the e-module shows that its implementation is efficient in terms of time and is effective in increasing student learning motivation. |
| Language experts (n=4) | The language used in the e-module is very communicative. |
| | The message conveyed in the e-module is easy for readers to understand. |
| | The language used in the e-module is simple and precise in its use. |
| | The use of capital letters and lowercase letters in the e-module is correct. |
| | The terms and words used in the e-module are easy to understand. |
| | Sentences and paragraphs in the e-module meet the Indonesian language writing conventions. |

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**Table 2.** Research instruments

| Aspect | Assessment items |
|---|---|
| Media experts (n=4) | The appearance of the e-module is very interesting. |
| | The media components are appropriate. |
| | The size and color of the letters in the e-module are balanced. |
| | The typeface used in the e-module is easy to read. |
| | The appearance of text, tables, and images on the e-module is correct. |
| | The display for presenting material and videos on the e-module is correct. |
| Product practicability (n=35) | Suitability of the material with the learning objectives (learning plan). |
| | The presentation of the material is very practical and easy to understand. |
| | The language used is easy to understand. |
| | E-module is very interesting and increases learning motivation. |
| | E-module can improve the ability to learn tennis. |
| | E-modules can be used anytime and anywhere (online and offline). |

Note- The assessment was scored with the following points: very valid/practical (score 5), valid/practical (score 4), quite valid/practical (score 3), less valid/practical (score 2), and not valid/practical (score 1).

*Statistical analyses*

Inter-rater validity testing in this research was performed using Aiken's V validity coefficient (Aiken, 1985), while ICC (Cho, 1981) was used to measure the reliability. Then, the product practicality testing was analyzed with percentages (achievement score/maximum score*100%) (Firdaus et al., 2023). The classification for this assessment is presented in Table 3.

Aiken's: $V = \frac{\sum s}{n(c-1)}$

"V" is the rater agreement index, "s" is the score assigned by each rater minus the lowest score in the category, "n" is the number of raters, and "c" is the number of categories selected by the rater.

ICC: $ICC = \frac{\sigma_s^2}{\sigma_s^2 + \sigma_o^2 + \sigma_e^2}$

"σ2" is the measure of variation, "s" is the subject, "o" is the observer, and "e" is random error.

**Table 3.** Classification for validity, reliability, and practicality

| Validity | | Reliability | | Practicality | |
|---|---|---|---|---|---|
| Index V | Classification | ICC | Classification | Score | Classification |
| V < 0.4 | Low | > 0.80 | Very high | 81-100% | Very practical |
| 0.4 ≤ V ≤ 0.8 | Medium | 0.61-0.80 | High | 61-80% | Practical |
| V > 0.8 | High | 0.41-0.60 | Medium | 41-60% | Practical enough |
| | | < 0.41 | Low | 21-40% | Less practical |
| | | | | 0-20% | Not practical |

## Results

*Product validity*

This section provides information about the product's validity after being tested in several stages. Validity testing at stage 1, for example, obtained an average validity of 0.790 (medium), as shown in Table 4. Expert comments at the revision stage are presented in Table 5, and Figure 1 shows the final form of the resulting product. Then, validity testing after the product was revised in stage 2 generated an average validity of 0.904 (high) (Table 6). The differences in product validity tests before and after revision are presented in Figure 2.

**Table 4.** Testing the validity of stage one (before revision)

| Items | Material experts (n=4) | | | | s1 | s2 | s3 | s4 | ∑s | n(c-1) | V | Classification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | | | | | | | |
| 1 | 4 | 4 | 5 | 4 | 3 | 3 | 4 | 3 | 13 | 16 | 0.813 | High |
| 2 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 13 | 16 | 0.813 | High |
| 3 | 5 | 4 | 5 | 5 | 4 | 3 | 4 | 4 | 15 | 16 | 0.938 | High |
| 4 | 3 | 3 | 4 | 3 | 2 | 2 | 3 | 2 | 9 | 16 | 0.563 | Medium |
| 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 12 | 16 | 0.750 | Medium |
| 6 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 12 | 16 | 0.750 | Medium |

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**Table 4.** Testing the validity of stage one (before revision)

| Items | Material experts (n=4) | | | | s1 | s2 | s3 | s4 | ∑s | n(c-1) | V | Classification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | | | | | | | |
| 7 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 | 11 | 16 | 0.688 | Medium |
| 8 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 | 11 | 16 | 0.688 | Medium |
| 9 | 4 | 4 | 4 | 5 | 3 | 3 | 3 | 4 | 13 | 16 | 0.813 | High |
| 10 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 15 | 16 | 0.938 | High |
| | | | | | ẋ | | | | | | 0.775 | Medium |
| Items | Language experts (n=4) | | | | s1 | s2 | s3 | s4 | ∑s | n(c-1) | V | Classification |
| | 1 | 2 | 3 | 4 | | | | | | | | |
| 1 | 4 | 5 | 4 | 4 | 3 | 4 | 3 | 3 | 13 | 16 | 0.813 | High |
| 2 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 12 | 16 | 0.750 | Medium |
| 3 | 3 | 4 | 3 | 3 | 2 | 3 | 2 | 2 | 9 | 16 | 0.563 | Medium |
| 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 15 | 16 | 0.938 | High |
| 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 16 | 16 | 1.000 | High |
| 6 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 12 | 16 | 0.750 | Medium |
| | | | | | ẋ | | | | | | 0.802 | High |
| Items | Media experts (n=4) | | | | s1 | s2 | s3 | s4 | ∑s | n(c-1) | V | Classification |
| | 1 | 2 | 3 | 4 | | | | | | | | |
| 1 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 8 | 16 | 0.500 | Medium |
| 2 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 16 | 16 | 1.000 | High |
| 3 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 14 | 16 | 0.875 | High |
| 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 15 | 16 | 0.938 | High |
| 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 16 | 16 | 1.000 | High |
| 6 | 3 | 3 | 2 | 3 | 2 | 2 | 1 | 2 | 7 | 16 | 0.438 | Medium |
| | | | | | ẋ | | | | | | 0.792 | Medium |
| | | | | | ẋ (overall) | | | | | | 0.790 | Medium |

Note- "S" is the score assigned to each rater and subtracted from the lowest score in the category, while "V" is the agreement index of the rater.

**Table 5.** Expert comments

| Experts (N = 12) | Comment |
|---|---|
| Material (n=4) | E-modules need to be arranged systematically.<br>The e-module material needs to be completed.<br>Examples of the implementation of the e-module materials need to be completed.<br>E-modules should be tailored to the needs of students (online and offline).<br>The e-module material needs to be supplemented with supporting theories. |
| Language (n=4) | The message conveyed in the e-module should be improved to make it easier for readers to understand.<br>The language used in the e-module should be simplified.<br>Sentences and paragraphs in the e-module must comply with the writing rules. |
| Media (n=4) | The appearance of the e-module as a whole is more refined.<br>Views for presenting material are more refined. |

**Table 6.** Testing the validity of stage two (after revision)

| Items | Material experts (n=4) | | | | s1 | s2 | s3 | s4 | ∑s | n(c-1) | V | Classification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | | | | | | | |
| 1 | 4 | 4 | 5 | 4 | 3 | 3 | 4 | 3 | 13 | 16 | 0.813 | High |
| 2 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 13 | 16 | 0.813 | High |
| 3 | 5 | 4 | 5 | 5 | 4 | 3 | 4 | 4 | 15 | 16 | 0.938 | High |
| 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 12 | 16 | 0.750 | High |
| 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 16 | 16 | 1.000 | High |

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**Table 6.** Testing the validity of stage two (after revision)

| Items | Material experts (n=4) | | | | s1 | s2 | s3 | s4 | ∑s | n(c-1) | V | Classification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | | | | | | | |
| 6 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 16 | 16 | 1.000 | High |
| 7 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 15 | 16 | 0.938 | High |
| 8 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 16 | 16 | 1.000 | High |
| 9 | 4 | 4 | 4 | 5 | 3 | 3 | 3 | 4 | 13 | 16 | 0.813 | High |
| 10 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 15 | 16 | 0.938 | High |
| | | | | | ẋ | | | | | | 0.900 | High |
| Items | Language experts (n=4) | | | | s1 | s2 | s3 | s4 | ∑s | n(c-1) | V | Classification |
| | 1 | 2 | 3 | 4 | | | | | | | | |
| 1 | 4 | 5 | 4 | 4 | 3 | 4 | 3 | 3 | 13 | 16 | 0.813 | High |
| 2 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 16 | 16 | 1.000 | High |
| 3 | 4 | 5 | 4 | 4 | 3 | 4 | 3 | 3 | 13 | 16 | 0.813 | High |
| 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 15 | 16 | 0.938 | High |
| 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 16 | 16 | 1.000 | High |
| 6 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 15 | 16 | 0.938 | High |
| | | | | | ẋ | | | | | | 0.917 | High |
| Items | Media experts (n=4) | | | | s1 | s2 | s3 | s4 | ∑s | n(c-1) | V | Classification |
| | 1 | 2 | 3 | 4 | | | | | | | | |
| 1 | 4 | 4 | 4 | 5 | 3 | 3 | 3 | 4 | 13 | 16 | 0.813 | High |
| 2 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 16 | 16 | 1.000 | High |
| 3 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 14 | 16 | 0.875 | High |
| 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 15 | 16 | 0.938 | High |
| 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 16 | 16 | 1.000 | High |
| 6 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 12 | 16 | 0.750 | High |
| | | | | | ẋ | | | | | | 0.896 | High |
| | | | | | ẋ (overall) | | | | | | 0.904 | High |

Note- "S" is the score assigned to each rater and subtracted from the lowest score in the category, while "V" is the agreement index of the rater.

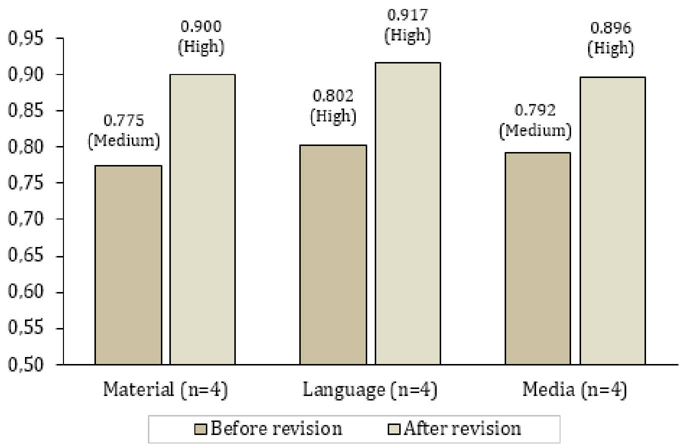


FIGURE 2. Differences and classification of validity levels before and after revision

*Product reliability*

As presented in Table 7, the average level of reliability is 0.754 (high). This means that raters in this research have no difference in assessing the product ($P<0.05$).

*Product practicality*

This research also measures how practical the product is. Table 8 indicates the average student response to the product (e-module), by 89.71 (very practical). The student responses to each item are presented in Figure 3.

## Discussion

The results of this product development show a difference in the average validity between before and after revisions, by

**Table 7.** Reliability testing

| Material experts (n=4) | ICC | Value | F test with true values | | |
|---|---|---|---|---|---|
| | | | df1 | df2 | P* |
| Single measures | 0.406 | 3.732 | 9 | 27 | 0.004 |
| Average measures | 0.732* | 3.732 | 9 | 27 | 0.004 |
| Language experts (n=4) | ICC | Value | F test with true values | | |
| | | | df1 | df2 | P* |
| Single measures | 0.444 | 4.200 | 5 | 15 | 0.014 |
| Average measures | 0.762* | 4.200 | 5 | 15 | 0.014 |
| Media experts (n=4) | ICC | Value | F test with true values | | |
| | | | df1 | df2 | P* |
| Single measures | 0.451 | 4.286 | 5 | 15 | 0.013 |
| Average measures | 0.767* | 4.286 | 5 | 15 | 0.013 |
| ẋ (ICC) | | | 0.754 | | |

Note- Average measures are the ICC values of each expert. There is no difference in assessment among experts (P<0.05).

**Table 8.** Product practicality

| Items | Answer score | N | Percentage | Classification |
|---|---|---|---|---|
| 1 | 150 | 35 | 85.71 | Very practical |
| 2 | 163 | 35 | 93.14 | Very practical |
| 3 | 169 | 35 | 96.57 | Very practical |
| 4 | 140 | 35 | 80.00 | Practical |
| 5 | 150 | 35 | 85.71 | Very practical |
| 6 | 170 | 35 | 97.14 | Very practical |
| | ẋ | | 89.71 | Very practical |

Note- Percentage is obtained from the achievement score/maximum score*100%. The maximum item score is 175, while the minimum item score is 35.

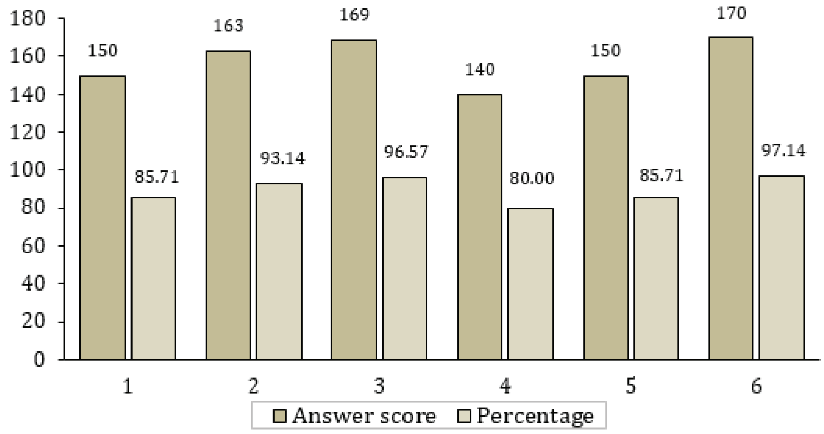


FIGURE 3. Answer scores and the percentage of each item

0.790 (medium) and 0.904 (high). Meanwhile, the average reliability was 0.754 (high). Then, the average product practicality was 89.71 (very practical). These scores imply that digital-based e-modules in tennis learning can be used for undergraduate sports education students. This e-module can be used online or offline, so it can be accessed anytime and anywhere (during and outside the course schedule) (Lu'mu, 2017). Using the e-module is expected to increase knowledge, collaboration with others, and learning experience (McQuiggan, McQuiggan, Sabourin, & Kosturko, 2015).

The learning media developed in this research has gone through the validity and reliability testing stages. These stages are fundamental and must be fulfilled (Rifki et al., 2022). According to some scholars, the minimum requirement for all developed instruments is to have content validity (Almanasreh, Moles, & Chen, 2019). Content validity is different from other types of validity. It describes what is required of the content of the instrument and is not related to the scores obtained on the constructs (Sireci & Faulkner-Bond, 2014). It is carried out by involving two or more assessors who are independently tasked with reviewing and evaluating the relevance of the content represented in the instrument (Wynd, Schmidt, & Schaefer, 2003).

On the other hand, the determination of reliability shows no differences in assessments (Robertson, Burnett, & Cochrane, 2013). As mentioned earlier, the ICC value was used to analyze the level of agreement between several raters (Koo & Li, 2016). These results were consulted to make improvements until an agreement was reached to produce a product in the form of a digital-based e-module in tennis learning for undergraduate sports education students.

The use of technology in learning is highly recommended to improve optimal learning outcomes. Previous studies reported that online instructional formats such as e-modules and computer-based simulation programs can improve knowledge (Sitzmann, Kraiger, Stewart, & Wisher, 2006) and promote opportunities for flexible learning at low cost (Dankbaar & Jong, 2014). Likewise, online teaching has better learning effects on tennis skills, knowledge of tennis theory, and academic performance compared with traditional teaching methods (Wang, 2021). Specific performance of the role of technology can be seen in designing learning activities, promoting the learning process, helping to solve students' psychological problems, and caring for the overall development of all students (Dascal et al., 2017). In this process, lecturers must try to raise student interest. The lecturers need to gain knowledge from students, while monitoring and correcting mistakes made by students in the learning process (Chen et al., 2022).

The development stage to product practicality has informed us about several limitations in this research. There were 12 experts involved according to their expertise, so a wider size of experts was needed to validate the developed product. In addition, product practicality involved 35 undergraduate students in sports education, so a wider sample size was needed. Then, this research suggests that the first and the second stages should be carried out with an experimental design to prove the effectiveness of the developed product. The stages need to be compared (for example, one of the basic tennis techniques contained in the e-module to prove its improvement).

## Conclusion

In conclusion, this research promotes the development of a product in the form of a digital-based e-module in tennis learning for undergraduate sports education students. This product development seems convincing since the average values of product validity before and after revision increase from 0.790 (medium) to 0.904 (high). In addition, other indicators also show strong support, such as the average reliability of 0.754 (high) and the average product practicality of 89.71 (very practical). Thus, digital-based e-modules can be used to teach tennis among undergraduate students in sports education. This research is hoped to facilitate undergraduate sports education students, lecturers, and tennis practitioners to overcome limitations in teaching tennis. Nevertheless, future research is still needed to test the effectiveness of the product. Experimental and comparison designs are two suggested options that subsequent researchers can use.

**Acknowledgments**:
The author would like to thank the Institute for Research and Community Service at Universitas Negeri Padang, Indonesia, for funding this research with contract number 803/UN35.13/LT/2021.

**Conflict of interest**:
There is no potential conflict of interest.

**Received:** 10 May 2023 | **Accepted:** 14 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240208

ORIGINAL SCIENTIFIC PAPER

# A Qualitative Study on Psychological Skills Training Experiences of Rapid-fire Pistol Athletes

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**Abstract**

The objectives of this study were twofold: (1) to help high school athletes who lacked psychological skills a) overcome psychological difficulties in practice and competition situations and b) reach peak performance, and (2) to understand the effects of psychological skills training on perceived performance of high school rapid-fire pistol athletes. By using a purposive sampling method, this study selected four male rapid-fire pistol athletes from the shooting team of H High School in the Republic of Korea, who were registered with the Korea Sports Federation in 2021. A psychological skills training program was applied for 10 weeks to the treatment group, and this study integrated and analyzed data collected through individual in-depth interviews and participatory observation to test the effectiveness of the program. It was confirmed that the subjects learned how to overcome psychological and physical tension and anxiety by actively applying the acquired psychological skills on the field and improved their confidence in specific skills by using the 10-week psychological skills training, in-depth interviews, and participatory observation. It was also found that the level of personally expected performance increased. These results showed that the psychological skills training program had a partial and positive impact on the perceived performance of high school rapid-fire pistol athletes. It is hoped that the results of this study will serve as a meaningful basis for the development and application of more scientific and systematic psychological skills training programs optimized for each individual while considering the psychological characteristics of athletes.

***Keywords:*** *psychological skills training, self-confidence, perceived performance, rapid-fire pistol athletes*

## Introduction

Psychological skills training is a systematic training program designed to help athletes achieve peak performance in competitive situations by equipping them with optimal psychological skills. Psychological skills consist of "all mental strategies and techniques needed to overcome the stress in sporting situations and maximize performance through the regulation of thoughts and emotions," and psychological skills training refers to "a training process that helps athletes obtain these self-regulatory skills so that they can perform at the highest level possible" (Chung & Kim, 1999). Psychological skills training is one of the major areas of interest of sports psychologists, and it has been the subject of ongoing study to find the optimal techniques for each sport while considering the unique characteristics of that sport.

Psychological skills have been studied in shooting sports as well. Chun (2010) conducted a single case study on elite shooting athletes and reported that athletes who had received psychological skills training had better psychological stability and improved ability to cope with crises, which led to increased self-confidence and improved performance. Ma (2011) also evaluated female national pistol athletes and revealed that athletes who had experienced psychological skills training showed significant differences in arousal control, pressure relief, achievement motivation, and self-confidence, which resulted in improved performance. Furthermore, a study by

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Kim and Shin (2010) found that psychological skills training improved the performance of shooting athletes with disabilities. In addition, a study by Jun, Kim, and Choi measured the results of neurofeedback psychological skills training using an electroencephalograph (EEG) signals and found positive results in shooting athletes. These studies suggested that psychological skills training could induce a positive psychological state in shooting athletes that could improve performance.

Coaches and athletes on the field have been focusing on finding the culprit in technical training alone (Jung, Kim, & Oh, 2017). As a result, they do not realize the importance of psychological skills training due to a lack of experience and knowledge. Consequently, even high school athletes, who are the future of Korean shooting, do not recognize the importance of psychological training and focus solely on technical training, which is problematic. Although most studies (Lee, 2004; Cheon, 2010; Ma, 2011; Jang, 2012) have examined adult athletes such as university and business team athletes, their research was limited to 10M air pistol athletes. Therefore, only a few studies have evaluated the application of psychological skills training to rapid-fire pistol athletes. Consequently, this study is intended (1) to help high school athletes who lacked psychological skills (a) overcome psychological difficulties in practice and competition situations and (b) reach peak performance, and (2) to understand the effects of psychological skills training on perceived performance of high school rapid-fire pistol athletes.

*The concept of psychological skills training*

In post-game interviews, athletes and coaches often state, "I lost it due to tactics and strategy" or "I was outperformed physically," but they just as frequently complain, "I couldn't concentrate until the last minute" or "I lost in mental strength." This means that while external factors such as physical fitness, tactics, strategy, and refereeing decisions are important, internal factors such as a player's psychological state also have a substantial impact on the outcome of a match.

Therefore, sports psychologists have sought to develop methods to enhance psychological skills to allow athletes to perform at their best in practice or competition situations. They have used various terms such as "mental training," "mental practice," "mental imagery," and "mental rehearsal" to describe training intended to improve psychological skills that influence athletes' performance. According to Vealey (1988), the term "psychological skills" refers to the ability to regulate one's psychological state through confidence, willpower, concentration, and motivation to perform at one's best. This can lead to positive changes, such as positive self-awareness, anxiety reduction, self-confidence, and stress coping. On the other hand, the expression "psychological methods" refers to training such as goal setting, mental imagery, focused attention, and routines to maintain the aforementioned psychological skills (Vealey, 1988).

*The importance of psychological skills training*

Many athletes experience various negative psychological factors (e.g., anxiety and decreased confidence and concentration) both before and during competition. These are triggered by a range of factors such as excessive greed, pressure, and fear of failure, and it is difficult to determine which factors have the strongest influence because they are internal to the athlete. Simone Biles of the United States, who won four gold medals in women's gymnastics at the 31st Olympic Games in Rio in 2016, was expected to win six gold medals at the 32nd Olympic Games in Tokyo in 2021. However, after performing poorly in the first event of the team final, she withdrew because she could not withstand the psychological pressure. It became a big topic. This is because she suffered from the "twisties" indicating a phenomenon in which an athlete loses their sense of direction due to tension (Lee, 2021). Many athletes choke because they fail to overcome such psychological difficulties.

Porter and Foster (1987) reported that psychological skills could determine at least 50% of the outcome of any sport and 80–90% of the outcome in such sports as tennis, golf, and figure skating. The results suggest that an athlete's physical condition is not the only factor determining the outcome of a match. Studies conducted in South Korea support this argument. For example, Lee and Yoo (2020) reported that the application of psychological skills training to high school swimmers positively affected their emotional state, sports performance strategies, and ability to overcome slump symptoms. In a single case study on golfers, Kim (2003a) found that psychological skills training improved players' concentration, lack of countermeasures against competition anxiety, poor emotional control, and lack of a detailed practice plan for competition. In a study of psychological skills training for archers, Hong (2005) found that it significantly improved their ability to control their mental images, positively affected their mental management and training management, and increased their performance.

Despite its proven effectiveness, psychological training remains neglected in the field due to structural problems such as lack of awareness and outcome mindset of coaches, as well as temporal and economic problems (Jung et al., 2017). In a study of middle and high school golfers, Lee (2015) found that only approximately 19% of the participants were receiving psychological training. Choi et al. (2021) examined players registered with the KLPGA and reported that approximately 90% of the participants were aware of the need for psychological training, but only approximately 14% participated in psychological training. These results are consistent with Kim (2003b), which revealed that more than 90% of the participants (national team athletes) wanted psychological skills training, but only approximately 16% participated in such training. Taken together, these studies show that most athletes recognize the need for psychological training, but the frequency of actual participation is very low.

## Methodology

*Study participants*

As subjects and participants, this study selected male rapid-fire pistol athletes from the shooting club of H High School in Seoul, South Korea, who were registered with the Korean Sports Federation in 2021. This study used a purposive sampling method, a nonprobability sampling method, which is suitable to evaluate the effect of applying psychological skills training to high school rapid-fire pistol athletes. We conducted the study after explaining the objective and content of the study to the coaches of the team and obtaining their approval. First, the coaches of the team recommended tenth- and eleventh-grade athletes who were considered to need psychological skills training, excluding twelfth-grade athletes who were stressed by the pressure of the college entrance exam. This study ultimately selected four athletes who agreed to participate in the study. The characteristics of the participants are shown in Table 1.

**Table 1.** Characteristics of Study Participants

| Subjects | Age (year) | Height (cm) | Weight (kg) | Athlete Career (year) |
|---|---|---|---|---|
| A | 17 | 168 | 54 | 1 |
| B | 17 | 172 | 60 | 1 |
| C | 18 | 180 | 80 | 2 |
| D | 18 | 183 | 103 | 2 |

*Psychological skills training program*

This study chose goal setting, routine, positive self-talk, relaxation, mental imagery, focused attention, and neurofeedback training as the main components of the program through a meeting of an expert group, which consisted of a professor majoring in coaching psychology, a Ph.D. majoring in sports psychology, a sports psychology Ph.D. student who was providing mental coaching, and the manager and coaches of the team to develop a suitable psychological skills training program.

*In-depth interviews*

This study conducted individual in-depth interviews (of approximately 10 minutes each) for each athlete immediately before and after the 10-week psychological skills training program to understand the personal psychological state of the four high school rapid-fire pistol athletes in greater depth. The collected pre- and post-interview data were used as the indices for the qualitative analysis conducted in this study. The in-depth interview used a semi-structured interview method, which combined the advantages of structured and unstructured interviews appropriately (Lee, 2018). The first half of the semi-structured interview asks mostly structured, organized, and systematic questions that are prepared by a researcher, while the latter half uses open-ended questions. As a result, it draws more in-depth, rich, free, and honest responses from an interviewee. The semi-structured interview is a stable interview format because it has a lower interview failure rate than the unstructured interview (Kim, 2015). However, a counselor must possess a certain level of interviewing skills because the semi-structured interview also requires counselors to strive to elicit more effective information based on the formation of human trust between counselors and clients (Kim, 2009). For this purpose, we watch videos related to psychological counseling and participate in seminars related to counseling, so that we can apply the techniques required for counseling in the field. This study used a semi-structured interview method and collected various responses to psychological skills training and related information from the athletes. The semi-structured interview questionnaire was prepared by modifying, supplementing, and reorganizing the interview questionnaires constructed by Park (2016) and Lee (2018) for this study. The interviews were recorded using a smartphone recorder (Samsung Galaxy Note 10) for storage and organizational purposes.

*Observation*

The participatory observation in this study was intended to closely identify all situations that could involve the subjects in the field and to evaluate the effectiveness of the application of psychological skills training (Shin, 2010). Therefore, this study actively drew on the researcher's experiences and feelings while closely observing and describing the training situation at International Shooting Range and the situation with respect to the surrounding members on the site. Participatory observation was conducted twice a week, using observations based on the situational circumstances of the field as data, and included observations from key players (e.g., coaches advising on technical aspects and teammates) (Seol, 2010). Moreover, if necessary, the main practice situations of the study subjects were filmed with a smartphone (Galaxy Note 10) and used as a reference to increase the validity and reliability of the observation analysis.

*Validity and reliability of data*

The design and analysis methods of a qualitative study can increase the validity and reliability of the study through direct participatory observation and in-depth interviews based on the researcher's honesty and exclusion of bias (Park, 2010). However, due to the nature of the method, the researcher's subjective judgment may be involved and have a decisive impact on the results (Jo, 2011). Therefore, studies must employ procedures to increase their validity and reliability (Jo, 2011). Accordingly, this study conducted multilateral verification, a review of the subjects, and an expert review to ensure the validity of the collected data and the analysis results during the study.

Several aspects to this approach are worth highlighting. First, multilateral verification is a process of drawing conclusions about the same research topic through various source materials, and it was an essential method for securing the validity of the data collected in this study (Shin, 2010). This study sought to confirm the consistency and increase the validity of the collected data (e.g., basic information about the subjects, in-depth interviews, participatory observations, and video recordings) by comparing and analyzing them. Second, the review of the subjects (inter-subject) refers to a review process that directly confirms the classification and interpretation of the collected data to the subjects (Sandelowski, 1993). This is a representative feature of the qualitative paradigm, which emphasizes the role of the study participants in the outcome of the study (Lincoln & Guba, 1985). It recognizes that study subjects understand the observed complex interactions better than the researcher and can provide some value in their interpretation (Lincoln & Guba, 1985). Therefore, this study asked the subjects to check the accuracy and error of the analysis results and interpretation of the collected raw data. Third, an expert review is a process to ensure the trustworthiness and unobtrusiveness of the data collected and derived while experts in the field conduct the study (Kim, 2009). Consequently, this study drew conclusions by correcting or supplementing results when an opinion contrary to the analysis results of this study was expressed in an expert meeting consisting of one professor majoring in coaching psychology, one Ph.D. majoring in sports psychology, one Ph.D. student majoring in sports psychology, and two coaches of the team.

Moreover, in a qualitative study, reliability is determined by the amount of time spent forming a rapport (Lee, 2004). Therefore, I first met the athletes while conducting educational service activities for the shooting club of H High School in January 2023 and continued to visit the International Shooting Range 2–3 times a week to form a rapport. In May, I went to H High School for a school practicum. Athlete C and Athlete D were students in my class, so I was able to have more conversations with them. I also made great effort to form a rapport with Athlete A and Athlete B by keeping in contact with them.

## Results

*Previous experiences with psychological skills training*

The transcript of the pre-in-depth interview revealed that most athletes were aware of the existence of psychological skills training, but they were not fully aware of its specific procedure and effectiveness. In addition, none of the athletes had ever experienced a formal psychological skills training program before participating in this study.

*Pre-interview about previous experience with psychological skills training*

*Researcher: Are you familiar with psychological skills training?*

*Athlete A: No. I don't know much about it.*

*Athlete B: Uh. I've heard of it, but I don't know exactly "what it is or how to do it."*

*Athlete C: I've heard of it, but I'm not sure what kind of training it is.*

*Athlete D: I've heard of it, but I'm not sure what it is...*

*Researcher: Have you ever received psychological skills training?*

*Athlete A: No, never.*

*Athlete B: I am sure if it qualifies for this. When I was in middle school, my coach once showed me some kind of video related to psychology. It was just like how to motivate, not how to train. It was something like that.*

*Athlete C: No. not at all. I've been wanting to get one for a while, and I'm so glad I got it this time. First of all, my parents liked it, too.*

*Athlete D: Uh, no, never.*

*Perceptions about tension and anxiety before psychological skills training*

The transcript of the pre-in-depth interview showed that every athlete experienced a variety of psychological difficulties in competition situations. The main symptom was tension, such as constantly thinking that something was wrong while performing, body stiffness, and body trembling.

This phenomenon was common during match firing among all athletes. Athlete A and Athlete D experienced nervousness or anxiety almost every moment of the main event, from the start to the end. Athlete B and Athlete C did not feel nervous or anxious as much during the eight-second and six-second series, but they experienced extreme nervousness and anxiety as they entered the four-second series. Participatory observation also revealed that, in general, before the four-second series, athletes continued to bounce the magazine spring or shake their legs habitually because their preparatory action became more urgent than the eight-second and six-second series. Athletes experienced nervousness and anxiety mainly because of fear of making a mistake, along with excessive greed for high scores and medals in competition situations.

*Pre-interview about tension and anxiety*

*Researcher: Do you experience nervousness or anxiety in practice or competition situations?*

*Athlete A: A little bit in competition. It is not too serious, but I think it depends on the situation.*

*Athlete B: Player B: Well, I think I am on the severe side. When I am in the line, my legs and arms are shaking, and my whole body is trembling a lot. I don't think I'm anxious or nervous in my head, but my body tells me differently. It's like my head and my body are working separately.*

*Athlete C: Not when I am practicing, but during a competition, I get a little nervous, so my body feels very unstable, and I often don't know what I'm doing.*

*Athlete D: Yes. I feel nervous and anxious during practice and competition about the same. So, when I'm about to shoot, my hands and my legs are shaking. It's a little bit worse in competition.*

*Researcher: When do you usually experience nervousness or anxiety?*

*Athlete A: I think I am like that before every series in the rapid-fire.*

*Athlete B: I experience it in practice when I'm shooting well. In competition, it is really bad during practice shots at the beginning, and it gets a little better during matching firing. Then, it gets really bad again before the four-second series.*

*Athlete C: I think I feel that most often before the four-second series. Even in a competition, I don't feel much anxiety during the eight-second series or six-second series, but I keep having those thoughts from the four-second load time, and my heart seems to beat a little faster.*

*Athlete D: It continues from before a competition until the end of it. I feel somewhat frustrated. It's kind of scary. Then it feels okay during practice shots, but when I get into the eight-second match firing, my heart starts palpitating again.*

*Researcher: In your opinion, what may cause you to experience emotions like nervousness and anxiety?*

*Athlete A: I think it's just because of "what if I make a mistake?" Yeah. I think it's because of a mistake because if I make a mistake, my score will drop a lot.*

*Athlete B: I think it's because of greed. Since I just want to shoot well, I care so much about my score. When I'm shooting well, I'm always nervous, and then I make one mistake or something, and then I get relaxed. When I shoot well, I think like "Oh, if I shoot like this, I'm going to make it to the finals" or "I'm going to get a medal." So I feel nervous and anxious about making a mistake. When I'm not shooting well, I don't feel anxious or nervous because I'm not thinking about that at all.*

*Athlete C: I don't know that. I just get nervous or anxious whenever I go to a competition. If I have to think about it, I think I get nervous because I try too hard to do well. As my manager and coach say, I just need to do what I can do, but when I go into a competition, I just think about the score instead of thinking about that.*

*Athlete D: I think it's because I'm afraid that I'm not going to shoot well. It's just the thought that I'm going to make a mistake. Oh, I think the biggest thing is that I'm going to misfire. I've been misfiring a lot in practice lately, and I did that in the first match of the year. I missed three shots, and it ruined the match. But I can't find the cause of it, and I have to have a good record next year to get into college! So I think that's what makes me nervous, too.*

*Perception of perceived performance before psychological skills training*

The transcript of the pre-in-depth interview indicated that most athletes perceived that their shooting skills were not at a high level. Specifically, they recognized that technical aspects such as firing and aligning the sight were lacking. In particular, participatory observation revealed that the athletes engaged in self-deprecating self-talk after shooting due to problems such as yanking the trigger or misfiring. Next, when asked about the level of performance they expected in a match situation, most of the players had low expectations. A small difference was apparent between tenth-grade and eleventh-grade athletes: tenth-grade athletes expected between 530 and 540 points, while eleventh-grade athletes expected between 540 and 550 points. Moreover, they had lower expectations for the four-second series than the other series.

*Pre-interview about perceived performance factors*

*Researcher: How would you rate your shooting skills?*

*Athlete A: I don't think it's too bad, but my scores fluctuate because I keep yanking it when I'm firing. So I think my firing is kind of bad.*

*Athlete B: I don't think I'm good at rapid-fire. Since I won an individual medal in air rifle this time, I have a lot of confidence in my performance. But a rapid-fire game is a bit difficult because I haven't even been to the finals yet. So I don't think I'm technically good or high.*

*Athlete C: I don't think my skills are good. I originally thought I was good at aligning my aim and keeping my eyes on the target, but lately, I've been losing my eyes a lot, so I've lost confidence in my skills.*

*Athlete D: I think I'm just average. I don't think I'm really good at anything.*

*Researcher: What level of performance do you expect from yourself in a competitive situation?*

*Athlete A: I don't expect much for rapid-fire. Maybe in the 30s or 40s? I don't have any record expectations.*

*Athlete B: I think I expect the 40s. I don't think I can have better because I am not good at the four-second.*

*Athlete C: I don't think it's that high. I think it's in the 40s or 50s. I think the 40s or 50s is like "Well, I can shoot at least this."*

*Athlete D: I think I can shoot in the 40s. I think I can shoot about 95 in the eight-second and six-second, but the four-second is the issue. If I shoot about 88 in the four-second, I feel like I've done a good job.*

*Perceptions of tension and anxiety after psychological skills training*

According to the transcript of the post-in-depth interview, all the athletes indicated that psychological skills training helped them to control their fears when shooting. Despite their inability to completely control their fears, they were able to overcome some of the nervousness and anxiety they experienced in certain situations. Relaxation training and routine training were the most frequently applied skills that athletes used to overcome these psychological difficulties during psychological skills training. Specifically, Athlete B and Athlete C said that when they conducted relaxation training while shooting, their bodies became more relaxed and calmer to make their swing movements smoother and allow them to move as intended. Athlete D said that by paying attention to and following the routine he had developed, he was able to eliminate his anxiety about misfiring, which had been a problem for him. Participatory observation also confirmed this. For example, the athletes practiced their own pre-shooting routines or relaxed by closing their eyes or fixing their gaze on a single point after loading live ammunition and before raising the gun.

*Post-interview about competitive anxiety*

*Researcher: Did the psychological skills training help you control your fears, such as nervousness or anxiety?*

*Athlete A: Yes, I think it does work. I used to tremble a little bit and was nervous when I was looking at that red light before my first shot, but now I feel a little bit more relaxed.*

*Athlete B: I think it has really helped me a lot. I don't think that psychological training can eliminate anxiety or nervousness completely. But as I know what to do in those situations after the training, it's literally made me realize that I can mitigate it to a certain extent. In particular, my arms and legs tend to shake a lot before I shoot, and I think that I can tremble a little bit less by thinking about what I've learned in the psychological training and preparing myself calmly.*

*Athlete C: Yes, I think it has really helped me a lot. Even in practice, I was fine at the eight-second and the six-second, but my body was shaking a little bit before shooting the four-second. But after the psychological training, I got rid of a lot of nervousness when shooting the four-second. Frankly speaking, my biggest problem was shaking at shooting the four-second, but once I solved it, my record kept going up. Nowadays, I keep shooting in the 60s. So it's too bad that the competition is canceled for the second half.*

*Athlete D: Yes. It has been helpful. I think it helped me get rid of my anxiety about misfiring.*

*Researcher: Have you ever applied (or do you think you can apply) the psychological skills training you learned to overcome emotions such as nervousness and anxiety in practice and competition situations?*

*Athlete A: I've been using that positive self-talk while shooting. Oh, the routine as well. I've been paying attention to the post-shot routine, and I think that even if I'm nervous in a competition, as long as I stick to the routine, I'll be able to do well.*

*Athlete B: I've been practicing what I learned in the relaxation training every day. Even if I'm not necessarily nervous or anything like that, sometimes when I'm shooting, my hands and arms can get really tense. I just relax them when it happens. Then, my swing gets much smoother because I'm not tensing up. I don't know if I can do it in the competition, but I think I can do it to some extent.*

*Athlete C: Yeah. I continue to do the relaxation and routine in practice. I check it every day by keeping a journal so that I can do the things I do in practice like a habit when I go out to compete. I perform the relaxation activity, focusing on the abdominal muscles, before raising my gun in the line. I feel that my stomach is more comfortable when I raise my gun afterward. My body becomes calm, and my initial swing is right in the center. I continue to do the routine in this way, and I think I can shoot well if I apply it in the competition.*

*Athlete D: Yes. I practice the routine that I made for loading during the routine training during the practice. When I do that, the anxiety about misfiring disappears, so I try to shoot while just thinking about the routine during the competition like in practice. And when I relax and raise my gun, it seems my legs and hands don't shake. I didn't know it before because I did not know, and I think I can do it easily during the competition.*

*Perceived performance after psychological skills training*

The transcript of the post-in-depth interview showed that all the athletes had increased their belief and confidence in their shooting skills. In particular, the pre-interview revealed that most athletes were quite intimidated by firing, but after the psychological skills training, their belief and confidence increased, and it even became their strength. Furthermore, the transcript showed that their expectations that they could demonstrate their desired performance in the competition situation had increased. Even though the pre-interview indicated that they had low expectations or that their actual performance was poor despite high expectations, most athletes' expectations increased after the psychological skills training was completed. Moreover, expectations that they would be able to perform at a corresponding level increased simultaneously. Specifically, Athlete B and Athlete C stated that they would perform at the level of their expectations even in the competition, and Athlete D stated that his expectations had increased drastically and that he would no longer have outrageous records.

*Post-interview about perceived performance factors*

*Researcher: Did you notice any changes in your belief or confidence in your shooting skills after the psychological skills training?*

*Athlete A: Yes, I think it's increased: my goal was to fix yanking when firing, and it's gotten a lot better. So I think I have a little more confidence in my firing now.*

*Athlete B: Well, I wasn't that bad at firing. You know, firing is really important in rapid-fire. I tried to focus on the basic actions when firing during this psychological training. I became more confident in my firing, and that's why my score went up.*

*Athlete C: The thing I was most confident in was aligning the sight, but I couldn't do it well after the Changwon Mayor's Cup. During the focused attention training, I looked for distractions and realized what I needed to do to keep my eyes on the target. Then I gained my confidence again about that part.*

*Athlete D: I wasn't confident in firing at all because of misfiring, but now I think I've gotten a lot better. I rarely misfire now since I am shooting with the idea that I'm just going to hold it boldly and just let it go on my timing.*

*Researcher: Do you think you will be able to perform as well as you expect in future matches?*

*Athlete A: I don't know for sure until I play a match, but I think I'll be able to shoot better than I did in the first half. I think I'll shoot in the 50s.*

*Athlete B: Well, I think my expectations have been raised a lot. I think it'll be at least come close to the record I'm thinking of right now.*

*Athlete C: Yes. I think that if I compete now, I'm not going to shoot so much worse than my expected score like before. I think I'm going to score close to my expectation. I think I'm going to be able to shoot in the 50s.*

*Athlete D: Uh, I don't think it's going to be easy to shoot the same score that I shoot in practice, because I'm shooting so well in practice now. I don't think I'm going to get a ridiculous score or anything like that. I just feel like I'm going to be easily qualified for the final.*

*A comprehensive review of psychological skills training*

The transcript of the post-in-depth interview revealed that the routine training was the most helpful program for the athletes, followed by the relaxation training after the psychological skills training. This was also confirmed by participatory observation: the athlete put a sheet of paper that recorded their routine on the line and looked at it before shooting and engaged in relaxation exercises with their arms crossed and eyes closed before attention after loading. Among the routines, the one-minute post-load routine was the most beneficial. As they repeatedly performed the routines that they had developed, athletes corrected bad habits with respect to certain skills and improved their confidence. The relaxation training also had a positive impact on their performance because it relieved some of the physical tension they experienced due to fear or anxiety in certain situations. They said that they wanted to make it a habit by making efforts, such as continuously recording it so they could check it easily on their own, to continue to apply programs that had been helpful for them.

*Post-interview on the experience of psychological skills training*

*Researcher: Which psychological skills training program helped you the most or was the most memorable?*

*Athlete A: To me, they were the positive self-talk and the routine. I used to get mad when I missed a shot. I was looking for excuses or something to blame. But as I learned from the self-talk training that bad thoughts didn't help at all, I tried to change my thoughts positively, and it made me feel better, and it seemed I could shoot better. And, as I made a routine, it felt new every time I shot a series. So I could concentrate better, and it felt good.*

*Athlete B: Well, the relaxation training and the routine training were memorable, but actually all the rest of them were good. The relaxation training helped me the most. As I said before, when I'm nervous, I shoot with a lot of force in my hands and arms. But then I thought about what you taught me last time, and I thought it was funny because when your body was nervous, your muscles would contract, and I was just trying to make them contract even more. So now I try to relax when it happened, and it really helped me a lot. I had a routine before, but it was a very simple routine before the psychological training. Then after the psychological training, I made my own perfect routine. I think it will be really helpful in the future, especially the pre-load routine.*

*Athlete C: I really liked the relaxation training and the routine training. When I'm nervous, I feel like my body just stiffens up, and I'm so nervous that I can't align my aiming line well. When I repeatedly tighten and release my abdominal muscles, it seems to loosen my body a little. After I learned that famous players generally had a routine, I participated in it very hard. In particular, the loading routine was really helpful. I feel like I can shoot well if I just pay attention to this.*

*Athlete D: The routine and the mental imagery training. First of all, I think the routine fixed my bad habits. Once they were* *fixed, I didn't misfire any longer. Then my coach touched my firing to make it smoother, and my score went up by a lot. Mental imagery did not show a clear effort or something, but I can see that my alignment is moving when I'm at a shooting range or dozing off on the subway. But it felt perfect, and it had the feeling of 10 points just there. Even when I'm shooting at the line, I feel good when I think about that. Uh, I also liked the relaxation training.*

*Researcher: How will you continue to practice the training program that helped you?*

*Athlete A: You know, I can do the positive self-talk and the routines even during training. I'm going to keep trying to do this. And I'm going to make a card and put it in the gun case so that I don't forget. When I shoot, I'm going to take it out and read it whenever I fire.*

*Athlete B: I do relaxation training every day before I go to bed, in bed. I'm going to keep doing that. I'm checking the routine as I'm shooting. I'm writing it down on my phone to make sure I'm doing it right. Before daily training, I read what I wrote the day before and then start practicing. I'm going to keep doing that.*

*Athlete C: First of all, I'm going to write a journal for the routine practice every day to check it because I can cope with that situation during the game only when I keep checking my routine when I shoot well or poorly. And for relaxation, I tense and release my arms and abs after I load the gun and before raising it. I'm going to do the same thing when I go to the match.*

*Athlete D: I'm going to keep doing the routine and the relaxation because I can do it even when I'm shooting. I don't think I'm going to practice mental imagery consistently, but I'll try to do it once in a while.*

## Discussion

This study qualitatively analyzed the perceived performance of high school rapid-fire pistol athletes due to the psychological skills training program they received and found significant differences. These results suggested that the psychological skills training program increased athletes' perceived performance, which was consistent with the results of studies (Yang et al., 2015; Lee, 2018; Lee & Ryu, 2020) that showed the positive effect of psychological skills training on athletes' perceived performance.

The qualitative analysis results of perceived performance revealed that most of the athletes were aware of problems with their shooting skills (pre-interviews), and as a result, they did not rate their performance highly. In particular, three out of the four subjects were top-ranked air pistol athletes; they had great confidence in certain techniques related to air pistol. However, participatory observation confirmed that they lacked confidence in shooting in the rapid-fire pistol game. When asked about their performance expectations in a competition situation, most of the athletes indicated that their performance level was low. They expected a score between 530 and 550 points. In the same event, expected scores differed between tenth-grade athletes and eleventh-grade athletes, likely due to the different levels of experience in the rapid-fire pistol game between the two grades. Given that the athletes in this study had only one or two years of experience in the sport, one may question whether these results were a consequence of the psychological skills training program or a natural outcome of their development.

Park (2013) applied a psychological skills training program to adolescent billiard players with approximately two years of experience and found that the treatment group had significantly better arousal control, anxiety control, attention, and confidence than the control group. Kang (2016) applied a psychological skills training program to secondary school shooters with approximately one year of experience and found that the treatment group showed significantly better sports psychological skills such as goal setting, mental imagery, and anxiety control than the control group. Kim (2018) also evaluated the effect of a psychological skills training program by the length of dancing experience using high school dance majors. Kim (2018) reported that such a program decreased the level of cognitive and physical anxiety in both beginner (1–2 years of experience) and advanced (5–7 years of experience) groups, but it increased perceived performance only in the beginner group. These results suggest that psychological skills training can have a positive impact even on inexperienced athletes and that its effect may vary because athletes have different psychological skill levels depending on their experience.

Yun (2008) reported that the more experienced athletes had higher levels of psychological skills such as arousal control, self-confidence, and mental image control, which was supported by Lee and Yoo (2011), who analyzed the differences in sports psychological skills among yacht athletes and found that the more experienced athletes had higher levels of psychological skills. Considering the results of other studies, it cannot be ruled out that the effect of psychological skills training may be lower for more experienced athletes because they would have higher levels of psychological skills. Moreover, it is possible that less experienced athletes, such as the subjects of this study, benefit more from psychological skills training because they have lower levels of psychological skills. Therefore, it is believed that the results of this study reflect the effect of psychological skills training, rather than the naturally improved performance of inexperienced players.

The post-interview after 10 weeks of psychological skills training showed an overall increase in the athletes' belief and confidence in their shooting skills. In particular, it was observed that athletes' confidence in their shooting skills decreased due to technical problems such as misfires, misses, and lost alignment before treatment, but they became more confident in their shooting skills after treatment. It can be inferred that the athletes learned how to overcome the psychological difficulties through the psychological skills training program and actively applied them in the field. In addition, when asked whether they would perform as expected in a competition, most of the athletes answered that they would perform as expected, which confirmed that the program induced a positive change in their belief and confidence in their performance. Compared to the pre-interview, the expected performance of the athletes increased. It is believed that the athletes' confidence increased because, unlike previously, their mental state did not collapse in certain situations in which they experienced psychological difficulties and that they calmly overcame those difficulties by applying the psychological skills they had acquired.

Nevertheless, this study confirmed through the pre-in-depth interviews that no participants had knowledge of and experience with psychological skills training. It is believed that most student-athletes are likely to be constrained from participating in psychological skills training for reasons (e.g., time and cost) suggested by previous studies (Heo & Park, 2010;

Choi et al., 2021). Although studies have already proved both the importance and effectiveness of psychological skills training programs by developing and applying them scientifically and systematically, these programs have not been widely used in the field. Moreover, even though psychological skills training can be implemented efficiently when a counselor has a thorough knowledge of the sport and considerable experience, and athletes also value the counselor's expertise and field experience (Lee, 2021), the number of coaches with both expertise and experience is seriously lacking. Therefore, it is hoped that future studies will prepare plans and measures to overcome challenges required for the field application of psychological skills training and that elite athletes will be cultivated in line with contemporary trends.

Taken together, these findings suggest that the psychological skills training program contributed to an increase in the perceived performance of high school rapid-fire pistol athletes. However, this study could not determine the effect of perceived performance on actual performance because competitions were postponed or canceled due to COVID-19. Therefore, future studies need to evaluate the effect of increased perceived performance on the actual performance of rapid-fire pistol athletes.

