Innovative Technologies in Sport and Physical Activity

www.pastechl.me/journal

December 2025

Vol. 4
No. 2

ISSN 2957-2525

Innovative Technologies in Sport and Physical Activity

Index Coverage

Cobiss; CrossRef; Google Scholar; DOAJ; Index Copernicus; Scilit

Proofreading Service

Zana Gavrilovic

Prepress

Milicko Ceranic

Print

Proarte d.o.o.

Print Run

1500

PASTECHL
Physical Activity and Sports Tech for Healthy Lifestyles

Western Balkan L★B Sport Innovation

ISSN 2957-2525 eISSN 2957-2533

INNOVATIVE TECHNOLOGIES IN SPORT AND PHYSICAL ACTIVITY

International Scientific Journal

Vol. 4(2025), No.2 (1-46)

TABLE OF CONTENTS

Full-text available free of charge at https://pastechl.me/past-issues/

Dear Colleagues, Authors, Reviewers, and Readers,

It is with great honor and enthusiasm that I introduce myself as the newly appointed Editor-in-Chief of Innovative Technologies in Sport and Physical Activity (IT-SPA), the official journal of Physical Activity and Sports Tech for Healthy Lifestyles, published by the Western Balkan Sport Innovation Lab. As we embark on this new chapter, I am committed to upholding the journal's mission of providing open-access, timely, and impactful scholarship in the realms of sports and health sciences.

In an era where advancements in technology are reshaping human performance and well-being, IT-SPA stands at the forefront of exploring these innovations. From biomechanical analysis and wearable devices to data-driven coaching and virtual training environments, it is the development of innovative technologies that will guide the future trajectory of sports science. By fostering interdisciplinary dialogue across exercise physiology, sports psychology, nutrition, rehabilitation, sports management and beyond, we can illuminate the multifaceted field of sports and physical activity.

I extend a warm invitation to all stakeholders–researchers, practitioners, educators, and enthusiasts–to contribute your expertise. Whether through original research, reviews, or editorials, your submissions will enrich our collective understanding and drive meaningful progress. Together, let us harness technology to promote healthier lifestyles and enhance athletic achievement.

I look forward to your active participation and collaboration.

Sincerely,

Radenko M. Matić

Editor-in-Chief Innovative Technologies in Sport and Physical Activity

ORIGINAL SCIENTIFIC PAPER

Physical Activity and Nutritional Status of Preschool-Aged Children and Their Parents

Iva Blazevic[1], Mirela Sunda[2], Tamara Brussich[3]

Affiliations: [1]Juraj Dobrila University of Pula, Faculty of Educational Sciences, Pula, Croatia, [2]Josip Juraj Strossmayer University of Osijek, Faculty of Kinesiology Osijek, Osijek, Croatia, [3]Teaching Institute of Public Health of the Istria County, Pula, Croatia

Correspondence: I. Blazevic. Juraj Dobrila University of Pula, Faculty of Educational Sciences, Ulica Alda Negrija 6, 52100 Pula, Croatia. E-mail: iva.blazevic@unipu.hr

Abstract

The period of early and preschool age is very important in shaping children's health habits. The parents' approach to physical activity and nutritional habits is important for long-term behavior patterns in children. The aim of this study is to determine the relationships between preschool-aged children and their parents' physical activity and nutritional status, and their nutritional habits. As many as 234 parents completed a questionnaire on their preschool-aged children's nutritional habits and another on children's and parents' physical activity. The children's and parents' level of nutrition was determined by body mass index (BMI). The results show that parents decide on the size of meals and the choice of foods included in the daily nutrition of children and are satisfied with the quality and size of meals that children consume during their stay in kindergartens. A significant correlation was found between the physical activity of children and their parents, as well as the level of nutrition. No statistically significant differences were found between preschool-aged girls and boys. The results obtained show that parents play a key role in creating healthy lifestyle habits and encouraging physical activity of preschool children.

Keywords: *physical activity, nutritional status, healthy habits, children, parents*

Introduction

Insufficient physical activity and inadequate nutrition in children represent a complex problem of modern lifestyle, which is manifested through the increase in excess body weight and the occurrence of obesity from early and preschool age. Movement is a primary biological need and is extremely important for the entire process of a child's growth and development, so physical activity is one of the key factors in the development of all dimensions of the anthropological status of children.

There are different definitions of physical activity. Caspersen et al. (1985) define physical activity as "any bodily movement that increases energy expenditure over resting energy expenditure". The World Health Organization (2018) defines physical activity as "any bodily movement produced by skeletal muscle that requires energy expenditure". Physical activity in children is not limited to sports, but includes all forms of movement such as walking, cycling, active play and recreation, sports activities, household chores, structured family exercises, as well as preschool and social activities, etc. (Tomac et al., 2015).

Numerous authors highlight physical activity as a major factor in promoting and maintaining good health throughout life, as physical inactivity has been identified as one of the leading risk factors for global mortality and a contributor to the increase in overweight and obesity (WHO, 2019). In the early days of physical activity research not much attention was paid to physical activity in early and preschool children, as it was believed that young children were naturally physically active enough. The sedentary lifestyle in modern society, where reduced physical activity and the availability of modern technologies dominate, has prompted numerous studies on children's physical activity. Studies related with physical activity and various health indicators in children show that insufficient physical activity is one of the main factors in the increase in obesity, given that young children

Received: 29 October 2025 | Accepted after revision: 09 December 2025 | Early access publication date: 15 December 2025 | Final publication date: 15 December 2025

Conflict of interest: None declared.

spend more than 75% of their waking hours in a sedentary position (Carson et al., 2016).

Along with adequate physical activity, proper nutrition is an important part of children's healthy growth and development, and balanced nutrition is a key factor in the growth and development of early and preschool-age children. Early childhood development is associated with a greater demand for nutrients and energy to meet the body's physical needs, which is why early and preschool children are particularly sensitive to the lack of proper nutrition (Taylor et al., 2004).

In creating healthy eating habits, it is important for parents to understand what proper nutrition is and what effect nutrition has on a child's growth and development. Children most often observe and imitate the behavior of their parents. Research conducted by Brown and Ogden (2004) has shown that children's eating behavior is very similar to that of their parents and that a positive parental role model can be a better method of improving a child's diet than trying to control their diet.

Children spend seven to eight hours a day in kindergarten, so the food served there should be properly balanced to provide energy and nutrients in the right amounts and proportions in relation to children's needs. In addition, kindergartens provide an excellent environment to promote positive habits and attitudes towards healthy eating and physical activity as an integral part of a healthy lifestyle.

According to the social cognitive theory, children learn by observing the behavior of others (Klarin, 2017). Observational learning is particularly effective when the child respects or is similar to the person they are observing. Parents' physical activity can directly influence the physical activity of their children, while educators have a great influence on children's attitudes towards preschool activities. Su et al. (2022) point to the multidimensionality of the mechanisms of these influences, which include "parental attitudes, beliefs and values towards physical activity and social support". Parents influence children's physical activity patterns through encouragement, logistical support, behavioral modelling, parent-child play, family communication and general social support (Chiarlitti & Kolen, 2017). Children at an early age are still not independent and need help in meeting their basic need for movement from their family and educators. Children whose parents regularly engage in physical activity are more likely to practice some form of physical activity themselves (Blažević et al., 2021).

Mechanisms used to determine the relationship between parent and child activity levels included parents as role models, sharing activities with family members, active parents' enhancement and support of the child's participation in physical activity, and genetically transmitted factors that predispose the child to increased levels of physical activity.

Sedentary lifestyles lead to reduced levels of physical activity in children, while fast-paced life and the availability of industrially processed foods are potential risks of unbalanced nutrition in children. Sedentary behavior and unbalanced nutrition can lead to various non-communicable diseases and psychological disorders, lack of self-esteem, discrimination and stigmatization of overweight children. Negative effects can be prevented through the acceptance and promotion of physical activity and proper nutrition (Pedišić et al., 2025; Sunda, Brkic & Blazevic, 2025).

The aim of this study is to determine the relationships between preschool-aged children and their parents' physical activity and nutritional status, and the parents' attitudes about children's eating habits.

The partial objectives of this study are (1) to determine whether there are differences in the nutritional status and physical activity levels between girls and boys, (2) to determine whether there is a significant correlation between physical activity and indicators of nutritional status in children and parents, and (3) to analyze parental practices in influencing and monitoring children's eating habits.

Methods

Research design

This research used a cross-sectional study design. Before conducting the research, a positive opinion was obtained from the Research Ethics Committee of the Juraj Dobrila University of Pula (Croatia).