## Conclusion

The qualitative analysis of this study confirmed that the 10-week psychological skills training program helped the rapid-fire pistol athletes learn how to overcome psychological challenges and increased their belief and confidence in their shooting skills and performance. However, cultivating elite athletes is still difficult due to the narrow-minded perspective in the field, which tries to situate the cause of poor performance in skills training alone. Therefore, it is necessary to break away from the obsolete mindset of the past; recognize the importance of psychological skills; and seek ways to provide systematic education and training for student-athletes, who represent the future of elite sports. In this sense, this study makes recommendations for future studies as follows.

First, it is difficult to generalize the given results because this study evaluated only four high school rapid-fire pistol athletes and applied a psychological skills training program. College and general athletes with more experience and excellent performance may be experiencing different types of psychological difficulties than less experienced high school athletes. Therefore, future studies need to develop and apply a psychological skills training program suitable for college and general athletes and analyze its effectiveness systematically.

Second, this study carried out a psychological skills training program consisting of goal setting, positive self-talk, routine, relaxation, mental imagery, and focused attention for 10 weeks. Since the period was relatively short, the study did not consider the individual implementation level of the subjects while providing many psychological techniques. In the post-in-depth interviews, participants almost universally mentioned that two techniques were the most helpful, suggesting that the positive results might be a function of program quality rather than quantity. Therefore, future studies should try to analyze the effects of one or two more sophisticated and applied psychological skills training programs according to the individual characteristics of the subjects.

Third, this study did not examine the effect of psychological skills training on performance, which was one limitation of the study. It was found that the performance of three athletes except for Athlete B improved after the psychological skills training program when competition results were compared before and after the program. However, it is difficult to conclude that the increased performance was due to the program because the competition, which was scheduled immediately after the end of the program, was postponed until about 60 days after the treatment due to COVID-19. Therefore, future studies need to analyze the effect of a psychological skills training program by comparing the performance of the athletes immediately after the treatment and whether that program is continued.

**Acknowledgments**
There are no acknowledgments.

**Conflict of Interest**
The author declares that there is no conflict of interest.

**Received:** 11 January 2024 | **Accepted:** 23 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240209

ORIGINAL SCIENTIFIC PAPER

# Physical Fitness Status of Tertiary Students under the New Physical Activity towards Health and Fitness (PATHFit) Course: A Quasi-Experimental Study

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**Abstract**

According to the latest findings of the World Health Organization (2022), most young people nowadays are deficient in fulfilling the global standard for moderate- to vigorous-intensity physical activities. Concurrently, the issue of girls being less active than boys in most countries, including the Philippines, remains. To address this health issue, the Philippines' Commission on Higher Education (CHED) implemented the new Physical Activity Towards Health and Fitness (PATHFit) Courses. Thus, this study aimed to evaluate existing program models that focused on developing students' cardiorespiratory and muscular fitness. An exercise model underwent a quasi-experimental analysis using three fitness tests: Prone Bridge Test (PBT), 3-minute Step Test (STEP), and Wall Squat (WS). Results revealed that participants showed significant improvement after the 12-week fitness program, with $p<0.01$ in PBT, STEP, and WS scores. However, while differences in means were all significant (N=155), Cohen's d results show that small to medium effects occurred for the three performance test scores after the treatment period. Effects also showed that female participants still exhibited lower effect magnitudes. These findings recommend developing innovative exercise models incorporating health motivation and gamification. It is also suggested that tertiary PE consider modified models for female students, addressing their sports fitness needs and attraction to sports participation. Lastly, the Philippine Commission should vigilantly endorse tertiary program models following the availability of exercise and sports scientists in institutes, effectively implementing PATHFit on the ground and improving the overall sports fitness of students.

***Keywords:*** *physical fitness, physical activity, physical education, fitness exercise, cardiorespiratory endurance, muscular fitness*

## Introduction

Physical fitness (PF) is a "physiological state of well-being that provides the foundation of the tasks of daily living, a degree of protection against chronic disease, and a basis for participation in sport" (Bakinde, 2022, p. 124). It entails the execution of moderate to vigorous physical activities that "allow the body to respond or adapt to the needs and stress of physical effort" (Guidangen, 2016; Bakinde, 2022) without being quickly exhausted (Guidangen, 2016; Nurhasan et al., 2020; Bakinde, 2022). It helps avoid heart-related diseases,

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cancer, diabetes, and others (Bakinde, 2022).

Even if it is expected for young people to lead more active lives because of their play and recreational activities, both at home and school, surprisingly, the World Health Organization (2022) still found that 81% of boys and girls aged 11 to 17 years spend less than one hour a day doing moderate- to vigorous-intensity physical activity (PA). Moreover, "more girls are inactive (85%) than boys (77.6%) in most countries" (p. 8). In Asia, in particular, this situation could be attributed to the fact that promoting PA is not a priority in Asia's low- to middle-income countries, such as the Philippines (Lee et al., 2023). Cagas et al.'s study (2022) on the PA level of young Filipinos found that their PA is rated as F or the lowest out of the 16 countries that joined the Global Matrix 4.0 compilation.

Most studies found that students have insufficient levels of PA and PF (Bora & Dutta, 2020; Nurhasan et al., 2020; Osipov et al., 2021; Xia et al., 2021; Kyrychenko et al., 2023). These were attributed to the inefficiency of the existing Physical Education (PE) Program (Prontenko et al., 2019), lack of sports participation and sedentary lifestyle (Bora & Dutta, 2020), and lack of awareness of the importance of physical exercise and proper nutrition (Guidangen, 2016). Only three studies have revealed favorable results; two were from the Philippines (Giron, 2011; Kim & So, 2018; Pituk & Cagas, 2019). Some studies also found no difference in the PF level of male and female young adults (Guidangen, 2016; Kim & So, 2018; Xia et al., 2021), while others found that males have better PF levels than females (Cheng & Ting, 2011; Ribeiro et al., 2013; Pituk & Cagas, 2019).

With the abovementioned alarming results on young adults' PF status at present, studies recommended that more information and attractive physical activities for them (Cheng & Ting, 2011; Multani, Bhawna, & Singh, 2013), especially young female adults (Pituk & Cagas, 2019; Osipov et al., 2021) be provided in their PE classes.

Only three studies on this topic have been conducted in a Philippine university context. Also, none of the studies conducted an experimental study on the interventions to improve the PF status of the students in a PE class. Most of them were descriptive (surveys) and cross-sectional studies. Also, most studies offered generic explanations of the cause of the decline of young people's PF levels, and the recommendations for addressing this pressing health issue were not very context-specific.

Also, while there have been continued efforts to increase the PA and decrease the sedentary behavior of students locally and abroad, many of these programs are not sustainable. Thus, there is still a need for measurable and systematic PE programs that educate and motivate more young people to engage in more PA and appreciate and live an active and healthy lifestyle to improve their PF (Singh et al., 2013; Cagas et al., 2022; Shakya et al., 2022; Lee et al., 2023).

The decreasing trend in PA and PF among children has become a threat to the level of higher education physical education. The Commission on Higher Education (CHED) in the Philippines recognized this and introduced new guidelines for implementing the Physical Activity Towards Health and Fitness (PATHFit) courses. Its direction is to integrate fitness engagement with sports participation, social interaction, and diversity of movement. One of the program's objectives is to address the deficiencies in fitness levels so students may be ready for sports- or recreation-specific education, which students will bring along with them for lifelong fitness. The program has three phases, namely the drill-based or movement competency phase (PATHFit 1), exercise-based or fitness phase (PATHFit 2), and sport-specific and recreational-based education (PATHFit 3 and 4).

As the new framework implementation begins, several exercise program prototypes emerge primarily based on the feasibility of their application per institute. Thus, this study aims to evaluate how a fitness program model influences the fitness testing scores of students in a school setting, particularly in core strength, aerobic, and muscular fitness tests. Anthropometric measurements will also be collected and included in the analysis of certain health variables. It is hypothesized that the structured program will direct positive changes in fitness test scores after the intervention, and results will be delimited to cardiorespiratory and muscular fitness components only. This study can possibly contribute to an evidence-based advancement of the tertiary PE programs in the Philippines and countries with sports education models.

## Method

*Participants and Ethics*

One hundred fifty-five (N=155) Physical Education students participated in this quasi-experimental study, including 88 males and 67 females, with a mean age of 18.79±0.9 years, all officially enrolled in a private university in Manila. Subjects were screened through the Physical Activity Readiness Questionnaire (PARQ) and by the university physician to ensure they were healthy and activity-safe research participants.

Twenty (20) students, 11 males and nine females, were excluded from the study due to any of the following conditions: (1) not compliant with the pre-requisite course (PathFit 1 – Movement Competencies); (2) has vices such as smoking or drinking alcohol; (3) healing from or under medication due to cardiovascular ailments, injuries, or fracture; (4) athletes or member of any sports club in the university; and (5) transferee from other schools due to possible curriculum mismatch.

This study was approved by the San Beda University Research Ethics Board (SBU-REB). The committee has approved SBU-REB 2022-006 No. 11-11 under the expedited category. The students were asked to sign an informed consent form that indicated their willingness to undergo the study. The data gathered were only accessible to the students and the researchers and were kept in a safe online repository. They will not be shared with anyone and will be retained until the study is published.

*Research Design and Procedures*

This study using a One-Group Pretest-Posttest Design determined the significant difference between the results of the tertiary students' PF pre-and post-tests and examined if the progressive exercise model influences the core strength, aerobic, and muscular fitness test outcomes.

The participants' age, height, weight, waist, and hip were taken by the university physician and a nurse. An orientation was facilitated as a pre-participation briefing for research participants, which explained the schedule, study process, exercises, and risks for physical activity before the accomplishment of the PARQ and physician's clearance. Qualified participants then proceed to fitness test demonstrations. Body Mass Index (BMI) and Waist-Hip Ratio (WHR) were computed as participants' anthropometric health-related scores.

Next, the university physician, Sports Science teacher, and cardiologist supervised the implementation of the pre-test protocols using the following tests.

*Prone Bridge Test or PBT*

This aims to test the student's core stability by holding a position with the upper body off-the-ground, elbows and forearms as the base of support, and legs straight down to the toes where the weight is also supported. The head is facing toward the ground, and as the stopwatch starts, the subject maintains the position until unable to hold back and the hips are straight (Bohannon et al., 2018).

*Wall Squat or WS*

This measures isometric leg endurance, requiring students to warm up for 5 to 10 minutes. They will assume a sitting position with their back against the wall, hips, and knees bent 90 degrees. The duration of the wall sitting will be measured using a stopwatch (Biscarini et al., 2020).

*Three-Minute Step Test or STEP*

This assesses the aerobic fitness level based on the standard and guidelines published by the Young Men's Christian Association (YMCA) and recently validated in Kieu et al.'s study in 2020.

A 12-week structured exercise program (see Table 1) was implemented as the study's independent variable. It was hypothesized to improve participants' lower body strength, core strength, and cardiovascular endurance. The progression in intensity, variety, and difficulty levels were gradually increased according to the model. Specific workouts were adopted from common exercises and the implementation guidelines set by the National Strength and Conditioning Association (Baechle & Earle, 2008). Lastly, the post-test was administered with identical conditions and protocols as the pretest.

**Table 1.** The 12-Week Cardiorespiratory and Muscular Fitness Progressive Exercise Model

| PHASE 1 | Week 1 | | | Week 2 | | | Week 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| MODERATE<br>60 – 70 maximal heart rate | No. of Set(s) | No. of Rep(s) | Rest (Secs) | No. of Set(s) | No. of Rep(s) | Rest (Secs) | No. of Set(s) | No. of Rep(s) | Rest (Secs) |
| 1. Sit to stand<br>2. Seated hip hinge<br>3. Assisted lunge<br>4. Bird Dog (arm & leg moving up-do<br>5. Assisted lunge<br>6. Up and down plank<br>7. Inclined burpees | 3 | 8 | 30 | 3 | 10 | 30 | 3 | 12 | 30 |
| PHASE 2 | Week 4 | | | Week 5 | | | Week 6 | | |
| MODERATE<br>60 – 80 maximal heart rate | No. of Set(s) | No. of Rep(s) | Rest (Secs) | No. of Set(s) | No. of Rep(s) | Rest (Secs) | No. of Set(s) | No. of Rep(s) | Rest (Secs) |
| 1. Normal squats<br>2. Good mornings (leg exercise)<br>3. Split Squats<br>4. Bird dog (arm and leg – moving sideways)<br>5. Side lunge<br>6. High planks with shoulder tap<br>7. Gentle burpees | 3 | 8 | 30 | 3 | 10 | 30 | 3 | 12 | 30 |
| PHASE 3 | Week 7 | | | Week 8 | | | Week 9 | | |
| MODERATE TO VIGOROUS<br>60 – 90 maximal heart rate | No. of Set(s) | No. of Rep(s) | Rest (Secs) | No. of Set(s) | No. of Rep(s) | Rest (Secs) | No. of Set(s) | No. of Rep(s) | Rest (Secs) |
| 1. Narrow – wide squats<br>2. Half kneeling 1- leg straight hip hinge<br>3. Reverse lunge<br>4. Bird dog (knee to elbow contralateral)<br>5. Courtesy lunge<br>6. Contralateral planks<br>7. Baby burpees | 3 | 8 | 30 | 3 | 10 | 30 | 3 | 12 | 30 |
| PHASE 4 | Week 10 | | | Week 11 | | | Week 12 | | |
| VIGOROUS<br>60 – 100 maximal heart rate | No. of Set(s) | No. of Rep(s) | Rest (Secs) | No. of Set(s) | No. of Rep(s) | Rest (Secs) | No. of Set(s) | No. of Rep(s) | Rest (Secs) |
| 1. Single leg sit to stand-pistol squats<br>2. Single leg - romanian deadlift<br>3. Front lunge<br>4. Bird dog (knee to elbow unilateral)<br>5. Elevated side lunge<br>6. High planks with trunk rotation<br>7. Hop squat burpees | 3 | 8 | 30 | 3 | 10 | 30 | 3 | 12 | 30 |

*Statistical Treatments*

The ratio type of data acquired from the tests, PBT, STEP, and WS, were analyzed using the Wilcoxon Signed-rank Test, calculating the W value from the pre-test and post-test scores of the participants. The significant differences in the means of anthropometric data were also examined using the same statistical test. On the other hand, Cohen's d was used to analyze the magnitude of the 12-week program's effect on the mentioned variables and performance scores. GNU PSPP (2015) was the program used in analyzing the gathered quantitative data.

## Results

The following results were revealed after the 16-week implementation of the progressive exercise and testing. Figure 1 shows the dynamics of score change from the pretest results and after the 12-week progressive model. BMI and WHR scores were derived from the anthropometric measurements of participants, which were post-measured after the treatment period. BMI scores showed a 0.19 difference, from 23.22 before the exercise involvement to 23.03. WHR also scored less than 0.867, a 0.005 difference from the pretest. Both measures are considered to be optimal, if not near, according to the WHO standards (2011).

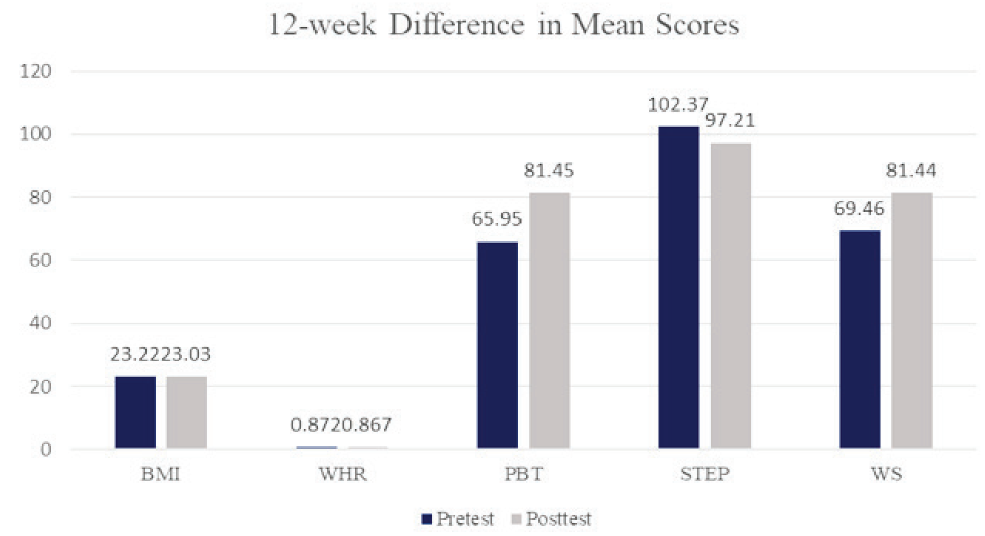


FIGURE 1. Mean scores of Anthropometric and Performance Scores Pre-Test and Post-Test Data

For the performance fitness tests, the PBT, STEP, and WS results showed a score difference of 15.5 seconds, 5.16 bpm discrepancy, and 11.98 seconds, respectively. PBT and WS were positively different from the pre-treatment scores, lasting from 65.95 to 81.45 seconds and 69.46 to 81.44 seconds, respectively. Figure 1 also showed positively different heart rate scores after treatment in STEP, from 102.37 to 97.21 bpm.

Using a Wilcoxon Signed-rank analysis, the mean difference in PBT scores resulted in a W value of 141.5; STEP scores resulted in a W value of 317; and WS had a 26 W value (see Table 2). All scores appeared to be significant at $p<0.01$, N=155. The p-values show that the score difference among participants in the three fitness tests exhibited consistency.

BMI and WHR scores derived from anthropometric data were also statistically analyzed regarding their mean differences before and after the treatment. BMI and WHR results showed significant score differences with Z values of -5.65 and -3.08, as presented in Table 3.

**Table 2.** W and Z Values from Performance Fitness Tests via Wilcoxon Signed-rank Test

| Fitness Tests Administered | | Mean | SD | W | Z |
|---|---|---|---|---|---|
| PBT (seconds) | Pre-test | 65.95 | 30.09 | 141.5* | -10.283 |
| | Post-test | 81.45 | 36.70 | | |
| STEP (bpm) | Pre-test | 102.37 | 10.76 | 317* | -9.692 |
| | Post-test | 97.21 | 11.37 | | |
| WS (seconds) | Pre-test | 69.46 | 26.31 | 26* | -10.468 |
| | Post-test | 81.44 | 30.91 | | |

*p-value = 0.01

Effect magnitudes of the anthropometric and performance test scores were also analyzed using Cohen's d. Table 4 shows small to moderate effects on performance-based fitness tests for all participants. Male participants exhibited medium effect size scores in PBT and STEP, while a small effect was shown for females. Both sexes showed medium effect size scores in the WS fitness test. Males showed the greatest effect in WS scores with a Cohen's d score of 0.726.

The Cohen's d results also revealed that the 12-week program had minimal to no effect on BMI and WHR for both sexes. Table 4 presents the lowest BMI effect in females after the intervention, with a d score of 0.029. Generally, the effect on female participants shows lower effect sizes than their male counterparts except in WHR.

**Table 3.** Z Values of BMI and WHR and their Significance Based on the Wilcoxon Signed-rank Test

| | N | | Mean Rank | Z |
|---|---|---|---|---|
| BMI | Negative Ranks | 11 | 47.36<br>41.77 | -5.65* |
| | Positive Ranks | 73 | | |
| | Ties | 71 | | |
| | Total | 155 | | |
| Waist-Hip Ratio | Negative Ranks | 18 | 23.44<br>30.89 | -3.08* |
| | Positive Ranks | 38 | | |
| | Ties | 99 | | |
| | Total | 155 | | |

*p-value < 0.01

**Table 4.** Effect Size of Anthropometric and Performance Test Variables Using Cohen's d

| Variable | | N | Cohen's d |
|---|---|---|---|
| BMI | Male | 88 | 0.060 |
| | Female | 67 | 0.029 |
| Waist-Hip Ratio | Male | 88 | 0.067 |
| | Female | 67 | 0.072 |
| PBT | Male | 88 | 0.720** |
| | Female | 67 | 0.296* |
| STEP | Male | 88 | 0.682** |
| | Female | 67 | 0.300* |
| WS | Male | 88 | 0.726** |
| | Female | 67 | 0.605** |

*small effect; **medium effect

## Discussion

While physical fitness is understood as a "physiological" concept, lack of physical fitness due to low participation time transcends physiological exercise variables, migrating the issue to psychological approaches in exercise participation. Self-efficacy and competence motivation are starter factors, and increased participation has been seen to continue, resulting in improved physical fitness levels of college students. The group of Liu (2023) provided this psychological view in addressing exercise participation and has posed new strategies for achieving this outcome. Promotion of exercise participation through health motivation is observed to work in the Western region and the Asian cluster. Improvement of physiological domains from psychological methods are some of the many strategies that seem to work, which makes the inclusion of competence motivation in exercise program structures imperative.

Relating competence motivation and the Philippine PATHFit model, using sports education as a pathway in attaining participation and increased fitness scores is a viable option as it involves task orientation, engagement, social support, and stress relief among students. This is validated by a recent Asian investigation (Li et al., 2022), showing significantly longer student participation and opening doors for sport education as a compelling motivation for lifelong physical activity and well-being. The rules in exercise structures increase stimuli engagement and chunking motor adaptation, strengthening bioelectrical and physiological dependence.

Demands in sports education entail fitness before incorporating rules in exercise models. Gamifying the development of fitness parameters poses a critical factor for student motivation for sport-related fitness. Gamified fitness programs (Mora-Gonzalez, Navarro-Mateos & Perez-Lopez, 2023) have been reported to improve cardiorespiratory, upper, and lower muscular fitness significantly. Stimuli diversity makes exercise unpredictable in training and enhances the body's physiological response, delaying progress plateau as stated by the Principle of Diminishing Returns. Variation and limiting the structure through gamification make the experience alive, not merely a structure written on paper.

The pandemic, aside from willpower as an intrinsic form of physical activity barrier, also played a significant role in the global physical activity status. In Feng et al., 2023, it was observed that the lockdown caused by the COVID-19 pandemic increased the BMI levels and affected some running performance results of college women. While women are most vulnerable in physical activity access and opportunities for participation, this bears a problem across all genders and perhaps all age groups.

Specific to the Philippine context, the development of the PATHFit course highlights how tertiary PE students are being prepared for sport-specific physical activity, fitness, and participation. This made the fitness status issue transcend students' health-related fitness and concerns, the skill component, and the preparation for sports education. Being at their prime condition, students' health-related anthropometric scores are close to the ideal for both BMI and WHR scores. Overall, it can be said that the students who participated in the study are generally fit to take the PATHFit 2 course.

Part of the pathway to sport-specific fitness and education is training specific fitness parameters for the demands of sports participation, and this entails that no fitness model will work for all types of sports. In Wang et al.'s study (2023), no functional training effectively covers all parameters of fitness, which makes training for sports be given in a highly specialized manner. Specific Adaptation for Imposed Demands (SAID) is a driving mechanism progressing from PATHFit 2 (fitness-related phase) to PATHFit 3 and 4 (sport-specific education). The fitness levels acquired in the fitness training phase theoretically contribute to positive performance in sports education later in the PATHFit course. This is expected, as observed in other studies, including Portillo et al. (2022).

Apart from preparing students for sports performance fitness, specific training adaptations were also intended to prepare their bodies for the forces and stress of sports participation. Adaptations include optimizing the musculoskeletal structures to prevent and minimize the occurrence of injuries in sports effectively. Lee, Hsu, and Lee (2022) stressed how special fitness testing and scientific knowledge of implementors are essential references in formulating the fitness program. No fixed curriculum can address all performance parameters for sports and even beyond performance, particularly sport-specific conditioning and injury prevention.

With the details of sports performance and education preparation, heavily trained individuals are expected to be part of the implementation for the transition and groundwork. Sports participation being highly specialized, the inclusion of interferences is also highly dependent on specific cases, which demands teachers to have the ability to customize their interventions. This will be a problem if the findings of Miguel (2012) regarding PE teachers in the Philippines having poor teaching competencies in content knowledge are investigated.

Lastly, the lack of readiness of PE teachers for customization and modification of training to achieve fitness goals is also validated in another Philippine-based study where physical educators in the Philippines reported the need for sports injury prevention training and increased knowledge about PE injuries and prevention (Marcaida et al., 2022).

## Conclusion and Recommendations

The progressive cardiorespiratory and muscular fitness exercise was a prototype experimental treatment for the PATHFit 2 course. After the 12-week intervention period, differences in health-related anthropometric and performance-related scores were all significant, and the progressive exercise model has little to no effect on BMI and WHR. The program has a medium effect on WS scores for both genders and on PBT and STEP for male participants, while small effects were documented among female participants for PBT and STEP scores post-treatment.

It is then recommended to revisit the value of gamification and inclusion of play-like rules in the structure of tertiary PE programs that may lead to increased participation, engagement, and fitness levels. Secondly, an innovative exercise design is suggested for female participants to address their fitness preferences and motivate them to intensify their exercise participation. Lastly, it is recommended that PE teachers be equipped with knowledge in exercise science, as progression from the fitness phase to the sport-specific phase demands technical and case-to-case knowledge in exercise programming and customization.

While the study is the first of its kind in the Philippines, limitations arise, particularly in the lack of several versions of different exercise models to be evaluated to identify better how program elements affect the test scores. Also, this study is limited to using only the three performance tests mentioned. Future studies may further expand the variables to be tested and fitness tests to be used.

**Acknowledgments**
There are no acknowledgments.

**Conflict of Interest**
The author declares that there is no conflict of interest.

**Received:** 04 October 2023 | **Accepted:** 14 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240210

ORIGINAL SCIENTIFIC PAPER

# Integration of Bivariate Logistic Regression Models and Decision Trees to Explore the Relationship between Socio-Demographic and Anthropometric Factors with the Incidence of Hypertension and Diabetes in Prospective Athletes

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**Abstract**

Hypertension and diabetes are two medical conditions that are often associated with athletes' health. Hypertension or high blood pressure is a condition where the blood pressure in the arteries becomes too high. Meanwhile, diabetes is a condition where the body cannot produce or use insulin properly, thereby causing high blood sugar levels. Athletes' health is very important because they need optimal physical conditions to be able to compete effectively. Hypertension and diabetes can affect athletes' health and their performance. Socio-demographic and anthropometric factors are believed to play an important role in the development of both conditions. The aim of this study is to determine the relationship between socio-demographic and anthropometric factors on the incidence of hypertension and diabetes in prospective athletes in athletics and determine whether prospective athletes pass the initial screening process. This study integrates bivariate logistic regression models and decision trees to analyze data collected from 200 athlete selection participants. The univariate logistic regression model showed that waist circumference, father's occupation, and salary category 2 had a significant influence on hypertension, while BMI had a significant influence on diabetes. Meanwhile, the bivariate logistic regression model found that BMI and salary category 2 had a significant effect on hypertension. The optimal classification tree was formed using variables such as BMI, Salary Category 2, Hypertension, and Diabetes. The accuracy of the prediction data was 72%, indicating that the optimal tree is well-formed and suitable for classifying athletes' data. This study concludes that there is a significant relationship between sociodemographic and anthropometric factors and the incidence of hypertension and diabetes in prospective athletes. This study provides valuable insight into physiological adaptation, fitness, recovery, and other factors that influence athlete performance.

***Keywords:*** *athletes, bivariate, decision tree, diabetes, hypertension, logistic regression*

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## Introduction

Intense training in athletes at risk of hypertension and diabetes can have a significant impact on their health. The study by Fagard (2005) showed that hypertension has a significant effect on athlete performance, especially in athletic sports such as marathon running. On the one hand, intense exercise can help reduce the risk of developing both conditions by improving cardiovascular conditions, increasing insulin sensitivity, and aiding in maintaining a healthy weight (Luan et al., 2019). However, some aspects need to be carefully considered.

Training too intensely and too often without enough recovery time can increase the risk of injury and overtraining, which can negatively affect an athlete's health (Impellizzeri et al., 2020). In addition, intense training can also cause a temporary increase in blood pressure during physical activity, which is normal but needs to be carefully monitored, especially if the athlete is at risk of hypertension (Alpsoy, 2020).

Additionally, athletes who have insulin resistance or diabetes need to understand how intense training can affect their blood sugar levels. This may require more careful diet planning and proper dosing of insulin or medications (Muhtar & Lengkana, 2021).

In this context, careful management of intense exercise is essential. This includes regular health monitoring, adjustment of exercise intensity as per individual needs, appropriate diet planning, stress management, and consultation with a medical team experienced in treating athletes with these health risks (Jimenez et al., 2007). With a holistic and professional approach, intense training can still be a powerful tool in improving an athlete's health and performance while managing the risk of hypertension and diabetes (Trojian et al., 2022).

Hypertension, or high blood pressure, is a condition in which the blood pressure in the arteries persistently rises above normal levels (Fuchs & Whelton, 2020). In athletes, hypertension can be caused by overtraining, dehydration, and taking certain supplements. Hypertension in athletes can lead to serious health problems, including the risk of heart disease and stroke (Basilico, 1999). Therefore, it is important for athletes to keep their blood pressure within the normal range by paying attention to adequate fluid and electrolyte intake and avoiding overexertion (Sathish et al., 2012; Berge et al., 2015).

Diabetes is a condition in which the body cannot produce or use insulin properly, leading to elevated blood sugar levels (Mukhtar et al., 2020). In athletes, type 2 diabetes, which is often caused by being overweight and lack of physical activity, can be managed by adopting a healthy diet and regular physical exercise (Kurniawati, 2019). However, athletes also need to pay attention to their blood sugar levels during training and competition, as low or high blood sugar levels can affect their performance (Siwi et al., 2017). Diabetes can affect an athlete's health by causing disruptions to the nervous system and blood circulation, resulting in fatigue and decreased endurance (Mileva & Zaidell, 2022). A study published in the the Sports Medicine journal showed that diabetes can affect athletes' performance by reducing the body's ability to produce energy effectively during physical activity (Burke & Hawley, 2018; Absil et al., 2019; Scott et al., 2019).

Hypertension and diabetes are two very common medical conditions worldwide and both are considered significant global public health problems (Zhou et al., 2021). Socio-demographic and anthropometric factors are believed to play an important role in the development of both conditions (Manios et al., 2019). Overall, it is suspected that socio-demographic factors, such as age, gender, education, and socioeconomic status, and anthropometric factors are vital to a person's risk of developing hypertension and diabetes (Dey et al., 2022). Several studies have shown that people who are older, male, less educated, and have low socioeconomic status have a higher risk of developing hypertension and diabetes (Bovet et al., 2002; Ford, 2005).

Anthropometric factors such as body weight, body mass index (BMI), waist circumference, and height are also associated with the risk of hypertension and diabetes. A study conducted by Misra et al. (2007) has shown that people who are overweight or obese, have a higher BMI, larger waist circumference, and lower height have a higher risk of developing hypertension and diabetes.

In addition, several studies have examined the relationship between hypertension and diabetes with socio-demographic and anthropometric factors in the general population (Mackenbach et al., 2000; Lim et al., 2012; Schrier et al., 2012). According to the results of these studies, it appears that there is a significant relationship between socio-demographic and anthropometric factors with the risk of hypertension and diabetes in the general population, but there has never been any study related to this in the field of sports, especially in athletics. In addition, in terms of methods of approaching the problem, the integration of bivariate logistic regression models and decision trees is used, which have not been combined by many researchers. The novelty in this study lies in 2 points, namely the application of science in the field of sports, especially athletic sports, and the integration of bivariate logistic regression models and decision trees.

## Methods

The data obtained is primary data from 200 athlete selection participants at the University of Surabaya and the East Java Indonesian National Sports Committee. In the selection process, data collection was carried out on prospective athletes through 2 processes. In the first screening, two observations were made, namely socio-demographics and anthropometry.

### *Procedure*

Socio-demographic observations involve collecting data on the social and demographic characteristics of individuals or groups. This includes factors such as age (divided into 2 categories, <21 years and ≥21 years), gender (divided into 2 categories, female and male), father's education (divided into 2 categories, school and college), mother's education (divided into 2 categories, school and college), father's occupation (divided into 2 categories, formal and informal), mother's occupation (divided into 2 categories, formal and informal), and salary (divided into 3 categories, <3 million, 3-6 million, and >6 million). To conduct socio-demographic observations, survey methods, interviews, direct observation, and secondary data analysis were used. Anthropometric observations on athletes were conducted with the aim of understanding body proportions and physical characteristics that affect athletes' abilities in certain sports, includings factors such as height (divided into 2 categories, <170 cm and ≥170 cm), weight (divided into 2 categories, <60 kg and ≥60 kg), body mass index (divided into 2 categories, <25 and ≥25), and waist (divided into 2 categories, <85 cm and ≥85 cm).

*Measurement*

In the second screening process, 2 measurements regarding hypertension and diabetes were taken. Hypertension measurement was carried out by measuring the blood pressure of prospective athletes. If a prospective athlete has blood pressure above 120/80 mmHg, then they are indicated as having hypertension. Diabetes measurements include blood sugar tests and diabetes symptoms. After the observation and data collection process were carried out, the next stage was the data analysis process as a determinant of the initial screening results of prospective athletes to decide whether they pass or fail.

*Statistics*

In accordance with the problems to be studied, this study uses an integrated method in the problem-solving approach, namely combining bivariate logistic regression analysis and decision trees. First, bivariate logistic regression was used to observe the relationship between the incidence of hypertension and diabetes with socio-demographic and anthropometric factors. This method can be used to identify the effect of predictor variables on the dependent variable as well as to make predictions of the dependent variable category based on the values of the predictor variables (Liao, 1994; Sloane & Morgan, 1996; Hosmer et al., 2000).

A decision tree is a decision-making method in the form of a tree structure used to solve classification or regression problems (James et al., 2013). In a decision tree, each node on the tree represents a decision or prediction, while each branch of the tree represents a rule or condition that separates the data into smaller subgroups. Decision trees can be used to explore existing patterns or rules in data as well as to make predictions or classify new data. Both bivariate logistic regression and decision trees can be used to make predictions or classify data based on given predictor variables. However, the main difference between the two is the form of representation of the analysis results. Bivariate logistic regression produces a mathematical equation in the form of a logistic function used to estimate the probability of success or failure of the dependent variable based on the predictor variables. Meanwhile, decision tree produces a tree structure that describes the rules or conditions that must be met to make a prediction or classification (Kavakiotis et al., 2017; Rabbani et al., 2022; Ueshima et al., 2003). Integrating bivariate logistic regression analysis and decision trees is hoped to speed up the initial screening process for prospective athletic athletes with more accurate results.

*Equations Bivariate Logistic Regression*

Bivariate logistic regression is a statistical analysis technique used to analyze the relationship between two categorical or binary variables. In bivariate logistic regression analysis, the dependent variable is a binary or categorical variable, while the independent variable can be either categorical or continuous. The results of the analysis can be expressed in the form of odds ratio, which is a measure of the effect of the independent variable on the dependent variable.

Estimation of the parameter value  is conducted using the Maximum Likelihood Estimation method by maximizing the natural logarithm of the likelihood function with the following formula (Hosmer et al., 2000):

$$\frac{\partial \ln L(\boldsymbol{\beta})}{\partial \boldsymbol{\beta}} = \sum_{i=1}^{n} \left\{ \frac{y_{11}}{\pi_{11}} \frac{\partial \pi_{11}}{\partial \boldsymbol{\beta}} + \frac{y_{10}}{\pi_{10}} \frac{\partial \pi_{10}}{\partial \boldsymbol{\beta}} + \frac{y_{01}}{\pi_{01}} \frac{\partial \pi_{01}}{\partial \boldsymbol{\beta}} + \frac{y_{00}}{\pi_{00}} \frac{\partial \pi_{00}}{\partial \boldsymbol{\beta}} \right\}$$

n is the number of independent random samples, while  are binomially distributed bivariate random variables with probability values of .

*Decision Tree*

Decision trees are one of the popular data analysis techniques in data science and computer science. This technique is used to generate prediction models based on existing data (Cheung Chiu & Webb, 1998). In decision tree analysis, data is divided into smaller subsets and then decisions are made based on a series of questions or rules applied to each subset. This method is used to predict the value of the dependent variable based on the independent variables.

The method used in decision trees is CART (Classification and Regression Trees). CART can be used to build decision trees for classification and regression. The CART algorithm goes through three stages, namely the formation of classification tree, pruning of the classification tree, and determination of the optimum classification tree.

*Integrated Methods*

The analysis procedure in this study is to integrate the bivariate logistic regression model and Decision Tree. The stages of analysis carried out were describing the data of respondents who participated in the athlete selection process by conducting descriptive statistical analysis. Then, modelling Bivariate Logistic Regression Analysis was carried out to determine Anthropometric and Socio-demographic Variables that have a significant influence on indications of hypertension and diabetes, where the level of significance is 0.05. Variable results obtained were then inputted to perform decision tree analysis with the CART method. To calculate the classification accuracy of the decision tree, the analysis was carried out using R studio software.

## Results

An overview of the characteristics of respondents who participated in the selection of athletes at University of Surabaya and the Indonesian National Sports Committee of East Java will be provided based on anthropometric and sociodemographic factors that influence the indication of hypertension and diabetes. The data is presented in Table 1.

Table 1 shows a related percentage between anthropometric and sociodemographic factors with early screening for hypertension (high blood pressure) and diabetes (high sugar levels). First, the initial screening for hypertension in respondents with a height above 170 cm had a greater hypertension percentage of 17.50%, leading by 0.50% compared to those with a height less than 170 cm. On the other hand, during the initial screening for diabetes, respondents with a height below 170 cm showed a greater percentage of 20.50% compared to respondents above 170 cm with that of around 17%.

**Table 1.** Percentage of respondents' characteristics during initial screening

| Variable | | Hypertension (%) | | Diabetes (%) | |
|---|---|---|---|---|---|
| | | Yes | No | Yes | No |
| Height | < 170 cm | 17.0 | 30.5 | 20.5 | 27.0 |
| | ≥170 cm | 17.5 | 35.0 | 17.0 | 35.5 |
| Weight | < 60 kg | 18.0 | 35.5 | 21.0 | 32.5 |
| | ≥ 60 kg | 16.5 | 30.0 | 16.5 | 30.0 |
| Body Mass Index (BMI) | < 25 | 11.5 | 14.5 | 15.0 | 11.0 |
| | ≥ 25 | 23.0 | 51.0 | 22.5 | 51.5 |
| Waist | < 85 cm | 15.5 | 17.0 | 14.0 | 18.5 |
| | ≥ 85 cm | 19.0 | 48.5 | 23.5 | 44.0 |
| Age | < 21 years | 22.5 | 40.0 | 24.5 | 38.0 |
| | ≥ 21 years | 12.0 | 25.5 | 13.0 | 24.5 |
| Gender | Female | 15.5 | 36.0 | 18.5 | 33.0 |
| | Male | 19.0 | 29.5 | 19.0 | 29.5 |
| Father's Education | School | 14.5 | 24.5 | 16.5 | 22.5 |
| | College | 20.0 | 41.0 | 21.0 | 40.0 |
| Mother's Education | School | 14.0 | 25.0 | 17.0 | 22.0 |
| | College | 20.5 | 40.5 | 20.5 | 40.5 |
| Father's Occupation | Formal | 14.5 | 33.5 | 17.5 | 30.5 |
| | Informal | 20.0 | 32.0 | 20.0 | 32.0 |
| Mother's Occupation | Formal | 14.0 | 19.5 | 14.5 | 19.0 |
| | Informal | 20.5 | 46.0 | 23.0 | 43.5 |
| Salary | < Rp 3.000.000 | 19.0 | 29.5 | 20.5 | 28.0 |
| | 3.000.000-6.000.000 | 13.5 | 28.5 | 15.0 | 27.0 |
| | > Rp 6.000.000 | 2.0 | 7.5 | 2.0 | 7.5 |

*Univariate Logistic Regression*

Modeling logistic regression with one predictor variable is used to find out how much influence each predictor variable has on each response variable partially. The steps taken include making an estimate of the parameters for each predictor variable in the partial model.

*Variable of Hypertension*

The modeling results of independent variables on the hypertension response variable demonstrates that not every predictor variable exhibits a significant effect on the indication of hypertension suffered by athletes. The test results are presented in Table 2.

**Table 2.** Univariate logistic analysis for the hypertension response variable

| Variable | Estimate | Std. Error | Z-value | P-value | Exp(Coef.) |
|---|---|---|---|---|---|
| Intercept | -1.232 | 0.441 | -2.797 | 0.005** | 0.292 |
| Height | -0.110 | 0.366 | -0.300 | 0.764 | 0.896 |
| Weight | -0.068 | 0.352 | -0.193 | 0.847 | 0.934 |
| Body Mass Index (BMI) | 0.289 | 0.398 | 0.725 | 0.468 | 1.335 |
| Waist | 0.737 | 0.363 | 2.030 | 0.042* | 2.090 |
| Age | 0.461 | 0.352 | 1.308 | 0.191 | 1.585 |
| Gender | -0.388 | 0.350 | -1.107 | 0.269 | 0.679 |
| Father's Education | 0.180 | 0.334 | 0.539 | 0.590 | 1.197 |
| Mother's Education | -0.073 | 0.365 | -0.200 | 0.842 | 0.930 |
| Father's Occupation | -0.703 | 0.333 | -2.109 | 0.035* | 0.495 |
| Mother's Occupation | 0.312 | 0.361 | 0.862 | 0.389 | 1.366 |
| Salary_1 | 0.387 | 0.349 | 1.110 | 0.267 | 1.473 |
| Salary_2 | 0.753 | 0.376 | 2.001 | 0.045* | 2.124 |

Legend : *significant level 5%, **significant level 1%

In the univariate logistic regression analysis model with independent variable of hypertension, there are significant dependent variables, namely waist, father's occupation, salary category 2.

*Variable of Diabetes*

The univariate logistic regression modeling between independent variables and diabetes response variable is shown in Table 3.

**Table 3.** Logistic regression model with diabetes response variable

| Variable | Estimate | Std. Err. | Z-value | P-value | Exp(Coef.) |
|---|---|---|---|---|---|
| Intercept | -1.238 | 0.435 | -2.843 | 0.005** | 0.290 |
| Height | 0.224 | 0.356 | 0.630 | 0.529 | 1.251 |
| Weight | 0.002 | 0.347 | 0.005 | 0.996 | 1.002 |
| Body Mass Index (BMI) | 1.095 | 0.390 | 2.810 | 0.005* | 2.989 |
| Waist | -0.028 | 0.364 | -0.078 | 0.938 | 0.972 |
| Age | 0.383 | 0.340 | 1.128 | 0.259 | 1.467 |
| Gender | -0.181 | 0.346 | -0.523 | 0.601 | 0.834 |
| Father's Education | 0.370 | 0.326 | 1.134 | 0.257 | 1.447 |
| Mother's Education | 0.331 | 0.356 | 0.930 | 0.352 | 1.393 |
| Father's Occupation | -0.267 | 0.320 | -0.835 | 0.404 | 0.766 |
| Mother's Occupation | 0.105 | 0.358 | 0.294 | 0.769 | 1.111 |
| Salary_1 | -0.277 | 0.344 | -0.806 | 0.420 | 0.7582 |
| Salary_2 | 0.307 | 0.368 | 0.834 | 0.405 | 1.360 |

Legend : *significant level 5%, **significant level 1%

In the univariate logistic regression analysis model with independent variable of diabetes, body mass index (BMI) serves as a significant dependent variable.

*Bivariate Logistic Regression*

To conduct bivariate regression analysis, it is necessary to assume the existence of a relationship or correlation between the response variables.

According to the table above, it can be concluded that there is a significant relationship between the two response variables.

Based on the table above, it is worth noting that BMI and Salary coefficients have an influence on the hypertension response variable. This is proven by the test statistical values on the independent variable being -3.400 and 2.233 respectively, which are smaller than ). As specified by the results of the bivariate logistic regression analysis, BMI and Salary category 2 are the variables with a significant influence. Therefore, these variables will be included in the independent variables in the decision tree analysis.

*Decision Tree*

Out of 4 predictor variables which comprises variables of BMI, Salary category 2, Hypertension, and Diabetes in the classification tree, variables provide optimum classification results. The formed optimum classification tree is illustrated in Figure 1.

**Table 4.** Correlation test results between the two response variables

| Relationship between response variables | | p-value | Summary |
|---|---|---|---|
| Y1 and Y2 | 18.835 | 0.000 | Reject H0 |

**Table 5.** Bivariate Binary Logistic Regression Analysis of Each Predictor Variable

| Coefficient | Estimate | Std Error | Z value | P-value |
|---|---|---|---|---|
| (Intercept):1 | 0.548 | 0.151 | 3.626 | 0.000*** |
| (Intercept):2 | 0.620 | 0.153 | 4.052 | 0.000*** |
| (Intercept):3 | 0.956 | 0.258 | 3.713 | 0.000*** |
| BMI:1 | -0.145 | 0.221 | -0.659 | 0.510 |
| BMI:2 | -0.752 | 0.221 | -3.400 | 0.001*** |
| Waist:1 | -0.395 | 0.210 | -1.884 | 0.060 |
| Waist:2 | -0.011 | 0.214 | -0.052 | 0.959 |
| Father's Occupation:1 | 0.284 | 0.189 | 1.507 | 0.132 |
| Father's Occupation:2 | 0.140 | 0.189 | 0.740 | 0.459 |
| Salary_2:1 | -0.446 | 0.200 | -2.233 | 0.026* |
| Salary_2:2 | -0.334 | 0.2018 | -1.657 | 0.098 |

Legend : *significant level 5%, **significant level 1%, *** significant level 0.1%

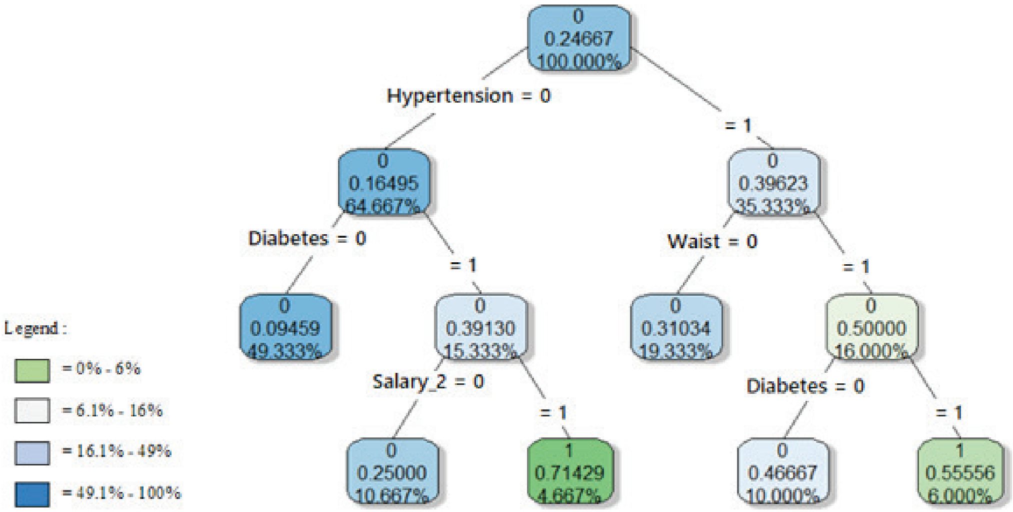


FIGURE 1. Optimum Classification Tree

The tree plot above exhibits the variables used to build the tree. The selected tree contains 4 variables with 6 splits. These variables are Hypertension, Diabetes, Waist Circumference and Salary category 2. Based on the decision tree structure in Figure node 3, after experiencing splitting, node 3 branches into two subsequent nodes. The first one is labeled as node 4 with no indication of diabetes, leading to it becoming the terminal node. Meanwhile, the second one is labeled as node 5 which represents indicated diabetes, further branching into node 8, namely salary category 2 (less than 6,000,000) and node 9, denoting salary category 2 (more than 6,000,000). Similarly, at node 3, it branches into two subsequent nodes. One, node 6 represents waist circumference of less than 80 cm, serving as a terminal node. The other is node 7 with a waist circumference of more than 80 cm which is divided into node 10, signifying those without diabetes, and node 11 with diabetes.

The next step is to calculate the classification accuracy of the CART tree obtained. The classification accuracy results for the learning data are presented in Table 6.

**Table 6.** Classification accuracy results

| Athletes | Failed | Succeed |
|---|---|---|
| Fail | 31 | 10 |
| Succeed | 4 | 5 |

The calculation of accuracy, sensitivity and specificity for the testing data is as follows:

$$\text{Accuracy} = \left(\frac{31+5}{50}\right)x100\% = 72\%$$

$$\text{Precision} = \left(\frac{31}{31+10}\right)x100\% = 75.61\%$$

$$\text{Sensitivity} = \left(\frac{31}{31+4}\right)x100\% = 88.57\%$$

$$\text{Specificity} = \left(\frac{5}{5+10}\right)x100\% = 33.33\%$$

Based on the conducted calculations, the accuracy value of the prediction data is 72 percent. Therefore, it is arguable that the optimal tree formed is good and suitable for classifying new data. Alongside this number, the precision, sensitivity and specificity values are also obtained, amounting to 75.61%, 88.57% and 33.33% respectively.

## Discussion

A research conducted by Ruspriyanty and Sofro (2018) examined hypertension using Logistic Regression and Probit. Such research that integrates bivariate logistic regression models and decision trees in this study is a novel approach, especially in the context of athletics, and contributes to the methodological advances in this field. The findings of the bivariate logistic regression analysis and decision tree modeling provide valuable insights into the relationship between socio-demographic and anthropometric factors with the risk of hypertension and diabetes in prospective athletes. The significant relationship between both factors and the risk of hypertension and diabetes in athletes underscores the importance of taking them into account during the athletes selection and training to mitigate health risks and optimize their performance.

The results of the analysis revealed that hypertension was influenced by socio-demographic factors, namely the father's occupation and income. Apart from that, anthropometric factors also contribute a significant influence on hypertension, namely through waist circumference. This finding is in line with the research conducted by Park and Kim (2018) on 1,032 adults aged 20-80 years which found that the waist circumference variable had a significant effect on hypertension.