Participants

The sample of participants in this study consisted of 234 parents and children aged 6 attending kindergartens in Croatia (Istria county, Croatia). The survey questionnaires were completed by the parents, and of the total number of parents included who completed the questionnaire, there were 92.74% of mothers. The average age of parents who completed the questionnaire was 30 to 39 years (54.7%), 40.17% of parents were aged 40 to 49, and 4.7% were aged 20 to 29. The study included 53.42% of girls and 46.58% of boys aged 6.

Research Instruments

Based on the information obtained from parents on body height and body weight, the body mass index (BMI) of the children and parents included in the study was calculated.

The level of physical activity of preschool children was assessed using the Netherlands Physical Activity Questionnaire (NPAQ). The NPAQ is a questionnaire completed by parents and provides a general insight into the child's daily activities.

Parents completed a short version of The International Physical Activity Questionnaire (IPAQ), a questionnaire that uses standardized questions to monitor physical activity in young people and adults (aged 15-69) and as a result provides internationally comparable data for monitoring activity or inactivity.

Parents completed the Child Feeding Questionnaire (Buratta et al., 2020) to assess parental awareness of the importance of dietary habits, monitoring of children's dietary habits, and parental practices that may influence children's dietary patterns. Author consent was obtained for the use of the questionnaire.

Data Analysis

The data analysis is divided into four parts. In the first part, the BMI of children and parents was calculated according to the following formula: BMI = weight (kg) / height (m)2. Parental and children BMI was calculated based on self-reported height and body weight. The obtained values of the nutritional status were calculated according to the BMI - to-age z-score values. The normality of the distribution was tested by the Kolmogorov-Smirnov test.

The second part of the data analysis refers to determining differences in nutritional status according to gender in girls and boys, and differences by gender were determined using the Mann-Whitney U test.

DOI 10.56886/itspa.251201

In the third part of the data analysis, correlation analysis was used to (1) determine the association between physical activity and inactivity with BMI in girls and boys, (2) for the relationships between variables that assess the nutritional status and physical activity of parents, and (3) for the relationships between variables that assess the nutritional status of children and parents and the variables of physical activity and inactivity in girls and boys and the physical activity of parents.

The fourth part of the data analysis refers to all qualitative variables about children's eating habits for which frequency analysis was used.

Results and Discussion

According to the BMI-to-age z-score values, 53.6% of boys and 59.63% of girls have a normal level of nutrition. The results in Figure 1 show that there is a higher percentage of boys with excess body weight (13.6%) and obesity (8.8%) compared to girls.

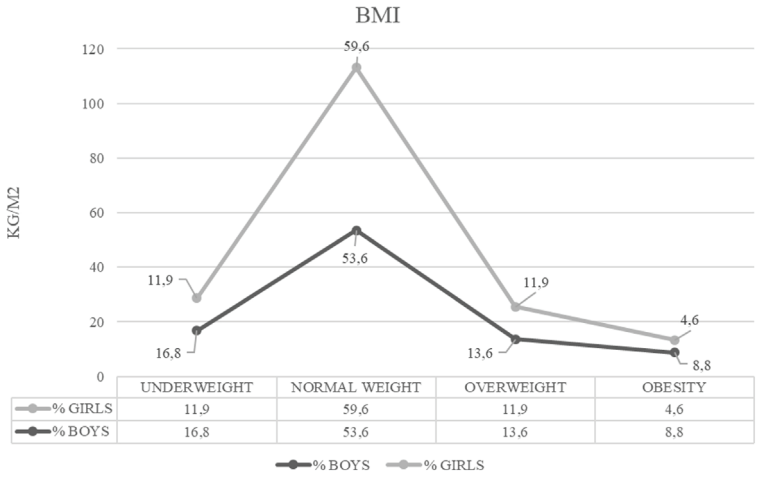


FIGURE 1. BMI in girls and boys

Statistically significant differences in the level of nutrition according to gender were analyzed with the Mann-Whitney U test, since the results of the Kolmogorov-Smirnov test had confirmed that the distributions of the mentioned variables significantly deviated from normal. The results show that there is no statistically significant difference between girls and boys in the level of nutrition according to the BMI results.