Another research conducted by Chen et al. (2018) on 211,833 teenagers over 20 years old in China concluded that there was a linear association between baseline BMI and the risk of developing diabetes which increased with each kg/m2 of BMI and was associated with 23% (95% CI 1.22% to 1.24%) higher risk of incident diabetes. The risk of incident diabetes grew by 35% (95% CI 1.29% to 1.40%) for each kg/m2 increase of BMI in the group of 20–30 years old and by 31% (95% CI 1.29% to 1.33%) in the group of 30–40 years old.

The odds ratio values obtained from the logistic regression models offer specific insights into the magnitude of influence exerted by different socio-demographic and anthropometric variables on the risk of hypertension and diabetes in athletes, providing valuable information for targeted interventions and support. The decision tree analysis, particularly using the CART method, offers a practical and effective approach to predicting the risk of hypertension and diabetes based on the identified socio-demographic and anthropometric factors which can be valuable for developing tailored intervention strategies. The integration of bivariate logistic regression model and decision tree was used to determine the relationship. The optimal classification tree formed from the data showed that the diabetes variable had the most significant impact on the participants' success as athletes. The accuracy of the prediction data was found to be 72%, indicating that the optimal tree formed was good and suitable for classifying athletes' data. This research provides valuable insights into physiological adaptation, fitness, recovery, and other factors that influence athletic performance. The research findings contribute to the existing body of knowledge on the relationship between socio-demographic and anthropometric factors and the risk of hypertension and diabetes, particularly in the context of athletes, and provide a foundation for further research and practical applications in sports medicine and athlete management. The implications of the research findings extend to the development of evidence-based guidelines for athlete selection, training, and support programs, focusing on mitigating the risk of hypertension and diabetes through targeted interventions based on socio-demographic and anthropometric considerations.

**Acknowledgements**
The authors express their gratitude to the Directorate General of Higher Education, Ministry of Education and Culture for the basic research grant that provided funding to support this research.

**Conflict of Interest**
The author declares that there is no conflict of interest.

**Received:** 25 November 2023 | **Accepted:** 13 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240211

ORIGINAL SCIENTIFIC PAPER

# Gender Differences in Cognitive Functions of Youth Water Polo Players

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**Abstract**

Water polo (WP) as a highly demanding contact team sport, requires from players to have well developed cognitive functions, similar as in other team sports. Following same rules for females and males it is important to realize differences between them, which may contribute to their sports success and help coaches to develop adequate training models. Therefore, the aim of this study was to compare cognitive functions between female and male youth WP players. There were 36 female (25%) and 106 male (75%) youth WP players aged 12 to 14 years enrolled in this study. Variables measured included anthropometric indices, specific functional swimming capacities and cognitive functions testings using the Stroop test. Females showed better psychomotor speed (Stroop Off) (females 61.79±6.79 s vs. males 64.83±8.31 s, p=0.048) and response inhibition (Stroop On) (females 73.44±10.74 s vs. males 78.67±14.82 s, p=0.025) than males. Female youth WP players showed better results in psychomotor speed, inhibitory control and motor speed compared to males, taking both age and gender into account. Such differences might be of interest for coaches in WP, as well as in different sports to help them develop appropriate training strategies for each athlete.

***Keywords:*** *sports, water polo, children, executive functions*

## Introduction

*Cognitive functions*

Cognition is the mental activity through which people acquire and process knowledge. It is affected by biological, environmental, experiential, social and motivational factors, as well as the pace and pattern of mental growth, including age-related changes (Gauvain & Richert, 2016). These processes include basic mental activities such as attention, sensation and perception, as well as more complex functions such as memory, problem solving, reasoning and executive function. Executive functions (EF) include attention, inhibitory control, decision making, planning and working memory (Zelazo, Carter, Reznick, & Frye, 1997). EF make it possible to mentally play with ideas, quickly and flexibly adapt to changed circumstances, take time to consider what to do next, resist temptations, stay focused and meet novel, unanticipated challenges which is necessary for playing many complex team sports on high level (Diamond, 2013). These skills begin to develop in early childhood, between the ages of 3 and 5 (Best & Miller, 2010), continuing through adolescence or even early adulthood and their development corresponds with changes in the frontal cortex of the brain (Davidson, Amso, Anderson, & Diamond, 2006). Adults, more than adolescents, appeared aware of making an inhibition error as they momentarily slowed their response for the next trial in order to prevent further error (Davidson et al., 2006; Gauvain & Richert, 2016), which suggests the contribution of metacognitive development even after adolescence. Another factor that may influence the age range of maturation is pubertal development. Pubertal changes are significant in adolescence and have been shown to have an effect on cortical maturation and sex differentiation in cog-

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nitive development (Roivainen, Suokas, & Saari, 2021).

Gender differences in cognitive abilities have been widely analyzed in the psychological and neuropsychological literature (Hyde, 2005; Benbow, 2010; Scheuringer, Wittig, & Pletzer, 2017; Roivainen et al., 2021). The gender similarities hypothesis asserts that males and females are similar on most, but not all, psychological variables meaning that men and women, as well as boys and girls, are more alike than they are different (Hyde, 2005; Benbow, 2010). Differences between cognitive abilities in men and women, girls and boys, are smaller than once thought, and probably occur largely due to either strategy differences, and/or societal expectations (Roivainen et al., 2021). There is a small difference in favor of males on the nonverbal, verbal and working memory subtests, while females outperform males on the psychomotor processing speed tests (Leahey & Guo, 2001; Benbow, 2010; Scheuringer, Wittig, & Pletzer, 2017) .

Researchers who underline biological differences in ability and interest may refer to puberty as partly responsible for the appaerance of gender differences in the high school years. From a neuro-psychological perspective, the strong sex differences in processing speed, particularly through early adolescence suggest intriguing possibilities for understanding the developmental and neurological bases of these differences (Hyde, 2005; Davidson et al., 2006; Best & Miller, 2010; Roivainen et al., 2021).

*Cognitive functions and sports*

It is hypothesized that physical activity has a positive effect on cognitive functions, which is partly due to the physiological changes in the body (Mann, Williams, Ward, & Janelle, 2007; Gauvain & Richert, 2016). In addition, both motor and cognitive skills may have a similar developmental timetable with accelerated development during childhood (Anderson, 2002). To date, the literature supports the causal link between regular physical activity and brain development particularly in the prefrontal cortical area (Best & Miller, 2010). The long-term practice has also been observed in some perceptual motor skills, like reaction time, as well as EF in general (Mann et al., 2007; Best & Miller, 2010; De Waelle, Laureys, Lenoir, Bennett, & Deconinck, 2021). Moreover, playing high-level team sport games demands well-developed cognitive functions (Kamijo et al., 2011; Bidzan-Bluma & Lipowska, 2018; De Waelle et al., 2021), contributing to their development in general.

*Cognitive functions and water polo*

Water polo as a highly demanding physical contact team sport, has been developing in recent years for both, boys and girls (Noronha et al., 2022). All activities during the game take place in water, with frequent changes of high-intensity actions separated by moderate-intensity and lower-intensity tasks. Players constantly move through the field using different swimming intensity, receiving, dribbling and passing the ball, as well as shooting accurately on the goal and acomplishing many complex technical-tactical actions (Smith, 1998; Botonis, Toubekis, & Platanou, 2019). They need to have well developed cognitive functions such as anticipation, problem solving and decision making, inhibition and cognitive flexibility, similar as in other team sport games (Botonis et al., 2019; Melchiorri, Triossi, Bianchi, Tancredi, & Viero, 2022). Kovačević et al. (2023) showed superiority of children playing water polo in cognitive functions (psychomotor speed, inhibitory control and motor speed) over their sedentery peers of the same chronological age.

Following same rules in female and male water polo (except smaller dimensions of the field and smaller ball for females) (Canossa et al., 2022) it is important to realize differences between girls and boys, female and male players which may contribute to their sports success at certain age and help coaches to develop adequate training models. Falk et al. were subjectively evaluated cognitive functions of youth water polo players by the coaches during only 2-3 games each season, indicating better scores by the players selected to the youth national team (Falk et al., 2004). Also, Kovačević et al. showed better cognitive functions of the selected players, objectively evaluated using the Stroop test (Kovačević et al., 2023). Those recent studies evaluated only cognitive functions of selected youth water polo players, without the comparison between girls and boys, presenting the research gap and the need for more studies about cognitive functions of youth water polo players (Falk et al., 2004; Kovačević et al., 2023). In many countries girls and boys in early years train together and play in mixed teams. Since pubertal development tends to begin earlier for girls than boys (girls: ages10-12; boys: ages12-14), girls achieve their full athletic development and potentials earlier than boys. Still, boys are on average 7-10 % higher than girls, with stronger upper body, contributing to motor and functional capacities (Thibault et al., 2010).

Properly directed stimuli in this developmental phase have maximum efficiency, but impropperly loaded stimuli may also lead to morphological and functional disturbances. Therefore, it is important for coaches to be aware of gender differences and capacities in youth athletes in order to avoid the wrong influence on their development, giving them convenient opportunity to develop their skills and potentials for playing water polo on high level.

Therefore, the aim of this study was to compare cognitive functions between female and male youth water polo players of the same chronological age. It was hypothesized that female youth water polo players would show better cognitive functions, especially concerning cognitive flexibility and inhibition.

## Methods

*Participants*

This cross-sectional study was conducted in full accordance with the ethical principles, including the World Medical Association Declaration of Helsinki and it was approved by the Ethical Committee of the University of Split School of Medicine, Split, Croatia (No: 2181-198-03-04-19-0053). Informed consent was obtained from parents or legal guardians of children participating in the study after they were introduced to the background and the aim of the study.

There were 36 female (25%) and 106 male (75%) youth water polo players included in this study. All of them were participants in the Croatian Water Polo Federation training camps during the playing seasons 2019/2020, 2020/2021, 2021/2022 and 2022/2023. Youth water polo players self-reported at least 2 years of training experience with 5 training sessions per week, lasting approximately 2 hours.

*Measurements and procedures*
*Anthropometric Characteristics*

The experimental setup included anthropometric measurements, specific functional swimming tests and cognitive functions testings. Anthropometric measurements were measured using digital scale and stadiometer while participants wore only light clothes and variables measured included body mass and body height. Body mass index (BMI) was calculated as body mass (kg) divided by height squared (m2).

*Cognitive Functions*

For cognitive functions testings The EncephalApp_Stroop application was used. A detailed description of the test can be found in previous studies by Kovačević et al. (Kovacevic et al., 2023; Kovačević, Mihanović, Lušić Kalcina, et al., 2023). In the present study identical procedures were followed. Participants were taken in groups of 10 to a room free of distractions and individually given an explanation of the task, as well as a demonstration and a brief practice session. Subjects were told to use the hand they preferred. The following four variables of the Stroop test were included in the analysis: Stroop OffTime, primarily assessing psychomotor ability, Stroop OnTime, a measure of response inhibition and motor speed, OnTime minus OffTime, the measure of cognitive processing controlling for psychomotor speed and OffTime plus OnTime, showing a composition measure of psychomotor speed and response inhibition (Bajaj et al., 2013; Scarpina & Tagini, 2017).

*Specific Functional Swimming Tests*

Specific functional swimming tests included 25 m crawl, 50 m crawl, 100 m crawl, 400 m crawl and 25 m ball dribbling. The players were instructed to swim at maximum speed for each test performing various distances and styles in 25-m swimming pool, starting at the sound signal from the water and they were timed with hand-held digital stopwatch (Longines, Saint-Imier, Switzerland). They were allowed to push-off the wall at the start and after the turn, but a flip turn was not allowed. For 25 m dribbling the ball players were instructed to dribble the ball from wall to wall of the swimming pool, without throwing it and to touch the wall with one hand, as previously described in the study of Kovačević et al. (Kovačević, Mihanović, Hrbić, Mirović, & Galić, 2023).

*Statistical analyses*

Data analyses were performed using statistical software MedCalc for Windows, version 19.4. (MedCalc Software, Ostend, Belgium). Continuous data were presented as mean±standard deviation while categorical variables were presented as whole number and percentage. The Kolmogorov-Smirnov test was used to assess normality of data distribution. Differences in anthropometric variables, cognitive functions and specific functional swimming capacities between female and male youth water polo players were tested using independent samples t-test with the correction for unequal variances (Welch-test) with the statistical significance was set at $p<0.05$. Additionally, a multiple regression analysis was used to determine a relationship between selected independent variables (age, gender) with the outcomes of the Stroop test as dependent variables (StroopOn Time, StroopOff Time, Offtime plus Ontime, Ontime minus Offtime).

## Results

There were 36 female (25%), mean age 13.13±0.78 years and 106 male (75%) youth water polo players (WP) with the mean age 12.92±0.79 years (p=0.158). Descriptive statistics of the whole study sample is presented in Table 1.

**Table 1.** Descriptive Statistics for Total Sample of Participants

| | Variables | Total study sample N=142 |
|---|---|---|
| Anthropometric characteristics | Age (years) | 12.99±0.78 |
| | Body height (cm) | 168.19±8.09 |
| | Body mass (kg) | 60.43±13.03 |
| | Body mass index (kg/m2) | 21.25±3.73 |
| Cognitive functions | StroopOff time (s) | 64.08±8.07 |
| | StroopOn time (s) | 77.40±14.09 |
| | StroopOff plus StroopOn time (s) | 141.48±21.33 |
| | Ontime minus Offtime (s) | 13.32±8.48 |
| Specific functional swimming capacities | Crawl, 25 m (s) | 15.51±1.44 |
| | Crawl, 50 m (s) | 33.82±3.20 |
| | Crawl, 100 m (s) | 75.08±7.46 |
| | Crawl, 400 m (s) | 350.98±33.98 |
| | Dribbling, 25 m (s) | 16.09±1.81 |

Note Data are presented as mean±standard deviation.

Male youth water polo players were significantly taller than female players (male 169.75±8.06 cm vs. female 165.61±6.01 cm, p=0.002), while there were no significant differences in body mass and BMI (Table 2). Considering cognitive functions, female youth water polo players performed faster compared to male players in three out of four variables od the Stroop test, while male players performed faster in most of the specific functional swimming tests, which is presented in Table 2. A multiple regression analysis showed that age of participants contributed significantly to the prediction of higher cognitive performance measured by StroopOff Time (p<0.001, R2=0.107), StroopOn Time (p<0.001, R2=0.123), StroopOff plus StroopOn Time (p<0.001, R2=0.126) and StroopOnTime minus OffTime (p=0.004, R2=0.074), while gender did not show significant predictive value for the results of the Stroop test (Table 3).

**Table 2.** Comparison of Results of Anthropometric Variables and Specific Functional Swimming Capacities Between Female and Male Youth Water Polo Players

| | Variables | Female WP N=36 | Male WP N=106 | p |
|---|---|---|---|---|
| Anthropometric characteristics | Age (years) | 13.13±0.78 | 12.92±0.79 | 0.158 |
| | Body height (cm) | 165.61±6.01 | 169.75±8.06 | 0.002* |
| | Body mass (kg) | 59.49±13.20 | 61.64±12.74 | 0.389 |
| | Body mass index (kg/m2) | 21.61±4.29 | 21.31±3.57 | 0.679 |
| Specific functional swimming capacities | Crawl, 25 m (s) | 16.41±1.37 | 15.18±1.34 | 0.868 |
| | Crawl, 50 m (s) | 35.75±3.34 | 33.09±1.47 | <0.001* |
| | Crawl, 100 m (s) | 79.25±7.53 | 73.64±7.03 | <0.001* |
| | Crawl, 400 m (s) | 375.32±36.19 | 341.98±29.44 | <0.001* |
| | Dribbling, 25 m (s) | 17.85±1.50 | 15.45±1.47 | <0.001* |

Note Data are presented as mean±standard deviation; *Independent samples t-test with the correction for unequal variances (Welch-test); p<0.05.

**Table 3.** Multiple Regression Analysis Showing the Predictive Status of Age and Gender on Cognitive Performance

| | Coefficient | SE | t | p |
|---|---|---|---|---|
| StroopOff time | | | | |
| Gender | 2.521 | 1.502 | 1.678 | 0.096 |
| Age | -2.879 | 0.848 | -3.396 | <0.001 |
| | $R^2$=0.107; $R^2$-adjusted=0.094; F=8.120; P<0.001 | | | |
| StroopOn time | | | | |
| Gender | 4.173 | 2.602 | 1.604 | 0.111 |
| Age | -5.567 | 1.469 | -3.791 | <0.001 |
| | $R^2$=0.123; $R^2$-adjusted=0.110; F=9.495; P<0.001 | | | |
| StroopOff plus StroopOn time | | | | |
| Gender | 6.693 | 3.931 | 1.703 | 0.091 |
| Age | -8.445 | 2.219 | -3.807 | <0.001 |
| | $R^2$=0.126; $R^2$-adjusted=0.113; F=9.783; P<0.001 | | | |
| StroopOn minus StroopOff time | | | | |
| Gender | 1.652 | 1.613 | 1.024 | 0.308 |
| Age | -2.688 | 0.911 | -2.952 | 0.004 |
| | $R^2$=0.074; $R^2$-adjusted=0.060; F=5.405; P=0.006 | | | |

Note Coefficient – multiple regression coefficient; SE – standard error; t – test statistic; $R^2$ – coefficient of determination; $R^2$-adjusted – coefficient of determination adjusted for the number of independent variables in the regression model; F – F-statistic; *Significant difference between the groups, p<0.05.

## Discussion

The findings of the current study indicate that female youth water polo players showed better psychomotor ability, inhibition and motor speed, as well as a composition measure of those variables, measured by the Stroop test compared to male youth water polo players. Age of the participants showed significant predictive value for the cognitive functions of youth water polo players, while gender did not contribute to the prediction of the results on the Stroop test.

The results of our study are in accordance with some previous research showing that there is only a small difference in favor of males on the nonverbal, verbal, and working memory subtests, while females outperform males on the psychomotor speed tests (Camarata & Woodcock, 2006; Scheuringer, Wittig, & Pletzer, 2017; Roivainen et al., 2021). Hyde found that 78% of the studies showed sex differences to be small or negligible, even in areas classically held to robustly distinguish between males and females (Hyde, 2005). Differences between cognitive abilities in men and women, girls and boys, are smaller than once thought, and probably occur largely due to either strategy differences, and/or societal expectations (Sanders, 2013).

It could be speculated that differences between female and male youth water polo players in cognitive functions in our study occured because of the females' earlier development and pubertal maturity. Physical growth referring to changes in the body (such as height, weight, or hormonal changes) are usually the result of maturation, environmental experiences, or some interaction between these two factors.

It also involves neurological and sensory development, such as increased visual acuity and mastery of motor skills (Ferrari & Fernando, 2005). Researchers who emphasize biological differences in ability and interest may cite puberty and the differences that accompany it as partly responsible for the emergence of gender differences in the high school years. In the study of Upadhayay et al. (Upadhayay & Guragain, 2014) hormonal status influence on cognitive functions of female and male students was investigated. In Stroop test (executive task), during postovulatory phase, females had higher accuracy rates while they read colour interferences than males. This might have been caused by the effect of hormone, progesterone, which was probably responsible for modulating the female executive functions at this phase of the cycle and favoured females to properly discriminate the different colours and also be able to execute the tasks better than males (Upadhayay & Guragain, 2014). This clarified the fact that in tasks which required fine motor skills, females showed the highest efficiency (in postovulatory phase) as compared to males, while male cognitive functions (attentional, perceptual, executive and working memory) were comparable to those of the female preovulatory phase cognitive functions. This might be due to the analogous actions of testosterone (male) and oestrogen (female preovulatory) on the brain (Upadhayay & Guragain, 2014).

Although there has long been an interest in sex differences in cognitive abilities (Hyde, 2005; Camarata & Woodcock, 2006) and although a number of different cognitive factors have been suggested as correlates to this sex difference, there have been relatively little data exploring sex differences across development from preschool into elderly adulthood using comprehensive measures of cognitive abilities and related achievement areas. Such differences are of interest both from a theoretical perspective towards understanding different and convergent neuropsychological development in males and females and from an applied perspective as any consistent developmental differences in males and females may have important performance outcomes (Camarata & Woodcock, 2006). Such differences might be of interest of coaches in different sports where children participate together at the early age because it can help to develop appropriate training strategies for each athlete.

Since the age significantly influences cognitive functions which begin to develop from the ages of 3 and 5 (Best & Miller, 2010), corresponding with changes in the frontal cortex, while performance on more complex tasks does not mature until adolescence or even early adulthood (Anderson, 2002; Davidson et al., 2006; Roivainen et al., 2021), it would be expected that girls would otperform boys in the age of 12 to 14 years old because their pubertal development starts earlier. On the contrary, boys in our study were significantly taller than girls and showed better motor and specific functional swimming capacities. It is well known that males have longer limb levers, denser bones, greater muscle mass and strength, and greater aerobic capacity, while females exhibit less muscle fatigability and faster recovery during endurance exercise (Thibault et al., 2010). Boys show better motor abilities, especially in the motor dimensions under the primary influence of the movement regulatory mechanism (coordination, agility and balance) and energy supply regulation mechanism (strength/power), while girls at this age and older achieve better results in measures assessing flexibility which is an ability primarily under the influence of the synergy and tonus regulation mechanisms (Holden, 2004; Hyde, 2005; Roivainen et al., 2021). Such physiologic sex-based differences have led to a gap in sports performance between females and males in all sports (Holden, 2004; Ferrari & Fernando, 2005), therefore maybe better cognitive functions can help girls to compete with boys in the early age of sports training, giving them both possibilities to develop their capacities as much as possible.

The results of the multiple regression showed only predictive value of age on the outcomes of the Stroop test, which is in accordance with previous research. Although cognitive functions develop from early childhood to late adolescence and trough early adulthood (Anderson, 2002; Davidson et al., 2006; Gauvain & Richert, 2016), Huizinga et al. (2006) found continued improvement in both reaction time and accuracy measures on the Stop-Signal task and Eriksen Flankers task until age 15 and on a Stroop-like task (inhibiting saying a color word in order to state its conflicting font color) until age 21. Finally, adults, more than adolescents, appeared aware of making an inhibition error as they momentarily slowed their response for the next trial in order to prevent further error, which suggests the contributions of metacognitive development even after adolescence. Considering performance on the Stroop test there is an initial increase in reading errors from ages 6 to 10, followed by a substantial decrease in errors through age 17. This suggests that as word reading becomes more automatic from ages 6 to 10, inhibition of that process to say the color becomes more difficult, which negatively affects reading accuracy. Afterward, the inhibition mechanism needed may be mature enough to compensate for this reading automaticity (Zald & Iacono, 1998; Gauvain & Richert, 2016). Similarly, Davidson et al. (Davidson et al., 2006) found improvement from age 4 through adolescence. With increasing age, participants were more likely to slow down their responses on shift trials to ensure that they were responding accurately. Thus, improved metacognition – knowing that slowing helps performance and being able to detect when it is advantageous to do so may be one mechanism of developing accurate set shifting. The emergence of metacognition may also bring qualitative change when children learn to use feedback about errors to change their approach to the task (Anderson, 2002; Davidson et al., 2006). Knowing that such functions can be improved by physical activity and participation in sports, specially playing high-level team sport games (De Waelle et al., 2021), it would be advantageous to involve children, both girls and boys in organized sports activities early in their childhood for better and cognitive, social, and psychological development and better success later in school and in life (Best & Miller, 2010; Diamond, 2013; Bidzan-Bluma & Lipowska, 2018).

*Strengths and limitations*

Considering that studied variables are strongly influenced by the age of the subjects, given the existing developmental differences in functioning of the cognitive-motor areas, unique age distribution in both studied groups is one of the main strengths of this study.

Still, there are few major limitation of the present study. First is the nature of the sample. In general, the sample was quite small and had an uneven number of males and females, although used proportion is optimal compared to the number of female and male water polo players in general. Female superiority in psychomotor processing speed is associated with female superiority in fine motor speed; however, the underlying cause of the male/female gap in these skills remains unknown. In the present study we did not assess pubertal status which might influence the results, but future studies should examine the relationship between this factor and the rate of emergence of cognitive abilities in the type of cognitive domains evaluated in this study. Another limitation of the study is that processing speed was measured using one test instrument only, the Stroop test. We cannot rule out the possibility that some of the results may be test-specific to some extent. These features of the sample and methods call for caution when judging the generalizability of the results. Since studies about gender differences in cognitive functions are scarce, there is a need to confirm our results with more test instruments and larger sample of participants in future studies.

## Conclusion

The present study supported the hypothesis that there are some differences in inhibitory control, working memory and cognitive flexibility between female and male youth water polo players. Female high-level youth water polo players showed better results in psychomotor speed, inhibitory control and motor speed compared to males, taking both age and gender into account.

Despite the limitations of this study, the presented results contribute to the issue of sport activities as a tool in the stimulation of cognitive development. Considering that EFs are skills essential for mental and physical health, success in school and in life, and cognitive, social, and psychological development, based on the results of this study it would be advantageous to encourage children, both girls and boys, to participate in organized sports activities. Still, additional research is needed to compare executive skills development among female and male youth water polo players controlling for different phases of menstrual cycle, since it is well-known that sex hormones might influence cognitive functions and the brain. Finally, it is important to stress that well-developed cognitive functions may serve only as one of the factors contributing to development of an elite water polo player, together with anthropometric and functional capacities, as well as game intelligence and self-confidence.

**Acknowledgments**
There are no acknowledgments.

**Conflict of Interest**
The author declares that there is no conflict of interest.

**Received:** 12 January 2024 | **Accepted:** 23 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240212

ORIGINAL SCIENTIFIC PAPER

# Body Composition Variation among U-19 Futsal National Team Players from Bosnia and Herzegovina According to Playing Position

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**Abstract**

Elite futsal players in addition to other characteristics, must have suitable anthropometric and body composition according to their playing position. The research aimed to determine body composition of Bosnia and Herzegovina U-19 national futsal team players and also determine differences in anthropometric and body composition of players according to their playing position. The sample of respondents consisted of Bosnia and Herzegovina U-19 National Futsal Team players (n=14, average age 18.07±0.48 yrs, body height 181.40±5.72 cm, and body weight 77.66±10.60 kg). Anthropometric characteristics and body composition were evaluated by a battery of 11 variables: body height (BH), body mass (BM), triceps skinfold (TS), biceps skinfold (BiS), back skinfold (BS), abdominal skinfold (AS), upper leg skinfold (UlS), lower leg skinfold (LlS), body mass index (BMI), fat percentage (FP), and muscle mass percentages (MP). Futsal players were divided according to their positions in the team into goalkeepers, defenders, wingers and pivots. Based on ANOVA and post-hoc tests, the findings showed that there were significant differences between groups in 8 out of 11 anthropometric parameters. So, in relation to this, the main findings of the study indicate that: i) goalkeepers and pivots have significantly higher body mass and percentage of fat compared to defenders and wingers; ii) goalkeepers have a higher BMI than all other players, while pivots have higher BMI values than defenders and wingers; iii) muscle mass favors goalkeepers and pivots over wingers; iv) goalkeepers had significantly higher values in triceps and biceps skinfold measurements compared to other players, as well as in lower leg skinfold compared to defenders and wingers, and in back skinfold compared to wingers. Although this study is significant, because it examines the morphology of elite futsal players and indicates certain differences in the anthropometric characteristics of futsal players according to the positions in the team. However, we must interpret these results cautiously due to the limited sample size of participants.

***Keywords:*** *playing position differences, professional futsal players, morphological characteristics, body fat percentages*

## Introduction

Futsal is a variant of football played on a hard surface, smaller than a regular football field, and mostly indoors. Futsal is played between two teams of five players each, one of whom is a goalkeeper (Stojmenović, Stanković, Katanić, & Ilić, 2019). An important aspect of futsal development is that FIFA (Fédération Internationale de Football Association) has standardized this sport in the '5-a-side' version (Moore, Bullough, Goldsmith, & Edmondson, 2014). Thus, a futsal team consists of five players, namely a goalkeeper, a defender, two wingers (left and right), and a pivot. The basic characteristics of futsal include playing with significant intensity on a smaller field (20x40 m) and within a shorter time frame (2x20 min) (Queiroga et al., 2019).

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Recent authors have been striving to determine the demands of futsal. According to various authors, the total distance covered during a futsal match averages 3,133 m (Bueno et al., 2014), 3,749 m (Ribeiro et al., 2020), 4,277 m (Dogramaci, Watsford, & Murphy, 2011), and 4,313 m (Barbero-Alvarez, Soto, Barbero-Alvarez, & Granda-Vera, 2008). Milioni et al. (2016) confirmed that the total distance covered in halves was 1,986±74.4 m in the first half and 1,856±129.7 m in the second half. When considering average distances according to intensity zones, futsal players cover 9.0% and 39.9% of the total average distance in low-intensity walking and running, respectively. The average distance covered in moderate-intensity activity was 28.5%, high-intensity 13.7%, and sprinting 8.9% of the total match (Bueno et al., 2014). Dogramaci et al. (2011) highlight that elite teams cover a 42% greater total distance than sub-elite teams (4,277±1,030 versus 3,011±999 m). Additionally, elite players cover 58% more distance in running than sub-elite players. Regarding the physiological demands of the game, the average heart rate (HR) values during a futsal match were 174±7 b·min−1 (range: 164–181), representing 90±2% of maximum heart rate (HRmax; range: 86–93%). As HR is classified based on the percentage of time spent in different zones, players spent 0.3%, 16%, and 83% of the time at intensities ≤65%, 65–85%, and ≥85% of HRmax, respectively (Barbero-Alvarez et al., 2008). However, it should be noted that data from official matches showed slightly lower average HR values (86.4±3.8% HRmax; Rodriges et al., 2011). It has also been found that professional futsal players have significantly higher values of maximum oxygen consumption (VO2max) than sub-elite players (62.8 versus 55.2 ml·kg−1·min−1). Spyrou, Freitas, Marín-Cascales, and Alcaraz (2020) add that during a match, HR rarely drops below 150 b·min−1, which may be due to short and incomplete rest periods. These parameters indicate the high physiological demands placed on futsal players, thus futsal players should possess optimal physical performance accordingly.

It is well known that the anthropometric status of athletes is crucial, as morphological characteristics are directly linked to success in sports (López-Plaza, Alacid, Muyor, & López-Miñarro, 2017; Slimani & Nikolaidis, 2019; Banjević et al., 2022; Katanic, Bjelica, Rezic, Selimi, & Osmani, 2022). It has been established that athletes must possess an optimal level of morphological characteristics according to the demands of a specific sport (Popović, Akpinar, Jakšić, Matić & Bjelica, 2013; Slimani & Nikolaidis, 2019; Katanic, Bjelica, & Covic, 2022; Katanic et al., 2023). Although significant diversity in morphological status among football players is evident (Dowson, Cronin, & Presland, 1999; Reilly, Bangsbo, & Franks, 2000), it should be emphasized that body structure represents a crucial characteristic, as subcutaneous fat behaves as unnecessary weight during locomotion (Katanić, Ugrinić, & Ilić, 2020). When analyzing body composition, particular attention is paid to the percentage of body fat, which ranges from 7 to 12% in professional footballers (Shephard, 1999). Comparing with less successful teams, better teams have significantly lower percentages of body fat (Arnason et al., 2004). It is important to consider that an athlete's body composition can influence all measures of physical performance (Castillo et al., 2022). However, despite futsal being an indoor form of the world's most popular sport, there is little research on the morphological structure of futsal players.

On the other hand, research on the anthropometric characteristics of futsal players has been rarely conducted (Galy et al., 2015; Nikolaidis et al., 2019), and especially there are no studies that have examined body composition according to playing position in futsal. However, since differences in body composition between playing positions have been found in footballers (Silvestre, West, Maresh, & Kraemer, 2006), it is assumed that there will also be certain differences between positions in futsal. In this regard, the aim of this study was to determine the body composition of representative-level futsal players and to establish differences in body composition according to playing position. This research can provide reference values for parameters of body composition for a specific position in futsal, which can assist conditioning coaches in gaining deeper insight into the body composition parameters of elite futsal players and in creating an appropriate training program accordingly.

## Method

*Participants*

The sample of respondents consisted of players from the Bosnia and Herzegovina U-19 National Futsal Team (n=14, average age 18.07±0.48 years, body height 181.40±5.72 cm, and body weight 77.66±10.60 kg). The participants were categorized according to their playing positions as goalkeepers, defenders, wingers, and pivots. The inclusion criteria for participants were that they were representatives of Bosnia and Herzegovina, they were healthy, and they had not suffered any injuries in the last 6 months at the time of the study. Participation in the study was voluntary, and futsal players were informed about the study and provided written consent. The study was conducted in accordance with the Helsinki Declaration (World Medical Association, 2011) and approved by the Ethics Committee of the University.

*Anthropometric characteristics*

Anthropometric assessments were conducted following the guidelines of the International Biological Program (Eston & Reilly, 2009). Anthropometric characteristics and body composition were evaluated using a battery of 11 variables: body height (BH), body mass (BM), triceps skinfold (TS), biceps skinfold (BiS), back skinfold (BS), abdominal skinfold (AS), upper leg skinfold (UlS), lower leg skinfold (LlS), body mass index (BMI), fat percentage (FP), and muscle mass (MP). Anthropometers, calipers, and measuring tape were employed for the morphological measurements. A Tanita body fat scale (model BC-418MA) was utilized to assess body composition, specifically the parameters of fat percentage (FP) and muscle mass percentages (MP).

*Statistics*

The descriptive statistics were presented as mean, standard deviation, minimum, and maximum for each variable. Differences in anthropometric characteristics and body composition among the four groups of futsal players according to playing position were assessed using a discriminatory parametric procedure with ANOVA and post-hoc tests, with a level of statistical significance set at $p<0.05$. The data obtained in the research were analyzed using SPSS 26.0 software (Statistical Package for Social Sciences, v26.0, SPSS Inc., Chicago, IL, USA).

## Results

Based on the descriptive statistics (Table 1), it is noticeable that the futsal players of the Bosnia and Herzegovina national team had a body height of 181.40±5.72 cm, it should be noted that the shortest player measured 169.5 cm, while the tallest player measured 191.5 cm. The average body mass of the futsal players was 77.66±10.60 kg, with significant differences between the minimum (62.1 kg) and maximum values (94.4 kg). Looking at the average values of body fat percentage, they were 11.63±5.50%, also with considerable variation, where the lowest values recorded for one futsal player were 4.1%, while the highest values reached up to 20.4% body fat. On the other hand, the average values of muscle mass were 38.60±3.40 kg.

**Table 1.** Descriptive statistics of anthropometric characteristics in national futsal team players

| | Mean | SD | Min | Max |
|---|---|---|---|---|
| Age | 18.07 | 0.48 | 17.0 | 19.0 |
| Body height | 181.40 | 5.72 | 169.5 | 191.5 |
| Body weight | 77.66 | 10.60 | 62.1 | 94.4 |
| Triceps skinfold | 10.74 | 5.01 | 5.2 | 21.6 |
| Skinfold of the back | 11.42 | 4.49 | 6.0 | 20.4 |
| Biceps skinfold | 6.61 | 3.54 | 3.8 | 13.6 |
| Abdominal skinfold | 15.41 | 8.55 | 6.0 | 29.9 |
| Lower leg skinfold | 8.44 | 3.59 | 4.0 | 15.6 |
| Upper leg skinfold | 14.74 | 4.01 | 8.5 | 21.7 |
| Body mass index | 23.61 | 3.15 | 20.2 | 30.4 |
| Fat percentage | 11.63 | 5.50 | 4.1 | 20.4 |
| Muscle mass | 38.60 | 3.40 | 32.9 | 42.5 |

Note Mean - Arithmetic mean; SD - Standard deviation; Min – Minimum; Max - Maximum

Comparing anthropometric parameters according to playing position using ANOVA and post hoc tests, differences were found in the majority of parameters, specifically in 8 out of 11 variables (Table 2). It was found that goalkeepers and pivots had significantly higher body mass than defenders and wingers, and goalkeepers had a higher BMI than all other players, while pivots had higher BMI values than defenders and wingers. Regarding body composition, goalkeepers and pivots also had significantly higher values than defenders and wingers, and muscle mass favored goalkeepers and pivots over wingers. In terms of skinfold parameters, goalkeepers had significantly higher values in triceps and biceps skinfold than other players, in lower leg skinfold than defenders and wingers, and in skinfold of the back than wingers. There was no significant difference among the groups of futsal players in other anthropometric parameters (body height, abdominal skinfold, and upper leg skinfold).

**Table 2.** Descriptive data and ANOVA with post-hoc test of national futsal players by different playing position

| | Goalkepers Mean±SD | Defenders Mean±SD | Wingers Mean±SD | Pivots Mean±SD | Sig. | Post-hoc |
|---|---|---|---|---|---|---|
| Body height | 179.25±6.01 | 184.73±5.94 | 178.97±6.29 | 184.37±2.87 | .399 | / |
| Body weight | 93.70±0.99 | 73.23±4.17 | 69.67±5.65 | 87.40±3.48 | .000* | G>D, G>W, P>D, P>W |
| Triceps skinfold | 20.25±1.91 | 7.00±2.78 | 8.60±1.25 | 12.43±4.48 | .001* | G>D, G>W, G>P |
| Skinfold of the back | 17.95±1.34 | 10.07±3.23 | 8.90±2.13 | 13.47±6.12 | .044* | G>W |
| Biceps skinfold | 13.15±0.64 | 4.97±1.69 | 4.73±0.59 | 7.67±4.27 | .004* | G>D, G>W, G>P |
| Abdominal skinfold | 28.20±2.40 | 14.60±11.32 | 11.17±4.54 | 16.17±8.55 | .091 | / |
| Lower leg skinfold | 14.25±1.91 | 5.93±1.30 | 7.42±2.43 | 9.10±4.29 | .035* | G>D, G>W |
| Upper leg skinfold | 17.15±2.90 | 12.93±7.59 | 14.15±2.31 | 16.10±3.83 | .666 | / |
| Body mass index | 29.25±1.63 | 21.50±1.84 | 21.75±1.25 | 25.70±0.53 | .000* | G>D, G>W, G>P, P>D, P>W |
| Fat percentage | 20.25±0.21 | 5.93±1.80 | 9.30±2.58 | 16.23±2.37 | .000* | G>D, G>W, P>D, P>W |
| Muscle mass | 42.30±0.28 | 39.00±2.08 | 35.75±2.78 | 41.43±1.08 | .009* | G>W, P>W |

Note G – Goalkepers; D – Defenders; W – Wingers; P – Pivots; Mean - Arithmetic mean; SD - Standard deviation; * - significant difference

## Discussion

This study aimed to determine the body composition of representative-level futsal players and to establish differences in body composition according to playing position. It was found that there were differences between playing positions in the majority of futsal players' body composition parameters, specifically in 8 out of 11 variables. Therefore, the main findings of the study indicate that: i) goalkeepers and pivots have significantly higher body mass and percentage of body fat than defenders and wingers; ii) goalkeepers have a higher BMI than all other players, while pivots have higher BMI values than defenders and wingers; iii) muscle mass favors goalkeepers and pivots over wingers; iv) goalkeepers had significantly higher values in triceps and biceps skinfold than other players, as well as in lower leg skinfold than defenders and wingers, and in skinfold of the back than wingers.

When looking at the average values of the Bosnia and Herzegovina national team futsal players, it is noticeable that the body height was 181.40±5.72 cm, and the average body weight was 77.66±10.60 kg. The average values of total body mass and total body fat percentage of elite futsal players from Bosnia and Herzegovina were higher compared to the average values for futsal players from Brazil (171 cm and 67.4 kg; de Moura et al., 2013), Spain (175 cm and 69.8 kg; Barbero-Alvarez et al., 2009), Turkey (175.5 cm and 71.7 kg; Göral, 2014), and Croatia (176 cm and 70.4 kg; Milanović, Sporiš, Trajković, & Fredi Fiorentine, 2011). This difference between our study and previous results may be a result of selection since our study involved representatives of one country, representing an elite sample. Regarding the average values of body fat percentage, they were 11.63±5.50%, which were in line with the results of other studies (10.2-13.2%; de Moura et al., 2013). Muscle mass in kg of our players was 38.6 kg, which was slightly lower than the groups of Spanish futsal players.

When analyzed by playing positions, the average values of body height ranged from 179 cm for wingers and goalkeepers to 184 cm for defenders and pivots. The average values of body mass ranged from 69.7 kg for wingers to 93.7 kg for goalkeepers. A remarkably low percentage of body fat was measured in wingers (5.9%), while goalkeepers had 20.3% body fat. Defenders had 9.3% body fat, and pivots had 16.2% body fat, indicating a significant heterogeneity among groups regarding body composition. It was found that the differences in height between groups are not significant, while goalkeepers and pivots have significantly higher body mass and percentage of body fat than defenders and wingers. BMI values were also highest in goalkeepers (29.3), followed by pivots (25.7), while wingers and defenders had BMI values of 21.5 and 21.7, respectively. Based on the post-hoc test, it was determined that goalkeepers have a higher BMI than all other players, while pivots have higher BMI values than defenders and wingers. In line with the percentage of body fat, the distribution of subcutaneous fat tissue measured by skinfolds from specific sites showed a similar distribution among the groups. Goalkeepers, also had significantly higher values in triceps and biceps skinfold than other players, as well as in lower leg skinfold than defenders and wingers, and in skinfold of the back than wingers.

Research by de Moura et al. (2013) revealed that goalkeepers were slightly taller and heavier compared to defenders, pivots, and especially wingers, while the percentage of body fat was similar. Ramos Campo et al. (2014) obtained different results, where defenders were the tallest, followed by goalkeepers, pivots, and wingers, while goalkeepers and pivots had the highest body mass, followed by defenders and wingers. The highest percentage of total body fat was observed in pivots, followed by goalkeepers and wingers, while defenders had the lowest percentage. Comparing these results with our findings, differences among studies are noticeable. Specifically, in various studies, morphological and body composition parameters are differently distributed among groups according to playing position. This supports studies that have indicated significant diversity in the morphological status of football players (Dowson, Cronin, & Presland, 1999; Reilly, Bangsbo, & Franks, 2000). The reasons for these findings could be that players in the same position may differ in playing style, as well as in different tactical tasks. Therefore, it is not easy to establish reference values for specific anthropometric parameters for a given playing position of futsal players.

However, it should be emphasized that our study identified differences among playing positions in most parameters of futsal players' body composition, which is consistent with studies on football players (Silvestre et al., 2006; Katanic, Bjelica, & Milosevic, 2023). This knowledge can aid conditioning coaches in gaining a deeper understanding of the parameters of elite futsal players' body composition and, accordingly, in creating an optimal training program for improving body composition and physical performance, which requires specific periodization (Sermaxhaj et al., 2024).

This study is significant because it is one of the few that examines the morphology of elite futsal players, and to our knowledge, the first one to identify differences in anthropometric and body composition according to playing position in futsal. As a pioneering study, it can provide certain guidelines and encourage future researchers to further investigate the morphological and body composition of futsal players in more detail. Additionally, it should be noted that this study has yielded important findings by indicating certain differences in the morphology of futsal players according to team positions. However, these results must be interpreted with caution due to the small sample size, especially the subgroup of respondents, which represents one of the main limitations of this study. Therefore, a suggestion for future studies would be to include a larger sample size, and for a more comprehensive picture of body composition, bioelectrical impedance analysis with a greater number of parameters should be conducted (Đorđević et al., 2024), which would provide a deeper analysis of body composition parameters, both overall and segmental.

**Acknowledgments**
There are no acknowledgments.

**Conflict of Interest**
The author declares that there is no conflict of interest.

**Received:** 12 August 2023 | **Accepted:** 05 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240213

ORIGINAL SCIENTIFIC PAPER

# Effect of Scaling Racquet Using a Body-Scaling Approach on Badminton Match Performance

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**Abstract**

This research aimed to determine the ideal racquet size by modifying racquets based on a body-scaling approach employing arm-to-racquet length ratios. Twelve boys aged between 13 to 14 years (13.17±0.83) with one to two years of badminton experience volunteered to participate in the study. To calculate arm-to-racquet length ratios, participants' arm lengths for both hands were recorded. Participants were divided into six pairs and played a badminton match using three types of racquets which were racquets A (1.1:1.0), B (1.0:1.0), and C (0.9:1.0). Participants' hitting opportunities, successful strokes, winning strokes, rally length, and unforced errors were notated manually via video replay. Based on the one-way ANOVA with repeated measures, the results showed that the use of racquet B which had a pi ratio of 1.0:1.0 for arm length-to-racquet length ratios during badminton matches, recorded the highest mean scores in hitting opportunities, successful strokes, and winning strokes than racquets A (1.1:1.0) and C (0.9:1.0), p<.05. The results also demonstrated that the use of racquet B reduces the unforced errors during matches compared to racquets A and C, p<.05. It is suggested that giving children equipment that suits their physical characteristics (e.g., racquet length with arm length) might improve their performance and allow them to play badminton more efficiently.

***Keywords:*** *affordances, badminton, body-scaling, constraints-led approach, scaling equipment*

## Introduction

According to the dynamic system theory, practitioners can aid the learning of complicated tasks by modifying the tasks' demands or the practice environment (Woods et al., 2020). This theory suggests that changing one or more task, environmental, or performer constraints will probably affect the performer's information (perceptions) and movement options (action) (Broadbent, Buszard, Farrow, & Reid, 2021). The changes in the constraint (e.g., task constraints) have prompted the performer to explore new or more stable movement coordination patterns (Brocken, van der Kamp, Lenior, & Savelsbergh, 2021). There is a need for task modifications that considerably aid in the development of young talent while retaining the true nature of the individual movement coordination patterns displayed in adult games (Buszard, Reid, Masters, & Farrow, 2016; Buszard, Farrow, & Reid, 2020; Gorman, Headrick, Renshaw, McCormack & Topp, 2021). The court size and net height (Ortega-Toro, Blanca-Torres, Giménez-Egido, & Torres-Luq, 2020), the size of the ball (Afrouzeh, Musa, Suppiah, & Abdullah, 2020), and the size of the equipment (Azmi, Suppiah, Low, Noordin, & Samsir, 2020; Azmi, Low, & Nadzalan, 2023) being used are just a few examples of how junior sports are frequently modified.

Changing the practice environment through sports equipment modification is a crucial strategy for encouraging performers to seek functional movement patterns (Renshaw & Chow, 2019; Chow, Davids, Button, & Renshaw, 2021) and would increase participants' enjoyment during the games (Farrow & Reid, 2010). These sport equipment modifications have utilized the concept of affordances. Gibson (1986) de-

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fined affordance as the environment (i.e., the game's equipment) in terms of what it "offers" or "affords" the person. In other words, Gibson (1986) opted to explain the characteristics of the environment in terms of how they are related to individuals' attributes. As a result, affordances are body-scaled as people attempt to harness their abilities to excel in goal-directed tasks like competitive sports (Fajen, Riley & Turvey, 2009; Silva et al., 2013). Tennis researchers have used the racquet-to-racquet time (technical) (Timmerman et al., 2015) and height (physical maturity) (Limpens et al., 2018) measures to evaluate the effects of scaling in junior sports. Basketball researchers recently evaluated the relative difference between basketball players' hand span and ball size using this technique (Gorman et al., 2021). These situations created the opportunity to create a more cohesive plan for junior sports modification.

Pi-ratios, a body-scaling approach, have been designed to create methodical guidelines for junior sports modifications (Broadbent et al., 2021). The affordances theoretical idea from dynamic system theory was used to optimize modifying constraints in junior sports (Gorman, Renshaw, Headrick & McCormack, 2020). Pi ratios were calculated for the age group relative to the size of adult competition constraints (Broadbent et al., 2021). Given that youth rugby league games last half as long as adult games (40 minutes as opposed to 80 minutes), the task constraint ratio for match time (calculated based on action capabilities) in those games is 0.50. By comparing the average value of each group to the average adult, physical maturation ratios (calculations based on body/physical maturation) for each physical size measurement were established. If the children were half as tall as adults, the physical maturation ratio would be 0.50. To determine pi ratios, the task constraint was divided by the physical maturation ratio (Broadbent et al., 2021). Children's learning abilities are aided by giving them basketballs that fit their hands, which enables them to manage the ball in ways that adults do (Arias, 2012; Arias, Argudo & Alonso, 2012a,b; Gorman et al., 2020).

When designing talent development routes, the effectiveness of game modification is crucial to take into account (Buszard et al., 2020). For example, children had more opportunities to hit the shuttle and execute more successful strokes with a smaller court and racquet size in badminton (Suppiah, Low, Azmi, Noordin & Samsir, 2019; Azmi et al., 2020). However, the most crucial aspect is how the playing field, rules, and equipment have been altered in children's sports. The ability of the performer to attain motor competence may be significantly impacted by the scaling circumstances made available to them (Broadbent et al., 2021). Therefore, the study aimed to demonstrate the application of a body-scaling approach by modifying the racquet length based on children's physical characteristics (e.g., arm length) to identify the most appropriate badminton racquet size (from a selection of three racquet sizes; racquet A, B, and C). The study hypothesized that children might improve their match-play performance during badminton matches by utilizing a scaled racquet that employs a body-scaling approach. Children may be able to handle the racquet similarly to adult players, which could help them develop abilities appropriate for the adult game if the child's arm length and racquet size are matched.

## Methods

*Participants*

A minimum sample size of 12 participants was recommended by an a priori power analysis for ANOVA repeated measures ($\alpha$=0.05, 1-$\beta$=0.95, f=0.60). Therefore, the study included a total of 12 boys (13.17±0.83 years) who had played badminton for one to two years. The consent form was given to the parents of the research participants so that their children may participate in the study. The study was approved by Sultan Idris Education University's Ethics Committee for Human Research (2022-0498-02).

*Experimental procedure*

Participants' hands (right and left) were measured before the study started. The distance from the most distal crease of the wrist to the tip of the middle finger was measured using a segmometer to calculate the length of the hand (Fallahi & Jadidian 2011; Alahmari et al., 2017; Gorman et al., 2021). Hand length was measured twice on the right and left hands of each participant, and the mean values for hand length were calculated from the average of these measurements. The intra-rater and inter-rater reliability values were calculated using intra-class correlations, and they revealed incredibly high levels of reliability with scores between 0.97 and 0.99.

Participants completed badminton matches using three different types of racquets (racquet A, racquet B, and racquet C) (see Table 1) on a standard court. Racquet A is a standard racquet size used for official badminton tournaments. The length for racquet B was 100% of the participants' average arm length. The length for racquet C was 92% of the participants' average arm length. Based on the prior study, they manipulated the net height of badminton using 92% of the average height of children (Pirak, Nazarudin, & Suppiah, 2020). Pi ratios were calculated by dividing the task constraint by the physical maturation ratio (Broadbent et al., 2021). Table 1 displays the measurements for three different types of racquets. The following equation was used to get each racquet's pi ratio:

Pi ratio = task constraint ratio: physical maturation ratio

**Table 1.** The measurements for three different racquet types.

| Type of racquet | Racquet length (cm) | Pi ratios | Description |
|---|---|---|---|
| Racquet A | 68.0 | 1.1:1.0 | Adult size – Standard racquet used to play in official badminton tournaments. |
| Racquet B | 61.0 | 1.0:1.0 | 100% of the average arm length of participants. |
| Racquet C | 56.1 | 0.9:1.0 | 92% of the average arm length of the participants. |

Participants played using one type of racquet in a day to avoid exhaustion. Participants were unaware of which racquet they were using during the game. The order of the three types of racquets was counterbalanced across participants (Limpens et al., 2018). Before the match, participants were ranked based on their performance during the tasks performance (i.e., short serve, clear, and drop) to determine the pair. Participants played against the same opponent who was equally skilled at using all different kinds of racquets.

Participants completed 10 minutes of warm-up before starting their match. Participants played the best three sets of 21 points. All matches in all three types of racquets were recorded. One digital video camera brand Sony HDR-CX115 (Sony Tech, UK), has been set up 5 meters behind the baseline on each side to enable an analysis of the matches via video replay. The parameters (see Table 2) that were measured during match-play were as follows:

**Table 2.** Parameters in match-play.

| Parameters | Description |
| --- | --- |
| Hitting opportunities | The total number of hits, regardless of the result. |
| Successful strokes | The number of successful hits that fall in the desired playing area and pass the net. |
| Rally length | The total number of shots exchanged between the two players, beginning with the service and ending when the point is won (total shots regardless of the outcome). |
| Winning strokes | A point is awarded to the player who made the shot when it successfully penetrates the court and denies the opponent the chance to defend. |
| Unforced errors | A misjudgment in a serve or return shot cannot be traced to anything other than the player's bad judgment and is not the result of the opponent's ability or effort (Paserman, 2007). |

*Data analysis*

A Shapiro-Wilk test was used to determine if the data were normally distributed. The findings confirmed that the data were normally distributed, p>.05. The mean and standard deviation of the results of each skill test were calculated using descriptive statistics. A one-way repeated measures ANOVA was used to compare the parameters during the match-play between racquet A, racquet B, and racquet C. To compare the means of the three different types of racquets on the parameters measured, a Tukey post hoc test was performed. Cohens'd been employed to calculate effect sizes (ES). A modified scale with ES values of 0.25 trivial, 0.25-0.5 small, 0.5-1.0 medium, and >1.0 large was proposed by Rhea (2004). All statistical tests were run using the statistics package SPSS version 22.0. The statistical significance level was set at p<.05.

## Results

*Physical characteristics*

Table 3 shows the participants' physical characteristics in this study.

Table 4 depicts the overall descriptive statistics in the parameters of match-play performance of three types of racquets.

**Table 3.** Participants' physical characteristics

| Variables | N | Mean | Std. Deviation |
| --- | --- | --- | --- |
| Age (years) | 12 | 13.17 | 0.83 |
| Height (cm) | 12 | 155.42 | 2.40 |
| Weight (kg) | 12 | 47.00 | 3.46 |
| Arm length (Right) (cm) | 12 | 61.38 | 0.71 |
| Arm length (Left) (cm) | 12 | 61.29 | 0.79 |

**Table 4.** Descriptive analysis for match play performance

| Parameters | | Mean | Std. Deviation | Sig. | η2 |
| --- | --- | --- | --- | --- | --- |
| Hitting opportunities | Racquet A | 36.83 | 5.87 | .000 | .573 |
| | Racquet B | 47.17 | 6.05 | | |
| | Racquet C | 43.00 | 2.49 | | |
| Successful strokes | Racquet A | 25.66 | 5.45 | .000 | .615 |
| | Racquet B | 37.89 | 6.24 | | |
| | Racquet C | 32.14 | 2.62 | | |
| Rally length | Racquet A | 72.17 | 5.98 | .005 | .383 |
| | Racquet B | 79.00 | 8.07 | | |
| | Racquet C | 81.33 | 2.06 | | |
| Winning strokes | Racquet A | 8.00 | 0.74 | .000 | .696 |
| | Racquet B | 11.08 | 1.00 | | |
| | Racquet C | 9.58 | 1.31 | | |
| Unforced errors | Racquet A | 6.08 | 1.24 | .001 | .455 |
| | Racquet B | 4.25 | 0.97 | | |
| | Racquet C | 4.67 | 1.15 | | |

*Significant, p<.05.

*Hitting opportunities*

One-way ANOVA repeated measures demonstrated that there was a significant difference between racquets A, B, and C in hitting opportunities, $F(2, 22)=14.786$, $p<.001$, $\eta 2=.573$. Participants recorded the greatest means score in hitting opportunities when using racquet B(47.17±6.05) compared to racquet C(43.00±2.49) and A(36.83±5.87). The pairwise comparisons showed that there were significant differences between racquet A and racquet B; and racquet A and racquet C in hitting opportunities, $p<.05$. The hitting opportunities between racquets B and C, did not differ significantly ($p>.05$).

*Successful strokes*

One-way ANOVA repeated measures showed that there was a significant difference between racquets A, B, and C in successful strokes, $F(2, 22)=17.606$, $p<.001$, $\eta 2=.615$. Based on the result in Table 4, demonstrated that participants produced higher successful strokes in racquet B(37.89±6.24) than in racquet C(32.14±2.62) and A(25.66±5.45). The pairwise comparisons found that there were significant differences between racquets B and A; and A and C in successful strokes, $p<.05$. There were no significant differences between racquets B and C in successful strokes, $p>.05$.

*Rally length*

One-way ANOVA repeated measures showed that there was a significant difference between racquets A, B, and C in rally length, $F(2, 22)=6.824$, $p<.005$, $\eta 2=.383$. In the match-play, participants created longer rallies when utilizing racquet C(81.33±2.06) compared to racquet B(79.00±8.07) and A(72.17±5.98). The pairwise comparisons revealed that there were significant differences between A and racquet B; and racquet A and racquet C, $p<.05$. However, there was no significant difference in rally length between racquet B and C, $p>.05$.

*Winning strokes*

One-way ANOVA repeated measures revealed that there was a significant difference between racquets A, B, and C in winning strokes, $F(2, 22)=25.160$, $p<.001$, $\eta 2=.696$. Participants generated more winning strokes when using racquet B(11.08±1.00) during the match-play performance compared to racquet C(9.58±1.31) and A(8.00±0.74). The pairwise comparisons showed that there were significant differences between racquets B and A; B and C; and racquets A and C in winning strokes, $p<.005$.

*Unforced errors*

One-way ANOVA repeated measures demonstrated that there was a significant difference between racquets A, B, and C, $F(2, 22)=9.201$, $p<.001$, $\eta 2=.455$. Using racquet B(4.25±0.97) during match play resulted in fewer unforced errors, which is the opposite of what happened while using racquet C(4.67±1.15) and A(6.08±1.24). The pairwise comparison demonstrated that there was a significant difference between racquets A and B, and between racquets A and C in unforced errors, $p<.005$. However, there was no significant difference between racquets B and C in unforced errors, $p>.05$.

## Discussion

The study aimed to examine the effect of modifying racquet length based on a body-scaling approach on children's badminton match performance. The study hypothesized that children would perform well during match play because the technique maximizes affordances, making it smoother for children to play badminton than with a standard racquet. The results support our hypothesis, children produced more hitting opportunities, successful and winning strokes, and generated lower unforced errors during badminton matches when using racquet B which used 1.0:1.0 for arm length-to-racquet length ratios compared to racquets A (1.1:1.0) and C (0.9:1.0) (see Table 4). The use of a racquet scaled with 100% of participants' arm length-to-racquet length ratios led to better stroke performance and minimized unintentional fouls during the matches. The findings of this study are consistent with prior studies that equipment modification using a body-scaling approach increased motor skills proficiency in basketball (Gorman, Headrick, Renshaw, McCormack, & Topp, 2021), badminton (Azmi, Low & Nadzalan, 2023), and tennis (Limpens, Buszard, Shoemaker, Savelsbergh, & Reid, 2018). Therefore, simplifying the task by modifying the constraints based on children's physical capabilities allowed children to accomplish skills while maintaining information movement coupling that was unique to the sport (Fitzpatrick, Davids, & Stone, 2018; Buszard, Farrow, & Reid, 2020).

From the findings, racquet A is most likely too long for the participants to utilize during the matches. This racquet makes it harder for youngsters to create a better strokes leading to fewer opportunities for good hits, successful strokes, and winning strokes. A longer racquet may cause participants to commit more unforced errors, such as shots to the net (heavy to control) or shuttles hitting outside the court's boundaries (more power required to generate the strokes). According to the perception-action coupling theory, such a larger racquet is likely to limit the skills youngsters can learn and show off since it makes different kinds of information available to guide behavior than it would with scaled equipment (Broadbent, Buszard, Farrow, & Reid, 2021). Their reduced capacity to explore and develop novel movement solutions may also have an impact on the learning opportunities available to enhance their motor competence (Renshaw, Davids, & Savelsbergh, 2010; Azmi et al., 2023). Thus, it is conceivable that when using racquet A, participants were more reliant on conscious resources to manage their motions. When using difficult equipment, participants altered their technique more frequently, which shows a higher level of conscious involvement in the activity, decreasing the opportunity for participants to learn the skills implicitly (Buszard, Farrow, Reid, & Masters, 2014a).

The findings also indicated that racquet C, which utilizes 92% of the average arm length, performed better than racquet A. However, racquet B, which employs 100% of the participants' average arm length, performed better in match play than racquets A and C. It demonstrates that more desirable movement patterns may emerge if task constraints are scaled appropriately. The research suggested that children should employ racquets that used roughly 100% of their arm's length to obtain the same body-scaled affordances (Azmi et al., 2023). It was found that using racquets that were shorter and closer to the participants' arm lengths (racquet B, for example) made them easier to control, which in turn helped them enhance their stroke-making skills. In order to promote coordinated movement patterns, the application of scaled racquets may encourage participants to concentrate more on important perceptual aspects (Davids, Button, & Bennett, 2008; Buszard, Farrow, Reid, & Masters, 2014b). Modifying the task encourages children to look for novel solutions by examining the practice environment, which eventually supports unconscious learning processes - implicit learning (Renshaw, 2010). Therefore, using scaled equipment that has been modified depending on children's physical characteristics tends to encourage less cognitive processing to execute skills during the game (Buszard et al., 2014a).

Some previous studies also support the benefits of scaling equipment based on children's physical capabilities. When children are given basketballs that match their hands, it's simpler for them to handle the ball as adults do, which enhances their ability to learn (Farrow, Buszard, Reid, & Masters, 2016; Gorman, Renshaw, Headrick, & McCormack, 2020). Employing badminton racquets that match their physical abilities has been linked to positive effects, such as making it smoother for children to learn the game's basics (Suppiah et al., 2019; Azmi et al., 2020). This study has a few limitations, despite the fact that it offers strong results. The participants were limited to 13-year-olds with prior badminton expertise. A follow-up investigation with varied player traits and abilities would be intriguing. Other age groups must be taken into consideration in order to provide recommendations for the development of racquet sizes in junior badminton competitions. In addition, future studies should focus on how modifying equipment affects learning and determine if implicit or explicit learning is more common. The idea that the junior game ought to imitate the adult game in terms of match-play features and behaviors is one of the implicit assumptions of the scaling sport argument (Buszard et al., 2020).

## Conclusion

In conclusion, the findings of this study provide crucial practical application for coaches and teachers where scaling the task constraints based on physical attributes contribute to optimal learning experience for children to execute the skills effectively. The application of a racquet scaled at 100% of the participants' arm length-to-racquet length ratios improved stroke performance in terms of winning strokes and successful strokes and reduced unintentional fouls in terms of unforced mistakes throughout the matches. It would be feasible to build activities that take participants' constraints into account, which could be a useful tool for skill development.

**Acknowledgment**

The coaches and players from Kota Marudu, Sabah, are acknowledged by the authors for their help and support in completing this study. Additionally, a special thanks to Universiti Pendidikan Sultan Idris' Institute of Graduate Studies and Research Management and Innovation Centre for providing the funding necessary to publish this paper.

**Conflict of interests**

The authors declare no conflicts of interest.

**Received:** 19 August 2023 | **Accepted:** 21 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240214

ORIGINAL SCIENTIFIC PAPER

# Analysis of the Relationships between Sport Participation, Physical Activity, and Concurrent Substance Misuse in College Students: A Gender-Stratified Analysis in the Post-Pandemic Period

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**Abstract**

The COVID-19 pandemic resulted in increased substance use and misuse (SUM). The period in which one undergoes college education is known to be associated with a greater risk of SUM, and there is a need for greater awareness of the risks associated with concurrent SUM in the post-pandemic years. The aim of this study was to evaluate the gender-specific relationships between physical activity levels (PAL), sport participation, and concurrent SUM among college students in the first post-pandemic year. The participants were college students from Croatia and from Bosnia and Herzegovina (n=398) who were tested on sport factors (involvement in individual and team sports, time of involvement, frequency of training, sport achievement), physical activity levels (PALs), and concurrent SUM (simultaneous consumption of cigarettes and alcohol) by using structured anonymous previously validated questionnaires immediately after the pandemic period. Sport factors and PALs were not significantly associated with concurrent SUM in the total sample or in male students. In female students, higher competitive achievement in sports was shown to be associated with the risk of concurrent SUM (OR=1.45, 95%CI:1.11-1.98). The results evidenced an increased risk of concurrent SUM in female students who achieved greater success in sports. Therefore, it seems that public health authorities should develop specific educational and preventive programs in female athletes. The timing of this study was in the first post-pandemic year which could have at least partially influenced our findings.

***Keywords:*** *substance use, sport participation, physical activity, healthy lifestyle, pandemic*

## Introduction

Despite its decreased prevalence, cigarette smoking (smoking) remains the leading type of substance misuse (SUM) globally (Flor, Reitsma, Gupta, Ng, & Gakidou, 2021). It is well known that smoking has a significant negative impact on health, leading to increased healthcare resource use, lower quality of life, and higher healthcare costs. It is a major cause of various diseases, including cancer, cardiovascular disease, and respiratory conditions, and it is associated with adverse effects on pregnancy and newborns (Flor et al., 2021). Smoking behavior is often related to stress, and the time in which one obtains a college education is considered a period of increased risk of heavy smoking (Fitzgeorge, Tritter, Fgan, Nagpal, & Prapavessis, 2018). In general, authors have emphasized the importance of psychological and socioenvironmental determinants of smoking behavior, and they have underscored the need for comprehensive smoking policies and effective education and prevention programs on college campuses (Fitzgeorge, Tritter, Fagan, Nagpal, & Prapavessis, 2018). In addition, factors influencing health-promotive behaviors, in-

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cluding self-efficacy and avoidance of environmental tobacco smoke were identified (Martinelli, 1999). Unsurprisingly, positive effects of policies of limiting smoking on college campuses on smoking rates and improved academic outcomes were reported (Cannonier et al., 2019).

Alcohol is considered the second most popular type of SUM in the world today (King et al., 2023). Unlike smoking, for which there is a clear consensus about the (exclusively) negative consequences of consumption, the consequences of alcohol consumption are not as straightforward. Collectively, it seems that mild consumption of alcohol is not recognized as a problem, but the likelihood of negative health consequences exponentially increases with higher rates of alcohol consumption. In brief, serious problems related to alcohol dependence, including mortality, psychiatric conditions, and neurological deficits, are generally emphasized (Cargiulo, 2007), but some authors have noted that moderate consumption of alcohol can have beneficial effects, particularly in preventing heart thrombosis (Grønbæk, 2009). The impact of heavy drinkers' alcohol consumption on others' health and wellbeing is also a concern (Livingston, Matthews, Barratt, Lloyd, & Room, 2010). Last but not least, Rehm et al. (2010) provided a comprehensive overview of the causal impacts of alcohol consumption on various diseases and injuries and highlighted the need for further research to understand the nature of these relationships. Again, this problem is particularly important among college students, since this period of life imposes significant stress on young people, and a higher likelihood of alcohol consumption is associated with higher levels of stress (Metzger et al., 2017).

Two factors that have been frequently observed to be protective against SUM are physical activity (physical exercise) and sport participation. A range of studies have explored the complex relationship of physical activity levels (PALs) and sport participation with smoking and drinking but with inconsistent results results (Modric, Zenic, & Sekulic, 2011; Paavola, Vartiainen, & Haukkala, 2004; Zenic, Terzic, Rodek, Spasic, & Sekulic, 2015).. While some studies noted higher rates of smoking and drinking among physically inactive individuals, others evidenced higher levels of SUM in athletic and more physically active individuals (Modric et al., 2011; Paavola et al., 2004; Zenic, Terzic, et al., 2015), For example, Poortinga found that sports activities and heavy drinking were more prevalent among sports club members (Poortinga, 2007). Meanwhile, Paavola et al. found that smoking and alcohol use were positively correlated, with smoking being negatively correlated with leisure-time PALs (Paavola et al., 2004), which actually supported the findings of Conway and Cronan (1992) who previously demonstrated that smoking was associated with lower PALs and lower physical endurance even after controlling for exercise activity. Further, Audrain-McGovern et al. (2003) and Aaron et al. (1995) both found that higher PALs reduced the odds of the progression of smoking and the initiation of alcohol use, respectively. Meanwhile, Rainey et al. found that athletic youth were less likely to smoke but more likely to use smokeless tobacco and engage in alcohol use (Rainey, McKeown, Sargent, & Valois, 1996).

There is a large body of evidence that the COVID-19 pandemic led to an increase in SUM and a decrease in PALs (Puen, Cobar, Dimarucot, & Camarador, 2021; Kuna, Duvnjak, & Kokic, 2023). In general, factors such as stress, job loss, reduced wages, and interruptions in addiction care were associated with an increase in SUM (Grossman, Benjamin-Neelon, & Sonnenschein, 2020; Quadri et al., 2023). Studies that specifically examined college students found that the pandemic led to an increase in SUM, especially with regard to alcohol consumption (van Hooijdonk et al., 2022). It seems that the shift toward remote learning and increased anxiety have been linked to such trends (Fruehwirth, Gorman, & Perreira, 2021). In addition, the prevalence of mental health problems, including acute stress, anxiety, and depressive symptoms, was high among college students during the pandemic, and these all increased the likelihood of SUM (Li et al., 2021). At the same time, during the pandemic period, due to the imposition of social distancing and lockdown measures, PALs and sport participation decreased, and this was confirmed globally in various sociodemographic groups, including college students (Bertrand et al., 2021; Gilic, Zenic, Separovic, Jurcev Savicevic, & Sekulic, 2021).

Considering the increase in SUM rates, the simultaneous decrease in PALs, and the lack of sport activities during the pandemic period, researchers were interested in possible associations that may have existed between PALs and SUM among college students in the early post-pandemic period. A study carried out with college-/university-level students from the territory of southeastern Europe showed that neither PALs nor sport participation were associated with prevalence of smoking among the participants, which was at least partially the consequence of the studied period (the first year after the pandemic) and negative trends in PALs and SUM that occurred previously during the pandemic period (Drenjak, Pehar, Užičanin, Kontić, & Zenić, 2023). Meanwhile, in a study that explored associations between PALs and alcohol drinking, it was highlighted that an overall increase in PALs could be helpful in decreasing alcohol consumption among college/university students (Drenjak, Užičanin, & Zenić, 2023). However, previous studies were cross-sectional; therefore, the causality could not be interpreted. In addition, to the best of our knowledge, no study has shown associations that may exist between sport participation/PALs and concurrent SUM (simultaneous drinking and smoking) in college/university students in the early post-pandemic period.

Empirical evidence has suggested a complex interplay among PALs and sports, smoking, and drinking, thus demonstrating the clear necessity of further research on this problem, especially while considering concurrent SUM (Zenic, Rezic, Zovko, Vlahovic, & Sattler, 2020). Further, considering the increase in SUM and decrease in PALs that occurred during the pandemic, there is a clear need to explore these associations in the post-pandemic period. Finally, considering that SUM is generally correlated with (increased) stress, while college students face a range of stressors (e.g., academic pressure, interpersonal issues, and family-related stress), this population should be considered as a group of particular interest with regard to the evaluation of the factors associated with SUM in the post-pandemic period (Yikealo, Yemane, & Karvinen, 2018). Finally, research has consistently shown that the misuse of multiple substances (concurrent SUM) is associated with more severe physical and mental health outcomes than single SUM, and this is particularly concerning in young adulthood (Phillips, 2000; Marshall, 2006; Quek et al., 2013). These findings underscore the need for greater awareness of the risks associated with concurrent SUM. Therefore, the aim of this study was to evaluate the gender-specific associations between PAL, sport participation, and concurrent SUM among college students (students) from southeastern Europe in the first post-pandemic year. Initially, we hypothesized that higher PALs and sport participation would be associated with a lower likelihood of concurrent SUM, irrespective of gender.

## Methods

*Participants and study design*

The participants in this cross-sectional investigation were college/university students from Bosnia and Herzegovina (B&H) and Croatia. At the time of testing, all participants were aged from 18 to 21 years, and the total sample comprised 412 participants (52% females). The participants were selected from three convenient universities at which the investigators were engaged as teachers. A multi-stage sampling procedure was performed to select the subjects. In the first stage, the faculties (i.e., organizational units of the universities) were divided into two groups (small and large) on the basis of the number of full-time students in each faculty. Second, 50% of the faculties in each group were randomly selected. One academic year was then included by relative proportion in the sampling. It must be noted that the authors did not specify necessary requirements regarding the study program, meaning that each study program was (theoretically/statistically) proportionally represented. Prior to the study, approval was obtained from the Ethical Board of the Faculty of Kinesiology, University of Split, Croatia (EBO: 2181-205-05-02-05-14-005, 11 May 2017)

The participants were analyzed one to two months after the COVID-19 pandemic ended in Croatia and in Bosnia and Herzegovina. One month prior to testing, all participants were contacted by college authorities and asked for their participation in the study. Initially, we contacted 600 potential participants, who were randomly selected from the pool of the observed universities. Throughout the initial contact, the participants were informed about the purpose and objectives of the study, and they were informed about the study's importance. They were informed that if they agreed to participate, no personal information would be asked of them, and their responses would not be personally connected to them. An online survey was conducted on an internet-based platform. All participants who agreed to participate received a link to the survey by email. On the basis of the data obtained we calculated the intracluster correlation (ICC) between universities, which showed a proper within-university (within-cluster) variance (ICC=0.11).

*Variables*

Variables were collected with previously used and validated questionnaires: (i) the Alcohol Use Disorder Identification Test (AUDIT), (ii) the Questionnaire of Substance Use (QSU), and (iii) the International Physical Activity Questionnaire (IPAQ). All three questionnaires have already been extensively presented in the previous literature (Tahiraj et al., 2016; Zenic, Ostojic, et al., 2015; N. Zenic et al., 2020), so the tools used will be only briefly presented in the following.

The QSU collects data on sport factors, sociodemographic factors, and the misuse of substances. In this study, we specifically observed gender (responses included male, female, and other), age (in years), and country of origin (B&H and Croatia). The sport factors included in this study were assessed via four questions that examined different facets of involvement in sports, namely, (i) involvement in team sports, (ii) involvement in individual sports (both responses were on a scale that included "never been involved", "quit", and "currently involved"), (iii) the highest competitive achievement in sports (responses included "never competed/did not participate in sports", "local competitions", "national-competitions", and "international-level competitions"), (iv) time of involvement in sports (including "never involved", "<1 year", "2–5 years", and ">5 years"), and (v) the number of training sessions per week ("never participated, 1–2, 3–5, 6-7, >7 per week ). Although the QSU is used to examine the consumption of a variety of substances, in this study, we observed only smoking (please see the following for the evaluation of alcohol consumption). The participants were questioned about smoking on a five-point scale, which included the following responses: never smoked, quit, smoked but not daily, smoked daily). The responses were later dichotomized, and the participants were considered as nonsmokers (first two responses) or smokers.

The AUDIT questionnaire measures the consumption of alcohol and contains 10 items. Each item is scored on a scale ranging from 0 to 4, and the AUDIT score is later expressed as a summarized score of all items that ranges from a minimum of 0 to a maximum of 40. Later, the scores were dichotomized into harmful drinking (scores of 11 and higher) and non-harmful drinking (scores lower than 11).

If participants reported smoking (see the previous explanation) and HD (scores of 11 or higher on the AUDIT scale), they were categorized into the group with concurrent SUM.

The short version of the International Physical Activity Questionnaire (IPAQ) was used to assess PALs. The short version of the IPAQ applied here has been used in many studies around the world, and its validity and reliability in the local languages (i.e., Croatian, Bosnian, and Herzegovinian) were confirmed (Maric et al., 2020; Sekulic et al., 2021; Zenic et al., 2021). Shortly, the IPAQ assesses physical activity undertaken during leisure time, yard activities, work-related activities, and transport. The IPAQ contains questions about walking, moderate-intensity activities, vigorous-intensity activities, and sitting (sedentary time) to assess the frequency and duration of each activity. In this study, we observed PALs as the energy expenditure in METs.

*Statistics*

Kolmogorov–Smirnov tests were conducted to define the normality of the distributions for all variables, and the descriptive statistics included means and standard deviations (for normally distributed variables), as well as counts and percentages (for ordinal and nominal variables).

Differences between genders were established with a t-test (for the AUDIT score) and Chi-square test (for smoking and concurrent SUM).

The associations of sport factors and PALs (predictors) with concurrent SUM were established by calculating logistic regressions (see the following), but in the first stage, participants who were positively classified with concurrent SUM and those who did not report concurrent SUM were compared in terms of predictors by using a Chi-square test (for nominal predictors) and Mann–Whitney test (for ordinal predictors).

Logistic regressions were calculated for binarized concurrent SUM (Yes or No). Each predictor was independently correlated with concurrent SUM, and the odds ratio (OR) with a 95% confidence intervals (95%CI) was calculated. The logistic regressions were stratified by gender due to evidenced differences between genders in concurrent SUM (please see previous analyses, and later text for more details). The significance level of $p<0.05$ was applied, and Statistica ver. 13.5 (Tibco Inc., Palo Alto, CA, USA) was used for all calculations.

## Results

Males and females significantly differed in AUDIT score with higher scores in males (4.75±2.04 and 2.77±1.90 for males and females, respectively; t-test=3.72, p<0.001).

The prevalence of HD was higher in males than in females (20% and 5% for males, and females, respectively; Chi square=11.86, p<0.001).Smoking prevalence was similar in males and females (30% male and 27% female smokers; Chi square=0.04, p=0.83).

Concurrent SUM was higher among males, than among females (12% and 4.3% concurrent SUM among males and females, respectively; Chi square=4.22, p<0.05).

Table 1 presents descriptive statistics for sport factors, and differences between groups based on concurrent SUM. As presented, Mann Whitney coefficients indicated significant differences between groups in "Experience in sport" (Mann Whitney Z=2.11, p<0.05), "Competitive achievement" (Mann Whitney Z=2.77, p<0.05), and "Number of training/competitions sessions per week" (Mann Whitney Z=2.11, p<0.05). When observing more specifically, it is evident that experience in sport was higher in those participants who reported concurrent SUM. Also, those college students who reported concurrent SUM achieved better results in sport, and had more training sessions per week.

**Table 1.** Descriptive statistics (F – counts, % - percentages) for sport-factors in total sample, and separately in groups based on prevalence of concurrent substance misuse (Concurrent SUM), with differences between groups calculated by Mann Whitney test (* denotes significant differences between groups at p<0.05)

| | Concurrent SUM | | | | | | Mann Whitney test |
|---|---|---|---|---|---|---|---|
| | Total | | No | | Yes | | |
| | F | % | F | % | F | % | |
| Individual sport participation | | | | | | | 1.86 |
| Yes. still participating | 16 | 4.0 | 15 | 3.8 | 1 | 4.0 | |
| Yes. but quit | 203 | 51.0 | 181 | 47.0 | 22 | 67.9 | |
| No. never | 179 | 45.0 | 170 | 44.0 | 9 | 28.1 | |
| Missing | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | |
| Team sport participation | | | | | | | 0.10 |
| Yes. still participating | 48 | 12.0 | 48 | 12.3 | 3 | 10.0 | |
| Yes. but quit | 206 | 51.8 | 180 | 46.7 | 23 | 71.3 | |
| No. never | 144 | 36.2 | 138 | 35.8 | 6 | 18.8 | |
| Missing | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | |
| Experience in sport | | | | | | | 2.11* |
| Never participated | 97 | 24.4 | 95 | 24.6 | 2 | 6.3 | |
| < 1 year | 94 | 23.6 | 85 | 22.0 | 9 | 28.1 | |
| 2-5 years | 111 | 27.9 | 100 | 25.9 | 11 | 34.4 | |
| > 5 years | 96 | 24.1 | 86 | 22.3 | 10 | 31.3 | |
| Missing | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | |
| Competitive achievement | | | | | | | 2.77* |
| Never participated/Never competed | 201 | 50.5 | 192 | 52.5 | 9 | 28.1 | |
| Local rank | 165 | 41.5 | 146 | 39.9 | 19 | 59.4 | |
| National rank | 25 | 6.3 | 22 | 6.0 | 3 | 9.4 | |
| International rank | 4 | 1.0 | 3 | 0.8 | 1 | 3.1 | |
| Missing | 3 | 0.8 | 3 | 0.8 | 0 | 0.0 | |
| Number of training/competitions per week | | | | | | | 2.11* |
| Never participated | 96 | 24.4 | 94 | 26.0 | 2 | 6.3 | |
| 1-2 per week | 115 | 28.9 | 106 | 29.0 | 9 | 28.1 | |
| 3-5 per week | 146 | 36.7 | 131 | 35.8 | 15 | 46.9 | |
| 6-7 per week | 34 | 8.5 | 30 | 8.2 | 4 | 12.5 | |
| > 7 per week | 6 | 1.5 | 4 | 1.1 | 2 | 6.3 | |
| Missing | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | |

Differences between groups based on concurrent SUM in PAL are presented in Figure 1. As evidenced, no significant differences were found when t-test was calculated for total sample, and in gender-stratified analyses.

Results of the logistic regression calculated for criterion concurrent SUM in male college students are presented in Figure 2. In general, no significant association between sport factors, and PAL with concurrent SUM in males was found.

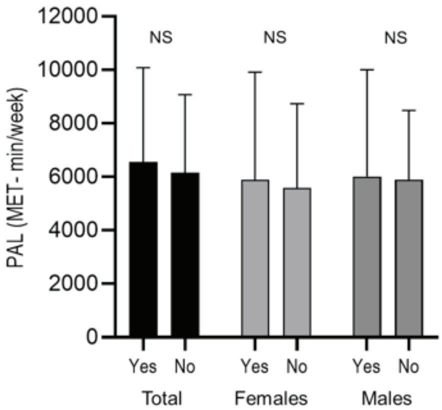


FIGURE 1. Physical activity levels obtained by IPAQ (presented as Mean + SD) and differences between groups based on concurrent substance misuse obtained by t-test for independent samples in total sample and gender-stratified (NS – non-significant differences between groups)

Correlations between sport factors and physical activity levels, and concurrent SUM (criterion) in female students calculated by logistic regression are presented in Figure 3. In brief, the only significant association was found between "Competitive achievement" and criterion (OR=1.25, 95%CI:1.05-1.45), with higher likelihood for concurrent SUM in females who achieved higher competitive success in sport.

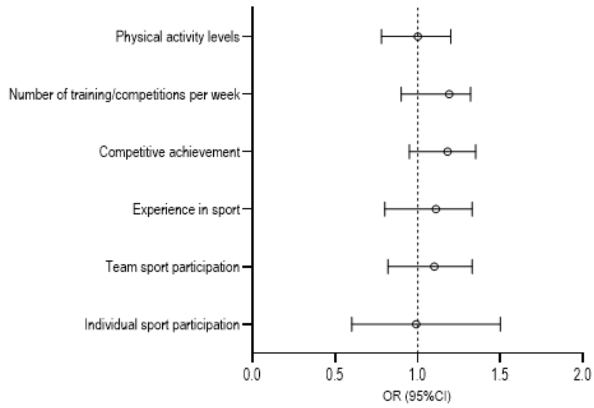


FIGURE 2. Logistic regression results; correlations between sport factors and physical activity levels, and concurrent SUM in males (OR – Odds Ratio, 95%CI – 95% Confidence Interval)

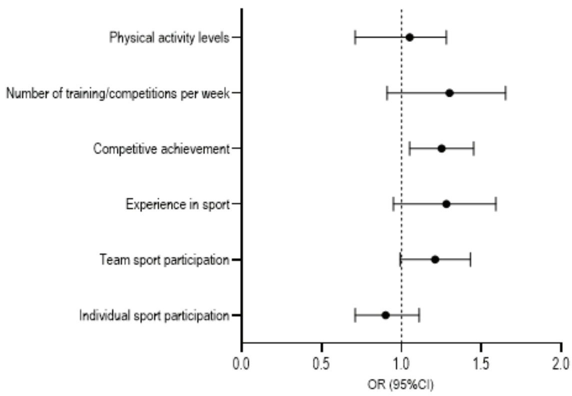


FIGURE 3. Logistic regression results; correlations between sport factors and physical activity levels, and concurrent SUM in females (OR – Odds Ratio, 95%CI – 95% Confidence Interval, * denotes significance of $p < 0.05$)

## Discussion

Considering the study's aims, the two most important findings will be discussed in the following. First, when observing the total sample of college students and when observing males, sport participation and PALs were not significantly associated with concurrent SUM. However, in females, competitive achievement in sports was associated with concurrent SUM, with a higher likelihood of concurrent SUM in female students who achieved better success in sports. Therefore, our initial hypothesis was rejected.

The problem of the association of sports/PALs with SUM is frequently studied, mostly because of the overall perception that sports and, consequently, higher PALs are related to a healthy lifestyle and, therefore, could be protective against

SUM (as an unhealthy habit) (Gilic et al., 2021; Zenic et al., 2021). However, the findings of empirical studies, including those in which authors specifically observed college-/university-level students, are generally controversial. Some studies have highlighted the potentially protective effects of sport participation and higher PALs on SUM (Zenic et al., 2021; Zenic, Ostojic, et al., 2015). Meanwhile, some authors found that extrinsically motivated athletes were at higher risk for SUM, and this was particularly evident among students engaged in team sports (Rockafellow & Saules, 2006; Ford, 2007). This was actually a confirmation of earlier findings of Leichliter et al. (1998) and a later study by Green et al. (2014), who also found a link between participation in sports and alcohol use. When examining this relationship more specifically, some authors studied the links between sport participation and the consumption of different substances. For example, some studies confirmed that participation in sports is linked to higher alcohol consumption, but it is also associated with lower levels of smoking and illegal drug use (Veliz, Boyd, & McCabe, 2015; Williams et al., 2020).

Even studies in which the authors specifically observed PALs (not necessarily in connection with sport participation) showed different findings. In general, while some authors highlighted that a positive association in which PALs were protective against SUM, others highlighted a higher risk of SUM in more physically active participants (Collingwood, Reynolds, Kohl, Smith, & Sloan, 1991; Zschucke, Heinz, & Ströhle, 2012). Therefore, our findings on the non-significant correlation between sports/PALs and concurrent SUM are not surprising. Namely, while we observed concurrent SUM, there is a certain possibility that sport participation and PALs were differentially associated with facets of concurrent SUM (e.g., smoking and harmful alcohol consumption), as suggested in previous studies (Zenic et al., 2021; Zenic et al., 2023). Altogether, this could logically result in a non-significant association between predictors and concurrent SUM as a criterion in college students.

However, there is a certain possibility that the period in which the study was conducted influenced our findings. Our study specifically focused on the first post-pandemic year. In the previous pandemic period, PALs and sport participation decreased as a consequence of the imposition of social distancing and lockdown measures (Gilic et al., 2021). On the other hand, there is evidence that SUM increased during the same period (Grossman et al., 2020; Quadri et al., 2023). As a result, it is possible that such changes even influenced the relationships between the variables. Namely, the quantitative changes in study variables could almost certainly result in qualitative changes (changes in the associations between the observed indicators).

Gender-stratified approaches to studying eventual relationships between sports/PALs and SUM are not common. While a great deal of studies have explored this problem among adolescents and young adults (Modric et al., 2011; Zenic, Ostojic, et al., 2015) researchers have rarely decided to evaluate these relationships specifically for each gender . However, more recent studies highlighted the necessity of such a method, especially in countries in which genders significantly differ in terms of their sport participation (Zenic et al., 2023; Zenic et al., 2021). In addition, a gender-stratified analysis appeared to be more convenient, since empirical evidence has underlined a sport-specific influence on SUM (i.e., with a higher risk of SUM in some typically male sports, such as rugby or football). Our results showed significant associations between sport participation and concurrent SUM in female students, but no association was shown for males, which clearly confirmed the appropriateness of separate analyses for males and females. As presented previously, among females, greater competitive success in sports was associated with a higher likelihood of concurrent SUM. From our perspective, the mechanisms of this association are both contextual and sociocultural. Therefore, in the following, we will provide an overview of both mechanisms.

The sociocultural context of sport participation in southeastern Europe (the territory of former Yugoslavia) is somewhat specific. There are no clear sociocultural barriers to female participation in sports at any level. Research on female sports in Croatia has identified several factors that influence women's engagement in sports; these are evidently general and not gender-specific, and they include the type of sport, educational level, marital status, and place of living (Sindik, Mikic, Dodigovic, & Čorak, 2016). Although we could not find any studies that directly investigated similar problems in B&H, considering the similarity of the cultural backgrounds of these two countries, we are convinced that evidence from Croatia is easily transferable to B&H. However, as long-term professionals in sports, the authors of this study are of the opinion that there is still a need for comprehensive implementation of a regulatory framework with a gendered perspective in the field of sports. Therefore, despite the proclaimed "equality" in the availability of sports for both men and women, we are still witnessing huge differences in sport participation between genders, with men being evidently more involved in sports than women, which was confirmed in this research

The literature from around the world has offered a variety of reasons for women being less involved in sports than men (e.g., women generally have less interest in sports, have lower competitiveness, and take fewer risks than men) (Deaner, Balish, & Lombardo, 2016). Meanwhile, in our region, another reason deserves attention. Namely, there is no doubt that in Croatia and in Bosnia and Herzegovina, typical female sports (i.e., aesthetic sports such as dance and gymnastics) are less represented than typical male sports (i.e., martial arts and team sports). Because of the characteristics of martial arts, girls rarely participate in them, which is mostly due to their sociocultural backgrounds (e.g., family constraints, stereotyping), as well as hygienic reasons (the menstrual cycle is a significant obstacle to female participation in sports in which physical contact is inevitable); therefore women are more oriented toward team sports. This was confirmed in our study, where the majority of the studied females who were involved in sports participated in team sports. This low female participation in sports probably generated a specific environment for (concurrent) SUM among females.

In brief, research has frequently—although not exclusively—presented an increased risk of SUM among athletes who play team sports. For example, attraction to one's team was found to predict alcohol and marijuana use among intercollegiate athletes (Grossbard, Hummer, LaBrie, Pederson, & Neighbors, 2009). Further, participation in team sports was associated with increased binge drinking and smokeless tobacco use among Canadian adolescent girls, while female soccer athletes were identified as being at the greatest risk of substance use (Boyes, O'Sullivan, Linden, McIsaac, & Pickett, 2017; Ford, 2007). To explain these trends, several of the most important reasons should be highlighted.

First (i), sports are a social activity, with team sports being particularly social. After sessions of playing team sports (e.g., training, competitions), gatherings are very common, and in such circumstances, substances (mostly alcohol and cigarettes) are frequently consumed (Drenjak, Užičanin, et al., 2023). Second (ii), athletes often travel for competition or training. In the period of adolescence, (female) athletes are less likely to be under the proper control of responsible adults (e.g., coaches, officials, physicians). Therefore, studies have confirmed that there is an earlier initiation of SUM for athletes than for their non-athletic peers (Zenic et al., 2020). Third (iii), athletes are competitive in nature. Because of that, they have a tendency to compete in SUM (especially in alcohol consumption) (Sekulic, Bjelanovic, Pehar, Pelivan, & Zenic, 2014). Fourth (iv), athletes have a certain tendency toward risk-taking, which unfortunately increases the risk of SUM (Cherpitel, 1993). The problem is even more aggravated among more successful (female) athletes simply because (i) post-sport gatherings in which success is celebrated are more common, (ii) they travel more often and further, (iii) they are more competitive than their less successful and non-athletic peers, and (iv) they almost certainly have a greater tendency toward risk-taking.

One could argue that the previous explanations are plausible for males as well; therefore, similar associations between sport factors and concurrent SUM should appear not only among females, but also among males. However, (concurrent) SUM is more frequent among males than among females. Consequently, the previously specified risks of higher SUM are not as influential on males as they are on females. Taken together, these reasons likely explain the fact that correlations between sport factors and concurrent SUM were solely found among females.

Regardless of the previous explanations of the established relationships, it seems that the COVID-19 pandemic did not significantly influence the associations between the study variables. Most probably, because the studied participants were young adults/college students, relative stability was found in all observed variables, since the trends in concurrent SUM, PALs, and sport participation did not change considerably over the course of the study. However, this points to another important problem, which goes beyond the aims of this study and should be investigated in more detail in the future.

*Limitations and strengths*

All variables observed in this study were collected with questionnaires, which was certainly the most considerable limitation. Therefore, it is possible that the participants did not respond honestly to some of the questions, especially those related to SUM. However, since we did not evaluate the consumption of illegal substances, we believe that the results are plausible. In addition, apart from the basic sociodemographic data, physical activity levels, and sport factors, other variables that were potentially related to concurrent SUM were not observed. Therefore, in some cases, we lack some important information that could hopefully help us create a more profound interpretation of the results.

On the other hand, this is one of the first studies to examine the associations between studied variables among college students after the pandemic period. Considering that this population is burdened with a great deal of stress and that SUM is known to be associated with stress, this is an important strength of this study. In addition, this is one of the rare studies in which PALs and sport participation were studied separately, and the sport factors included various indices related to sports. This allowed us to discuss the correlations more specifically, especially when considering the gender-stratified analysis.

In future investigation it would be therefore important to prospectively observe the problem in order to precisely evaluate causality between study variables. Also, investigations in other age-groups are warranted.

## Conclusion

The results showed the specific associations between sport participation and concurrent SUM among female students; those who achieved greater success in sports had a higher risk of concurrent SUM. Most probably, the specific sociocultural context of female sport participation influenced these relationships. Therefore, public health authorities should develop effective strategies for the prevention of SUM, especially among female athletes.

Sport factors were not shown to be related to concurrent SUM among male students. Therefore, there is no proof that sport participation is a factor with any influence on SUM among young adult males. It is important to note that practically all of the participants in the study were urban residents (full-time college students residing in urban centers); therefore, specific limitations related to sport participation in association with urban/rural differences in sport availability did not influence our results to a great extent.

Despite the previous conclusions and explanations, there is a certain possibility that the results were influenced by the specific period in which the study was performed (first post-pandemic year). Consequently, negative changes that occurred in the study variables during the pandemic could have influenced the relationships between variables in the post-pandemic period. Therefore, further studies are needed in order to explore the problem more accurately.

**Acknowledgments**
There are no acknowledgments.

**Conflict of Interest**
The author declares that there is no conflict of interest.

**Received:** 04 December 2023 | **Accepted:** 21 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240215

ORIGINAL SCIENTIFIC PAPER

# The Association between Regular Sports Participation and Immune Status in College Students Using Immune Status Questionnaire

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**Abstract**

College students may lack physical activity due to academic burden. This puts them at a higher risk of decreased immunity. This study aimed to investigate the association between sports participation and immune status. This was a cross-sectional retrospective study. Participants were 170 Atma Jaya Medicine and Health Science School students consisting of 59 boys (34.7%) and 111 girls (65.3%). Seventy-nine (46.5%) students participated in the Sports Students Club from December 2021 - December 2022, and 91 did not (53.5%). There were four sports, i.e., badminton, basketball, futsal, and volleyball. Data was taken from July-August 2023. Immune status was assessed using the Indonesian Immune Status Questionnaire (ISQ) version. The amounts of boys engaged in sports activity was significantly greater than girls [45(76.3%) vs 34(30.6%), p=0.001]. One hundred eleven students (65.3%) had good immune status, consisting of 65 girls (58.6%) and 46 boys (78%); 59 students (74.7%) participated in sports, and 52 students (57.1%) did not. Sex and sports participation were associated with immune status (p=0.000 and p=0.017, respectively). Students with good immune status had higher final ISQ scores than those with poor immune status (8.37±1.4 vs 3.84±1.4, p=0.000). Skin problems, headache, and muscle joint pain (MJP) were the three most common illnesses. Sports participation was a protective factor for skin problems, headache, and MJP (OR 0.27, 0.34, 0.41; 95%CI 0.14-0.53, 0.17-0.67, 0.20-0.84; p=0.000, 0.002, 0.013, respectively). Regular sports participation is associated with favorable immune status. Sport participation could be a protective factor for some symptoms.

***Keywords:*** *physical activity, immune system, immune assessment, low immune symptoms, young people*

## Introduction

Campus life is marked by academic challenges, increased social interaction, and strengthening students' independence (Worsley et al., 2021). However, campus life also causes students to experience stress, have irregular sleep patterns, and adopt an unhealthy lifestyle (Cena et al., 2021). Academic success, controlling social relationships, and planning for the future are significant stressors. Stress can cause anxiety, depression, and other mental health problems in college students (Mofatteh, 2020).

Stress can harm and weaken the immune system, making people more susceptible to infections, illnesses, and other health problems (Bains & Sharkey, 2022). Stress hormones, such as cortisol and adrenaline, will be released in response to deal with immunity threats. An increase in stress hormones causes immune cells to become less effective (Morey et al., 2015). This weakened immune response increases vulnerability to infection and can decrease the body's ability to fight diseases (Bains & Sharkey, 2022).

Previous studies have shown a link between exercise and the immune system. Exercise can directly increase immunity through increasing immunological activity or indirectly through reducing stress, sleeping better, and improving psychological health (Nieman & Wentz, 2019; Abd El-Kader & Al-

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Jiffri, 2020). Increased immunological activity due to exercise through increased blood circulation, thereby facilitating the transport of immune cells throughout the body. This increases the ability of immune cells to more effectively detect and neutralize pathogens, thereby reducing the risk of infection. Also, exercise triggers the release of endorphins, reducing stress and anxiety levels (Harber & Sutton, 1984). Lower stress levels are associated with a more robust immune response, making students more resistant to diseases.

Assessing the immune system is essential for overall health status and detecting potential vulnerabilities. There are several ways to evaluate the immune system. The method most frequently used is an objective qualitative and quantitative assessment of blood samples, such as the number and type of immune cells and mediators such as cytokines, chemokines, and antibodies (Institute of Medicine (US) Committee on Military Nutrition Research, 1999; Liu, 2021). However, these methods are usually expensive, time-consuming, and invasive. In addition, this method does not provide information on immune status from an individual perspective.

The Immune Status Questionnaire (ISQ) is a simple method designed to evaluate the health and function of a person's immune system by answering questions. The ISQ was developed from the Immune Fitness Questionnaire (IFQ) by simplifying complaints about decreased immunity and individual perceptions of their immune system (Reed et al., 2015; Versprille et al., 2019). The ISQ consists of seven questions regarding the patient's current complaints and opinions regarding his health and immune status. ISQ can be part of routine health checks so that health practitioners can proactively treat diseases related to decreased immunity before they worsen. Because it is simple and easy, the ISQ can also be used for mass screening of health and immune status so that it can be administered to determine the immune status of the community (Versprille et al., 2019).

Several previous studies have been conducted on the positive relationship between exercise and immune status in students. A study among Korean adolescents indicated that sports participation positively affected wellness (Lee et al., 2021). Physically inactive reduced immune status among Arabian teens has also been reported (Alharbi et al., 2023). Participation in sports and exercise could reduce anxiety, depression, and obesity and improve immune status among university students in Bangladesh (Hossen et al., 2020). Students ' participation in sports and physical exercise tends to decrease by up to a third during university education (Bray & Born, 2004; Kwan et al., 2012; Sigmundová et al., 2013). However, studies on regular sports' effect on college students' immune status in medical students have yet to be widely studied. This study investigates the relationship between regular sports and immune status in medical students as assessed by ISQ.

## Methods

*Design*

This study was cross-sectional with a retrospective approach conducted at Atma Jaya Catholic University of Indonesia, Jakarta, from July 2023 to August 2023.

*Participants*

Participants were 170 Atma Jaya Medical Students, including 111 females (65.3%) and 59 males (34.7%). The students who regularly participated in sports through the Student Sports Club in December 2021-December 2022 at least twice a week were recorded. Students participated in four sports: badminton, basketball, futsal, and volleyball. The students who had never participated regularly or less than twice a week in sports and exercise in or outside the campus were considered not to participate in sports. Participants with immune diseases, allergy history, chronic diseases, and taking immunosuppressant drugs were excluded. This study was approved by the ethics committee of the School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia, with approval number 27/06/KEP-FKIKUAJ/2023.

*Immune Status Questionnaire*

The validated Indonesian version of the ISQ was used (Azhar, Erdiansyah, & Rudiman, 2022). The Immune Status Questionnaire (ISQ) consists of seven immune-associated symptoms and complaints experienced over the last 12 months: sudden high fever, diarrhea, headache, skin problems (e.g., acne, eczema), muscle and joint pain (MJP), common cold, and coughing. Each symptom and complaint is scaled with a 5-point Likert scale ranging from 0-4 with 'never,' 'sometimes,' 'regularly,' 'often,' and 'almost/always.' The score obtained from the Likert scale is the raw score, ranging from 0-28. The raw score is then converted to a final score of ISQ from 0-10, as shown in the table. A higher raw score will become a lower final score and indicate a poorer immune status. The final ISQ score <6 is cut off for decreased immune function (Versprille et al., 2019).