Table 1. Differences in BMI index between girls and boys (Man-Whitney U test)

	MED-QR Girls	MED-QR Boys	Z	p-level
BMI	15.23 (2.22)	15.47 (2.29)	-0.95	0.34

Note. MED- QR - median-quartile rank; Z - z value; p - statistical significance

Of the total number of children included in the study, 22.4% of boys and 16.5% of girls aged 6 years were found to be overweight and obese. These results confirm previously obtained findings from the fifth round of the Childhood Obesity Surveillance Initiative (WHO, 2022) and the results obtained in the population of Croatian preschoolers, according to which 21.5% of children were found to be overweight and obese, with no significant differences in age or gender. This indicates a trend of increasing overweight and obesity in Croatia (Bučan Nenadić et al., 2025; Farkaš et al., 2015; Musić Milanović et al., 2020). Childhood overweight and obesity is associated with an increased risk of type 2 diabetes mellitus, metabolic syndrome and cardiovascular risk factors, and children are also exposed to other psychosocial consequences such as low self-esteem, body image disorders, depression, stigmatization, marginalization, etc. (Garrido-Miguel et al., 2019; Xu and Xue, 2016).

The level of physical activity of preschool children was assessed using the NPAQ, and correlation analysis was used to determine the correlation of physical activity and inactivity with BMI. The results of the correlation analysis for the variables physical activity (PA) and inactivity (SA) with BMI are shown in Table 2.

Table 2. Spearman's correlation coefficient between variables assessing nutritional status and physical activity and inactivity variables in girls and boys

Variables	PA	PI
BMI	-0.14*	0.16*

Note. PA - physical activity, PI - physical inactivity. * - p<0,05

Spearman's correlation coefficient between variables assessing nutritional status, PA and PI in girls and boys shows statistical significance, although the level of their correlation is low. PA is statistically significantly correlated with BMI (r=-0.14), indicating that BMI is lower in children who achieved higher physical activity values, i.e., in children who were more physically active. PI has a statistically significant correlation with BMI (r=0.16), indicating that children who spent more

time in sedentary activities have a higher nutritional status, i.e., higher BMI. Published research on the level of physical activity and sedentary behavior in preschool children shows that physical activity is generally lower and that sedentary behavior is generally higher than the recommended time values (Vukelja, Milanović & Šalaj, 2022). While some studies report impaired fitness and motor skills among overweight/obese preschoolers compared to normal-weight peers, others found no differences based on the weight status or BMI (Rico-González et al., 2024; Ma & Luo, 2023). The majority of studies prove that physical activity is associated with better fitness performances in preschool children (Serrano-Gallén et al., 2022), but previous research was mostly conducted on a sample of 3-to 6-year-old children. The correlations were stronger in older than in younger children, therefore the statistically significant correlation between BMI, PA and PI in this study can be explained by the fact that only children aged 6 were included in this study, which is why a low, but still statistically significant correlation of physical activity with the BMI was confirmed.

Table 3. Parents' BMI

BMI	N	Mean	Minimum	Maximum	Std.Dev.
PARENTS	234	23.73	15.79	39.65	3.72

Note. N – number of participants; Mean – average result; Minimum – lowest result; Maximum – highest result; Std.Dev. – standard deviation of the result from the arithmetic mean

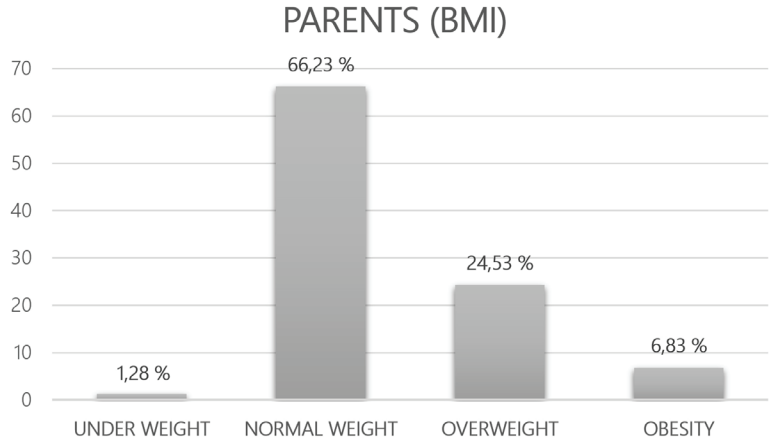


FIGURE 2. Parents BMIs

According to the parents' BMI values, it can be concluded that 66.23% of parents have a normal level of nutrition, 1.28% of parents are underweight, 24.53% have excessive body mass, and 6.83% of parents are obese. Previous research on the adult population in Croatia has shown that only 33.9% of adults have a normal BMI, while almost two-thirds (64.8%) are classified as overweight or obese (Maltarić, 2025). The data obtained in this study indicate a higher percentage of normal levels of nutrition and a lower percentage of overweight and obese compared to the same population.