**Table 1.** The ISQ score conversion

| Raw Score | Final Score |
|---|---|
| ≥ 15 | 0 |
| 14 | 1 |
| 13 | 2 |
| 11,12 | 3 |
| 10 | 4 |
| 8, 9 | 5 |
| 7 | 6 |
| 6 | 7 |
| 5 | 8 |
| 3, 4 | 9 |
| ≤ 2 | 10 |

*Statistical Analysis*

Numeric data was presented as mean±SD, while categorical data was presented as the number of participants (and frequency). Unpaired student t was applied to analyze differences in ISQ final score between the compared groups. The Chi-square or Fisher exact test was used to analyze the relationship between categorical variables (2x2 table), while Kolmogorov-Smirnov (KS) was used for the AxB table. ANOVA, followed by an LSD post hoc test, was applied to compare the mean between sports groups. The results were significant if p<0.05. Descriptive and analytics statistics were processed using SPSS 19.

## Results

Table 2. demonstrates the characteristics of the participants. Seventy-nine participants (46%) participated regularly in sports through the Student Sports Club (30.6% of females, 76.3% of males). Among 79 participants, 28 (35.4%) participated in futsal, 26 (32.9%) in badminton, 13(16.5%) in basketball, and 12 (15.2%) in volleyball. One hundred and eleven (65.3%) participants are considered to have 'good' immune status. The final ISQ score is 6.80±2.6.

Table 3. presents the association between the immune status with sex and sports participation. Sixty-five (58.6%) girls and 46 (78%) boys have a 'good' immune status. The association between immune status and sex is significant (p=0.000). Fifty-nine (74.7%) students participating in sports and 52 (57.1%) not participating in sports have a 'good' immune status. The association between immune status and sports participation is significant (p=0.017). Participants with 'good' immune status have greater final ISQ scores than those with 'poor' immune status (8.37±1.4 vs 3.84±1.4, p=0.000).

**Table 2.** Characteristics of participants

| | Frequency or mean±SD | Percentage |
|---|---|---|
| Sex | | |
| Girls | 111 | 65.3% |
| Boys | 59 | 34.7% |
| Sport Participation | | |
| Yes | 79 | 46.5% |
| No | 91 | 53.5% |
| Sport type | | |
| Futsal | 28 | 35.4% |
| Badminton | 26 | 32.9% |
| Basketball | 13 | 16.5% |
| Volleyball | 12 | 15.2% |
| Immune status | | |
| Good | 111 | 65.3% |
| Poor | 59 | 34.7% |
| Final ISQ score (mean±SD) | 6.80±2.6 | - |

ISQ: immune status questionnaire

**Table 3.** The association between immune status with sex and sports participation

| | Immune status | | Overall | p |
|---|---|---|---|---|
| | Good (n=111) | Poor (n=59) | | |
| Sex | | | | |
| Girls | 65 (58.6%) | 46 (41.4%) | 111 (100%) | 0.000 |
| Boys | 46 (78%) | 13 (22%) | 59 (100%) | |
| Sports participation | | | | |
| Yes | 59 (74.7%) | 20 (25.3%) | 79 (100%) | 0.017 |
| No | 52 (57.1%) | 39 (42.9%) | 91 (100%) | |
| Final ISQ score (mean±SD) | 8.37±1.4 | 3.84±1.4 | - | 0.000 |

ISQ-Immune Status Questionnaire

The association between sports type with sex and immune status and the difference in final ISQ score is shown in Table 4. Of the 79 students who participated in sports, 34 were girls (30.6% of girls) and 45 were boys (76.3% of boys). The association between sex and sports participation is significant (p=0.001). Kolmogorov-Smirnov test indicates no association between sports type and immune status (p=0.96). However, ANOVA indicates that the mean final ISQ scores between sports types differ significantly (p=0.044). Further post-hoc analysis shows that only the badminton and volleyball final ISQ scores differ (8.42±2.0 vs 6.33±2.7, p=0.039).

**Table 4.** The association between sports type with sex and immune status

| | Badminton | Basketball | Futsal | Volleyball | Overall | p |
|---|---|---|---|---|---|---|
| Sex | | | | | | |
| Girls (n=111) | 6 | 11 | 9 | 8 | 34 (30.6%) | 0.001 |
| Boys (n=59) | 20 | 2 | 19 | 4 | 45 (76.3%) | |
| Immune status | | | | | | |
| Good (n=111) | 21 | 10 | 21 | 7 | 59 (74.7%) | 0.96 |
| Poor (n=59) | 5 | 3 | 7 | 5 | 20 (25.3%) | |
| Final ISQ score | 8.42±2.0 | 7.69±2.3 | 7.43±2.1 | 6.33±2.7 | | 0.044 |

ISQ-Immune Status Questionnaire

Immunity-related complaints of ISQ are presented in Table 5. Skin problems, headache, and muscle joint pain are the top three complaints felt by participants, with a percentage of 40%, 32.4%, and 28.2%, respectively. Sudden high fever is the least experienced complaint by participants (5.9%).

The association between sports participation and immunity-related complaints of ISQ is then explored and described in Table 6. The five symptoms' frequency of a Likert scale was then adjusted into two categories: 'absent' and 'present.' 'Never' and 'sometimes' of the Likert scale become 'absent,' while 'sometimes-always' becomes 'present.' The association between variables was analyzed by Chi-square, except between sports participation and diarrhea by Fisher's exact test. The results indicated that headache, skin problems, and MJP

**Table 5.** Distribution of symptoms and complaints of ISQ

| | Never | Sometimes | Regular | Often | Always | Total complaint | Percentage |
|---|---|---|---|---|---|---|---|
| Skin problems | 49 | 53 | 45 | 20 | 3 | 68 | 40.0 |
| Headache | 36 | 79 | 41 | 12 | 2 | 55 | 32.4 |
| Muscle joint pain (MJP) | 49 | 73 | 34 | 13 | 1 | 48 | 28.2 |
| Coughing | 63 | 78 | 27 | 1 | 1 | 29 | 17.1 |
| Common cold | 71 | 70 | 25 | 4 | - | 29 | 17.1 |
| Diarrhea | 81 | 65 | 21 | 3 | - | 24 | 14.1 |
| Sudden high fever (SHF) | 121 | 39 | 10 | - | - | 10 | 5.9 |

**Table 6.** The association between sports participation and each symptom and complaint

| No | | | Sport participation | | Odd risk | 95% CI | p |
|---|---|---|---|---|---|---|---|
| | | | yes | no | | | |
| 1 | SHF | | | | | | |
| | | absent | 76 | 84 | 0.47 | 0.12-1.90 | 0.342 |
| | | present | 3 | 7 | | | |
| 2 | Diarrhea | | | | | | |
| | | absent | 71 | 75 | 0.53 | 0.21-1.31 | 0.164 |
| | | present | 8 | 16 | | | |
| 3 | Headache | | | | | | |
| | | absent | 63 | 52 | 0.34 | 0.17-0.67 | 0.002 |
| | | present | 16 | 39 | | | |
| 4 | Skin problems | | | | | | |
| | | absent | 60 | 42 | 0.27 | 0.14-0.53 | 0.000 |
| | | present | 19 | 49 | | | |
| 5 | MJP | | | | | | |
| | | absent | 64 | 58 | 0.41 | 0.20-0.84 | 0.013 |
| | | present | 15 | 33 | | | |
| 6 | Common cold | | | | | | |
| | | absent | 70 | 71 | 0.46 | 0.19-1.07 | 0.077 |
| | | present | 9 | 20 | | | |
| 7 | Coughing | | | | | | |
| | | absent | 61 | 80 | 2.15 | 0.94-4.88 | 0.064 |
| | | present | 18 | 11 | | | |

are associated with sports participation (p=0.002, p=0.000, and p=0.013, respectively). Sports participation has an association with headache, skin problems, and MJP [OR (95%CI) were 0.34 (0.17-0.67), 0.27 (0.14-0.53), and 0.41 (0.20-0.84), respectively].

## Discussion

The use of ISQ to assess immune status has probably been widely used. However, ISQ may not be commonly used to assess the immune status of college students participating in sports. This study explores the relationship between immune status and sports participation using ISQ. Our findings demonstrate that 65.3% of students have good immune status. Also, sports participation and sex are linked to better immune status. Students who participate regularly in sports have better final ISQ scores and immune status. Further investigation shows that students who participated in volleyball have better immune status than those who participated in other sports. Participation in sports is associated with several complaints about decreased immunity, i.e., headache, skin problems, and MJP.

Physical exercise has positive and negative impacts on the immune system and response. Exercise duration and intensity influence the positive or negative impacts of exercise (Nieman & Wentz, 2019; Forte, Branquinho, & Ferraz, 2022). Positive effects on the immune response are usually achieved at moderate intensity and appropriate duration. Some RCT studies reported that moderate exercise reduced incidence, days of illness, and disease severity (Barrett et al., 2012; Barrett et al., 2018). Several previous studies reported that sports participation improves immune function in students (Hossen et al., 2020; Lee et al., 2021; Alharbi et al., 2023). Even though there were differences regarding methods, immunity questionnaires used, and variables, the results were in line with the results of our study.

Otherwise, strenuous exercise attenuates the immune system and response. Studies involving long-distance runners, elite track and field athletes, and elite aquatic athletes indicated varying incidence of illness up to 6 times in those athletes (Nieman et al., 1993; Alonso et al., 2012; Prien et al., 2017; Timpka et al., 2017). Our findings show that most students who participated in sports had good immune status, indicating that sports participation positively impacted immune status and that the sports activity might be performed at moderate intensity. Also, our study revealed that students participating in volleyball had better immunity than in badminton. The effect of sports type on immunity has been investigated (Isaev et al., 2018). A possible mechanism for the difference in immunity between sports types has not been proposed, but it might be linked to sports work duration and intensity (Isaev et al., 2018).

The influence of sex on the immune system has been widely discussed but remains inconclusive. Many interfering factors, including age, reproductive status, sex chromosomes, sex hormones, and environmental factors, may cause the discrepancy between studies (Klein & Flanagan, 2016; Sciarra, Campolo, Franceschini, Carlomagno, & Venneri, 2023). Also, the immune system contains many immune elements (i.e., phagocytic capacity, cytokines production, natural killer cell number, antibody production, and expression of inflammation mediators) whose activities are different between males and females (Klein & Flanagan, 2016; Wilkinson, Chen, Lechner, & Su, 2022). Therefore, it cannot be concluded which gender has better immunity. However, our study indicated that sex was related to immune status, and girls had lower final ISQ scores. The number of girls participating in sports is significantly fewer than that of boys. This may cause girls' final ISQ score and immune status to be statistically lower than boys.

This study's three most common complaints were skin problems, headaches, and MJP. These three complaints were also related to sports participation. Also, sports participation is a protective factor for skin problems, headaches, and MJP. Most previous studies reported upper respiratory tract infection (URTI) and upper respiratory symptoms were the most common illness in sports. Gastrointestinal disturbances and skin problems are common diseases in athletes (Mellman & Podesta, 1997; Ahmadinejad, Alijani, Mansori, & Ziaee, 2014; Jaworski & Rygiel, 2019; Kelly, Pollock, Polglass, & Clarsen, 2022). However, our findings showed a different illness pattern. The slight differences in the patterns of the most common illnesses in sports may also be due to differences in participant characteristics. Headaches, for example, are rarely found in professional athletes but often in student-athletes. Academic problems might be the differentiator of health problems between professional and student-athletes.

Limitations of this study should be acknowledged. First, sample size was a significant issue of our study. A larger sample will increase the reliability of the results. Our study's smaller sample size was due to students' low participation in sports activities after the COVID-19 pandemic. Second, immunity is a system, not a single entity. Many factors influence immunity, including nutrition, resting time, and psychological problems. Thus, recording those influencing factors could minimize bias. Third, immune status from ISQ would be more reliable and valid if confirmed by laboratory examination, a routine and standard method. Last, only four types of sports are involved out of so many types of sports. Involving many sports types with different characteristics will advance helpful information for those involved in sports. Future studies should involve a larger sample size and many sports types, recording the duration and intensity of sports activity and confirming ISQ with laboratory methods.

## Conclusion

This study links immunity, sports participation, and sex in college students. Immunity is unrelated to sports type, but the final ISQ score in volleyball is greater than in badminton. The pattern of most diseases is different from the pattern in professional athletes. Sports activity is a protective factor for some complaints in ISQ. However, the findings of this study should be interpreted with caution due to some limitations. Our results could be used to encourage students to engage in sports activity and to encourage schools to facilitate sports activity.

**Conflict of interest**
The authors declare no conflict of interest.

**Acknowledgments**
The authors are grateful to all the students who were willing to participate in this study

**Received:** 18 October 2023 | **Accepted:** 21 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240216

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ORIGINAL SCIENTIFIC PAPER

# Examining the Influence of Children and Parents' Portable Device Use on Sedentary Behavior and Physical Activity Levels

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**Abstract**

The aim of this study was to explore the relationship between the usage of screen-based media devices by children and their parents and its influence on sedentary behavior and physical activity. A cohort of 43 parents with typically developing children aged 8 to 12 years was selected for the study, utilizing convenience sampling methods through social media platforms across Central Macedonia, Greece. Parents filled out a survey regarding their children and themselves, assessing daily portable device use, sedentary behavior, and physical activity. Two standard regression models were employed to examine how criterion variables (child portable device use in Model 1 and parent portable device use in Model 2) related to predictor variables: child age, child sex, child daily sedentary time, and child physical activity. The findings revealed a significant and positive association between child sedentary time and child portable device use. Similar, child sedentary time exhibited a significant and positive association with parent portable device use. Child age, sex, and physical activity did not show a significant relationship with either parent or child portable device use. In summary, there is a clear connection between child sedentary behavior and portable device use, whereas physical activity does not exhibit a significant relationship. This implies that young children who extensively use portable devices may be susceptible to adopting a sedentary lifestyle. Additionally, results suggest a potential correlation between adults' portable device use and sedentary habits, which may be reflected in similar behavior in their children.

***Keywords:*** *smartphone, tablet, physical activity, sedentary behavior, exercise, children*

## Introduction

Promoting the healthy development of children is a core objective across educational systems. The World Health Organization advises that children and adolescents aged 5–17 should engage in a minimum of 60 minutes of moderate-to-vigorous physical activity daily, encompassing vigorous aerobic exercises and muscle-and-bone-strengthening activities at least three days per week (Word Health Organization, 2020). Additional guidelines suggest limiting recreational screen time to no more than 2 hours per day, ensuring adequate sleep (9 to 11 hours for children aged 5–13 years) (Tremblay et al., 2016). Although research has recognized the significance of these factors in influencing children's overall health, their incorporation into educational and family environments for child development remains insufficient. Therefore, innovative studies in this area are crucial to offer effective solutions and enhance our understanding of the subject.

Contrastingly, contemporary children are extensive users of mobile devices like smartphones and tablets. Children and teenagers now engage in communication almost around the clock, constituting a significant portion of smartphone users. Notably, smartphones and tablets are observed in the hands of children under 2 years old (Markov & Grigoriev, 2015). The predominant reasons for the frequent use of mobile devices

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by children include web browsing, social network checking, and gaming. The excessive time spent on electronic devices solely for entertainment purposes, such as tablets, computers, and smartphones, has reached alarming levels (Saunders & Vallance, 2017). This situation necessitates clear policies at national or even global levels to curb further escalation. Prolonged screen time is associated with increased sedentary behavior, a well-acknowledged health concern (LeBlanc et al., 2015).

Numerous studies involving college-aged individuals have indicated that increased use of portable devices, predominantly smartphones, is associated with negative lifestyle factors (Barkley & Lepp, 2016a; Barkley, Lepp & Salehi-Esfahani, 2015; Lepp, Barkley & Karpinski, 2015; Lepp, Li, Barkley & Salehi-Esfahani, 2015; Rebold, Lepp, Sanders & Barkley, 2015). For instance, one study identified a negative correlation between portable device use and grade point average, coupled with a positive correlation with anxiety (Lepp, Barkley & Karpinski, 2014). Another recent study found that young adults reporting high levels of portable device use tended to achieve lower grade point averages, even when statistically controlling for other factors like self-efficacy for learning and high school grade point average (Lepp, Barkley et al., 2015). These findings highlight potential adverse academic outcomes associated with increased portable device use, possibly influenced by undesirable psychological factors such as heightened anxiety and distraction from the device itself. Excessive use of portable devices may also impact leisure time opportunities and enjoyment, as heavy users (exceeding 10 hours per day) were found to experience more leisure distress than their peers with lower usage (Lepp, Li et al., 2015). Considering the therapeutic effects of enjoyable leisure time, these findings suggest a mechanism through which extensive portable device use may contribute to increased anxiety.

A crucial consideration for public health is the balance between sedentary and physical activity during leisure time. Barkley et al. (2015) explored the relationship among portable device use, sedentary behavior, and physical activity. The study revealed a positive association between portable device use and sedentary behavior, but no correlation with physical activity. Further categorization into high, moderate, and low portable device users showed that the high-use group engaged in significantly more sedentary time, logging 18.7% more minutes of sitting than moderate users and 25.3% more than low users (Barkley et al., 2015). This increased sedentary behavior could negatively impact health characteristics and increase disease risk due to physical inactivity.

Another potential consequence of high portable device use is its interference with exercise, potentially reducing its intensity (Rebold et al., 2015; Barkley & Lepp, 2016a; Barkley & Lepp, 2016b). Studies have indicated a positive association between high volume portable device use and the likelihood of using a device during moderate and mild intensity exercise (Barkley & Lepp, 2016a). In acute settings, portable device use has been shown to lower the intensity of exercise bouts. For example, a study comparing texting, talking, listening to music, and a no smartphone use control during treadmill exercise found that participants chose a higher self-selected speed during the control condition compared to both talking and texting. Heart rate during the control was also higher than the texting condition, with no significant difference compared to the talking condition (Rebold et al., 2015). This implies that using a device during exercise diminishes its intensity, potentially impacting the quality of the exercise bout.

Additionally, portable device use may contribute to a reduction in the intensity of daily physical activity. Observations on college campuses revealed that walking while talking or texting on a smartphone led to a decrease in walking speed (Barkley & Lepp, 2016b). This reduction in intensity during exercise and physical activity may result in a decline in cardiorespiratory fitness levels. Lepp, Barkley, Sanders, Rebold & Gates (2013) found a negative correlation between daily smartphone use duration and cardiorespiratory fitness. Individuals reporting high smartphone use were more inclined to choose sedentary smartphone options over engaging in physical activity (Lepp et al., 2013).

The existing studies have predominantly concentrated on the college-age demographic, revealing a notable gap in understanding the potential impacts on younger age groups. Given the potential repercussions on health, including the risk of obesity, it becomes imperative to investigate the associations between variables linked to contemporary screen-based media use—especially the use of portable devices—and the physical activity and sedentary habits of young children and their parents. Uncovering such information holds the promise of informing strategies to enhance physical activity and diminish sedentary behavior among children, aiming to mitigate associated public health risks.

Therefore, the purpose of this study was to examine the relationship between the usage of screen-based media devices by children and their parents and its influence on sedentary behavior and physical activity. These findings could contribute to the formulation of guidelines concerning the use of such devices among children. The hypotheses of this study were: H1. Children reporting higher daily screen-time are expected to exhibit increased sedentary behavior; H2. No significant relationship is anticipated between physical activity and portable device use in children; H3. Parents characterized as high-volume users of portable devices are expected to have children who are similarly high-volume users; H4. A positive correlation is hypothesized between both child and parent physical activity and child and parent sedentary behavior.

## Methods

*Participants*

A cohort of 43 parents with typically developing children aged 8 to 12 years was selected for the study, utilizing convenience sampling methods through social media platforms across Central Macedonia, Greece. Inclusion criteria were applied to ensure participants met specific requirements. Child participants had to: a. fall within the age range of 8 to 12 years, b. reside in Greece, c. possess sufficient Greek language comprehension equivalent to that of a typically developing 8-year-old, d. have parental consent to participate, and e. be capable of providing signed consent themselves. Exclusion criteria included: a. not being acquainted with any members of the research team, and b. having no known diagnosis of physical, psychological, neurological, behavioral, intellectual, or learning difficulties.

For parents, inclusion criteria were: a. providing written consent for participation, b. furnishing third-party consent on behalf of their child for study involvement, c. being a parent of a participating child, d. residing in Greece, e. possessing sufficient language skills in Greek to read and write at an adequate level, and f. spending a satisfactory amount of time with their participating child to accurately assess the child's screen time use and engagement, and assist in completing relevant assessment tools. The exclusion criterion was not being known to the research team.

*Procedures*

To enhance participant recruitment, a flyer containing study information was distributed and promoted on parents' groups' Facebook pages and shared within local community groups. Researchers ensured that all participants received a plain language statement detailing the study's logistics and requirements before seeking their consent. This information covered aspects like voluntary participation, the right to withdraw, and the confidentiality of data. Parents were obligated to provide informed consent, while children were required to give both verbal assent and written consent to participate in the study.

Sixty parents initially signed up for the study. Following eligibility screening, 43 parents and their children (20 males and 23 females) who met the study's inclusion criteria returned completed questionnaires, constituting the final group for analysis. The mean age of the child participants was 9.7 years (SD = 1.24).

Subsequently, researchers emailed participants an information pack containing links to online questionnaires on Google Forms, focusing on their child's screen time use, sedentary time, and physical activity. Each questionnaire included instructions, and participants were required to return completed questionnaires within 2 weeks of receipt. The estimated time for questionnaire completion was approximately 15 minutes.

The research was carried out in adherence to the principles outlined in the Declaration of Helsinki, a set of ethical guidelines for medical and scientific research involving human subjects. In accordance with these guidelines, ethical review and approval were exempted for this particular study (Research Ethics Committee of DUTh, no. 9/29-05-2020), as it falls within the realm of educational research and does not encompass clinical treatment. The study did not involve the collection of sensitive data. Prior to participation, informed consent was meticulously obtained from all individuals involved. Participants were assured of complete anonymity, and they were provided with comprehensive and transparent information regarding the content, purpose, and procedures of the research in a comprehensible manner. Importantly, no individual was compelled or coerced into participating in the study, emphasizing the voluntary nature of their involvement.

*Measures*

A demographic questionnaire was administered to parents to collect background information on the child participant, aiding in the screening process. This questionnaire incorporated a plain language statement and a consent section, allowing participants to provide their consent online. In instances where a participant did not meet the inclusion criteria for the study, researchers communicated this information via email, notifying them that their participation was no longer necessary while expressing gratitude for their time and interest.

The assessment of physical activity was conducted using the validated Godin Leisure-Time Exercise Questionnaire (Godin & Shepard, 1985). Parents were tasked with indicating how frequently their child engaged in strenuous, moderate, or light-intensity exercise per week. The same set of questions was posed to parents regarding their own physical activity behaviors. Subsequently, a weekly physical activity score was computed using the following equation, where METs (metabolic equivalents) represent the intensity of the activities: Weekly Physical Activity Score = (9 METs x strenuous) + (5 METs x moderate) + (3 METs x light).

This scoring system allowed for a comprehensive evaluation of the weekly physical activity levels based on the intensity and frequency of different types of exercises.

Sedentary time was evaluated using a question derived from the validated International Physical Activity Questionnaire for both children and parents (Craig et al., 2003). This question was posed separately for weekdays and weekends. To derive an average weekly sedentary time, the following equation was employed based on the participants' responses for both weekdays and weekend days: Weekly sedentary behavior = (minutes of sitting per week day x 5) + (minutes of sitting per weekend day x 2). This calculation provided an overall measure of weekly sedentary behavior, considering both weekday and weekend patterns.

The screen-time assessment was conducted using survey information that had been previously utilized for young adults by Lepp, Barkley et al. (2015). Parents were asked to estimate their child's daily smartphone and tablet usage (portable screen use). Parents were then asked to record their own use of the same devices.

*Statistical analysis*

All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS, Version 26, Chicago, IL), with a pre-established significance level of $\alpha \leq 0.05$. Standard multiple regression analyses were employed to evaluate two models for both children and parents. The first model explored the association between average daily child portable screen use (smartphone, tablet) and the following predictor variables: child age, sex, average daily sedentary time, and physical activity. Similarly, the second model investigated the relationship between average daily parents' portable screen use (smartphone, tablet) and the same set of predictor variables as in the first model, namely, child age, sex, average daily sedentary time, and physical activity.

Specifically, two standard multiple regression analyses were employed to examine how criterion variables were related to predictor variables: child age, child sex, child average daily sedentary time, and child physical activity. The criterion variables considered were (a) child portable device use (Model 1) and (b) parent portable device use (Model 2). Various statistical techniques were applied to test the assumptions of the analyses. In particular, normal Q-Q Plots were utilized to assess the normality of residuals. The Durbin–Watson values for the two regression models were 2.03 and 1.98, respectively, indicating the absence of autocorrelation issues. The multicollinearity test indicated a low level of intercorrelation among independent variables (VIF range from 1.214 to 3.262; tolerance range from 0.312 to 0.969). VIF values below 5 are considered acceptable for multicollinearity (Hair, Babin, Anderson & Black, 2019). Additionally, bivariate correlation analysis results revealed correlation coefficients between independent variables below 0.70, indicating weak correlations among variables (Cohen, Cohen, West, & Aiken, 2003).

To further explore associations, Pearson's correlation analyses were utilized to examine the relationships between child and parent portable screen use, child and parent physical activity and child and parent sedentary behavior. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. Low correlation is indicated when the correlation coefficient (r) falls within the range of 0.1 to 0.3. Moderate correlation is observed when the correlation coefficient is between 0.31 and 0.5, and high correlation is identified when the coefficient exceeds 0.5 (Green & Salking, 2017).

## Results

The first multiple regression analysis was run to determine whether the interaction effect among child age, child sex, child average daily sedentary time, and child physical activity significantly predicted higher levels of child portable device use (Table 1). The overall Model 1 was found to be significant, $F(4,38)=24.3$, $p<.001$, explaining 35.6% of the variance. Furthermore, the results indicated that child sedentary time was significantly ($\beta=0.49$, $t=9.09$, $p<0.001$) and positively associated with child portable device use. In particular, as the use of portable screens by children increased, there was a concurrent increase in sedentary behavior among them. Conversely, child age ($\beta=0.021$, $t=0.43$, $p=0.67$), child sex ($\beta=0.094$, $t=0.86$, $p=0.39$), and child physical activity ($\beta=0.095$, $t=1.72$, $p=0.088$) were not significantly related to child portable device use.

**Table 1.** Regression model predicting child portable device use

| **Model 1: Child portable device use** | | | | | |
|---|---|---|---|---|---|
| | **B** | **SE** | **β** | **t** | **p** |
| Intercept | 39.626 | 96.97 | | 0.409 | 0.683 |
| Child age | 0.021 | 0.049 | 0.027 | 0.429 | 0.669 |
| Child sex | 0.094 | 0.109 | 0.053 | 0.86 | 0.391 |
| Child sedentary time | 0.487 | 0.054 | 0.561 | 9.089 | <.001 |
| Child physical activity | 0.095 | 0.056 | 0.106 | 1.715 | 0.088 |
| $R^2$ | 0.356 | | | | |
| Adjusted $R^2$ | 0.341 | | | | |

The second multiple regression analysis was run to assess whether the interaction effect among child age, child sex, child average daily sedentary time, and child physical activity significantly predicted higher levels of parent portable device use (Table 2). The overall Model 2 was deemed significant, $F(4,38)=17.8$, $p<.001$, explaining 28.8% of the variance. Moreover, the findings revealed that child sedentary time was significantly ($\beta=0.38$, $t=7.88$, $p<0.001$) and positively associated with parent portable device use. Specifically, as parent portable screen use increased, sedentary behavior in children also increased. In contrast, child age ($\beta=0.003$, $t=0.07$, $p=0.95$), child sex ($\beta=0.044$, $t=0.45$, $p=0.65$), and child physical activity ($\beta=0.066$, $t=1.33$, $p=0.186$) did not exhibit significant relationships with parent portable device use.

**Table 2.** Regression model predicting parent portable device use

| **Model 2: Parent portable device use** | | | | | |
|---|---|---|---|---|---|
| | **B** | **SE** | **β** | **t** | **p** |
| Intercept | 3.594 | 86.613 | | 0.042 | 0.967 |
| Child age | 0.003 | 0.044 | 0.004 | 0.067 | 0.947 |
| Child sex | 0.044 | 0.097 | 0.029 | 0.451 | 0.653 |
| Child sedentary time | 0.377 | 0.048 | 0.511 | 7.884 | <.001 |
| Child physical activity | 0.066 | 0.050 | 0.086 | 1.328 | 0.186 |
| $R^2$ | 0.288 | | | | |
| Adjusted $R^2$ | 0.272 | | | | |

The results of the correlational analyses indicate a strong positive correlation between parent portable screen use and child portable screen use ($r=0.879$, $p<0.001$). Additionally, child sedentary time exhibited a strong positive association with parent sedentary time ($r=0.738$, $p<0.001$). However, child physical activity did not show a significant relationship with parent physical activity ($r<0.14$, $p=0.56$).

## Discussion

The outcomes of prior and converging research suggest that information regarding the role of physical activity in maintaining and enhancing health is inadequately disseminated, and the resulting applications are not effectively incorporated into daily routines (Aubert et al., 2022). This deficiency is reflected in the low levels of physical activity observed in school-aged children and adolescents, as evidenced by Word Health Organization reports (2020). Additionally, the growing accessibility of electronic devices for young individuals does not contribute to an improvement in their condition; instead, it may promote a sedentary lifestyle, negatively impacting cognitive development and academic performance, as highlighted in studies conducted by other researchers (Korcz, Krzysztoszek, Bronikowski, Łopatka & Bojkowski, 2023).

Given the current state of knowledge, our study aimed to explore the correlation between the use of screen-based media devices by both children and their parents and its impact on sedentary behavior and physical activity. To pursue these objectives, we formulated specific assumptions to guide this research. The ensuing paragraphs present the obtained results and conclusions.

The first hypothesis (H1), stating that children reporting higher daily screen-time are expected to exhibit increased sedentary behavior, and, the second hypothesis (H2), suggesting no significant relationship between physical activity and portable device use in children, were both accepted. Particularly, the results of this study indicate a correlation between sedentary behavior and the use of portable devices in children, while no significant association was observed between physical activity and device use. This suggests that, similar to young adults, children who extensively use portable devices may engage in sufficient physical activity but still exhibit higher levels of sedentary behavior compared to their peers with lower device usage (Barkley et al., 2015).

Results from earlier research exploring the relationship between portable screen usage and physical activity in children were diverse (Trott, Driscoll, Irlado, & Pardhan, 2022). Some studies suggested adverse links between physical activity and various types of screen time, including overall, leisure, and educational screen time (Breidokienė, Jusienė, Urbonas, Praninskienė & Girdzijauskienė, 2021; Jáuregui et al., 2021). On the other hand, different studies reported inconclusive findings (Alves, Yunker, DeFendis, Xiang & Page, 2021; Cachón-Zagalaz, Zagalaz-Sánchez, Arufe-Giráldez, Sanmiguel-Rodríguez & Gonzalez-Valero, 2021). These disparities in results could stem from various factors, such as reporting biases and variations in statistical methodologies employed across studies.

Concerning sedentary behavior, a consistent association with screen time was identified in children (Stiglic & Viner, 2019; Alves et al., 2021; Stockwell et al., 2021). However, intriguingly, prior studies did not find a significant correlation between portable screen time and changes in BMI or weight gain (Saxena, Parmar, Kaur, & Allen, 2021). This lack of association is likely attributed to the fact that screen time typically occurs during periods of sedentary activity in children.

To sum up, the existing body of research on the subject presents a complex picture. While some studies indicate a negative relationship between physical activity and screen time in its different forms, others do not establish a clear connection. The nuances of these findings underscore the importance of considering factors such as reporting biases and methodological variations when interpreting the results. Furthermore, while previous studies have shown an inverse correlation between physical activity and sedentary behavior, it's important to note that these variables are also independent predictors of disease risk. It is possible for individuals to be highly physically active yet simultaneously highly sedentary, leading to increased risks of chronic diseases such as hypertension, diabetes, and hyperlipidemia (Owen et al., 2010; van der Ploeg, Chey, Korda, Banks, & Bauman, 2012). The use of portable screen time measures for data collection might not be sensitive to specific subtypes of electronic device use, and children may use electronic devices during physical activity (e.g., wearing headphones while exercising). Additionally, the impact of portable screen time on physical activity levels may vary across different cultural contexts.

Thus, further investigation is needed to understand the prevalence of this phenomenon in young children and its association with portable screen use. This could involve exploring specific subtypes of electronic device use, examining the simultaneous engagement in electronic device use and physical activity, and considering the potential cultural influences on the relationship between portable screen time and physical activity levels.

The third hypothesis (H3), suggesting that parents characterized as high-volume users of portable devices are expected to have children who are similarly high-volume users, and the fourth hypothesis (H4), which proposed a positive correlation between both child and parent physical activity and child and parent sedentary behavior, were partially accepted.

Specifically, the results of this study show a positive association between a child's use of portable devices and parental device use. Additionally, sedentary time in children is significantly and positively linked to sedentary time in parents. These findings align with previous research indicating that increased use of portable devices by parents is linked to greater use by their children, possibly influenced by positive parental attitudes toward such technology (Farah et al., 2021; Lauricella et al., 2015).

A meta-analysis conducted more recently not only reaffirms this positive association but also delves deeper into the dynamics. According to this comprehensive analysis, the status of parental portable screen use emerges as a noteworthy factor significantly influencing the screen habits of children. Intriguingly, the relationship between parental and child screen use is found to be intricately linked with the emotional well-being of parents (Trott et al., 2022). The meta-analysis highlights that the connection between parental screen engagement and child screen exposure is not merely direct but is intricately mediated by the emotional distress experienced by parents. This nuanced perspective sheds light on the complex interplay between parental behavior, emotional states, and the technological habits developed by their children.

The current results, along with prior findings, support the concept of parental modeling influencing a child's use of portable devices, which can be explained by elements of social cognitive theory. This theory suggests that behavior is shaped by environmental and interpersonal factors, with parents playing a significant role in shaping their child's behavior through the home environment they create (e.g., device availability) and their own behavior as observed by their children (e.g., behavior modeling) (Wright et al., 2010). In this context, a parent's actions may impact a child's health by modeling excessive sedentary behaviors, such as the use of portable devices. The potential for a parent's behavior to influence a child's behavior has implications for both current and lasting lifestyle habits. There is a possibility that a parent's modeling of a sedentary lifestyle could promote a similar pattern of behavior in their children.

As no correlation was found between a child's use of portable devices and physical activity, there might be a misconception among parents that incorporating some daily physical activity (e.g., participating in sports, going to the playground) for their children would be sufficient to counteract the negative effects of an otherwise sedentary lifestyle. However, this could be problematic, especially considering the prolonged sedentary time experienced by children during the school day. Opportunities for children to be physically active at home and after school become crucial in promoting a healthy lifestyle. Unfortunately, studies indicate that children may not significantly "make up" for sedentary time during school hours in their after-school behavior (Taverno Ross, Dowda, Colabianchi, Saunders & Pate, 2012). Given the limited control over sedentary time during the school day, parental influence and modeling, particularly regarding portable device use, emerge as crucial areas of interest for future exploration.

## Limitation

This study is subject to several limitations. Firstly, the small sample size may have resulted in limited statistical power during the analyses. Additionally, the use of convenience and snowball sampling methods for participant recruitment may introduce bias, as individuals who volunteered for the study might be inherently motivated.

Secondly, the reliance on self-report scales such as the Godin Leisure-Time Exercise Questionnaire, the International Physical Activity Questionnaire, and the screen-time questionnaire introduces the possibility of social desirability and recall bias. Participants may provide answers that align with perceived expectations or have difficulty accurately recalling their activities.

Lastly, the online recruitment method may have inadvertently excluded families without internet access, potentially introducing a selection bias. This limitation could impact the generalizability of the study's findings to a broader population, as those without online access may have different characteristics or behaviors.

## Conclusion

In summary, this study focuses on the portable screen time habits of children aged 8-12 and their potential impact on health. The results underscore a clear connection between sedentary behavior in children and the use of portable devices, while no significant correlation is observed with physical activity. This finding is noteworthy given the increasing body of evidence indicating that excessive screen time on portable devices may have detrimental effects on children's health.

The study adds value to existing literature by providing insights into portable screen time patterns specific to the Greek context. It emphasizes the necessity for additional research and awareness campaigns to address the potential risks associated with prolonged screen time in this demographic. Parents, educators, and policymakers should be educated about the potential health consequences of excessive portable screen time and encouraged to implement guidelines and strategies promoting a healthy balance between screen use and other activities. Such measures may involve setting limits on screen time, fostering outdoor play and physical activity, advocating for digital well-being, and encouraging face-to-face social interactions.

**Acknowledgments**
There are no acknowledgments.

**Conflict of Interest**
The author declares that there is no conflict of interest.

**Received:** 06 January 2024 | **Accepted:** 20 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240217

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ORIGINAL SCIENTIFIC PAPER

# Response of Pro-Inflammatory Cytokines After A Single Bout of Moderate-Intensity Endurance Exercise in Obese

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**Abstract**

Reducing the complications of obesity by controlling the balance of inflammation and losing weight with physical exercise can be used as a strategy to overcome obesity problems. This study aims to prove the effect of moderate-intensity endurance exercise on the acute response of proinflammatory cytokines in obese women. A total of 22 obese women aged 20-24 years, with body mass index 27-33 kg/m2, and body fat percentage ≥30%, were selected to be respondents and given moderate-intensity endurance exercise intervention (60-70% HRmax) for 40 minutes. ELISA Kit was applied to evaluate TNF-α levels in all samples. The data analysis technique uses an independent sample t-test with a significance level of 5%. The results show the average TNF-α levels between the control (CON) vs endurance exercise group (END) in pre-exercise (5.47±2.19 vs 5.39±1.45 pg/mL, p=0.932), post-exercise (5.76±2.08 vs 3.68±2.10 pg/mL, p=0.039), delta (value of pre-exercise – post-exercise) (0.29±2.27 vs -1.72±1.04 pg/mL, p=0.020). This study consistently proves that one session of moderate-intensity endurance exercise for 40 minutes reduces TNF-α levels in obese women.

***Keywords:*** *endurance exercise, obesity, pro-inflammatory cytokines, sedentary lifestyle*

## Introduction

It has now been reported that obesity is at an alarming rate (Becetti et al., 2023). Data from the World Health Organization (WHO) (2021) reports that 39% of the world's population aged ≥ 18 years are overweight, and 13% are obese. Obesity in adolescents is a cause of long-term health problems and has become a major concern in the health sector, a wider medical problem, and a public health concern (Loux et al., 2023). Adolescence is an important phase of life for achieving human potential, as physical, cognitive, social, and emotional development occurs within a complex network of family, peers, schools, media, and broader sociocultural influences (Agung et al., 2023). In addition, adolescence can be used as a foundation for future health and well-being (Silvers & Peris, 2023). Therefore, obesity in adolescents is still a health problem that needs attention.

Obesity is a chronic disease characterized by excessive accumulation of adipose tissue (Basu et al., 2023). Adipose tissue is the largest endocrine organ in the body (Pallio et al., 2023). In recent years, adipose tissue dysfunction in obesity has been associated with metabolic changes (Santillana et al., 2023), and causes a low-grade inflammatory state in adipose tissue which is characterized by increased levels of tumor necrosis factor (TNF-α) (Guan et al., 2023), thus having an impact on the development of chronic diseases (Zhang et al., 2023), metabolic diseases, and complications at the tissue and organ

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level (Kawai et al., 2023). Currently, adolescents with obesity are at greater risk of morbidity and mortality, possibly appearing before the age of 30 in both sexes (Horesh et al., 2021). In addition, in individuals with obesity, there is also a decrease in quality of life related to health status, and an increase in obesity co-morbidities, including type 2 diabetes mellitus, and non-alcoholic fatty liver disease (NAFLD), this risk has the potential to occur in adolescents with severe obesity (Lister et al., 2023). This phenomenon makes obesity one of the most common non-communicable diseases and a major public health burden (Khanna et al., 2022).

Developing an appropriate exercise program is an integral part of a comprehensive obesity management approach (Rejeki et al., 2023). Obesity is a complex multifactorial disease (Lin & Li, 2021), meanwhile, programmed physical exercise also has complex biological effects, involving polygenic interactions within cells, tissues/organs, and systems (Ruegsegger & Booth, 2018). Physical activity is defined as any movement that requires energy (Qiu et al., 2023). Exercise that involves physical activity contributes to reducing excess calories in obesity by increasing insulin sensitivity which results in increased glucose uptake (Han et al., 2023). Evidence shows that losing weight has been shown to reduce circulating TNF-α levels in adults with obesity (Mulas et al., 2023; Pranoto et al., 2023a). However, weight loss cannot be done in a short time (Wharton et al., 2023). Meanwhile, the results of other studies show that heavy resistance training can suppress the immune system and cause inflammation and muscle damage (Cerqueira et al., 2020; Liu et al., 2023). Determining the intensity of exercise is important in compiling an exercise program. Therefore, reducing the complications of obesity by controlling the balance of inflammation (Callegari, et al., 2023), and losing weight with physical exercise (Borer, 2023) can be used as a strategy to overcome obesity problems. The study by Honkala et al. (2020), reported that endurance exercise can significantly reduce TNF-α levels. Makarewicz et al. (2022) reported that endurance exercise was less effective in reducing TNF-α concentrations in overweight and obese adults. However, a study conducted by Andarianto et al. (2022) reported different results that moderate-intensity endurance exercise was effective in reducing TNF-α levels in obese women. Based on several research results above, there are still gaps in the research results. Therefore, this study aims to prove the effect of moderate-intensity endurance exercise on the acute response of proinflammatory cytokines in obese women.

## Methods

*Study design*

This study complies with the ethical principles of the Helsinki Declaration on medical research involving human subjects developed by the World Medical Association (WMA) and the protocol in this study was approved by the Health Research Ethics Commission (KEPK) Faculty of Medicine, Universitas Airlangga No. 16/EC/KEPK/FKUA/2022. This study used a true experimental method with a pretest-posttest control group design. A total of 35 prospective respondents underwent a screening process with several stages of examination, such as health status, body composition, anthropometry, and research demography. Thirteen people were declared not to meet the inclusion criteria. A total of 22 obese women aged 20-24 years, with body mass index 27-33 kg/m2, body fat percentage ≥30%, normal blood pressure, normal resting heart rate, normal oxygen saturation, and normal body temperature were selected to be respondents and carried out blood sampling. Information about the research has been conveyed to the participants clearly and the participants have stated consent to participate in the research by filling out and signing informed consent which was done consciously without any coercion. All selected respondents had no history of chronic disease, and for the last 5 years had no history of smoking or consuming alcohol. Group division was done randomly between the control group (CON; n=11), and the endurance exercise group (END; n=11).

*Protocol of endurance exercise*

All respondents came to the fitness center at 07.00 a.m. Before starting the endurance exercise, the subject underwent a 5-minute warm-up (dynamic stretching) and a leisurely walk on the treadmill for 5 minutes. Endurance exercise was applied once (acute exercise) with moderate intensity (60-70% HRmax), the duration of the exercise was 40 minutes/session using the Treadmill (Life Fitness 95t Inspire Treadmill., Schiller Park, Illinois 60176, U.S.A). Cooling down (static stretching) after resistance training was done for 5 minutes. While at the fitness center, each respondent was accompanied by a personal trainer to ensure that the respondent carried out the exercise program correctly, thereby minimizing the occurrence of injuries. During the intervention, exercise intensity was controlled using the Polar H10 Heart Rate Sensor. The environment used for training has a room temperature of 25°C with an indoor humidity level of 50%.

*Blood sample collection and examination of TNF-α levels*

Blood sampling (pre) was carried out after fasting overnight for 10-12 hours, while blood sampling (post) was carried out 6 hours after the intervention of 3 cc each. The collected blood samples were immediately centrifuged at 3000 rpm for 15 minutes, then the serum was separated and immediately examined for TNF-α levels. Examination of TNF-α levels using the ELISA Kit (Cat.No.: E-EL-H0109; Elabscience, Inc., USA) which has been validated by previous studies (Pranoto et al., 2023a).

*Statistical analysis*

The normality test with Shapiro Wilk was used to examine the distribution of the data. The parametric paired sample t-test was applied to see data differences per group, while the independent sample t-test was applied to see data differences per all groups. Data was declared to have a significant difference when 5%, and data was presented as mean ± SD. All statistical analyses used SPSS software version 20 for Windows 10.

## Results

The results of the analysis of the demographic characteristics of the study subjects are shown in Table 1 which shows that there were no differences in the characteristics of the two groups (p≥0.05). Therefore, the two groups are confirmed to be on the same basis. Meanwhile, the results of the analysis of TNF-α levels between pre-exercise and post-exercise in each group are shown in Figure 1, while Table 2 presents the differences in TNF-α levels between the control group (CON) and the endurance exercise group (END).

**Table 1.** The characteristics of the study subjects

| Parameters | Unit | n | CON | END | p-Value |
|---|---|---|---|---|---|
| | | | Mean±SD | Mean±SD | |
| Age | yrs | 11 | 22.00±1.42 | 22.30±1.57 | 0.659 |
| Weight | kg | 11 | 74.10±6.83 | 72.05±6.98 | 0.514 |
| Height | m | 11 | 1.58±0.06 | 1.57±0.05 | 0.728 |
| BMI | $kg/m^2$ | 11 | 29.61±2.82 | 29.04±1.76 | 0.595 |
| FM | kg | 11 | 33.65±6.19 | 30.48±4.76 | 0.218 |
| FFM | kg | 11 | 43.08±4.51 | 41.56±3.05 | 0.390 |
| SMM | kg | 11 | 20.31±4.27 | 18.43±1.89 | 0.226 |
| SBP | mmHg | 11 | 113.10±6.87 | 109.80±6.86 | 0.297 |
| DBP | mmHg | 11 | 77.40±7.26 | 77.70±5.34 | 0.917 |
| RHR | bpm | 11 | 78.30±10.02 | 77.50±6.87 | 0.838 |
| $SpO_2$ | % | 11 | 98.10±0.74 | 97.90±0.99 | 0.616 |
| BT | °C | 11 | 36.27±0.29 | 36.29±0.18 | 0.856 |

Note: BMI: Body mass index; DBP: Diastolic blood pressure; FM: Fat mass; FFM: Free fat mass; RHR: Resting heart rate; SBP: Systolic blood pressure; SMM: Skeletal muscle mass; $SpO_2$: Oxygen saturation. the p-Value obtained by independent sample t-test.

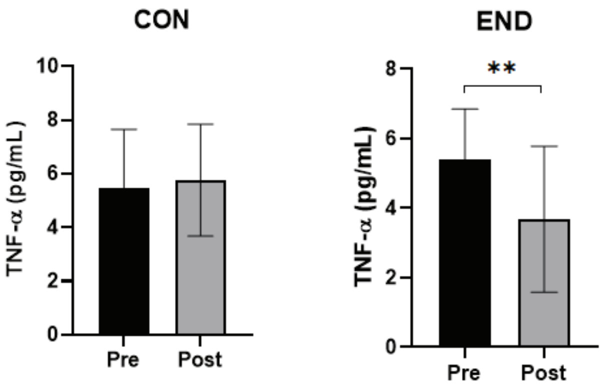


FIGURE 1. The comparison of TNF-α levels (pg/mL) between pre vs. post in each group; Note: (**) Significant at pre (p ≤ 0.001). p-Value obtained by paired sample t-test.

**Table 2.** The comparison of TNF-α levels (pg/mL) between CON vs. END

| Assessment | Unit | n | CON | END | p-Value |
|---|---|---|---|---|---|
| | | | Mean±SD | Mean±SD | |
| Pre-TNF-α | pg/mL | 11 | 5.47±2.19 | 5.39±1.45 | 0.932 |
| Post-TNF-α | pg/mL | 11 | 5.76±2.08 | 3.68±2.10* | 0.039 |
| Δ-TNF-α | pg/mL | 11 | 0.29±2.27 | -1.72±1.04* | 0.020 |
| TNF-α changes from pre | % | 11 | 15.08±47.44 | -35.27±23.87* | 0.008 |

Note: (*) Significant at CON (p ≤ 0.05). the p-Value obtained by independent sample t-test.

## Discussion

This study aims to prove the effect of moderate-intensity endurance exercise on the acute response of proinflammatory cytokines in obese women. The results of this study indicate that moderate-intensity endurance exercise significantly reduces TNF-α levels in obesity (Figure 1 & Table 2). This result is in line with the results by Accattato et al. (2017), which stated that endurance exercise can significantly reduce TNF-α levels. Likewise, a study conducted by Pranoto et al. (2023b) reported that moderate-intensity endurance exercise significantly reduced TNF-α levels in obese women. The study by Koh and Park (2017) also reported a reduction in TNF-α levels after endurance exercise in women with overweight and obese. Physical exercise plays a role in the treatment and prevention of various deadly non-communicable diseases because physical exercise has the potential to control inflammation in metabolic disorders due to obesity by reducing TNF-α levels, affecting macrophage infiltration and polarization (Callegari et al., 2023).

The training characteristics of elite/international and world-class athletes in endurance exercise have been extensively described in retrospective studies (González-Ravé et al., 2021; Casado et al., 2022; Staff et al., 2023). Endurance exercise is drawn by repeated isotonic muscle contractions of a large number of skeletal muscles (Morici et al., 2016). Various physiological functions are affected by time, such as core body temperature, cardiovascular function, respiratory control, endocrine factors, and subjective alertness, which can affect physiological adaptation in response to exercise (Kusumoto et al., 2021; Bruggisser et al., 2023). Exercise induces signaling metabolites that act as stimuli and as substrates for cellular energy sensors and molecular signaling, as adaptive responses and transcriptional sequences in response to exercise (Bennett & Sato, 2023). Approximately 40% of the human body consists of skeletal muscle, which is responsible for 90% of glucose elimination after eating (Kohler et al., 2023). When insulin binds to the insulin receptor on the surface of skeletal muscle cells, activation of the phosphoinoside-3-kinase (PI3K)/protein kinase B (Akt)/Akt substrate of 160 kDa (AS160; also known as TBC1D4) pathway causes translocation of GLUT4-containing vesicles from the cytosol to the cell membrane and as a result glucose uptake occurs (Leto & Saltiel, 2012; Kohler et al., 2023). During endurance exercise, there is a shift in the use of energy sources from glucose to ketone-bodies and fatty acids, which has an impact on improving the dulling of metabolic flexibility observed in obesity and type 2 diabetes mellitus (T2DM) and improving mitochondrial function (Di Francesco et al., 2018; Stekovic et al., 2019; Song & Kim, 2023). Improving metabolic health conditions and weight loss can suppress inflammation in obesity which is characterized by decreased levels of the pro-inflammatory cytokine TNF-α (Mulas et al., 2023). It can be concluded that exercise is effective in restoring the inflammatory balance in obesity.

The limitation of this study is that sample size of participants is small, indicating the need for larger sample sizes in future studies. Besides that we only measured the response of endurance exercise to decreased TNF-α levels as an inflammatory marker in obesity, so we cannot explain exactly the physiological mechanisms involved in reducing TNF-α levels to maintain inflammatory balance. Further studies are suggested to examine other parameters, such as IL-6, IL-10, and adiponectin to elucidate the mechanisms involved in the inflammatory balance in obesity.

## Conclusion

This study proves that one session of moderate-intensity endurance exercise for 40 minutes reduces TNF-α levels in obese women. Therefore, moderate-intensity endurance exercise can be used as an effective therapy in maintaining the balance of inflammation and is a recommendation in dealing with problems caused by obesity.

**Acknowledgments**
This study was supported by the internal research grant of the Faculty of Medicine (*Penelitian Unggulan Fakultas*), Airlangga University, Surabaya, Indonesia, under Grant No. 1309/UN3.1.1/HK/2022. We also thank all the subjects who participated in this study.

**Conflict of Interest**
The authors declare that they have no conflict of interest.

**Received:** 22 September 2023 | **Accepted:** 23 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240218

REVIEW PAPER

# Barriers to Physical Activity (PA) in the Working Population: A Review

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**Abstract**

Regular physical activity (PA) plays a crucial role in promoting overall health and preventing non-communicable diseases, with exercise both during and outside working hours reducing accumulated fatigue and stress caused by various job tasks. However, despite this, many people do not engage in sufficient levels of PA for various reasons. In line with this, this comprehensive research aimed to identify the barriers to physical exercise among the working population (WP). A search of literature was conducted using the following databases: Google Scholar, PubMed, Medline, and Mendeley, covering the period from 2002 to 2022. To potentially include in the study, all titles and abstracts were reviewed. A search of the databases based on keywords yielded 420 studies, then, through analysis and in accordance with the study's objectives, 50 studies were included for analysis. Through a detailed analysis of selected studies, various barriers to PA in the WP have been identified. All barriers can be divided into three main groups: i) Work schedule and workplace as barriers; ii) Marital and extramarital relationships, parenthood, family, and household obligations as barriers; iii) Time, behavioral, socio-economic, demographic, and ecological factors as barriers. The detected barriers suggest that interventions to overcome them should not be directed toward a single solution, given their diversity. In the context of the contemporary lifestyle where economic activities almost dominantly prevail, maintaining the health and adequate work level of employees is of utmost importance, further emphasizing the significance of PA and the identification of barriers of various kinds. Therefore, this research is of great value, as by determining the state and identifying different barriers to PA, it can serve as an initial step in devising various measures and solutions to eliminate these barriers and enable the WP to engage in physical activities for the improvement of their health and work potential.

***Keywords:*** *barriers to physical exercise, perceived barriers and physical activity, employees, workplace, leisure-time physical activity*

## Introduction

Regular physical activity (PA) plays a crucial role in promoting overall health and preventing non-communicable diseases (Cerdá et al., 2016), with exercise both during and outside working hours reducing accumulated fatigue and stress caused by various job tasks. Socioeconomic changes in most countries have influenced the lifestyle of the working population (WP), as well as the way of practicing PA (Kaleta & Jegier, 2005). The sustainability of the working age and the health of the WP in all age groups pose a global challenge and an important issue for economic prosperity, public health, and social protection. The complex interplay between the level of development of the social community and the level of individuals points to initiatives and measures that need to be taken to make the working age population healthy and sustainable, considering the multilayered interactions of physical, mental, cognitive, organizational, socio-economic, cultural, and other relevant factors (UNFPA &

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HelpAge International, 2012; World Economic Forum, 2016; Pensions at a Glance, 2018; Nilsson, 2020).

Lack of exercise, reduction, or cessation of PA can lead to a decline in health status (Mujika & Padilla, 2000a; Mujika & Padilla, 2000b) and is a health indicator of the "risk factor" for premature mortality and morbidity (Osuji, Lovegreen, Elliott & Brownson, 2006). Lost workdays, reduced work capacity, early disability pension, doctor visits, all depicted through indirect costs of illness due to insufficient PA, are high among the working-age population (Kaleta, Makowiec-Dabrowska & Jegier, 2006). Besides the benefits of regular physical exercise (PE), it is emphasized that the majority of the world's working-age population does not engage in sufficient physical activity (Drygas, Skiba, Bielecki & Puska, 2001), highlighting positive health effects in the domains of physical, mental, and social status in properly adapted and dosed physical activities (Puciato et al., 2018).

Currently available scientific indicators suggest that numerous factors can negatively impact the involvement in physical activities among the WP (Kaleta & Jegier, 2005). It is emphasized that regular PA outside working hours effectively reduces fatigue, while on-the-job fatigue can also inhibit PA outside working hours (Puetz, 2006). In this regard, some researchers indicate that a high level of physical fatigue as a barrier in manual jobs reduces physical activities, and a high level of PA is associated with reduced fatigue in sedentary jobs (de Vries et al., 2016; de Vries, van Hooff, Geurts & Kompier, 2017). Bernard and colleagues suggest that workers with sedentary jobs benefit more from strenuous PA during leisure time compared to those with non-sedentary jobs (Bernaards et al., 2006). Professional jobs that require a significant time and energy expenditure reduce the opportunity for PA during leisure time, where fatigue and lack of time are recognized as barriers to PA (Kaleta & Jegier, 2005; Angrave, Charlwood & Wooden, 2015; Bláfoss et al., 2019). Other authors point out that shift work is recognized as a barrier to engaging in PA among the WP (Fletcher, Behrens & Domina, 2008). Inadequate space and PE environment, as well as the feeling of discomfort exercising with colleagues, can be barriers to physical activity (Schwetschenau, O'Brien, Cunningham & Jex, 2008). Sara Edmunds and colleagues, in addition to the mentioned factors, indicate that attitudes toward PA, the culture of PA, low levels of physical fitness, and a sense of self-efficacy during exercise can be barriers to engaging in PA (Edmunds, Hurst, & Harvey, 2013), while other researchers recognize a lack of incentives and the distance to exercise locations as barriers to engaging in PA (Bredahl, Christensen, Justesen, & Christensen, 2019).

Socio-demographic factors and behavioral determinants such as education, household income, economic solvency, family type, age, education, unhealthy weight, smoking habits, and non-compliance with PE recommendations are perceived as barriers to engaging in PE (Kaleta & Jegier 2007; Borodulin et al., 2016). Family circumstances, the transition to parenthood, and the gender of parents are cited as barriers to PA among working parents due to a lack of time, energy, and feelings of guilt (Popham & Mitchell, 2006; Dombrowski, 2011; Mailey, Huberty, Dinkel & McAuley, 2014). Poor social climate regarding PA is highlighted as a barrier to engaging in PA (Tavares & Plotnikoff 2008). Health problems that hinder exercise are cited as barriers to engaging in PA (Lawton, Ahmad, Hanna, Douglas & Hallowell, 2006). Barriers are indicated as a reliable predictor of preventing or reducing the likelihood of engaging in physical activities, and they have the character of a previously unwanted event in relation to PA (Haynes & O'Brien, 2000). The lack of standardized measures developed to assess perceived barriers to PE makes it challenging to ensure the reliability and accuracy of measuring their impact on preventing PA (Brown, 2005).

Based on the existing information, it is noticeable that there are various barriers to physical activity among the working population. However, there is a need for a comprehensive overview research that will thoroughly examine this area and identify potential barriers to PA. Therefore, the aim of this a review was to determine the barriers to physical activity among the working population.

## Methods

The first step in writing the paper was collecting relevant research in line with the topic of the review. The search for papers was conducted using the following databases: Google Scholar, PubMed, Medline, Mendeley, in the period from 2002 to 2022. The search was performed using the following keywords and their combinations: physical activity, barriers to physical activity, working age population. In order to potentially include them in the study, all titles and abstracts were reviewed. The found research titles, abstracts, and full texts were then read and analyzed. Relevant studies were obtained after a thorough review, provided they met the inclusion criteria. A search of the database based on keywords resulted in 420 studies. Through analysis and in accordance with the set criteria, in line with the aim of this study, 50 studies were included for analysis.

## Discussion

Data collection from the 50 acceptable studies published between 2002 and 2022, including three review papers analyzing 138 articles (Kirk & Rhodes, 2011; Abbasi, 2014; Joseph, Ainsworth, Keller & Dodgson, 2015), and 47 studies with a total sample size of 346,037 participants ranging from 13 (Mayne, Hart, Tully, Wilson & Heron, 2022) to 135,340 participants (Alonso-Blanco et al., 2012), allowed for the identification of barriers to engaging in PA among the WP.

In 25 studies, a survey was used to collect data for identifying barriers to PA. Seven studies obtained the necessary data through interviews, while the International Physical Activity Questionnaire (IPAQ) was applied in four studies. Telephone interviews were used in three studies, postal surveys in one study, and an online survey in five studies. A mixed data collection method provided data for one study, while three studies conducted a systematic integrative literature review.

### *Occupational schedule and workplace as barriers*

Work hours, schedule of work duties, and fatigue as barriers to engaging in PA have been observed in a significant number of studies (Bowles, Morrow Jr, Leonard, Hawkins & Couzelis, 2002; Gidlow, Johnston, Crone, Ellis & James, 2006; Cerin, Leslie, Sugiyama & Owen, 2010; Brinthaupt, Kang & Anshel, 2010; Withall, Jago & Fox, 2011; Fransson, et al., 2012; Leicht, Sealey & Devine, 2013; Abbasi, 2014; Bardus, Blake, Lloyd & Suggs, 2014; Bredahl, Særvoll, Kirkelund, Sjøgaard, & Andersen, 2015; de Vries et al., 2016; Borodulin et al., 2016; Stankevitz et al., 2017).

A number of authors emphasize that work-related factors such as workload (Schneider & Becker, 2005; Dombrowski, 2011; Fransson, et al., 2012; Mayne, Hart, Tully, Wilson, & Heron, 2022), the structure, nature, and length of work duties (Fletcher et al., 2008), and psychosocial work demands (Kouvonen et al., 2005; Kirk & Rhodes, 2011; Ryde, Atkinson, Stead, Gorely & Evans, 2020) are barriers that negatively correlate with PA. Long working hours, especially in combination with lower-skilled jobs, can be a hindrance to exercise (Popham & Mitchell, 2006), considering that this work model reflects higher physical strain among lower-class occupations (Takao, Kawakami, & Ohtsu, 2003).

Takao (2003) states that male workers with higher physical strain had a lower threshold for engaging in PA than clerks and managers, while for female workers, the difference is not clearly pronounced (Takao et al., 2003). Cook and Gazmararian (2018) suggests that the WP with lower levels of work activity met the guidelines for engaging in PA compared to workers with higher levels of work activity. Some authors estimate that shift work, irregular working hours, night shift work, inflexible working hours, urgent unscheduled tasks, and unplanned work duties outside the workplace influence the prevalence of physical inactivity, indicating that the characteristics of work engagement can determine the attitude toward PA (da Silva Garcez, et al., 2015; Bredahl et al., 2015; Neil-Sztramko, Gotay, Demers, Muñoz & Campbell, 2017). Night shift work may initiate gender differences in PA, which can be explained by the cultural and family roles of different genders in society (da Silva Garcez, et al., 2015). The WP spends a significant portion of their time at work, resulting in psychophysical fatigue, lack of energy, will, and time, which can lead to a loss of interest in engaging in PA (Cerin, Leslie, Sugiyama & Owen, 2010; Edmunds, Hurst, & Harvey, 2013; Abbasi, 2014; Bardus et al., 2014; Hunter, Gordon, Bird, & Benson, 2018; Paudel, Owen, & Smith, 2021).

Lack of time and feelings of fatigue as perceptual barriers due to the characteristics and schedule of work engagement and assumed social obligations can result in a lack of self-motivation, which can be a determinant of physical inactivity behavior (Bowles, et al., 2002). A high level of stress caused by a high job role and significant responsibility could reduce the prevalence of exercise, indicating an assumption that there is a connection between job-related stress and the desire for physical activities (Takao et al., 2003; Mayne et al., 2022).

In her paper, Dombrowski (2011) presents, "most women stated that most of the time they do not feel confident in their ability to continue PA when faced with barriers" (Dombrowski, 2011). Results obtained in the study by Heesch & Mâsse (2004) indicate that, for African American and Hispanic American participants, PA is not a priority, and the lack of time seems to be used as an excuse for physical inactivity. Understanding the importance of PA and its beneficial psychophysical effects can be achieved through educational programs (Heesch & Mâsse, 2004).

Bredahl (2015) and colleagues in their study highlight the importance of organizing the workplace for the implementation of PA at the workplace (Bredahl, et al., 2015). Several authors note that urgent tasks outside the workplace, tight deadlines, overloaded work tasks, inaccessibility and inappropriate facilities, unhygienic conditions, lack of teamwork, poor self-assessment, physical discomfort, age, education, attitude toward exercise and motivation, lack of instructor competence, and an uninteresting program can be barriers to physical activity in the workplace (Edmunds, Hurst & Harvey, 2013; Bredahl, et al., 2015; Torquati, Kolbe-Alexander, Pavey, Persson & Leveritt, 2016; Stankevitz, et al., 2017; Hunter et al., 2018). In the study by Mariam and Mazin (2019), employed women, regardless of the length of their work experience, identified a lack of time and energy as the main barriers to physical activity at the workplace. Better organization of working hours may reduce barriers expressed in attitudes that it is uneconomical to spend working time and resources on PA during work procedures (Ryde et al., 2020). Awareness of barriers to the prevalence of PA during work schedules and necessary interventions to reduce them assumes that the workplace can be crucial for achieving PA (Al-Mohannadi, Albuflasa, Sayegh, Salman, & Farooq, 2020). Improving exercise at the workplace could be enhanced by individually tailored program adjustments (Bardus et al., 2014), as well as interventions in the structure of daily work duties, improvement of organizational challenges, and cultural-normative parameters of the workplace, directed at both employees and employers (Ryde, et al., 2020). Effective workplace programs, as a result of shared awareness among all employees, can reduce barriers to exercise, inaugurating the workplace as crucial for engaging in PA (Stankevitz, et al., 2017; Al-Mohannadi, et al., 2020).

It is important to emphasize that one-time measures to increase exercise engagement are likely to be ineffective, pointing to the need for continuous and tailored programs for specific categories and interests, considering the presence of different needs, motives, and interests of the WP (Fletcher, et al., 2008). Interventions should ideally focus on raising awareness of specific aspects of PA, which can help individuals as well as the entire population overcome identified barriers to PA (Schneider & Becker, 2005). Initiatives in the domain of social support, understanding gender differences, and improving exercise environments and facilities can create conditions for higher prevalence of physical exercise among the WP (Paudel, et al., 2021).

Angrave (2015) and colleagues, in their paper, present that, with the control of certain exogenous factors, they did not discover a significant link between long working hours and the prevalence of PA but confirm the findings of other authors that shift work can be a barrier (Angrave, Charlwood & Wooden, 2015).

It can be argued that psychophysically demanding occupations and their related psychosocial effects on lifestyle can reduce the prevalence of PA. This suggests that professional work activity and the workplace are areas where interventions should be directed to increase levels of PA (Schneider & Becker, 2005; Vandelanotte et al., 2015), which can lead to an improvement in the overall quality of life of the WP (Puciato et al., 2018). Study findings suggest that PA is crucial for the WP (de Vries et al., 2016).

*Marriage and extramarital relationships, parenthood, family, and household duties as barriers*

Entering marital and extramarital unions, transitioning to parenthood, and the associated shift in priorities can influence changes in the physical activity levels of partners and parents. This prioritization often favors childcare and family obligations over physical activity (Kouvonen et al., 2005; Popham & Mitchell, 2006; Roessler & Bredahl, 2006; Bellows-Riecken & Rhodes, 2008; Withall et al., 2011; Alonso-Blanco et al., 2012; Leicht et al., 2013; Mailey et al., 2014; Torquati et al., 2016). Barriers identified include a lack of time and energy, family and household obligations, feelings of guilt, and a lack of family and spousal support (Dixon, 2009; Hull et al., 2010; Abbasi, 2014; Mathews et al., 2016; Keohane, Mulligan & Daly, 2018; Al-Mohannadi et al., 2020; Paudel et al., 2021). Similar findings were reported by Joseph et al. (2015), identifying these as "interpersonal barriers" involving family care responsibilities, lack of social support, and a lack of a partner for physical activity.

Mailey et al. (2014) highlighted that within family obligations, children took precedence, and barriers to physical activity were more pronounced in fathers than mothers. Feelings of guilt were cited as a barrier for fathers in relation to family and self-care, and for mothers in relation to family, self-care, and work. Both fathers and mothers recognized a lack of support as a barrier to physical activity prevalence. Difficulty prioritizing due to schedule constraints and the need for balance, particularly due to limited daily time, was more frequently emphasized as a barrier by mothers than fathers (Mailey et al., 2014). Overload of daily routine, family, and household obligations were identified as barriers more commonly experienced by women than men (Leicht et al., 2013; Paudel et al., 2021). Despite the physical activity requirements of childcare and household chores, women are socio-culturally disadvantaged, with Abbasi (2014) underscoring that women, due to their gender roles in family and society, struggle to achieve desirable levels of physical activity. Results suggest that childcare, particularly in families with more children, is a central part of maternal household work, positively correlating with the number of children and the number of identified barriers. Identified barriers include household work, cultural beliefs, social isolation, and an insecure environment (Abbasi, 2014).

Despite maternal and spousal responsibilities at home, Heesch et al. (2004) suggest in their study that the lack of time due to work obligations is not decisive for physical inactivity. Participants in the study used a significant portion of their free time for reading, watching television, and relaxation. Predominant sedentary leisure was identified as a barrier to engaging in physical activity (Heesch & Mâsse, 2004). Joint physical activity by parents and children, along with a tandem focus on parental goals and interventions, can provide supportive conditions within the family (Mailey et al., 2014).

*Time, behavioral, socio-economic, demographic, ecological factors as barriers*

A significant number of studies highlight a lack of time, fatigue, lack of self-initiative and will, lack of exercise companionship, costs, lack of social support, non-aesthetic or insecure living environment, poor health, alcohol and tobacco consumption, physical incapacity, education, and poor weather conditions as possible barriers to PA (Bowles et al., 2002; Kouvonen et al., 2005; Schneider & Becker, 2005; Popham & Mitchell, 2006; Osuji et al., 2006; Gidlow et al., 2006; Roessler et al., 2006; Azevedo et al., 2007; Kaleta & Jegier, 2007; Godin, Bélanger-Gravel, & Nolin, 2008; Schwetschenau et al., 2008; Brinthaupt et al., 2010; Cerin, et al., 2010; Arango, Patiño, Quintero, & Arenas, 2011; Withall et al., 2011; Holtermann, Hansen, Burr, Søgaard & Sjøgaard, 2012; Thomas, Halbert, Mackintosh, Quinn & Crotty, 2012; Alonso-Blanco et al., 2012; Edmunds et al., 2013; Abbasi 2014; Bardus et al., 2014; Bredahl et al., 2015; Vandelanotte et al., 2015; Joseph et al., 2015; Borodulin et al., 2016; Mathews et al., 2016; Torquati et al., 2016; Stankevitz et al., 2017; Puciato et al., 2018; Keohane et al., 2018; Hunter et al., 2018; Bláfoss et al., 2019; Mariam & Mazin, 2019; Al-Mohannadi et al., 2020; Paudel et al., 2021; Mayne et al., 2022).

Professional, social, and family obligations can lead to a lack of time for exercise, with time scarcity being the most commonly cited barrier. Those who reported time pressure as an obstacle to exercise had a lower prevalence of PA (Bowles et al., 2002; Osuji et al., 2006; Roessler & Bredahl, 2006; Fletcher et al., 2008; Borodulin et al., 2016; Ryde et al., 2020; Paudel et al., 2021; Mayne et al., 2022). Gidlow and colleagues (2006) in their study emphasize that the lack of time for exercise is more present among those with lower socio-economic status. Work schedules and conflicts within schedules and busyness can contribute to a lack of time for PA (Leininger, Adams & DeBeliso, 2015; Neil-Sztramko et al., 2017; Mayne et al., 2022), which could be addressed by allocating time resources for PA, taking into account specific job needs (Leininger et al., 2015). Overtime hours, simultaneous tasks, weekend work, and a high level of responsibility can shape a lack of time recognized as a barrier to exercise (Kirk & Rhodes, 2011), while unemployed individuals are less likely to perceive time as a barrier to PA (Borodulin et al., 2016). High managerial positions and greater social engagement, despite better economic status, may result in less time as a barrier to PA (Takao et al., 2003). Interventions aimed at establishing flexible working hours and adjusted breaks can help reduce daily time pressure for higher exercise prevalence (Ryde et al., 2020). Lack of time as a barrier, due to childcare, family, and household responsibilities, may be a reason for not exercising (Withall et al., 2011; Leicht et al., 2013; Keohane et al., 2018; Paudel et al., 2021). The results of the study by Leicht et al. (2013) indicate that the lack of time and energy due to family and household responsibilities is more pronounced in women than in men, which aligns with the findings of Abbasi (2014), who indicates that women, due to family busyness, lack of spousal and family support, more than men, identify a lack of time as a barrier to PA. The results of the study by Al-Mohannadi (2020) and colleagues highlight that women recognize time as a barrier due to daily family responsibilities and difficulties in maintaining a routine. Efforts and interventions aimed at reducing social responsibility expectations and burdens, improving social, family, and partner support, can influence the reduction of time barriers in women and initiate their greater participation in exercise (Abbasi, 2014). Borodulin et al. (2016) identify that men and women in non-partner relationships and without children perceive time as a barrier less than those in partner relationships and with children.

Lack of interest (Stankevitz et al., 2017), reduced motivation and insufficient skills (Hunter et al., 2018; Paudel et al., 2021), the belief that exercise could lead to physical injury (Al-Mohannadi et al., 2020), discomfort caused by external factors (Mathews et al., 2016), the perception that exercise is boring, and a sense of body shame among colleagues during exercise (Edmunds et al., 2013), assessed low self-efficacy levels (Withall et al., 2011), lack of energy and knowledge

(Mariam & Mazin, 2019) are recognized barriers to engaging in PA. Leicht (2013) emphasizes that women more often cited lack of energy as a barrier than men, explaining this gender difference with traditional daily schedules and participation in household and family physical activities. Dombrowski (2011) presents that participants stated that facing barriers discourages them from engaging or continuing exercise and negatively impacts their self-confidence, while Al-Mohannadi et al. (2020) state that women expressed the view that PA is uninteresting. Arango (2011) and colleagues note that women reported higher barrier values when it comes to lack of will. Lack of motivation, in combination with a lack of skill and fear of injury, as barriers, has been increasing with age and in obese individuals, which could be alleviated by interventions aimed at increasing motivation an

Azevedo et al. (2007) present findings that men engaged in higher levels of PA compared to women, which can be explained by the busy schedules of women with household and family responsibilities, which are perceived as a barrier promoting a healthy lifestyle (Arango, et al., 2011). Older workers engage in lower levels of PA than younger workers, with age negatively correlating with exercise levels, making chronological age a barrier (Stankevitz et al., 2017; Bláfoss et al., 2019). Fear of injury and pain (Osuji, et al., 2006), age considered in the same-sex group, unhealthy weight associated with a sedentary lifestyle, smoking habits, alcohol consumption, and spending time in front of the TV as observed barriers to PA are variables significantly correlated with physical inactivity (Kaleta & Jegier, 2007). Schneider & Becker (2005) note that smoking and excessive alcohol consumption represent barriers to PA. Awareness that excess weight as such directly or indirectly affects reduced involvement in exercise underscores the importance of promoting a healthy lifestyle, health, and physically active living (Godin et al., 2008). Inactivity in the WP can pose a public burden, assuming interventions to raise awareness of the importance of PA and healthy behavior change (Kaleta & Jegier, 2007). Combined effects of lack of knowledge and instructions, fear, and low self-awareness regarding PA can emerge as barriers to exercise, which can be mitigated by involving appropriate educators and planning PA interventions (Fletcher et al., 2008).

Kaleta and Jegier (2007) report differences in the level of PA concerning the level of education and economic status. The level of education positively correlates with PE, while the risk of not exercising is several times higher in individuals with basic education than in college-educated men and women. Low monthly incomes can appear as a barrier, aligning with the findings of Kaleta and Jegier (2007), who present results that men and women with the lowest monthly incomes have a higher risk of physical inactivity than those with a higher monthly budget. Economic insecurity through a lack of savings and financial indebtedness can project life problems, reducing quality of life and personal financial solvency, with a consequent questionable active involvement in PE (Puciato et al., 2018). The positive interaction of low socio-economic status with exercise is confirmed by Azevedo et al. (2007) and Stankevitz et al. (2017), whose results indicate that a low level of socio-economic status can appear as a barrier to engaging in PA. It is assumed that individuals with lower levels of education possess less knowledge about the positive effects of exercise compared to those with higher levels of education, which somewhat explains the presence of barriers in the lower-educated population. Involvement in fitness centers requires financial resources, which are not always accessible to the population with lower economic status, leading to barriers in the lower socio-economic population (Azevedo, et al., 2007).

Lack of and distance to indoor and outdoor facilities and spaces for PA, lack of safety, and meteorological conditions can emerge as barriers to PA (Brinthaupt et al., 2010; Keohane et al., 2018; Paudel et al., 2021; Mayne et al., 2022). Edmunds (2013) and colleagues state that the distance between workplaces and exercise locations can be a barrier to exercise. Barriers in the form of inadequate hygiene conditions during and after exercise can influence the degree of involvement in physically active populations, which is essential for employees who would like to exercise during working hours. The inability to have proper hygiene treatment after exercising due to inadequate and insufficient numbers of bathrooms and showers can be a barrier to PA in the workplace, which can be overcome by identifying and intervening to improve space and facility standards (Torquati et al., 2016). An unsafe environment, such as narrow streets, wandering dogs, and poorly visible entrances, can be barriers, and addressing them requires a strategic approach to activities aimed at improving social and cultural norms in the community (Mathews et al., 2016). Risky social communities (Cerin et al., 2010) as barriers in the form of verbal and physical harassment may be challenging to resolve, considering the need for comprehensive engagement at political, security, economic, cultural, and social levels. Devastated pedestrian paths can hinder or discourage participants from exercising, emphasizing the importance of involving local government unit leaders and a creative architectural approach to overcoming this barrier. Involvement in joint action by security agencies, law enforcement, and community members can reduce security-related barriers, aiming to provide a better environment for involvement in exercise activities (Joseph et al., 2015). External weather conditions such as rain, snow, wind, hail, and temperature can pose a barrier to PA, although the strength of this barrier in this case is perceived to be of less significance.

The variability of exercise leaders and non-pedagogical work, misunderstanding exercises by exercisers, and rigid exercise content can act as barriers with the potential to project monotony, low perceived capability, and demotivation, lack of progress, and loss of attention in exercisers (Bredahl et al., 2015). Distrust towards the instructor (Withall et al., 2011), strict adherence to schedules, and the belief that they shouldn't exercise when the instructor is not present were detected as inconsistencies by exercisers. Lack of motivation can be explained by the fact that exercise content is monotonous and lacks creativity. By applying multidisciplinary knowledge regarding PA, more flexible, content-diverse programs, and simplified procedures for membership and participation in PA programs, it is possible to reduce barriers to PA (Schwetschenau et al., 2008; Bardus et al., 2014; Bredahl et al., 2015).

## Conclusion

Psychophysical subjective benefits and mental well-being, supported by experience and skill gained during PA, positively influence social interactions within the WP. A wide spectrum of presented barriers, aside from revealing the challenging circumstances faced by the WP in their efforts to engage in PE, demonstrates their interconnected and intricate impact that should not be overlooked. All barriers can be divided into three main groups: i) Work schedule and workplace as barriers; ii) Marital and extramarital relationships, parenthood, family, and household obligations as barriers; iii) Time, behavioral, socio-economic, demographic, and ecological factors as barriers. In the context of the contemporary lifestyle, where economic activities almost dominantly prevail, maintaining health and a adequately functional state among employees is of utmost importance, further emphasizing the significance of PA and the detection of barriers of various kinds. Findings underscore the need for synchronized and continuous interventions by various entities within the social community, both on an individual and societal level, in the domains of behavioral, socioeconomic, demographic, and ecological aspects. Interactive communication regarding PA between managers and employees should unveil its meaning to the WP, without discarding understanding of what it means in a comprehensive life context. Values highlighted in the working active population might be valued if they reflect the desired outcome of what people appreciate in terms of how PA can be designed to reflect the desired result. Study findings indicate the importance of promoting more frequent involvement in clubs and easier access to PA. The results of this study could potentially guide various interventions aimed at eliminating barriers associated with PE, and in that sense, future studies should adopt consistent procedures and approaches, rigorous analytical techniques, and deeper exploration of the context. The fact that awareness of barriers presupposes higher-quality implementation of PE programs, among other things, may suggest the need to establish related relationships and influences between encouraging factors of PA. Understanding and activating the obtained findings and their implementation in future research should provide a better understanding and design of interventions that reduce barriers and enhance factors that encourage participation in PA. Detected barriers suggest that interventions to eliminate them should not be directed at a single solution, given their diversity. Therefore, this research is of great value, as by determining the state and identifying different barriers to PA, it can serve as an initial step in devising various measures and solutions to eliminate these barriers and enable the WP to engage in physical activities for the improvement of their health and work potential. As PA is important for the WP, the design of exercise programs should be structurally and socially desirable, designed with a comprehensive perspective to be attractive and accessible to the widest WP.

**Acknowledgments**
There are no acknowledgments.

**Conflict of Interest**
The author declares that there is no conflict of interest.

**Received:** 07 September 2023 | **Accepted:** 05 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240219

REVIEW PAPER

# The Upper Quarter Y-Balance Test: A Scoping Review of Reference Values, Reliability, Determinants, and Practical Application

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**Abstract**

The aim of this scoping review was to comprehensively examine the Upper Quarter Y-Balance Test (UQYBT), including reference values, reliability, determinants, and its practical application. By including studies irrespective of publication date, participant demographics, or research purpose, provided they were in English and incorporated UQYBT as a primary or secondary variable, an extensive dataset was collected. The focus was on limb-length-normalized results to establish standardized reference metrics. Reliability studies highlighted the UQYBT's consistency across sessions and raters. The application of UQYBT to assess injury risk is questionable. Studies assessing its relationship with sports performance have also yielded varying results. UQYBT seems to be sensitive to various exercise based-interventions, as shown by several clinical trials. This review furnishes practitioners and clinicians with valuable insights for the application of UQYBT in sports and healthcare settings.

***Keywords:*** *injury prevention, athletic performance, reference values, scoping review, upper limb*

## Introduction

Postural balance, the ability of maintaining the body's centre of mass directly over its base of support, is pivotal in everyday life. It ensures the smooth execution of daily tasks and is also vital in sports. Proficient balance not only correlates with some aspects of sports performance (Hrysomallis, 2011), but may also offer protection against injuries (Hrysomallis, 2007; Gribble et al., 2012). Hence, in sports practice, balance assessment is of utmost importance. While sophisticated laboratory methods like tracking the centre-of-pressure movement using force plates have been commonly applied to athletes (Kiers et al., 2013; Trajković et al., 2021; Zemková, 2022), the practicalities and costs often make them less feasible for routine evaluations. In light of these constraints, previous researchers have investigated the reliability, validity and practical application of several field-based balance test alternatives (Sabchuk et al., 2012; Bhat & Moiz, 2013; Clarke et al., 2019; Velarde-Sotres et al., 2021). Star-excursion balance test, and its simplified adaptation, the lower-quarter Y-balance test, have been commonly applied to test lower-limb dynamic postural balance in athletes (Plisky et al., 2009; Gribble et al., 2012; Bhat & Moiz, 2013; Powden et al., 2019). However, tests for upper body postural balance and stability have not been as extensively studied.

Early attempts to establish a practically useful field-based test for upper body included The One-Arm Hop Test (Falsone et al., 2002) and The Closed-Kinetic Chain Upper Extremity Stability Test (Goldbeck & Davies, 2000). However, while requiring balance ability, these tests do not challenge the subject to the limits of stability, which motivated the development a new version of Y-balance test for upper body, also known as The Upper Quarter Y-Balance Test (UQYBT) (Gorman et al., 2012). Based on previous evidence on reliability and practical application of Y-test for lower limbs (Plisky et al., 2009; Coughlan et al., 2012), the researchers suggested that UQYBT could provide useful information about upper body balance and stability (Gorman et al., 2012; Westrick et

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al., 2012) and shoulder function (Hegedus et al., 2014). The UQYBT requires stability on the supporting arm and mobility of the thoracic spine by reaching the arm in the medial, inferolateral and superolateral directions during a push-up position. The inferolateral and superolateral are positioned at an angle of 135 degrees to the medial direction and there is 90 degrees between them. Executing a reach in each direction necessitates a combination of trunk stabilization, thoracic spine rotation, and scapular mobility and stability. Therefore, it evaluates an individual's balance, proprioception, strength, and range of motion. It can also provide an asymmetry index between the two sides (Gorman et al., 2012). Before undertaking the UQYBT, it is necessary to measure the arm's length in a standing position, shoulder in 90 degrees of abduction and elbow extended. The measurement is taken from the C7 spinous process to the tip of the middle finger (Gorman et al., 2012; Westrick et al., 2012). The test is first conducted on the non-dominant side, followed by the dominant side. The dominant side is determined by the arm used for throwing. The participant starts in a push-up position, with feet shoulder-width apart and supported by one arm. The tested arm first reaches in the medial direction, followed by IL, and finally SL. After each reach, the participant returns to the starting position. Initially, two familiarization repetitions are carried out. Subsequently, the participant performs three repetitions, taking a 30-second break between each. If the participant struggles to maintain balance in the push-up position or leans excessively on the board (used to measure reach distance), the test must be redone. Ultimately, the reach value for each direction is calculated and normalized to limb length (Gorman et al., 2012; Westrick et al., 2012). The composite score may be calculated as normalised mean of the three reach directions (Borms & Cools, 2018). Figure 1 shows the performance of UQYBT in all three directions.

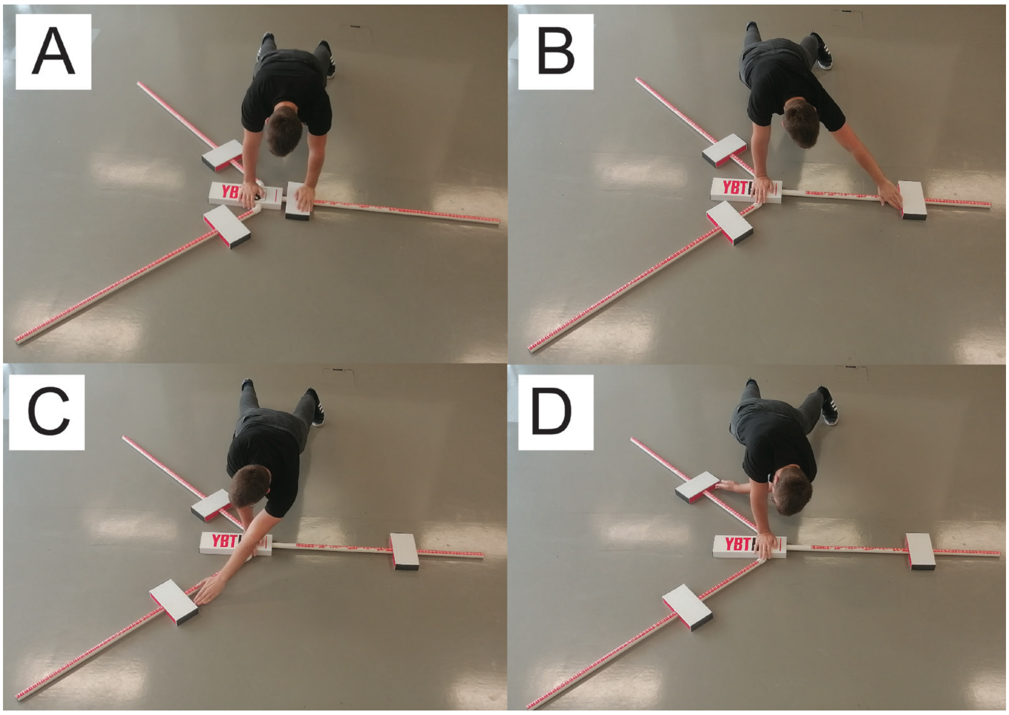


FIGURE 1. A display of performance of the UQYBT test. A – initial position; B – medial reach; C – superolateral reach; D – inferolateral reach.

Initial studies have already reported good to excellent intra-visit reliability for UQYBT in general population, with intra-class correlation coefficient (ICC) in range of 0.80 to 0.99. The highest intra-visit test-retest reliability was for the superolateral direction (ICC=0.92-0.99) and the lowest for the medial direction (ICC=0.80-0.96). Inter-rater reliability was perfect (ICC=1.0) (Gorman et al., 2012). Subsequent studies have also confirmed the excellent reliability in athletes (ICC=0.92-0.97) (Borms et al., 2016). Early studies showed a very low correlation with The Closed-Kinetic Chain Upper Extremity Stability Test (Taylor et al., 2016), suggesting the two tests yield different information on upper body postural stability and balance. Therefore, the UQYBT appears to be a reliable and potentially useful test. Based on a Delphi study involving 22 experts from sport science and medicine with an extensive knowledge of upper limb functional testing, UQYBT mainly assesses the stability of the gleno-humeral joint and the stability of the upper arm kinetic chain. The experts also highlighted that it is inexpensive and involves both the shoulder and the trunk They thought that it may be used for closed chain sports (e.g., wrestling), but not for open chain sports (e.g., volleyball) (Tooth et al., 2022).

Although the star-excursion balance test and the Y-balance test for the lower limbs have been subjects of past literature reviews (Gribble et al., 2012; Powden et al., 2019), there has yet to be a review on the UQYBT. Therefore, the aim of this article is to compile all existing research on the UQYBT. This will provide reference values for various age groups and sports and will examine the test's reliability, its correlation with other assessments, and its capability to identify injury risk. Understanding the intricacies and practical applications of the UQYBT is vital for clinicians, trainers, and sports professionals. A comprehensive review of the UQYBT can offer insights into its effectiveness as a diagnostic tool and its potential impact on training and rehabilitation strategies. By establishing reference values and examining its reliability, sports professionals can make informed decisions about athlete performance and injury prevention. Furthermore, this review aims to identify research gaps and areas that require further exploration, thereby motivating subsequent studies to expand our understanding of the UQYBT. As exercise science and sports medicine continues to evolve, staying updated with the latest assessment techniques and their implications is paramount. By pinpointing areas of uncharted territory in UQYBT research, the aim is to guide future investigations, ultimately advancing the field and enhancing athlete care and performance.

## Methods

A scoping review was conducted to map the extent and range of literature related to the UQYBT and to identify key concepts, gaps in the research, and evidence for practice. The scoping review was chosen due to its utility in synthesizing research evidence and providing comprehensive overviews of broad topics where many different study designs might be applicable. The literature was primarily searched in PubMed and Scopus, using the search string "upper quarter y balance test". In addition, a non-systematic search of Google Scholar was performed the reference lists were checked when screening the articles found by database search.

Studies were included if they met the following conditions: a) written in English b) including UQYBT as a primary or secondary variable. There were no restrictions on the date of the study, the population and the purpose of the study. For the purpose of collecting the reference values, the descriptive statistics and characteristics of the subjects (age, sex, sport, level of participation in sport) from the individual articles were extracted. The focus was on results normalised to limb length, as this approach enables comparison across individuals and groups. Consequently, the results are primarily expressed as a percentage of upper limb length (% ULL). In instances where values were not normalised, the raw values were considered. These instances are indicated in the supplementary table.

The literature was also synthesized narratively, addressing aspects of reliability, sex and sport differences, inter-limb asymmetries, limb dominance, injury risk, and the relationship of UQYBT results with other tests. This narrative synthesis allows for the integration of findings from diverse methodological approaches and facilitates a holistic understanding of the UQYBT's utility in both clinical and research settings.

### *Reference values*

In total, 68 articles were identified (56 from the PubMed database, 11 from the Scopus database and one after an additional unsystematic search of the Google Scholar database). Due to unavailability of articles or insufficient reporting, reference values could not be obtained for 15 articles. Thus, 53 articles were used to extract normative values, which were separated by different types of sports. The reference values are collected in Supplementary File 1 (http://www.sportmont.ucg.ac.me/clanci/Ribnarik_Supplementary.pdf), divided into several sections based on sport types. In the following, subsections, the results are briefly summarized. Aspects such as sex and sport differences are addressed in later sections.

### *Strength and power sports*

Five studies were included in the review, in which the subjects were representatives of "strength and power sports". In two studies, the subjects were from a specific sports discipline (one study Olympic weightlifting, one study CrossFit), and three studies stated the inclusion criteria as the subjects performing resistance training or weight training. Adults were the subjects in all of the studies reviewed. It should be noted that in the study by Guirelli et al. (2021), the authors used a modified version of the Y-test, while in the study by Silva et al. (2022), it is not entirely clear whether a modified version was used or not. The composite scores were relatively similar among the studies, mostly confined to 80 to 85% ULL. The results are shown in detail in Table 1 within the Supplementary file 1.

### *Swimming*

Three studies included the swimmers (Table 2). One of the studies included only adult subjects, one study assessed only adolescent subjects and included both adolescent and adult subjects. Interestingly, mean composite scores range from 83.4 to 88.3% ULL in adults, and from 94.8 to 96.0% ULL in adolescents. The results are shown in detail in Table 2 within the Supplementary file 1.

### *Sports with rackets, bats and sticks*

In the next larger group, due to the similarity of the functional requirements for the upper extremity, all the sports with rackets, sticks, bats and other similar equipment are included. In total, 11 studies were included, with baseball represented in seven studies, cricket and softball in two studies, and golf, hockey, lacrosse and tennis each in one study. The mean composite scores varied substantially; the lowest mean score was observed for female tennis players in 26-33 age group (77.9% ULL) and the highest in male baseball players (106.0% LL). The results are shown in detail in Table 3 within the Supplementary file 1.

### *Team sports with a ball*

Team sports with a ball were represented in 15 studies. Handball and volleyball prevailed (in eight and seven studies, respectively), basketball players were included in two studies, while Australian and American football players were represented in one study each. The most detailed study by Bauer et al., (2021) included male and female handball players from different playing positions (goalkeepers, backcourts, pivots and wingers) were included. Mean composite scores again varied widely across sports and studies; values as low as 61.9% ULL were found in female volleyball players and 67.6% ULL in female handball players (Saccol et al., 2022), while the values exceed 100% ULL in some handball subgroups. It should be noted that two studies (Arora et al., 2021; Bennett et al., 2022) conducted a modified version of the test. The results are shown in detail in Table 4 within the Supplementary file 1.

### *Athletics and gymnastics*

In this section, one study involved cross-country runners (range of mean composite scores: 79.8–83.5% ULL), one included track and field athletes from various disciplines (95.2–100.9% ULL), and one was conducted on children gymnasts (83.8–84.4% ULL). The results are shown in detail in Table 5 within the Supplementary file 1.

### *Martial arts*

There were two studies included in this overview, both included the wrestlers. One of the studies provided separation of wrestlers into two groups, indicating larger mean composite scores in Greco-Roman group (87.9% ULL) than freestyle group (83.4% ULL) (Tabasi et al., 2022). The results are shown in detail in Table 6 within the Supplementary file 1.

*Military personnel*

Four studies included military personnel or army recruits. All reported only a composite test result. It should be noted that in the study by Gottlieb et al. (2018), the result was normalised to the subjects' body height, not to the arm length, as is usually the case. Due to the different formula, the reported composite result deviated significantly from others, while the calculated standard deviation is not that different. Other than that, the studies were fairly consistent, reporting the composite score between 82.9% ULL and 89.5% ULL. The results are shown in detail in Table 7 within the Supplementary file 1.

*Other sports*

The next section summarises research that has covered broader groups of athletes or recreational athletes. It should be noted that two studies (Kim et al., 2020; Schwartzkopf-Phifer et al., 2021) did not normalise the result to the arm length. The composite scores were mostly in 80 – 90% ULL. Somewhat low mean composite scores were reported by Yildiz et al. (2022) for high impact sports (71.4% ULL), overhead sports (74.7% ULL) and overhead sports with sudden stops (72.4% ULL). The results are shown in detail in Table 8 within the Supplementary file 1.

*Non-athlete population*

Last group includes six additional studies in which the subjects were not athletes. Three of those studies included children as subjects and three adults. One study compared adolescent students with borderline intellectual functioning to age- and sex-matched controls (Bauer, Kammermeier, et al., 2021). Savitzky et al. (2021) provided only non-normalised results. In general, the mean values overlapped with values obtained with studies conducted on athletes, but were generally lower (e.g., no study reported a mean composite score >100% ULL). The results are shown in detail in Table 9 within the Supplementary file 1.

*Reliability*

Among the included studies, 6 aimed to provide reliability scores for UQYBT, and 5 reported reliabilities as a secondary result. In the following text, the results are summarized for each aspect of reliability. Relative reliability was assessed with intra-class correlation coefficient (ICC) in all studies. Some studies also provided measures of absolute reliability, such as standard error of measurement (SEM) and minimal detectable change (MDC). One study did not specify the type of reliability reported as a secondary outcome (Gottlieb et al., 2018), with ICC ranging from 0.80 to 0.89. In addition, it has been confirmed that there is a negligible effect of time of day on UQYBT scores (Heinbaugh et al., 2015).

*Intra-examiner reliability*

Intra-examiner reliability (measurements performed on the same day) was scarcely assessed. Xu et al. (2023) reported fair to good relative reliability for individual directions (ICC=0.70–0.86) and excellent reliability for the composite score (ICC=0.92) in adolescent swimmers. SEM ranged 0.48 to 0.82%, and MDC ranged from 1.11 to 2.23%. Williamson et al. (2019) reported nearly perfect reliability for limb length measurements (ICC=0.98 – 0.99).

*Inter-examiner reliability*

More studies are available on inter-examiner reliability. When scored by two examiners simultaneously (i.e., same trial is evaluated by the two examiners), the reliability seems to be perfect (ICC=0.99 – 1.0) (Gorman et al., 2012; Xu et al., 2023). When examiners record the test separately, the reliability is also excellent (ICC=0.98; SEM=0.35% ULL), which is also true for the modified version of the test (ICC=0.99; SEM=0.21% ULL) (Cramer et al., 2017). Studies reporting reliability as a secondary variable also report excellent or perfect inter-rater reliability (Ruffe et al., 2019; Mendez-Rebolledo, Ager, et al., 2022).

*Test-retest reliability*

Only two studies investigated test-retest (i.e., inter-visit) reliability. Westrick et al. (2012) reported excellent reliability of the composite score (ICC=0.91–0.92). Similarly, Gorman et al. (2012) reported excellent reliability of the medial (ICC=0.92), superolateral (ICC=0.94) and inferolateral (ICC=0.95) scores. SEM ranged from 2.2 to 2.9% ULL, and MDC ranged from 6.1 to 8.1% ULL. A study by Silva Barros et al. (2022) reported that test-retest reliability in theirs study range from fair to excellent (IC =0.55–0.97), but they included outcomes other than UQYBT.

In summary, relative reliability was consistently high, indicating excellent to perfect reliability in most cases. For intra-examiner reliability, limited studies showed fair to excellent reliability with ICC values ranging from 0.70 to 0.99. Inter-examiner reliability was extensively studied, with most studies reporting perfect or excellent reliability with ICC values approaching 1.0. Test-retest reliability was also reported to be excellent in the two studies that investigated it, with ICC values ranging from 0.91 to 0.95. Absolute reliability measures such as SEM and MDC were also reported in some studies, providing additional insight into the reliability of UQYBT measurements. Despite some variations, the overall evidence strongly supports the reliability of the UQYBT in different contexts and settings.

*Sex differences*

Sex differences represent one of the most intriguing aspects of the review. The 14 included articles allowed for a comparison of the results between women and men. Gorman et al. (2012) were the first to measure UQYBT, investigating differences between 51 men and 45 women. No statistically significant differences were reported, although men seemed to perform slightly better than women. The reported overall result for men was 85.1%, while the overall result for women was 83.9%. Guirelli et al. (2021) also reported slightly better results in men, except in the inferolateral direction for the latter. The absence of statistically significant differences between men and women is also highlighted in the article by Westrick et al. (2012), who tested a military student population. Although no statistically significant differences were found between the results of the male and female population, the overall results of females (82.9% for the dominant side and 85.2% for the non-dominant side) were slightly lower than males (86.5% for the dominant side and 88.1% for the non-dominant side) in this study.

Both Butler et al. (2014) and Bullock et al. (2017) included adult swimmers in their study. The latter study reports better results for male swimmers compared to female swimmers in all directions, with no statistically significant differences found only in the superolateral direction. Bullock et al. (2017) do not report overall results, but it can be seen from the results for each direction that in all directions, men reached further. Men generally performing better is confirmed by Teyhen et al. (2014) describing men's performance on average as 4.6% better than women's. Of the 14 mentioned studies, this one tested the largest sample (of the military population). The other studies reviewed do not provide actual values describing how much better men score on the test compared to women.

Taylor et al. (2016) who conducted a study among athletes from different disciplines, report that they identified differences between the overall performance of men and women, and between the medial and inferolateral performance of women and men. They also mention that the overall results obtained were significantly better than those reported by (Gorman et al., 2012). Furthermore, Schwiertz et al. (2019) presented results for both sexes combined and reported a statistically significant difference in the inferolateral direction, also in favour of men or better said boys, as the subjects included in this study were aged between 12 and 17 years, despite most authors reporting no statistically significant differences between men and women. The remaining studies where the results of men and women can be directly compared also report better results for men. The only exceptions are girls aged 10-11 (90.7%), who scored better overall on the right side than boys of the same age (88.4%), and girls aged 12-13, who scored better overall than boys aged 12-13 on both the left and the right side (Schwiertz et al., 2021).

As mentioned in the introduction, the UQYBT is most associated with the closed kinetic chain upper extremity stability test. The interest was to see whether there are differences between men and women for the latter as well. Taylor et al. (2016) reported statistically significant differences, with men scoring an average of 25 touches and women 22.9 touches. It should be noted that a modified version of the test was performed where to ensure better stability. The position of the upper limb was individually normalized, while the distance between the two targets remained constant. The authors also mention pre-established normative values that suggest that men perform better than women. Among other three reviewed articles (Westrick et al., 2012; Borms & Cools, 2018; Guirelli et al., 2021;) all reported better average scores for men.

*Within- and between-sports differences*

Most studies included in this review suggest that trained individuals generally outperform untrained ones, with continued improvement expected as the level of competition and player age increases (Taylor et al., 2016; Kokinda et al., 2018; Krysak et al., 2019; Schwiertz et al., 2020; Singla & Hussain, 2021). To illustrate, Taylor et al. (2016) noted that baseball players significantly outperformed athletes from other disciplines included in the study, such as basketball, volleyball, American football, lacrosse, track and field, and cross-country. Baseball players, whose sport demands substantial unilateral upper limb strength and stability, notably exceeded the performance of track and field, cross-country athletes, and lacrosse players on the UQYBT. Among the five studies testing baseball players, two had adolescents as subjects. The overall results for these younger participants did not surpass 90% in any study, a contrast to adult results which reported values above 90%, with Taylor et al. (2016) even noting values greater than 100%. When comparing cricket and baseball, all baseball results (across all ages) were superior to those for cricket. The overall outcomes for golf, hockey, and lacrosse are relatively similar, though older hockey players (seniors and U20) generally showed better performance in the medial direction than golfers and lacrosse players.

Studying athletes of different age groups, Borms and Cools (2018) reported the best overall results for men in the intermediate group, aged 26-33 years, and for women in the youngest group, 18-25 years. They also documented varying results by age group for other sports. The study indicated a lower performance of female volleyball players compared to female handball players, exclusively in the medial direction. Younger female handball players excelled over their volleyball counterparts (Saccol et al., 2022), a difference attributed to the distinct sport-specific movements characterizing each sport.

Two studies (Bauer et al., 2020; Bauer, Panzer, et al., 2021) both found better results for U14 handball players compared to U15, and similarly, 14-year-olds outperformed 15-year-olds. In another study by Bauer, Schwiertz, et al. (2021), the scores of handball players for different playing positions were described, showing no significant deviations for each playing position. Tabasi et al. (2022) discovered statistically significant differences among freestyle and Greco-Roman wrestlers, with the latter excelling on the UQYBT (87.98% vs. 83.38%). This superiority is attributed to the diverse training programs and extensive upper body training of Greco-Roman wrestlers. In addition, wrestlers exhibit significantly better scores than baseball pitchers (Myers et al., 2017), possibly highlighting the effect of predominantly close kinetic chain activities performed in wrestling (in contrast to predominantly open kinetic chain activities in baseball, ie., throwing) (Tooth et al., 2022).

*Asymmetries and arm dominance*

The UQYBT test is used to identify upper limb asymmetries, especially in sports that rely on one-arm dominance. Beyranvand et al. (2017) concluded that there is no difference between dominant and non-dominant arms in gymnasts with and without rounded shoulders. This is affirmed by two studies that found no statistically significant differences between dominant and non-dominant arms in UQYBT in injured and healthy baseball and softball players (Butler, Myers, et al., 2014; Chasse et al., 2018). Biaggi et al. (2021) also showed no statistical difference between the throwing and non-throwing arm in any direction of UQYBT in college softball players, a finding also found in baseball pitchers and other throwing athletes (Taylor et al., 2016; Borms et al., 2016; Bullock et al., 2018). No significant asymmetry reach was found in male and female swimmers in any direction (Butler, Arms, et al., 2014). In addition, composite scores are not different in sports where one side of the body does not dominate, like in CrossFit practitioners (Silva et al., 2022).

These results are confirmed by a study by two studies (Taylor et al., 2016; Westrick et al., 2012) in which healthy college students had no statistically significant differences in any direction between dominant and non-dominant sides. The limb asymmetry index was above 95% for superolateral side and above 98% for the M, IL, and composite score (Westrick et al., 2012). Based on the above results from these studies, it appears that the UQYBT test scores do not exhibit asymmetries between the dominant and non-dominant arm in healthy athletes involved in throwing and other sports. The failure to detect asymmetries where one would expect to see detectable differences, such as injury or strong one-arm dominance, may be attributed to too few subjects, inaccurate test performance, or the test design itself not being specific and sensitive enough to detect asymmetries. However, as presented in the subsequent section, UQYBT may nonetheless be useful to assess injury risk.

*Relationship to sports injuries*

In cases where asymmetry between arms is detected, it may signify a higher risk of injury. For female cross-country runners, an Inferolateral (IL) reach difference of less than four centimetres correlated with a 75% lower probability of a running-related injury. Similarly, male cross-country runners with a four-centimetre Superior Lateral (SL) reach difference saw a seven-fold increase in the risk of injury in the hip, thigh, or knee region (Ruffe et al., 2019). Elite football players with high posteromedial asymmetry, good agility performance, and no previous injury history had a 2.69 times increased risk of injury, and those with a past injury had a 3.26 times higher risk (Bennett et al., 2022). Analyses also displayed asymmetries among 14-, 15-, 16-, and 18-year-old male and female handball players, with greater asymmetry correlating with a higher probability of musculoskeletal injuries (Bauer, Panzer, et al., 2021). Contrarily, scores below 81.1% on the composite UQYBT have been linked to 2.66 times increase in injury likelihood, and scores in the Superior Lateral (SL) direction have shown 2.08 times increase in injury risk among healthy Armed Forces personnel (Campbell et al., 2022). A most recent study on handball players indicated that only the presence of an inferolateral reach asymmetry higher than 7.75% ULL was associated with a 2.18-times higher lower limb injury risk, but not upper or whole-body injury risk, suggesting that UQYBT has limited value to assess the risk of sport-related injuries in handball (Bauer et al., 2023). The test was not found to be a significant predictor of injury in female soldiers (Gottlieb et al., 2018) and another cohort of handballers (Mussigmann et al., 2020). However, experiencing pain during the test was associated with 3.3-fold higher attrition rates in infantry recruits during the first year of training (Fleischmann et al., 2023).

Injury history has been observed to impact the Superior Lateral (SL) reach in overhead athletes. Those with a shoulder injury recorded a significantly lower mean reach distance compared to their healthy counterparts (Kim et al., 2020). However, this is in contrast to (Chasse et al., 2018) who concluded that injury history does not influence the UQYBT results. Gymnasts with rounded shoulders have displayed poorer UQYBT results compared to those with normal anatomical shoulder shapes (Bennett et al., 2022). Moreover, male professional volleyball players with infraspinatus atrophy showed significantly lower superior-lateral and inferior-lateral reach UQYBT results compared to healthy individuals and their non-throwing side (Contemori et al., 2018). However, no change was noted for the UQYBT test values during the season in volleyball players, making usefulness of this test in volleyball players questionable (Tooth et al., 2023). Shoulder impingement syndrome has impacted the Medial (M) and Inferolateral (IL) reach direction in adults (Hazar et al., 2014), while scapular dyskinesis has not shown a significant effect on the UQYBT (Pires & Camargo, 2018). Additionally, CrossFit practitioners with shoulder pain did not show a statistically different composite UQYBT compared to the side without pain (Silva et al., 2022).

These insights highlight the need to consider specific injuries and their impact on different reach directions of the UQYBT, aiding in the development of targeted prevention and rehabilitation programs.

## Correlations and determinants

*Anthropometry*

Anthropometric measurements like height and weight can indirectly impact the test results by influencing the percentage of muscle mass and the length of the upper limb. A study on female soldiers revealed a slight positive correlation between average UQYBT scores and both height (right side: r=0.1; left side: r=0.11) and weight (right side r=−0.25; left side: r=−0.26) (Gottlieb et al., 2018). This suggests that anthropometric factors do hold some sway over UQYBT scores, albeit weakly.

*Strength*

Research indicates various correlations between the components of the UQYBT test and the strength of different muscle groups. Among CrossFit practitioners without musculoskeletal shoulder pain, a positive association exists between the superolateral component and the strength of the shoulder's abductor muscles. This correlation is absent in practitioners with shoulder pain, who instead show a positive association between the strength of external shoulder rotators and the medial component of the UQYBT test (Silva et al., 2022). In the dominant limb, moderate positive correlations are observed: between superolateral reach and serratus anterior muscle isometric strength (r=0.45), medial reach and lower trapezius muscle isometric strength (r=0.44), and inferolateral reach with both serratus anterior muscle (r=0.53) and lower trapezius muscle (r=0.53) isometric strength. Additional associations include rotators of the trunk (r=0.49), and lateral trunk flexor strength (r=0.56), as well as between the composite score and the strength of the serratus anterior muscle (r=0.52), lower trapezius muscle (r=0.58), rotators of the trunk (r=0.45), and lateral trunk rotators (r=0.51) in recreational swimmers. A negative moderate correlation is present between inferolateral reach and trunk flexion endurance time (r=−0.47) in the same group (Silva Barros et al., 2022). In addition, UQYBT test results were in moderate positive correlation with McGill trunk endurance test (r=0.46) when assessed on a sample of male collegiate athletes (Nuhmani, 2022). However, in another study, there was no difference in UQYBT results between basketball players with good and poor core stabilization (based on Sahrmann Core Stability Test; Chan et al., 2020), and there was also no effect of instructing the participants to activate their core musculature during the test (Arora et al., 2021).

Furthermore, lower trapezius isometric strength demonstrates a positive relationship with the inferolateral UQYBT reach, accounting for 70% of the UQYBT variability in the inferolateral direction (Mendez-Rebolledo, Cools, et al., 2022). However, no correlation is found between the variables of the UQYBT test and the strength of back muscles in cricket players (Singla et al., 2018). In conclusion, various studies highlight the diverse relationships between the UQYBT test components and muscle group strength. These findings emphasize the variable associations between UQYBT test components and muscle strength, suggesting the influence of specific sports and physical conditions on these relationships.

*Clinical tests*

In amateur volleyball players, a negative moderate correlation was found with inferolateral UQYBT (r=–0.57) and the UQYBT composite score (r=–0.43) and the Active joint position sense measurements at 90° of internal rotation (Mendez-Rebolledo, Ager, et al., 2022). This article also disclosed that the active joint position sense measurements at 90° of internal rotation have the greatest influence on the change in the inferolateral direction of the UQYBT test. However, there was no association between the medial reach in UQYBT and Closed Kinetic Chain Upper-Extremity Stability Test performances. On the other hand, Taylor et al. (2016) established that there is a very low correlation between the Closed Kinetic Chain Upper-Extremity Stability Test scores and UQYBT composite score (r=0.04–0.18) in healthy college athletes. A statistically significant positive association was also found between medial reach of UQYBT test and the Closed Kinetic Chain Upper-Extremity Stability Test in healthy CrossFit practitioners (Silva et al., 2022). The reason for the low correlation may be that the two tests assess different abilities. The Closed Kinetic Chain Upper-Extremity Stability Test includes power, speed, and stability, whereas the UQYBT challenges the limits of stability of an athlete, including components of balance, proprioception, and mobility of the thoracic spine and scapula. Finally, In male adolescent handball players, various correlations with the Bourban test were noted for both throwing and non-throwing hands across different directions and composite scores (Bauer et al., 2022).

*Sports performance*

In addition to correlations with the strength of individual muscle groups, the UQYBT test was also found to correlate with other movement components important for sports performance. Bartolomeu et al. (2023) found a positive moderate correlation between swimming speed and UQYBT test scores of left (r=0.54) and right hand (r=0.57). In youth handball players there was a small correlation between UQYBT performance and throwing velocity (TV) or accuracy (A) of the throw (13-year-old females: TV: $-0.01 \le r \le -0.37$; A: $0.01 \le r \le 0.31$; 14-year-old males: TV:$0.10 \le r \le 0.45$; A: $-0.01 \le r \le -0.51$; 15-year-old males: TV: $0.06 \le r \le 0.34$; A: $0.01 \le r \le -0.45$) (Bauer, Schedler, et al., 2020). More studies are urgently needed to assess relationships between UQYBT and sport-specific performance.

*Effects of interventions*

Following upper-extremity balance training with Biodex device, the UQYBT composite score increased for ~9-10 %, which was more than in the control group that performed upper extremity resistance training (Abdelraouf et al., 2022). Moreover, core stability training was reported to increase UQYBT composite scores by as much as 15% (Jha et al., 2022). Furthermore, Bodyblade™ training in athletes with traumatic anterior shoulder instability improved the scores for ~4-6 % (Pulido et al., 2023). Exercises focused on improving awareness of lumbar spine position and thoracic spine mobility did not improve the UQYBT in any direction in active females, however, the sample size was very small (n=12) (Schwartzkopf-Phifer et al., 2021). Savitzky et al. (2021) compared two approaches for rotator cuff rehabilitation: 1) ShoulderSphere, an innovative device that uses resistance to centrifugal force, 2) TheraBand as a traditional device that uses resistance to elasticity. Both approaches improved inferolateral direction with large effects size (d=0.75 to 0.89), but there were no group × time interactions. Next, performing the FIFA 11+ Shoulder programme for 8 weeks resulted in an increase (+8% ULL) in composite score (Zarei et al., 2021). After a local vibration application shoulder joints, an increase in UQYBT scores was reported, with mean non-normalized composite score increasing from 211.1±26.8 cm to 244.3±30.1 cm (Jung & Moon, 2015). In contrast, application of Kinesiotape did not improve immediate UQYBT scores in a male collegiate athletic population with rounded shoulder posture (Dittmer et al., 2021).

Three studies have also assessed the influence of fatigue on UQYBT. Bauer, Hagen, et al. (2020) effects of fatigue protocol (consisting of sets of push-ups until failure) on throwing performance and UQYBT scores in male adolescent handball players. Fatigue caused a significant decrease in throwing velocity (−3%) and superolateral reach direction (throwing arm: −5%; non-throwing arm reach: −10%) and the composite score (throwing arm: –2%; non-throwing arm: –4%), but not for the medial and the inferolateral reach directions. Finally, Salo & Chaconas (2017) demonstrated ~2–12 cm reductions in absolute scores after upper extremity fatigue protocol in recreational weightlifters.

In summary, the various impacts on UQYBT composite scores highlight the sensitivity of the UQYBT to different interventions, underlining its practical utility as a measure in upper extremity balance training and rehabilitation. The marked improvement in UQYBT scores with the use of specialized devices and training methods, such as the Biodex device and core stability training, underscores their effectiveness. This underlines the significance of the UQYBT as a discerning tool for evaluating and guiding upper extremity balance and stability interventions, ensuring the application of the most beneficial and efficient methods for individuals.

## Conclusions

The scoping review UQYBT reveals its utility in evaluating upper limb stability, predicting injury risks, and informing training regimens across various sports disciplines. The aggregation of limb-length-normalized data is a step towards enhancing the test's standardization. Our analysis confirms the UQYBT's reliability and consistency across diverse populations, reinforcing its validity as a functional assessment tool. The relationship between UQYBT scores and muscle is complex, with sport-specific variations suggesting a need for a careful interpretation. In some sports, the UQYBT may serve as a predictor for potential injuries. Ultimately, the UQYBT stands out as a valuable component of an athlete's assessment protocol, with its ability to reflect underlying musculoskeletal functions and potential for individualization of training in line with sport-specific demands. It is crucial for future research to further explore this relationship, enabling an evidence-based application of the UQYBT that could help improve injury prevention strategies and elevate athletic performance through training interventions.

**Acknowledgments**
There are no acknowledgments.

**Conflict of interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

**Funding:** The study was supported by the Slovenian Research Agency through the research program KINSPO - Kinesiology for the effectiveness and prevention of musculoskeletal injuries in sports (P5-0443).

**Received:** 10 November 2023 | **Accepted:** 17 January 2024 | **Published:** 01 February 2024

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DOI 10.26773/smj.240220

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REVIEW PAPER

# The Influence of Therapeutic Massage on Muscle Recovery, Physiological, Psychological and Performance in Sport: A Systematic Review

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**Abstract**

This study aims to identify the effects of therapeutic massage on muscle recovery, physiological, psychological and performance in sport. Articles were identified from several databases by searching MEDLINE, Embase, CINAHL, PEDro, Web of Science, Scopus, Google Scholar, and PubMed starting from 2010 to 2023, related through databases according to predefined inclusion criteria that were identified previously. In the review, 31 studies were considered to be eligible for inclusion by recruiting male (n=558) participants, aged between 12 and 60 years, and females (n=226) participants, aged between 12 and 60 years. Compared with the active control, twelve studies found massage to have a significant and measurable benefit, whereas five studies found no obvious advantage. Comparing massage with an inactive control, four studies reported massage to have a significant and considerable effect, whereas three studies did not. For massage compared with other therapies, three studies reported massage to have a measurable and considerable effect, whereas two studies did not. Massage as a stand-alone treatment provided a considerable and substantial benefit in two studies, whereas one study found no significant impact on muscle healing, performance, physiological, and psychological. In conclusion, the current study revealed that massage had a large and substantial advantage when compared with an inactive and active control, but not when compared with other interventions, as examined in this review. There was a shred of conflicting evidence to prove the superior outcomes of massage when administered as a stand-alone treatment and relative to other forms of therapies. However, the efficiency of massage is rarely assessed.

***Keywords:*** *massage, endurance, musculoskeletal health, confidence, performance, delayed onset muscle soreness*

## Introduction

Therapeutic massage is described as the intentional and structured handling of soft tissue for therapy, with the goals of preventing or reducing pain, spasms, tension, or stress and promoting health and wellness (Bervoets et al., 2015). Studies have reported that massage is effective when the noxious stimuli are obstructed, a practice that is in harmony with the gate-control theory (Bender, da Luz, Feldkircher, & Nunes, 2019), thereby increasing the flow of blood and lymphatic system, which is likely to quicken the removal of catabolites and the excretion of endorphins, which is responsible for the promotion of a feeling and sense of wellness in the recipient (Mancinelli et al., 2006; Poppendieck et al., 2016).

Massage techniques such as friction, petrissage, effleurage, vibration, and tapotement are frequently used to treat ailments (Guo et al., 2021). Massage is also used to relieve sore muscles, increase local circulation (Angelov, Gotova, Albert, & Tishinov, 2019; Wiewelhove et al., 2022), loosen muscle spasms and adhesions (McKechnie, Young, & Behm, 2007), rekindle Golgi tendon organs and muscle spindles

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(Wiewelhove et al., 2022), and reduce local inflammatory responses (Bervoets et al., 2015).

Massage is frequently utilised in sports to enhance pain relief and avoid delayed-onset muscular soreness following physical activity (Kheyruri, Sarrafzadeh, Hosseini, Abiri, & Vafa, 2021; Paul et al., 2021). Although massage may be beneficial for athlete rehabilitation, there is little data to support its use in clinical practise for sports (Weerapong, Hume, & Kolt, 2005; Paul et al., 2021). Current research conducted using 22 randomised papers with the aid of meta-analysis postulated that massage has little and flexible results on recovery after exercise (Davis, Alabed, & Chico, 2020). These include system or methods of employing approaches that are non-manual, such as vibration or water-jet massage, which are uncommon, whereas other important factors or variables such as anxiety, stress, and depression are left uninvestigated.

In clinical practise, massage is used to help athletes recuperate from less taxing activities such as competitive jogging and soccer (Andersen et al., 2013). A previous study found that massage alleviated acute discomfort and tiredness in the quadriceps of triathletes following a long-distance Ironman event (Nunes et al., 2016). However, most of the research that examines the effect that massage has on athletes for the sake of recovery has adopted the intervention approach in cases of extreme necessity, which in any case does not show the average condition of most athletes in most sports (Ogai, Yamane, Matsumoto, & Kosaka, 2008). To date, there is a dearth of literature evaluating the effects of massage on athlete recovery at the end of an exercise or sporting game that does not involve a high level of depression, fatigue, anxiety, and stress and may not cause muscle soreness.

Nevertheless, questions remain about massage and its effects, especially as numerous elite athletes consider massage to be an integral component of their success (Gasibat & Suwehli, 2017). Practitioners perform massage at the site of the injury because they anticipate that massage will increase blood flow to the area of the injury and, as a result, aid in healing and recovery (Duñabeitia et al., 2022). For realigning the fibres, massage mechanical pressure is usually adopted to cure adherent or knotted connective tissue (Galloway & Watt, 2004). However, there is little to no empirical study that provides support for this argument.

In recent years, a novel technique combining pressure, vibration, and movement has been developed: percussive massage (Barcala-Furelos, Abelairas-Gomez, Romo-Perez, & Palacios-Aguilar, 2013; Rey, Padrón-Cabo, Costa, & Barcala-Furelos, 2019). This treatment is administered using a therapeutic gun that can be controlled in terms of vibration and allows for simple application over the body (Cullen et al., 2021). With the increase in muscle tone regulation and the flow of blood, it is argued that the combination of vibration and pressure over the tissues has a great influence on the autonomic nervous system (Beardsley & Škarabot, 2015; Behm & Wilke, 2019; Behm et al., 2020). Moreover, because it is assumed that massage may aid in improving recuperation and preparing athletes for upcoming competitions, it is frequently administered between tournaments. However, the effects of massage on recuperation have not yet been thoroughly studied, and there is scant scientific evidence to support these claims (Konrad, Nakamura, Bernsteiner, & Tilp, 2021: Lakhwani & Phansopkar, 2021).

According to Isar, Halim, and Ong (2020), and Moran, Hauth, and Rabena (2018), before exercise or competition, coaches and sports scientists collaborate to provide warmups and performance enhancement. Meanwhile, Bell (2008), and Zainuddin, Newton, Sacco, and Nosaka, (2005) asserted that most athletes termed it a tiresome process of reducing force production. Muscle fibre modifications that reflect the increased effort necessary to maintain a certain level of mechanical performance are related to fatigue (Correa et al., 2012). This decrease in strength may be detrimental to the future performance of elite athletes (Nédélec et al., 2013). In addition to other aspects of performance, such as range of motion, in which the athlete must compete at an elite level, strength is only one component of performance (Phillips, Diggin, King, & Sforzo, 2021). When delayed-onset muscle pain develops, the affected muscles frequently contract, resulting in a restricted range of motion (Su et al., 2017). Massage is believed to help lengthen muscles and increase their pliability, thus allowing for a greater range of motion and enhancing the performance of the body (Davis et al., 2020). Because of the absence of well-conducted studies, the effects of massage on performance have not yet been established.

Athletes in the public spotlight for mental health concerns such as depression, anxiety, and stress have negative consequences on athletic performance by impairing the capacity to concentrate and focus, primarily because of psychological symptoms that cause distraction (Rathod, PS, Sahana, & Rathod, 2021). Psychological elements also have a significant influence on performance determination (Zadkhosh, Ariaee, Atri, Rashidlamir, & Saadatyar, 2015). However, every athlete needs a certain level of stress to perform optimally (Brilian, Ugelta, & Pitriani, 2021). As in other aspects of life, stress in sports may be acute, episodic, or persistent (Brilian et al., 2021). It is typically episodic in sports, whether during a friendly competition or a championship game (Ardern, Taylor, Feller, & Webster, 2013). While acute stress might be a challenge, if left unchecked, it can become not only an episodic stressor with long-term effects but also a hindrance to one's play (Strehli et al., 2021). Hemmings, Smith, Graydon, and Dyson (2000) claimed that rather than being physiological, the effects of sports massage are primarily psychological. Therefore, the initial feeling of recovery following a massage may be the result of these psychological effects, which could have a positive impact on recovery and subsequent levels of performance. Reduced depression, anxiety, and stress may be attributable to a sense of comfort experienced in the process of massage; however, the biological mechanism underlying the effects of massage on the physiological and psychological aspects of the body has not yet been fully elucidated. Existing research has primarily focused on specific aspects, such as pain relief or the psychological benefits of massage, while overlooking a holistic examination of its impact on athletes (Strehli et al., 2021). While traditional massage techniques and their effects have been explored to some extent, emerging modalities such as percussive massage have received limited empirical attention (Konrad et al., 2021). The introduction of percussive massage, which combines pressure, vibration, and movement, introduces a novel therapeutic approach that may have unique effects on the autonomic nervous system and muscle recovery. (Davis et al., 2020). The purpose of this systematic review is to determine the influence of therapeutic massage on muscle recovery, physiological, psychological, and performance in sport due to a dearth of research on this topic.

## Materials and Methods

*Registration and Ethics*

This systematic review was registered on PROSPERO (ID: CRD42022364318) and conducted according to the PRISMA guidelines. The results of this review will be disseminated through peer-reviewed publications. Because all the data used in this systematic review have been published, this review does not require ethical approval.

*Study selection process and identification*

By searching through online databases between 2010 and 2023, suitable articles were identified. These databases included: MEDLINE, PEDro, PubMed, Google Scholar, Embase, Web of Science, Scopus, and CINAHL with the aid of key words such as: ("Vigour "OR" Massage" OR "Pain "OR "Isometric Strength" OR "Sport" OR "Recreational Athletes" OR "Pressure Pain Threshold" OR "Confusion" OR "Sports Massage" OR "Muscle Function" OR "Recovery" OR "Jump" OR "Pain Behaviour" OR "Cardiovascular Performance" OR "Agility" OR "Delayed Onset Muscle Soreness" OR "Muscle Damage" OR "Squat Jump Sitting" AND "Lying Flexibility" OR "Swelling" OR "Performance" OR "Grip Strength" OR "Endurance" OR "Range of Motion" OR "Sprint Performance" OR "Depression" OR "Anxiety" OR "Stress" OR "Confidence" OR "Mood" OR "Tension" OR "Gait" OR "Physical Fitness" OR "Plasma Creatine Kinase" OR "Blood Pressure" OR "Heart Rate Variability" OR "Blood Lactate" OR "Anger" AND "Hostility" OR "Elite Athletes" OR "Perceived Fatigue" AND "Muscle Stiffness"). The studies were conducted entirely in English. Relevant published literature was also searched through an electronic medium to be checked for any potentiality as located by the references of the systematic view. A single intervention, the experimental design that evaluated the effect of any type of therapeutic massage, compared with no therapy or other therapies in sport, has been published (during, or after training, exercise or competition). The selection was performed independently by four reviewers (QG and MA). First, the titles and abstracts were reviewed for eligibility. The full-text papers were then separately vetted for inclusion. Disagreements among the authors were resolved in the form of dialogue or with the help of the author (AR).

*Participants*

For recreational athletes, elite athletes, or normal participants, the effects of massage on parameters were assessed (before, during, or after training, exercises, or competition etc.). Participants were aged over 12 years without nationality, gender, and economic level, race, or severity constraints.

*Experimental intervention*

The interventions within the experimental group consisted of any type of massage therapy such as effleurage, friction, petrissage, and pressing. There were no restrictions on the massage methods, duration, frequency, or measurement instruments.

*Control interventions*

The interventions of the control group involved a therapy other than massage (e.g., medication, placebo, routine care, etc.).

*Eligibility Criteria*

In the assessment of study eligibility, the following PICOS criteria were employed: P: Participants: The effects of massage on various parameters were evaluated for individuals categorised as recreational athletes, elite athletes, or normal participants. The assessment encompassed individuals aged over 12 years, without imposing constraints based on nationality, gender, economic level, race, or severity. The evaluation considered the impact of massage before, during, or after training, exercises, or competition. I: Intervention: The experimental group received various massage therapies, including but not limited to effleurage, friction, petrissage, and pressing. There were no restrictions on the methods, duration, frequency, or measurement instruments associated with the massages administered. C: Comparator: The control group received therapies other than massage, such as medication, placebo, and routine care. O: Outcome: The study considered at least one measure to assess pain, disability, perceived fatigue, performance, or endurance. S: Study Design: The inclusion criteria comprised experimental study designs, encompassing both randomised and non-randomised controlled trials.

*Data Extraction*

Relevant data from all included studies were extracted, encompassing sample characteristics, interventions in different groups, and a detailed examination of massage techniques, doses, durations, and their effects. The discussion of outcomes included relevant metrics related to pain, disability, perceived fatigue, performance, and endurance. The focus remained on publications featuring a singular intervention, employing an experimental design that evaluated the effects of any therapeutic massage type compared with either no therapy or alternative therapies in the context of sports, whether administered during or after training, exercise, or competition. In cases where additional information was required, emails were dispatched to the corresponding authors of the included research for clarification.

*Quality Assessment*

Using the PEDro scale, we evaluated the methodological quality of the trials and selected papers (de Morton, 2009). Eleven items on the PEDro scale evaluate four fundamental methodological features of a study, including randomization, blinding techniques, group comparison, and data analysis processes. Two independent raters assessed the quality of trials in the PEDro database, and conflicts were settled by a third rater (Lucas et al., 2019). Item 1 (eligibility criteria) was not included in the overall score because it had no bearing on the internal or statistical validity of the research. PEDro scores vary from 0 to 10 (Moseley, Herbert, Sherrington, & Maher, 2002). The quality of a procedure is proportional to its PEDro score. Using the following criteria, the quality of the approach is evaluated: a PEDro score below 5 denotes poor quality, whereas a score above 5 suggests outstanding quality (de Morton, 2009; Table 1).

*Data Syntheses and Analysis*

This research is a synthesis of both quantitative and qualitative data meta-aggregation. Best evidence synthesis, also known as best evidence synthesis, was used to evaluate the weight of scientific evidence (Cruz-Ferreira et al., 2011). This rating system takes into account the quantity of studies, the quality of the methodologies used in those studies, and the consistency of the results across all five levels of evidence: (1) strong evidence, which is provided by generally consistent findings in multiple (at least two) high quality studies; (2) moderate evidence, which is provided by generally consistent findings in one high quality study and one or more low-quality studies or in multiple low-quality studies; (3) limited evidence, which is provided when only one study is available or when findings are inconsistent in multiple (at least two) studies; and (4) conflicting evidence, which is provided by conflicting findings in case–control studies that have been found (Burns, Rohrich, & Chung, 2011).

## Results

*Flow of studies through the review*

The preliminary search yielded 16,300 results. Following the removal of duplicates, only 1,520 unique hits were saved for further analysis. The titles and abstracts of 1,480 records were used to exclude them, and 40 papers were evaluated to determine eligibility. 31 papers were acceptable for inclusion in the current analysis, while nine were eliminated (Figure 1).

*Description of the studies*

All selected studies were published in the English language. The design of the studies was systematically reviewed as follows: Randomised controlled trial (n=14), repeated measures design experiment (n=5), Individualised design (n=2), classical experimental design (n=1), randomised crossover design (n=6), quasi-experimental design (n=2) and an experimental study were conducted using a similar subject design (treated by subject design) (n=1). The distribution of publication countries was as follows: United States (n=4), United Kingdom (n=2), Canada (n=4), India (n=2), Iran (n=4), Turkey (n=2), China (n=1), Syria and Lebanon (n=1), Singapore (n=1), Brazil (n=2), Korea (n=2), Australia (n=1), Spain (n=2), Thailand (n=1), Indonesia (n=1), and Poland (n=1). The most important output of the studies is shown in Table 2.

*Methodical Quality*

On the PEDro scale, the values ranged from 0 to 5. It appears that there was a mixture of high-quality and low-quality research because there were 2 studies that scored less than 5 while the others (n=29) scored 5 or higher. There was no correlation between the year of publication and the quality of the studies because the studies of the lowest quality were published in 2010, whereas the studies of the highest quality were published between 2011 and 2022 (Table 1). Eligibility criteria (n=31), group similarity at baseline (n=29), point measure and variability (n=28), random allocation (n=29), between-group comparisons (n=29), and follow-up (n=31) were met most of the time. The criteria of a blind subject or therapist were not satisfied in any of the studies that were analysed; however, the criterion of a blind assessor was satisfied in two of those studies: concealed allocation (n=5) and intention-to-treat analysis (n=27; Table 1).

*Participants*

The sample size among the studies consisted of males (n=558, participants) aged between 12 and 60 years and females (n=226, participants), aged between 12 and 60 years. Overall, only 19 studies included athlete participants, and seven studies included recreational athletes. Six studies included normal participants. The effects of massage on the parameters of these subjects were investigated after receiving exercise sessions.

*Interventions*

Several massage methods of wide variety, frequency, and duration were adopted in the current study. The massage therapies included sports massage (n=5), Thai massage (n=1), Swedish massage (n=3), Western massage (n=2), musculotendinous massage (n=1), ice massage (n=1), or a combination of techniques (e.g., Effleurage, Petrissage, Tapotement, Friction, Vibration) (n=18); (Table 2). Seven of the studies assigned respondents to the no-treatment inactive control group (Huang et al., 2010; Dawson, Dawson, Thomas, & Tiidus, 2011; Lau & Nosaka, 2011; Crane et al., 2012; Boguszewski, SzkodaAdamczyk, & Białoszewski, 2014; White et al., 2020; Zhong et al., 2018). Seventeen studies included an active treatment control group , which included continuing training, sham hip and knee mobilisation, placebo ultrasound, wrestling training, active and passive rest, eccentric exercise, etc. (Guest, 2010; Arroyo-Morales et al., 2011; Pinar et al., 2012; Rasooli, Jahromi, Asadmanesh, & Salesi, 2012; Imtiyaz, Veqar, & Shareef, 2014; Han et al., 2014; Zadkhosh et al., 2015; Shin & Sung, 2015; Nunes et al., 2016; Kargarfard et al., 2016; Kong et al., 2018; Moran et al., 2018; Bender et al., 2019; Kaesaman & Eungpinichpong, 2019; Ambarawati et al., 2021; Alonso-Calvete et al., 2022; Aeini, 2022). Five studies compared massage with other interventions such as static stretching, dynamic stretching, and cold-water immersion (Fletcher, 2010; Delextrat, Calleja-González, Hippocrate, & Clarke, 2013; Imtiyaz et al., 2014; Moran et al., 2018; Fakhro, Chahine, Srour, & Hijazi, 2020). Three trials massage was as a stand-alone treatment (Sharma & Noohu, 2014; Vickcales, 2018; Bayer & Eken, 2021). Treatment periods varied from one session (n=19) to 4 weeks three times a week, for a total of 12 sessions, and the massage session remained for 30 seconds (n=2), 5 minutes (n=1), 7 minutes (n=1), 8 minutes (n=1), 9 minutes (n=1), 10 minutes (n=4), 15 minutes (n=4), 16 minutes (n=1), 20 minutes (n=6), 24 minutes (n =1), 25 minutes (n=1), 30 minutes (n=7), and different durations of 5, 10, and 15 minutes (n=1). The point time after completing the massage varied from immediately after the massage session to 10 days.

Compared with the active control, twelve studies found massage to have a significant and measurable benefit (Arroyo-Morales et al., 2011; Rasooli et al., 2012; Imtiyaz et al., 2014; Han et al., 2014; Zadkhosh et al., 2015; Shin & Sung, 2015; Nunes et al., 2016; Kargarfard et al., 2016; Bender et al., 2019; Kaesaman & Eungpinichpong, 2019; Ambarawati et al., 2021; Aeini, 2022), whereas five studies found no obvious advantage (Guest, 2010; Pinar et al., 2012; Kong et al., 2018; Moran et al., 2018; Alonso-Calvete et al., 2022). Comparing massage to an inactive control, four studies reported massage to have a significant and considerable effect (Huang et al., 2010; Crane et al., 2012; Boguszewski et al., 2014; Zhong et al., 2018), whereas three studies did not (White et al., 2020; Dawson et al., 2011; Lau & Nosaka, 2011). In comparison to other therapies, three studies reported massage to have a measurable and considerable effect (Fletcher, 2010; Delextrat et al., 2013; Imtiyaz et al., 2014), whereas two studies did not (Moran et al., 2018; Fakhro et al., 2020). Massage as a stand-alone treatment provided a considerable and substantial benefit in two studies (Vickcales, 2018; Bayer & Eken, 2021), whereas one study found no significant impact on muscle healing, performance, physiological, and psychological (Sharma & Noohu, 2014).

**Table 1.** Summary of the methodological quality assessment scores

| Author and Year | Eligibility criteria | Random allocation | Concealed allocation | Group similar at baseline | Blind subject | Blind therapist | Blind assessor | Follow-up | Intention-to-treat analysis | Between-group comparisons | Point measure and variability | PEDro score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Guest (2010) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Huang et al. (2010) | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 7 |
| Fletcher (2010) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Dawson et al. (2011) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Lau & Nosaka (2011) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 5 |
| Arroyo-Morales et al. (2011) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Pinar et al. (2012) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Crane et al. (2012) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Rasooli et al. (2012) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Delextrat et al. (2013) | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 7 |
| Sharma & Noohu (2014) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Imtiyaz et al. (2014) | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 7 |
| Han et al. (2014) | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 7 |
| Boguszewski et al. (2014) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Zadkhosh et al. (2015) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Shin & Sung (2015) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Hoffman et al. (2016) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |

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| Author and Year | Eligibility criteria | Random allocation | Concealed allocation | Group similar at baseline | Blind subject | Blind therapist | Blind assessor | Follow-up | Intention-to-treat analysis | Between-group comparisons | Point measure and variability | PEDro score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nunes et al. (2016) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Kargarfard et al. (2016) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Zhong et al. (2018) | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 7 |
| Kong et al. (2018) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 5 |
| Vickcales (2018) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Moran et al. (2018) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Bender et al. (2019) | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 7 |
| Kaesaman & Eungpinichpong (2019) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Fakhro et al. (2020) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 5 |
| White et al. (2020) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Ambarawati et al. (2021) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Bayer & Eken (2021) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Alonso-Calvete et al. (2022) | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 7 |
| Aeini (2022) | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Total | 31 | 29 | 5 | 29 | 0 | 0 | 2 | 31 | 27 | 29 | 28 | |

**Table 2.** Overview of the included studies (n=31)

| Author and Year | Intervention | Massage Technique | Duration | Time Point after Intervention | Outcome Measure | Effect of Massage |
|---|---|---|---|---|---|---|
| Guest (2010) | Massage vs Passive Recovery | Effleurage<br>Petrissage<br>Tapotement<br>Vibration | 20 min<br>for 24 h | 24, 48 h | Mood State<br>(Profile of Mood States-Standard Questionnaire)<br>Range of Motion<br>(Goniometer)<br>Sports Performance<br>(Vertical Jump Test)<br>Perceived Performance<br>(Plyometric Exercises) | In terms of mental health, athletic ability, and flexibility, no significant differences were observed. The massage group had considerably better perceived performance than the passive recovery group at the 24-h mark |
| Huang et al. (2010) | Massage vs Control with no treatment | Musculotendinous Massage<br>(friction) | 10, 30 s<br>a 1-week period | 10, 30 s | Flexibility<br>(Electromyography)<br>Range of Motion<br>Manual Goniometer, Passive Straight Leg Raise Technique, Handheld Dynamometer | Musculotendinous massage for 10–30 s improves hamstring flexibility, tolerance to stretching, and compliance |
| Fletcher (2010) | Massage vs Massage and Warm-up vs. Traditional Active Warm-up | Effleurage<br>superficial and fast techniques | 9 min<br>3 sessions | Weekly intervals | Sprint Performance<br>(Manual 2-Dimensional Digitising System,<br>20-m Sprint Performance | Massage tends to lower the 20-m sprint performance relative to a typical warm-up. Therefore, pre-competition massage seems ineffective in improving sprint performance |
| Dawson et al. (2011) | Massage vs Control with no treatment | Swedish Massage<br>(Petrissage, Effleurage strokes) | 30 min<br>7 of the 10 weekly massages | Weeks 1, 5, and 9 | Muscle Strength<br>(CYBEX NORM Dynamometer)<br>Leg Pain at Rest<br>During and after Running<br>(7-Point Pain Scale)<br>Functioning<br>(7-point capability scales)<br>Running Behaviour<br>(9-Point Intensity Scale)<br>Running Confidence | Muscle strength, pain perception, everyday functioning, and running confidence were not improved by regular massage during training |
| Lau & Nosaka (2011) | Massage vs Control with no treatment | Vibration<br>(Dynamic Tissue Stimulation) | 30 min<br>for 5days | 30 min, 24, 48, 72, 96, 120, 168 h | Muscle Strength<br>(Isokinetic Dynamometer)<br>Range of Motion<br>(Plastic Goniometer)<br>Pressure –Pain Threshold<br>(Electronic Algometer)<br>Serum Plasma Creatine Kinase Level Activity<br>(Venipuncture Technique)<br>Delayed-Onset<br>Muscle Soreness<br>(Visual Analogy Scale)<br>Circumference<br>Constant-Tension Tape | The effects of vibration massage on edema, muscular strength recovery, or serum creatine kinase activity were not observed. However, vibration massage was beneficial in reducing delayed-onset muscle soreness and restoring range of motion |

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**Table 2.** Overview of the included studies (n=31)

| Author and Year | Intervention | Massage Technique | Duration | Time Point after Intervention | Outcome Measure | Effect of Massage |
|---|---|---|---|---|---|---|
| Arroyo-Morales et al. (2011) | Massage vs Sham Ultrasound | Effleurage<br>Petrissage<br>Tapotement | 20 min | 10 min | Mood States<br>Tension<br>Anxiety<br>Depression<br>Dejection<br>Anger<br>Hostility<br>Vigour<br>Fatigue<br>Confusion<br>(Profile of Mood States Questionnaire)<br>Muscle Performance<br>(Isokinetic Dynamometry) | Muscle performance was significantly impacted by pre-massage massage, as measured by lower isokinetic peak torque at higher speeds. Neither the content of cortisol in the saliva nor the activity of a-amylase changed noticeably. There was a notable increase in the mechanical detection thresholds at both sites after the massage intervention. The tension subscale of the profile of mood states was significantly lower following massage than placebo |
| Pinar et al. (2012) | Massage vs Electrical Muscle Stimulation vs Passive Rest | Stroking<br>Effleurage<br>Kneading<br>picking up<br>wringing<br>rolling | 24 min | After the session immediately | Perceived Exertion<br>(Borg Scale)<br>Recovery<br>(Total Quality of Recovery Scale)<br>Blood Lactate<br>(Scout Lactate Analyser) | Physiological and psychological recovery after intense exercise was not affected by massage |
| Crane et al. (2012) | Massage vs Control with no treatment | Effleurage<br>Stroking<br>Petrissage | 10 min | 2.5 h | Muscle Damage<br>(Muscle Biopsies) | Clinical evidence suggests that massage treatment is helpful, in part because it decreases inflammation and boosts mitochondrial biogenesis |
| Rasooli et al. (2012) | Massage vs Active Recovery vs Passive Recovery | Sport Massage<br>(Effleurage, Petrissage, Tapotement, Compression) | 10 min<br>3 times over a period of 3 weeks | 24, 48, 72 hours | Blood Lactate<br>(Accoutred Portable Lactate Analyser)<br>Performance<br>Endurance<br>(Sprint 200 m Swimming) | Compared with passive recovery, massage was more successful in removing blood lactate. Active and massage recovery were more effective than passive recovery in enhancing swimming performance |
| Delextrat et al. (2013) | Massage vs Cold-Water Immersion or Control | Western Massage<br>(Effleurage, Petrissage) | 30 min | 0, 24 h | Fatigue<br>(Visual Analogue Scale)<br>Recovery Physical Performance<br>(Countermovement Jump Test)<br>Repeated-Sprint Ability Test | Massage increased psychological markers of recovery but had little effect on repeated sprint performance or jumping ability |
| Sharma & Noohu (2014) | Massage | Ice Massage | 5 min | After the session immediately | Weight Discrimination Ability<br>(Weight Discrimination Ability Testing)<br>Functional Performance<br>Functional Performance Tests<br>Single Hop Test<br>Crossover Hop Test) | Hamstring (biceps femoris) proprioception is relatively unaffected by ice massage of the tendon (biceps femoris) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Imtiyaz et al. (2014) | Massage vs Vibration Therapy vs Control before Eccentric Exercise | Stroke | 15 min | 24, 48, 72 hours | Muscle Soreness (Visual Analog Scale) Range of Motion (Goniometer) Maximum isometric force (Mounted on a Wall) Repetition Maximum (Lift a Certain Weight Once) Creatine Kinase Leve (Creatine Kinase Test) | Massage is beneficial for preventing delayed-onset muscle soreness and restoring concentric strength (1 RM) |
| Han et al. (2014) | Massage vs Control with TENS Equipment Pad | Light Stroking Milking Friction Skin Rolling | 15 min | After the session immediately | Delayed Onset Muscle Soreness (Commander Algometer) Gait (Gaitrite Electronic Walkway) | Delayed-onset muscular soreness can be alleviated by massage, which in turn affects both pain and gait speed |
| Boguszewski et al. (2014) | Massage vs Control with no treatment | Sport Massage (Sliding, Effleurage, Rubbing, Kneading, Vibration) | 20 min | 24, 48,72,96 hours | Muscle Soreness (Visual Analogue Scale) Exercise Intensity (Borg Rating of Perceived Exertion Scale) Jump Performance (Friedman Test with Post hoc Testing) Lower Limb Power (Vertical Jump Test) | Massage may be a useful treatment for muscular discomfort because it speeds up healing and enhances muscle performance after exercise |
| Zadkhosh et al. (2015) | Massage vs Control with Wrestling Training | Sports Massage (Effleurage, Petrissage, Tapotement, Friction, Vibration) | 25 min 10 sessions for 10 days | 10 days | Depression Anxiety Stress (Depression Anxiety and Stress Scale) | Massage has been shown to have a measurable and substantial effect on reducing depression, anxiety, and stress in wrestlers, which in turn has been shown to improve the mental health and performance of the athletes |
| Shin & Sung (2015) | Massage vs Control received An Attached Transcutaneous Electrical Nerve Stimulation Pad | Light Stroking Milking Friction Skin Rolling | 15 min | After the session of massage immediately | Muscle Activity (Sonography Surface Electromyography) Proprioception Lactate (Dual Inclinometer Lactate Pro Analyser) | Massage of the gastrocnemius can increase muscular strength and proprioception by affecting the superficial layer of the muscle |
| Hoffman et al. (2016) | Massage vs Control with no treatment | Effleurage Compression Tapotement | 20 min | after the completion of a 161-km ultramarathon and 7 days following Postrace | Perceived Fatigue Pain (Plasma Creatine Kinase) | When compared with the control group, those who received massage reported much less fatigue and pain |

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**Table 2.** Overview of the included studies (n=31)

| Author and Year | Intervention | Massage Technique | Duration | Time Point after Intervention | Outcome Measure | Effect of Massage |
|---|---|---|---|---|---|---|
| Nunes et al. (2016) | Massage vs Control Resting in Sitting | Effleurage Petrissage Tapotement | 7 min | After the session of massage immediately | Pain<br>Perceived Fatigue<br>(Visual Analogue Scale,<br>Pressure Pain Threshold,<br>Digital Pressure Algometry) | Subjective reports of pain and fatigue were reduced after the massage, but there was no change in the pain threshold to pressure |
| Kargarfard et al. (2016) | Massage vs Control with Passive Recovery | Western Massage (Effleurage, Petrissage, Vibration) | 30 min for 72 h | 24, 48, 72 hours | Plasma Creatine Kinase<br>(Standard Venipuncture Technique)<br>Muscle Soreness Rating<br>(Visual Analogue Scale)<br>Perceived Soreness Levels<br>Agility<br>(Agility Test)<br>Vertical Jump<br>(Vertical Jump Test)<br>Maximum Isometric Torque<br>(Isokinetic Dynamometer) | It has been shown that receiving a massage after strenuous exercise might speed up the recuperation process and increase performance |
| Zhong et al. (2018) | Massage vs Control with no treatment | Mechanical-Bed Massage (Pangguang Jing) | 20 min | 24 h | Fatigue<br>(Visual Analogue Scale)<br>Endurance<br>(Heart Rate Variability<br>Back Muscle Endurance) | Bed massage may assist athletes overcome exercise-induced weariness and balance sympathetic and parasympathetic activity. Bed massage may reduce muscular and central weariness after training or competition |
| Kong et al. (2018) | Massage vs Ultrasound | Swedish Massage (Effleurage, Wringing, Kneading, Tapotement) | 16 min | 24, 48,72,96 hours | Muscle Stiffness<br>(Hand-Held Myotonometry Device)<br>Perceived Muscle Soreness<br>(11-Point Numerical Rating Scale)<br>Plasma Creatine Kinase<br>(Biochemical Marker of Muscle Damage) | Changes in major leg muscle stiffness were not improved by massage |
| Vickcales (2018) | Massage | Primal Reflex Release | 15 to 20 min for 72 h | 48, 72 h | Stress and Anxiety Heart Rate<br>(State Trait Anxiety Inventory)<br>Blood Pressure<br>(Pulse Oximeter)<br>Pain<br>(Numeric Pain Rating Scale) | Reducing stress and anxiety with the help of the primal reflex release technique is possible right away |

| | | | | | | |
|---|---|---|---|---|---|---|
| Moran et al. (2018) | Pre-Competition Massage vs Traditional Warm-up vs Combination of Massage and Traditional Warm-up vs Placebo Ultrasound | Effleurage<br>Petrissage<br>Tapotement<br>Circular Friction<br>Jostle | 10 to 15 min | 48 h | Acceleration and sprint performance (20-metre and 30-metre acceleration and 76 & 60-metre Sprint Performance) | There is no evidence that massage improves sprinting performance or accelerating abilities more than other therapies |
| Bender et al. (2019) | Massage vs Control with Sham Hip and Knee Mobilisation | Effleurage<br>Petrissage | 10 min | 0, 24, 48, and 72 h | Pain and Perceived Fatigue (Numerical Rating Scale, McGill Pain Questionnaire)<br>Pain Behaviour (Mobile Phone App)<br>Mood Profile (Brunel Mood Scale)<br>Flexibility<br>Jump Performance<br>Isometric Strength (Hand-Held Dynamometer) | Although massage helped lessen the severity of the pain, the improvement was marginal at best. Perceived weariness, flexibility, strength, and jumping ability were not significantly affected |
| Kaesaman & Eungpinichpong (2019) | Massage vs Control with Passive Rest | Traditional Thai Massage (Effleurage) | 10 min | 0, 72 h | Heart Rate Variability<br>Physical Fitness (Sit and reach test)<br>Grip Strength (Grip Dynamometer)<br>Strength (Back-Leg-Chest Dynamometer) | There is a more immediate effect of Thai traditional massage on recovery, making it a viable method for restoring muscular function and enhancing athletic performance |
| Fakhro et al. (2020) | Massage vs Static Stretching vs Dynamic Stretching | Deep Transverse Friction | 30 seconds 4 weeks three times a week for 12 sessions | 4 weeks | Flexibility<br>Agility<br>Strength<br>(Straight Leg Raises, Maximum Tests, T-Drill Test) | When compared with static and dynamic techniques, the effects of massage on soccer performance did not outweigh those of static and dynamic techniques |
| White et al. (2020) | Massage vs Control with no treatment | Effleurage | 30 min | 1, 2, 24 h | Muscle Soreness (Likert Scale)<br>Muscle Function (Squat and Drop Jump) | Performance and measures of muscle pain were not improved after massage. Inflammation caused by physical exertion may be alleviated by massage |

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**Table 2.** Overview of the included studies (n=31)

| Author and Year | Intervention | Massage Technique | Duration | Time Point after Intervention | Outcome Measure | Effect of Massage |
|---|---|---|---|---|---|---|
| Ambarawati et al. (2021) | There was a 3-day interval between the first treatment (Massage) and the second (Active Resting) | Sport Massage | 30 min | 4 days | Fatigue<br>Lactic Acid<br>(Accurted Lactate) | When it comes to lowering lactic acid levels, sport massage is superior to active resting |
| Bayer & Eken (2021) | Massage | Swedish Massage (Effleurage, Friction, Petrissage, Pressing) | 5, 10, 15 min for 24 h | 5, 10, 15 min | Jump<br>(Counter Movement Jump)<br>Squat Jump Sitting and Lying Flexibility<br>(Squat Jump<br>Sit and Flexibility | Massage durations had favorable impacts on flexibility, squat jump, and counter movement jump performances |
| Alonso-Calvete et al. (2022) | Massage vs Passive Recovery | Sport Massage (Percussive massage with a gun) | 8 min | 24 h | Perceived Fatigue<br>(Rating Perceived Exertion Scale)<br>Blood Lactate<br>(Capillary Device) | Percussive massage does not appear to aid recovery |
| Aeini (2022) | Massage vs Control, with both groups continuing training | Aromatherapy Massage (Effleurage, Tapotement, Friction, Petrissage) | 30 min 12 sessions in two weeks | 2 weeks | Fatigue<br>(Rating of Perceived Exertion)<br>Mood<br>(Mood Questionnaire) | Massage can alleviate fatigue and improve mood |

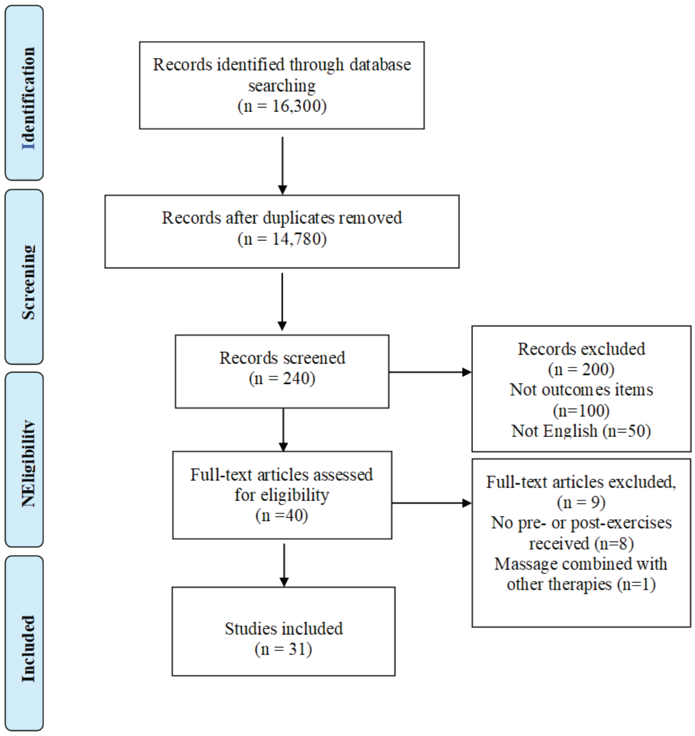


FIGURE 1. PRISMA flow chart for systematic review of studies

## Discussion

In summary, the body of research on the effects of massage reveals a nuanced picture. Most studies suggest that massage provides a significant and measurable benefit compared with active control, demonstrating its potential positive influence on muscle recovery and performance across various contexts (Arroyo-Morales et al., 2011; Rasooli et al., 2012; Han et al., 2014; Imtiyaz et al., 2014; Shin & Sung, 2015; Zadkhosh et al., 2015; Kargarfard et al., 2016; Nunes et al., 2016; Kaesaman & Eungpinichpong, 2019; Bender et al., 2019; Ambarawati et al., 2021; Aeini, 2022).

However, a notable subset of studies contradicts these findings, reporting no discernible advantage of massage (Guest, 2010; Pinar et al., 2012; Kong et al., 2018; Moran et al., 2018; Alonso-Calvete et al., 2022). When contrasted with inactive control, several studies emphasise the efficacy of massage, showcasing significant and considerable effects (Huang et al., 2010; Crane et al., 2012; Boguszewski et al., 2014; Zhong et al., 2018). Conversely, another set of studies fails to find such an impact, indicating variability in outcomes (Dawson et al., 2011; Lau & Nosaka, 2011; White et al., 2020).

In the realm of comparisons with other therapies, the evidence is mixed. Some studies report measurable and considerable effects of massage, aligning with its potential as a therapeutic intervention (Fletcher, 2010; Delextrat et al., 2013; Imtiyaz et al., 2014), whereas others do not observe such benefits (Moran et al., 2018; Fakhro et al., 2020). As a stand-alone treatment, some studies indicate considerable and substantial benefits (Vickcales, 2018; Bayer & Eken, 2021), but a divergent view exists, with one study showing no significant impact on various aspects (Sharma & Noohu, 2014).

Furthermore, Rasooli et al. (2012) discovered that massage is more effective than passive recovery in eliminating blood lactate. Active and massage recovery were more successful in improving swimming performance than passive recovery; various studies have shown that massage promotes more blood lactate removal than passive recovery (Herbert et al., 2012). The subjects and procedures of the study by Rasooli et al. (2012) were comparable to those of Greenwood et al. (2008), which validates these findings. Findings of certain research did not confirm the findings of Rasooli et al. (2012) and revealed that there was no change between blood lactate levels following massage and active recovery (Weerapong et al., 2005).

While the study by Bender et al. (2019) suggested that massage had a minimal effect in reducing discomfort and found no statistically significant changes in fatigue, flexibility, strength, or leaping ability, the findings are contradicted by Shin and Sung (2015) and Nunes et al. (2016), who argued that massage had a positive impact on outcomes. In addition, Hopper et al. (2005) reported a positive effect of massage on hamstring flexibility in ice hockey players, and Shin and Sung (2015) observed increased ankle plantar flexion strength in healthy individuals after receiving massage following eccentric activity. The varied effects of massage were further highlighted in the context of recovery for different activities, such as volleyball players experiencing a boost in vertical leap after receiving massage and runners showing a decline in physiological and physical performance after a 10k run (Mancinelli et al., 2006). This suggests that the effectiveness of massage may be context-dependent and not universally applicable to all forms of recovery.

Kargarfard et al. (2016) suggested that receiving a massage after strenuous exercise may expedite the recovery process and enhance performance. This finding aligns with the research of Delextrat et al. (2013), who demonstrated that 6–15 min of petrissage massage could increase muscular strength and performance. In contrast, Behm and Colado (2012) reported that reduced muscle strength might persist for approximately a month despite exercise. Filipa et al. (2010) found that after eight weeks of exercise, massage had no effect on muscle performance. In another context, Nunes et al. (2016) observed that a brief quadriceps massage reduced pain and subjective exhaustion in individuals who had just completed a 226-kilometer Ironman race. This observation is consistent with the notion that the beneficial effects of massage on perceived fatigue may be linked to increased localised blood circulation, aiding in the removal of metabolic waste (Weerapong et al., 2005; Hennenfent et al., 2006; Best et al., 2008; Wiltshire et al., 2010; Portillo-Soto et al., 2014).

The study by Bayer and Eken (2021) indicated that massage durations have positive effects on counter movement jump performance, squat jump, and flexibility, consistent with similar findings in studies exploring the influence of massage before exercise or competition. Several studies have supported the idea that massage stimulates the neurological system and increases muscle suppleness and performance (Nelson & Kokkonen, 2001; McHugh & Cosgrave, 2010). Sykaras et al. (2003) examined the effect of a 2-min massage on knee extensor peak torque among Taekwondo players and found positive outcomes. Additionally, Brooks et al. (2005) discovered that grip performance significantly improved with a 5-min manual forearm massage, and Farr et al. (2002) determined that muscle strength increased after 40 min of downhill treadmill walking followed by 30 min of massage. These studies collectively highlight the potential positive impact of massage on various aspects of physical performance.

Shin and Sung (2015) demonstrated that gastrocnemius massage can enhance muscular strength and proprioception, consistent with Jakeman et al. (2010), who found that massage prevents the loss of muscle strength. However, Zainuddin et al. (2005) contradicted these findings, suggesting that massage has no substantial protective effect on muscle strength loss, attributed to inadequate blood flow for tissue healing. Moraska (2005) indicated that a successful massage should last at least 10 min in each body area, and Butterfield et al. (2008) highlighted the significance of factors such as timing, length of massage, massage type, and exercise-damaging regimens in determining effectiveness. Davis et al. (2020) emphasised that differences in massage length and technique may lead to contradictory effects on muscle activity.

In contrast, White et al. (2020) asserted that massage did not improve the measures and performance of muscle discomfort, contradicting the potential alleviation of inflammation caused by physical activity. This is consistent with the findings of Nédélec et al. (2013), who found no significant difference between the massage and control legs in terms of isometric and dynamic peak torques up to 96 h after exercise, suggesting that massage may not be helpful in the short term for restoring muscle function. Moran et al. (2018) also found no evidence that massage improved sprinting performance or acceleration abilities more than other therapies, consistent with the results of Goodwin et al. (2007), who observed no significant effects on sprint performance. These studies collectively suggest a divergence in the effectiveness of massage across different measures and contexts.

Pinar et al. (2012) reported that massage had no significant effect on recovery from a psychological and physiological perspective after strenuous exercise. This finding contrasts with the positive impact of electrical muscle stimulation on the activation rate of motor units, which may aid in the healing of injured patients, as suggested by Smith et al. (2003). However, conflicting evidence exists, as Lattier et al. (2004) found no meaningful benefit of electrical muscle stimulation in post-recovery performance. Martin et al. (2004) reported a negative effect on post-recovery anaerobic exercise performance and maximal voluntary contraction force, whereas Cortis et al. (2010) found no meaningful influence on physiological markers of submaximal aerobic performance. In a sport-specific rock-climbing test, Heyman et al. (2009) revealed that electrical muscle stimulation was more damaging to performance than active recovery.

On the other hand, Zadkhosh et al. (2015) demonstrated that massage has a measurable and substantial effect on reducing depression, anxiety, and stress in wrestlers, leading to improved mental health and performance. These findings align with Noto et al. (2007), who also found that physical contact during massage can alleviate anxiety and improve psychological well-being. Hemmings (2001) categorised the impacts of massage into three categories: performance, psychological, and physiological, noting an improvement in temperament as one of the psychological effects. Aeini (2022) further supported the psychological benefits of massage, suggesting that it could alleviate weariness and improve emotions, consistent to some degree with the findings of Sherman et al. (2009).

Arroyo-Morales et al. (2011) reported that pre-massage significantly affected muscle performance, leading to a decline in isokinetic peak torque at higher speeds. However, salivary cortisol levels and alpha-amylase activity did not significantly change. After the massage, mechanical detection thresholds increased significantly, and the tension subscale of the Profile of Mood States was considerably reduced compared with the placebo. This reduction in tension is associated with improved athletic performance, despite a decrease in vigour, as observed in a previous study (Arroyo-Morales et al., 2008). The findings align with research indicating that decreased stress has a favourable impact on performance, consistent with other studies on the psychological effects of massage, such as Szabo et al. (2008). It is noteworthy that the beneficial effect of massage on emotional state is particularly evident in short-duration, open-skill, individual sports, emphasising the potential recommendation of pre-event massage for athletes prone to pre-event tension (Beedie et al., 2000).

*Limitations of the Study*

This study has several notable limitations. First, the research exhibits a heterogeneous quality, encompassing both high- and low-quality investigations, as denoted by the PEDro scale, where two studies scored below the threshold of 5. A complete absence of subject or therapist blinding was observed across all scrutinised studies, coupled with a prevailing lack of a blind assessor in most cases, thereby potentially compromising the reliability of the obtained results. The study's comprehensive consideration of diverse massage methods, marked by variations in frequency, duration, and techniques, introduces a substantial degree of heterogeneity, thereby complicating the formulation of specific conclusions regarding the optimal approach to massage. Furthermore, the study concedes to a restricted evaluation of massage efficiency, thereby highlighting a discernible gap in comprehending the precise conditions that render massage the most effective. Additionally, the predominantly athletic composition of participants in the analysed studies imposes constraints on the generalisability of findings to the broader population. Finally, the absence of uniformity in treatment durations, spanning from single sessions to four weeks three times weekly, poses a formidable challenge in determining the optimal temporal parameters for achieving the desired effects.

*Strengths and Implications of the Study*

This study is distinguished by several commendable characteristics. First, it is underpinned by a substantial dataset meticulously assembled through an exhaustive review of 31 studies, thereby contributing to a robust analytical framework. The deliberate inclusion of diverse massage methods and systematic comparisons with disparate controls enriches the breadth and depth of the study findings. The study's global representation, characterised by the inclusion of research from varied countries, imparts a comprehensive perspective on the effects of massage therapy, thereby augmenting the generalisability of the derived conclusions. Furthermore, the methodological quality of the study is subjected to rigorous scrutiny through a critical analysis using the PEDro scale, a practice that contributes transparency to the overall review process.

Moreover, the study exhibits a commendable feature in its capacity to identify notable research lacunae. Specifically, it underscores the imperative for a more thorough evaluation of massage efficiency and the establishment of standardised treatment parameters. Finally, the study holds practical significance for athletes, positing discernible advantages stemming from massage therapy in the realms of muscle recovery and performance. Consequently, it provides valuable insights to sports professionals and athletes, steering them toward evidence-based strategies for enhancing training outcomes.

In summary, while the observed benefits of massage therapy in terms of muscle recovery and performance compared with controls are noteworthy, the study underscores the imperative for heightened standardisation of research methodologies and treatment parameters. In addition, a deeper understanding of the underlying mechanisms governing the efficacy of massage is advocated to enhance the credibility and applicability of the findings.

## Conclusion

The study asserts that massage therapy manifests a substantial and noteworthy advantage in fostering muscle recovery, promoting physiological and psychological well-being, and enhancing athletic performance compared with both inactive and active controls. Nonetheless, when compared against alternative interventions, the evidence reveals a confluence of outcomes, thereby introducing a conflicting pattern of results with conflicting implications. Moreover, when implemented as an independent treatment modality, massage shows a significant benefit in specific studies; however, a divergence of evidence surfaces concerning its influence on aspects such as muscle healing, performance, physiological and psychological aspects.

**Author Contributions:**

QG and MA performed the literature search, selection of studies, and study quality assessment. Following an initial screening of titles and abstracts (QG and MA), full scrutiny of potentially eligible studies was independently screened by QG and AR using specific inclusion criteria. MA arbitrated any disagreements in study inclusion. All authors contributed to the revision of the manuscript and have read and approved the final version of the manuscript.

**Acknowledgments**

There are no acknowledgments.

**Conflicts of interest:**

The authors have no conflicts of interest to declare.

**Received:** 15 October 2023 | **Accepted:** 13 January 2024 | **Published:** 01 February 2024

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# Guidelines for Authors

Revised September 2019

*** Please use the bookmark function to navigate within the guidelines. ***

When preparing the final version of the manuscripts, either NEW or REVISED authors should strictly follow the guidelines. Manuscripts departing substantially from the guidelines will be returned to the authors for revision or, rejected.

## *1. UNIFORM REQUIREMENTS*

### 1.1. Overview

The *Sport Mont* (SM) applies the Creative Commons Attribution (CC BY) license to articles and other works it publishes.

The submission with SM is free of charge but author(s) has to pay additional 215 euros per accepted manuscript to cover publication costs. If the manuscript contains graphics in color, note that printing in color is charged additionally.

SM adopts a double-blind approach for peer reviewing in which the reviewer's name is always concealed from the submitting authors as well as the author(s)'s name from the selected reviewers.

SM honors six-weeks for an initial decision of manuscript submission.

Authors should submit the manuscripts as one Microsoft Word (.doc) file.

Manuscripts must be provided either in standard UK or US English language. English standards should be consistent throughout the manuscripts accordingly.

Format the manuscript in A4 paper size; margins are 1 inch or 2.5 cm all around.

Type the whole manuscript double-spaced, justified alignment.

Use Times New Roman font, size eleven (11) point.

Number (Arabic numerals) the pages consecutively (centering at the bottom of each page), beginning with the title page as page 1 and ending with the Figure legend page.

Include line numbers (continuous) for the convenience of the reviewers.

Apart from chapter headings and sub-headings avoid any kind of formatting in the main text of the manuscripts.

### 1.2. Type & Length

SM publishes following types of papers:

Original scientific papers are the results of empirically- or theoretically-based scientific research, which employ scientific methods, and which report experimental or observational aspects of sports science and medicine, such as all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side. Descriptive analyses or data inferences should include rigorous methodological structure as well as sound theory. Your manuscript should include the following sections: Introduction, Methods, Results, and Discussion.

☑Open Submissions ☑Indexed ☑Peer Reviewed

Original scientific papers should be:
- Up to 3000 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 30;
- Maximum combined total of 6 Tables/Figures.

Review papers should provide concise in-depth reviews of both established and new areas, based on a critical examination of the literature, analyzing the various approaches to a specific topic in all aspects of sports science and medicine, such as all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side.

☑Open Submissions ☑Indexed ☑Peer Reviewed

Review papers should be:
- Up to 6000 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 100.

Editorials are written or commissioned by the editors, but suggestions for possible topics and authors are welcome. It could be peer reviewed by two reviewers who may be external or by the Editorial Board.

☐Open Submissions ☑Indexed ☑Peer Reviewed

Editorials should be:
- Up to 1000 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 10.

Short reports of experimental work, new methods, or a preliminary report can be accepted as two page papers. Your manuscript should include the following sections: Introduction, Methods, Results, and Discussion.

☑Open Submissions ☑Indexed ☑Peer Reviewed

Short reports should be:
- Up to 1500 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 15.

Peer review - fair review provides authors who feel their paper has been unfairly rejected (at any journal) the opportunity to share reviewer comments, explain their concerns, and have their paper reviewed for possible publication in SM.

☑Open Submissions ☑Indexed ☐Peer Reviewed

Peer review - fair review should be:
- Up to 1500 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 15.

Invited papers and award papers include invited papers from authors with outstanding scientific credentials. Nomination of invited authors is at the discretion of the SM editorial board. SM also publishes award papers selected by the scientific committee of the International Scientific Conference on Transformation Processes in Sport.

☐Open Submissions ☑Indexed ☐Peer Reviewed

Invited papers and award papers should be:
- Up to 3000 words (excluding title, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References);
- A structured abstract of less than 250 words;
- Maximum number of references is 30;
- Maximum combined total of 6 Tables/Figures.

## 1.3. Submission

SM only accepts electronic submission to the e-mail of the Journal Office: **sportmont@ucg.ac.me**.

Submitted material includes:

- A manuscript prepared according to the Guidelines for the Authors;
- A signed form that states the study was not previously published, nor has been submitted simultaneously for consideration of publication elsewhere, that states that all of the authors are in agreement with submission of the manuscript to SM, and that, for studies that use animal or human individuals, authors must include information regarding their institution's ethics committee, and which identifies the official approval number;
- A signed form that there is no conflict of interest.

Name the files according to the family name of the first author. Authors submitting revised versions of the manuscript can use the identification number of their manuscript as provided by the Journal Office. *See* example:

- ✓ FAMILY NAME-manuscript.doc – (main manuscript file)
- ✓ FAMILY NAME-statement.PDF – (authorship statement)
- ✓ FAMILY NAME-declaration.PDF – (declaration of potential conflict of interest)
- ✓ FAMILY NAME-fig1.tiff – (Figure 1)

## 1.4. Peer Review Process

A manuscript submitted for publication will be submitted to the review process as long as it fits the following criteria:

- The study was not previously published, nor has been submitted simultaneously for consideration of publication elsewhere;
- All persons listed as authors approved its submission to SM;
- Any person cited as a source of personal communication has approved the quote;
- The opinions expressed by the authors are their exclusive responsibility;
- The author signs a formal statement that the submitted manuscript complies with the directions and guidelines of SM.

The editors-in-chief and associate editors will make a preliminary analysis regarding the appropriateness, quality, originality and written style/grammar of the submitted manuscript. The editors reserve the right to request additional information, corrections, and guideline compliance before they submit the manuscript to the ad-hoc review process.

SM uses ad-hoc reviewers, who volunteer to analyze the merit of the study. Typically, one or two expert reviewers are consulted in a double-blind process. Authors are notified by e-mail when their submission has been accepted (or rejected). Minor changes in the text may be made at the discretion of the editors-in-chief and/or associate editors. Changes can include spelling and grammar in the chosen language, written style, journal citations, and reference guidelines. The author is notified of changes via email. The final version is available to the author for his or her approval before it is published.

## 1.5. Open Access License and Publisher Copyright Policies

SM applies the Creative Commons Attribution (CC BY) license to articles and other works it publishes. If author(s) submit its paper for publication by SM, they agree to have the CC BY license applied to their work. Under this Open Access license, the author(s) agree that anyone can reuse their article in whole or part for any purpose, for free, even for commercial purposes. Anyone may copy, distribute, or reuse the content as long as the author(s) and original source are properly cited. This facilitates freedom in re-use and also ensures that SM content can be mined without barriers for the needs of research. On the other hand, the author(s) may use content owned by someone else in their article if they have written permission to do so. If the manuscript contains content such as photos, images, figures, tables, audio files, videos, et cetera, that the author(s) do not own, SM will require them to provide it with proof that the owner of that content has given them written permission to use it, and has approved of the CC BY license being applied to their content. Otherwise, SM will ask the author(s) to remove that content and/or replace it with other content that you own or have such permission to use. SM provides a form the author(s) can use to ask for and obtain permission from the owner.

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The editors of SM consider plagiarism to be a serious breach of academic ethics. Any author who practices plagiarism (in part or totality) will be suspended for six years from submitting new submissions to SM. If such a manuscript is approved and published, public exposure of the article with a printed mark ("plagiarized" or "retracted") on each page of the published file, as well as suspension for future publication for at least six years, or a period determined by the editorial board. Third party plagiarized authors or institutions will be notified, informing them about the faulty authors. Plagiarism will result in immediate rejection of the manuscript.

SM only publishes studies that have been approved by an institutional ethics committee (when a study involves humans or animals). Fail to provide such information prevent its publication. To ensure these requirements, it is essential that submission documentation is complete. If you have not completed this step yet, go to SM website and fill out the two required documents: Declaration of Potential Conflict of Interest and Authorship Statement. Whether or not your study uses humans or animals, these documents must be completed and signed by all authors and attached as supplementary files in the originally submitted manuscript.

## 1.6. After Acceptance

After the manuscript has been accepted, authors will receive a PDF version of the manuscripts for authorization, as it should look in printed version of SM. Authors should carefully check for omissions. Reporting errors after this point will not be possible and the Editorial Board will not be eligible for them.

Should there be any errors, authors should report them to the Office e-mail address **sportmont@ucg.ac.me**. If there are not any errors authors should also write a short e-mail stating that they agree with the received version.

## 1.7. Code of Conduct Ethics Committee of Publications

C O P E COMMITTEE ON PUBLICATION ETHICS

SM is hosting the Code of Conduct Ethics Committee of Publications of the **COPE** (the Committee on Publication Ethics), which provides a forum for publishers and Editors of scientific journals to discuss issues relating to the integrity of the work submitted to or published in their journals.

# *2. MANUSCRIPT STRUCTURE*

## 2.1. Title Page

The first page of the manuscripts should be the title page, containing: title, type of publication, running head, authors, affiliations, corresponding author, and manuscript information. *See* example:

Body Composition of Elite Soccer Players from Montenegro

Original Scientific Paper

Elite Soccer Players from Montenegro

Dusko Bjelica[1]

[1]Univeristy of Montenegro, Faculty for Sport an Physical Education, Niksic, Montenegro

Corresponding author:

*Dusko Bjelica*

*University of Montenegro*

*Faculty for Sport and Physical Education*

*Narodne omladine bb, 81400 Niksic, Montenegro*

*E-mail: sportmont@t-com.me*

Word count: 2,946

Abstract word count: 236

Number of Tables: 3

Number of Figures: 0

**2.1.1. Title**

Title should be short and informative and the recommended length is no more than 20 words. The title should be in Title Case, written in uppercase and lowercase letters (initial uppercase for all words except articles, conjunctions, short prepositions no longer than four letters etc.) so that first letters of the words in the title are capitalized. Exceptions are words like: “and”, “or”, “between” etc. The word following a colon (:) or a hyphen (-) in the title is always capitalized.

**2.1.2. Type of publication**

Authors should suggest the type of their submission.

**2.1.3. Running head**

Short running title should not exceed 50 characters including spaces.

**2.1.4. Authors**

The form of an author’s name is first name, middle initial(s), and last name. In one line list all authors with full names separated by a comma (and space). Avoid any abbreviations of academic or professional titles. If authors belong to different institutions, following a family name of the author there should be a number in superscript designating affiliation.

#### 2.1.5. Affiliations

Affiliation consists of the name of an institution, department, city, country/territory (in this order) to which the author(s) belong and to which the presented / submitted work should be attributed. List all affiliations (each in a separate line) in the order corresponding to the list of authors. Affiliations must be written in English, so carefully check the official English translation of the names of institutions and departments.

Only if there is more than one affiliation, should a number be given to each affiliation in order of appearance. This number should be written in superscript at the beginning of the line, separated from corresponding affiliation with a space. This number should also be put after corresponding name of the author, in superscript with no space in between.

If an author belongs to more than one institution, all corresponding superscript digits, separated with a comma with no space in between, should be present behind the family name of this author.

In case all authors belong to the same institution affiliation numbering is not needed.

Whenever possible expand your authors' affiliations with departments, or some other, specific and lower levels of organization.

#### 2.1.6. Corresponding author

Corresponding author's name with full postal address in English and e-mail address should appear, after the affiliations. It is preferred that submitted address is institutional and not private. Corresponding author's name should include only initials of the first and middle names separated by a full stop (and a space) and the last name. Postal address should be written in the following line in sentence case. Parts of the address should be separated by a comma instead of a line break. E-mail (if possible) should be placed in the line following the postal address. Author should clearly state whether or not the e-mail should be published.

#### 2.1.7. Manuscript information

All authors are required to provide word count (excluding title page, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References), the Abstract word count, the number of Tables, and the number of Figures.

### 2.2. Abstract

The second page of the manuscripts should be the abstract and key words. It should be placed on second page of the manuscripts after the standard title written in upper and lower case letters, bold.

Since abstract is independent part of your paper, all abbreviations used in the abstract should also be explained in it. If an abbreviation is used, the term should always be first written in full with the abbreviation in parentheses immediately after it. Abstract should not have any special headings (e.g., Aim, Results…).

Authors should provide up to six key words that capture the main topics of the article. Terms from the Medical Subject Headings (MeSH) list of Index Medicus are recommended to be used.

Key words should be placed on the second page of the manuscript right below the abstract, written in italic. Separate each key word by a comma (and a space). Do not put a full stop after the last key word. *See* example:

**Abstract**

Results of the analysis of

***Key words:*** *spatial memory, blind, transfer of learning, feedback*

### 2.3. Main Chapters

Starting from the third page of the manuscripts, it should be the main chapters. Depending on the type of publication main manuscript chapters may vary. The general outline is: Introduction, Methods, Results, Discussion, Acknowledgements (optional), Conflict of Interest (optional). However, this scheme may not be suitable for reviews or publications from some areas and authors should then adjust their chapters accordingly but use the general outline as much as possible.

#### 2.3.1. Headings

Main chapter headings: written in bold and in Title Case. *See* example:
- ✓ **Methods**

Sub-headings: written in italic and in normal sentence case. Do not put a full stop or any other sign at the end of the title. Do not create more than one level of sub-heading. *See* example:
- ✓ *Table position of the research football team*

#### 2.3.2 Ethics

When reporting experiments on human subjects, there must be a declaration of Ethics compliance. Inclusion of a statement such as follow in Methods section will be understood by the Editor as authors' affirmation of compliance: "This study was approved in advance by [name of committee and/or its institutional sponsor]. Each participant voluntarily provided written informed consent before participating." Authors that fail to submit an Ethics statement will be asked to resubmit the manuscripts, which may delay publication.

#### 2.3.3 Statistics reporting

SM encourages authors to report precise p-values. When possible, quantify findings and present them with appropriate indicators of measurement error or uncertainty (such as confidence intervals). Use normal text (i.e., non-capitalized, non-italic) for statistical term "p".

#### 2.3.4. 'Acknowledgements' and 'Conflict of Interest' (optional)

All contributors who do not meet the criteria for authorship should be listed in the 'Acknowledgements' section. If applicable, in 'Conflict of Interest' section, authors must clearly disclose any grants, financial or material supports, or any sort of technical assistances from an institution, organization, group or an individual that might be perceived as leading to a conflict of interest.

## 2.4. References

References should be placed on a new page after the standard title written in upper and lower case letters, bold.

All information needed for each type of must be present as specified in guidelines. Authors are solely responsible for accuracy of each reference. Use authoritative source for information such as Web of Science, Medline, or PubMed to check the validity of citations.

#### 2.4.1. References style

SM adheres to the American Psychological Association 6th Edition reference style. Check "American Psychological Association. (2009). Concise rules of APA style. American Psychological Association." to ensure the manuscripts conform to this reference style. Authors using EndNote® to organize the references must convert the citations and bibliography to plain text before submission.

#### 2.4.2. Examples for Reference citations

One work by one author
- ✓ In one study (Reilly, 1997), soccer players
- ✓ In the study by Reilly (1997), soccer players
- ✓ In 1997, Reilly's study of soccer players

Works by two authors
- ✓ Duffield and Marino (2007) studied
- ✓ In one study (Duffield & Marino, 2007), soccer players
- ✓ In 2007, Duffield and Marino's study of soccer players

Works by three to five authors: cite all the author names the first time the reference occurs and then subsequently include only the first author followed by et al.

- ✓ First citation: Bangsbo, Iaia, and Krustrup (2008) stated that
- ✓ Subséquent citation: Bangsbo et al. (2008) stated that

Works by six or more authors: cite only the name of the first author followed by et al. and the year

- ✓ Krustrup et al. (2003) studied
- ✓ In one study (Krustrup et al., 2003), soccer players

Two or more works in the same parenthetical citation: Citation of two or more works in the same parentheses should be listed in the order they appear in the reference list (i.e., alphabetically, then chronologically)

- ✓ Several studies (Bangsbo et al., 2008; Duffield & Marino, 2007; Reilly, 1997) suggest that

**2.4.3. Examples for Reference list**

Journal article (print):

Nepocatych, S., Balilionis, G., & O'Neal, E. K. (2017). Analysis of dietary intake and body composition of female athletes over a competitive season. *Montenegrin Journal of Sports Science and Medicine, 6*(2), 57-65. doi: 10.26773/mjssm.2017.09.008

Duffield, R., & Marino, F. E. (2007). Effects of pre-cooling procedures on intermittent-sprint exercise performance in warm conditions. *European Journal of Applied Physiology, 100*(6), 727-735. doi: 10.1007/s00421-007-0468-x

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Bangsbo, J. (2003). The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Medicine and Science in Sports and Exercise, 35*(4), 697-705. doi: 10.1249/01.MSS.0000058441.94520.32

Journal article (online; electronic version of print source):

Williams, R. (2016). Krishna's Neglected Responsibilities: Religious devotion and social critique in eighteenth-century North India [Electronic version]. *Modern Asian Studies, 50*(5), 1403-1440. doi:10.1017/S0026749X14000444

Journal article (online; electronic only):

Chantavanich, S. (2003, October). Recent research on human trafficking. *Kyoto Review of Southeast Asia, 4*. Retrieved November 15, 2005, from http://kyotoreview.cseas.kyoto-u.ac.jp/issue/issue3/index.html

Conference paper:

Pasadilla, G. O., & Milo, M. (2005, June 27). *Effect of liberalization on banking competition*. Paper presented at the conference on Policies to Strengthen Productivity in the Philippines, Manila, Philippines. Retrieved August 23, 2006, from http://siteresources.worldbank.org/INTPHILIPPINES/Resources/Pasadilla.pdf

Encyclopedia entry (print, with author):

Pittau, J. (1983). Meiji constitution. In *Kodansha encyclopedia of Japan* (Vol. 2, pp. 1-3). Tokyo: Kodansha.

Encyclopedia entry (online, no author):

Ethnology. (2005, July). In *The Columbia encyclopedia* (6th ed.). New York: Columbia University Press. Retrieved November 21, 2005, from http://www.bartleby.com/65/et/ethnolog.html

Thesis and dissertation:

Pyun, D. Y. (2006). *The proposed model of attitude toward advertising through sport.* Unpublished Doctoral Dissertation. Tallahassee, FL: The Florida State University.

Book:

Borg, G. (1998). *Borg's perceived exertion and pain scales*: Human kinetics.

Chapter of a book:

Kellmann, M. (2012). Chapter 31-Overtraining and recovery: Chapter taken from Routledge Handbook of Applied Sport Psychology ISBN: 978-0-203-85104-3 *Routledge Online Studies on the Olympic and Paralympic Games* (Vol. 1, pp. 292-302).

Reference to an internet source:

Agency. (2007). Water for Health: Hydration Best Practice Toolkit for Hospitals and Healthcare. Retrieved 10/29, 2013, from www.rcn.org.uk/newsevents/hydration

## 2.5. Tables

All tables should be included in the main manuscript file, each on a separate page right after the Reference section.

Tables should be presented as standard MS Word tables.

Number (Arabic) tables consecutively in the order of their first citation in the text.

Tables and table headings should be completely intelligible without reference to the text. Give each column a short or abbreviated heading. Authors should place explanatory matter in footnotes, not in the heading. All abbreviations appearing in a table and not considered standard must be explained in a footnote of that table. Avoid any shading or coloring in your tables and be sure that each table is cited in the text.

If you use data from another published or unpublished source, it is the authors' responsibility to obtain permission and acknowledge them fully.

### 2.5.1. Table heading

Table heading should be written above the table, in Title Case, and without a full stop at the end of the heading. Do not use suffix letters (e.g., Table 1a, 1b, 1c); instead, combine the related tables. *See* example:

- ✓ **Table 1.** Repeated Sprint Time Following Ingestion of Carbohydrate-Electrolyte Beverage

### 2.5.2. Table sub-heading

All text appearing in tables should be written beginning only with first letter of the first word in all capitals, i.e., all words for variable names, column headings etc. in tables should start with the first letter in all capitals. Avoid any formatting (e.g., bold, italic, underline) in tables.

### 2.5.3. Table footnotes

Table footnotes should be written below the table.

General notes explain, qualify or provide information about the table as a whole. Put explanations of abbreviations, symbols, etc. here. General notes are designated by the word *Note* (italicized) followed by a period.

- ✓ *Note.* CI: confidence interval; Con: control group; CE: carbohydrate-electrolyte group.

Specific notes explain, qualify or provide information about a particular column, row, or individual entry. To indicate specific notes, use superscript lowercase letters (e.g. [a, b, c]), and order the superscripts from left to right, top to bottom. Each table's first footnote must be the superscript [a].

- ✓ [a]One participant was diagnosed with heat illness and n = 19.[b]n =20.

Probability notes provide the reader with the results of the texts for statistical significance. Probability notes must be indicated with consecutive use of the following symbols: * † ‡ § ¶ || etc.

- ✓ *P<0.05,†p<0.01.

### 2.5.4. Table citation

In the text, tables should be cited as full words. *See* example:

- ✓ Table 1 (first letter in all capitals and no full stop)
- ✓ ...as shown in Tables 1 and 3. (citing more tables at once)
- ✓ ...result has shown (Tables 1-3) that... (citing more tables at once)
- ✓ ....in our results (Tables 1, 2 and 5)... (citing more tables at once)

## 2.6. Figures

On the last separate page of the main manuscript file, authors should place the legends of all the figures submitted separately.

All graphic materials should be of sufficient quality for print with a minimum resolution of 600 dpi. SM prefers TIFF, EPS and PNG formats.

If a figure has been published previously, acknowledge the original source and submit a written permission from the copyright holder to reproduce the material. Permission is required irrespective of authorship or publisher except for documents in the public domain. If photographs of people are used, either the subjects must not be identifiable or their pictures must be accompanied by written permission to use the photograph whenever possible permission for publication should be obtained.

Figures and figure legends should be completely intelligible without reference to the text.

The price of printing in color is 50 EUR per page as printed in an issue of SM.

**2.6.1. Figure legends**

Figures should not contain footnotes. All information, including explanations of abbreviations must be present in figure legends. Figure legends should be written bellow the figure, in sentence case. *See* example:

- ✓ **Figure 1.** Changes in accuracy of instep football kick measured before and after fatigued. SR – resting state, SF – state of fatigue, *p>0.01, †p>0.05.

**2.6.2. Figure citation**

All graphic materials should be referred to as Figures in the text. Figures are cited in the text as full words. *See* example:

- ✓ Figure 1
    - × figure 1
    - × Figure 1.
    - ✓ ….exhibit greater variance than the year before (Figure 2). Therefore…
    - ✓ ….as shown in Figures 1 and 3. (citing more figures at once)
    - ✓ ….result has shown (Figures 1-3) that... (citing more figures at once)
    - ✓ ….in our results (Figures 1, 2 and 5)... (citing more figures at once)

**2.6.3. Sub-figures**

If there is a figure divided in several sub-figures, each sub-figure should be marked with a small letter, starting with a, b, c etc. The letter should be marked for each subfigure in a logical and consistent way. *See* example:

- ✓ Figure 1a
- ✓ …in Figures 1a and b we can…
- ✓ …data represent (Figures 1a-d)…

## 2.7. Scientific Terminology

All units of measures should conform to the International System of Units (SI).

Measurements of length, height, weight, and volume should be reported in metric units (meter, kilogram, or liter) or their decimal multiples.

Decimal places in English language are separated with a full stop and not with a comma. Thousands are separated with a comma.

| Percentage | Degrees | All other units of measure | Ratios | Decimal numbers |
|---|---|---|---|---|
| ✓ 10% | ✓ 10º | ✓ 10 kg | ✓ 12:2 | ✓ 0.056 |
| × 10 % | × 10 º | × 10kg | × 12 : 2 | × .056 |

| Signs should be placed immediately preceding the relevant number. | | |
|---|---|---|
| ✓ 45±3.4 | ✓ p<0.01 | ✓ males >30 years of age |
| × 45 ± 3.4 | × p < 0.01 | × males > 30 years of age |

## 2.8. Latin Names

Latin names of species, families etc. should be written in italics (even in titles). If you mention Latin names in your abstract they should be written in non-italic since the rest of the text in abstract is in italic. The first time the name of a species appears in the text both genus and species must be present; later on in the text it is possible to use genus abbreviations. *See* example:

✓ First time appearing: *musculus biceps brachii*

Abbreviated: *m. biceps brachii*

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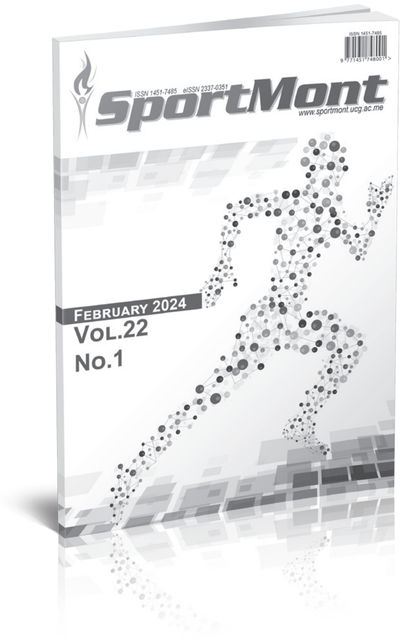


ISSN 1451-7485

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SMJ covers all aspects of sports science and medicine; all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side.

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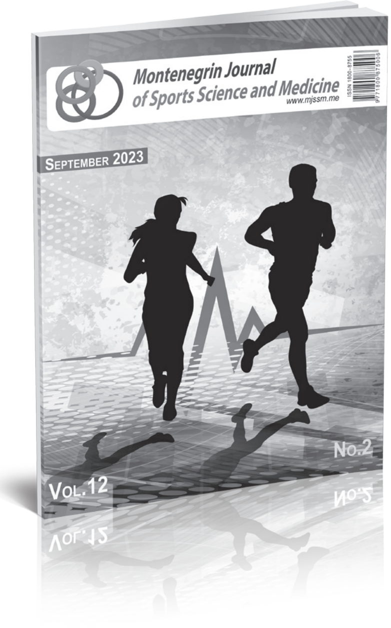
Publication date: Summer issue – June 2024
Autumn issue – October 2024
Winter issue – February 2025

Montenegrin Journal
of Sports Science and Medicine

# MONTENEGRIN JOURNAL OF SPORTS SCIENCE AND MEDICINE




ISSN 1800-8755

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Damir SEKULIC, Editor-in Chief – damirsekulic.mjssm@gmail.com

Publication date: Spring issue – March 2024
Autumn issue – September 2024

# MONTENEGRIN SPORTS ACADEMY

Founded in 2003 in Podgorica (Montenegro), the Montenegrin Sports Academy (MSA) is a sports scientific society dedicated to the collection, generation and dissemination of scientific knowledge at the Montenegrin level and beyond.

The Montenegrin Sports Academy (MSA) is the leading association of sports scientists at the Montenegrin level, which maintains extensive co-operation with the corresponding associations from abroad. The purpose of the MSA is the promotion of science and research, with special attention to sports science across Montenegro and beyond. Its topics include motivation, attitudes, values and responses, adaptation, performance and health aspects of people engaged in physical activity and the relation of physical activity and lifestyle to health, prevention and aging. These topics are investigated on an interdisciplinary basis and they bring together scientists from all areas of sports science, such as adapted physical activity, biochemistry, biomechanics, chronic disease and exercise, coaching and performance, doping, education, engineering and technology, environmental physiology, ethics, exercise and health, exercise, lifestyle and fitness, gender in sports, growth and development, human performance and aging, management and sports law, molecular biology and genetics, motor control and learning, muscle mechanics and neuromuscular control, muscle metabolism and hemodynamics, nutrition and exercise, overtraining, physiology, physiotherapy, rehabilitation, sports history, sports medicine, sports pedagogy, sports philosophy, sports psychology, sports sociology, training and testing.

The MSA is a non-profit organization. It supports Montenegrin institutions, such as the Ministry of Education and Sports, the Ministry of Science and the Montenegrin Olympic Committee, by offering scientific advice and assistance for carrying out coordinated national and European research projects defined by these bodies. In addition, the MSA serves as the most important Montenegrin and regional network of sports scientists from all relevant subdisciplines.

The main scientific event organized by the Montenegrin Sports Academy (MSA) is the annual conference held in the first week of April.

Annual conferences have been organized since the inauguration of the MSA in 2003. Today the MSA conference ranks among the leading sports scientific congresses in the Western Balkans. The conference comprises a range of invited lecturers, oral and poster presentations from multi- and mono-disciplinary areas, as well as various types of workshops. The MSA conference is attended by national, regional and international sports scientists with academic careers. The MSA conference now welcomes up to 200 participants from all over the world.

It is our great pleasure to announce the upcoming 21th Annual Scientific Conference of Montenegrin Sports Academy “Sport, Physical Activity and Health: Contemporary Perspectives” to be held in Dubrovnik, Croatia, from 18 to 21 April, 2024. It is planned to be once again organized by the Montenegrin Sports Academy, in cooperation with the Faculty of Sport and Physical Education, University of Montenegro and other international partner institutions (specified in the partner section).


The conference is focused on very current topics from all areas of sports science and sports medicine including physiology and sports medicine, social sciences and humanities, biomechanics and neuromuscular (see Abstract Submission page for more information).

We do believe that the topics offered to our conference participants will serve as a useful forum for the presentation of the latest research, as well as both for the theoretical and applied insight into the field of sports science and sports medicine disciplines.

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# Sports Science and Medicine Journals

## from Montenegrin Sports Academy

We have expanded the quality of our journals considerably over the past years and can now claim to be the market leader in terms of breadth of coverage.

As we continue to increase the quality of our publications across the field, we hope that you will continue to regard MSA journals as authoritative and stimulating sources for your research. We would be delighted to receive your comments and suggestions, mostly due to the reason your proposals are always welcome.

# Look Inside!


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Managing Editor: **Borko Katanic**, Montenegro; **Nedim Covic**, Bosnia and Herzegovina

*Volume 22, 2024, 3 issues per year; Print ISSN: 1451-7485, Online ISSN: 2337-0351*

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*Volume 12, 2023, 2 issues per year; Print ISSN: 1800-8755, Online ISSN: 1800-8763*

Montenegrin Journal of Sports Science and Medicine (MJSSM) is published biannually, in September and March of each year. MJSSM publishes original scientific papers, review papers, editorials, short reports, peer review - fair review, as well as invited papers and award papers in the fields of Sports Science and Medicine, as well as it can function as an open discussion forum on significant issues of current interest. MJSSM covers all aspects of sports science and medicine; all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side.

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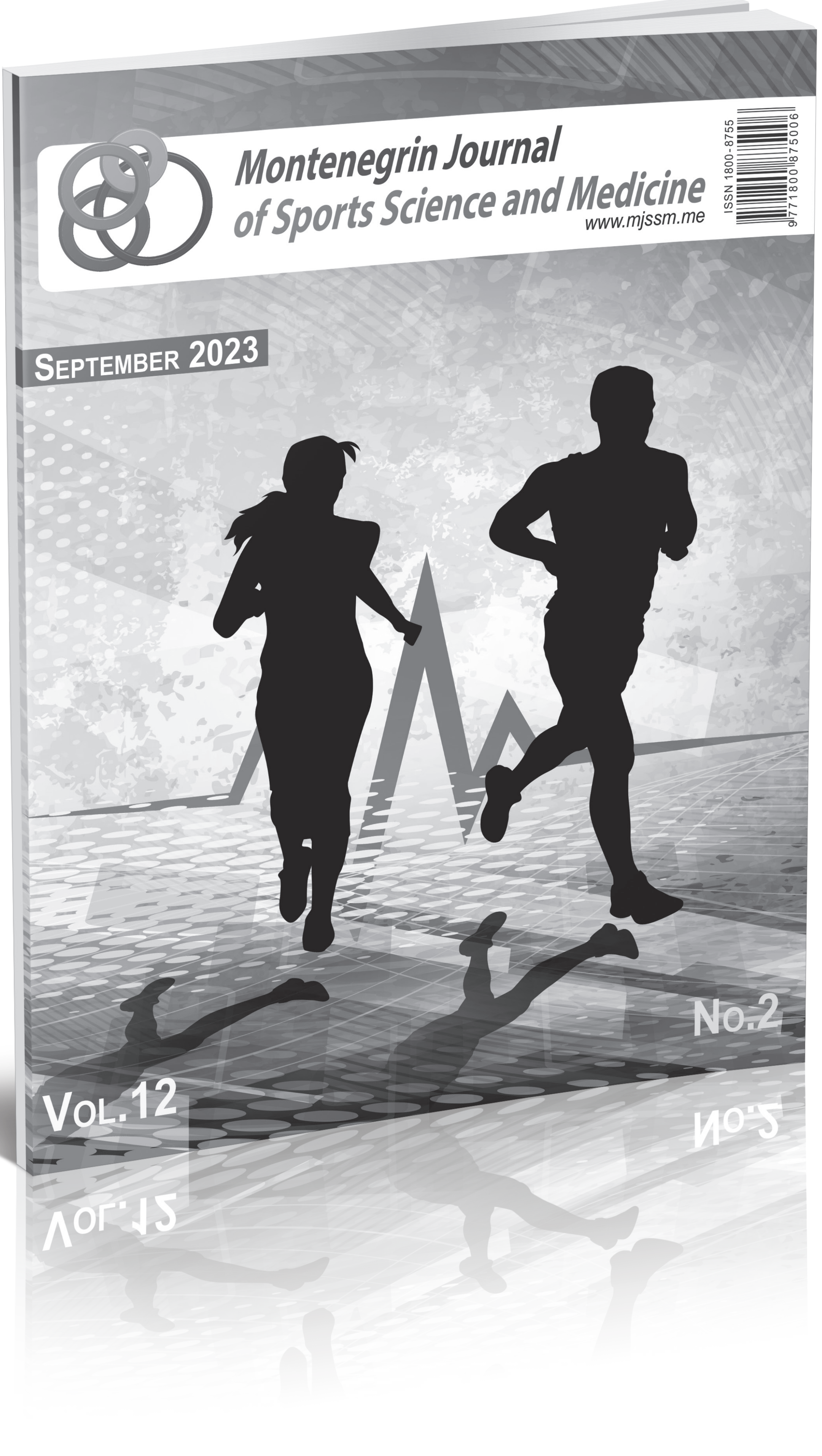

Montenegrin Journal
of Sports Science and Medicine
www.mjssm.me
ISSN 1800-8755
9771800875006
September 2023
No.2
Vol.12

CRNOGORSKI OLIMPIJSKI KOMITET
MONTENEGRIN OLYMPIC COMMITTEE

Каталогизација у публикацији
Национална библиотека Црне Горе, Цетиње

ISSN 1451-7485
COBISS.CG-ID 33857808

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