Table 4. Spearman correlation coefficient between variables assessing the nutritional status and physical activity of parents

Variables	PA parents
BMI parents	-0.02

Note. PA parents - physical activity of parents

Spearman's correlation coefficient between variables assessing the nutritional status and physical activity of parents shows that there is no statistically significant correlation between these variables. A large number of studies show that there is a negative correlation between the level of physical activity and BMI in adults, i.e., a higher level of physical activity is associated with a lower BMI (Cleven, 2023; Muti et al., 2023; Tiusanen, 2023). A sedentary lifestyle and demographic factors significantly influence the aforementioned relationship, and the intensity of activity (moderate to vigorous physical activity) is a significant factor.

Table 5. Spearman correlation coefficient between variables assessing the nutritional status of children and parents, PA and PI in girls and boys and the physical activity of parents (MET)

Variables	BMI kids	PA kids	PI kids
PA parents	0.21*	-0.11	0.08
BMI parents	0.22*	-0.16*	0.17*

Note. PA parents - physical activity of parents, PA kids – children`s physical activity, PI - children`s physical inactivity. * - p<0,05

DOI 10.56886/itspa.251201

Correlation analysis between variables assessing the nutritional status of children and parents, PA and PI in girls and boys and the MET shows that there is a statistically significant correlation (Table 5), but the level of their correlation is low. This confirms the results of previous research according to which high adult activity increased odds of children being active (Grant et al., 2018). The obtained results show that there is a statistically significant correlation between the BMI of children and parents, as well as the children's BMI and the level of parents' physical activity. The BMI of parents is statistically significantly correlated with the PA and PI in girls and boys, which confirms previous findings that children of active parents were less likely to be overweight and obese (Erkelenz et al., 2014). The level of physical activity in preschool age is influenced by numerous factors, but one of the most important is the BMI of the father, i.e., fathers who have a lower BMI also have the most active children (Finn et al., 2002).

The frequency analysis of children's eating habits (Child Feeding Questionnaire) shows that 62.2% of parents believe that they are always responsible for their children's nutrition, while 30.2% of parents are often responsible for their children's nutrition. There are 42.7% of parents who always decide on the size of their child's meals. As many as 43.9% of parents always decide on the mandatory consumption of certain foods, and 29% of parents often do so. The results confirm previous findings that parents have a crucial role in children's eating habits and health, and parental feeding practices in the early years contribute to the development of children's eating in terms of quantity and quality of daily energy intake, especially during mealtime (Power et al., 2019; de Souza Rezende et al., 2019). The assessment of the children's nutritional status shows that most parents consider their children to be normally nourished, i.e., 94.6% of parents consider their child to be of normal body weight, 2.1% consider their child to be underweight, and 1.7% to be overweight. Parents' concern about obesity is very low. Namely, 70.1% of parents do not express concern, and only 4.2% are concerned about the possible development of obesity. There are 59.2% of parents who monitor their children's intake of the so-called unhealthy foods, i.e., 59.2% of parents very often control their children's intake of sweets, 27.1% do so often, and 31.3% of parents always control their children's intake of snacks. Fatty food intake is often monitored by 53.4% of parents, and always by 31.7%.

The percentage of parents who do not use food as a reward is 47.3%, while 50.6% of parents do not use their child's favorite food as a reward for appropriate behavior. As many as 61.1% of parents do not insist that the child always eat all the food offered, and 62.6% of parents respect the child's appetite, i.e., do not force the child to eat the entire meal if they say they are not hungry. Early and preschool children who attend kindergarten spend a large part of their waking hours in kindergarten, and 81% of parents state that they are not concerned about the fact that their children eat too much when their parents are not with them. The above indicates that parents are familiar with the menus and nutrition in kindergartens, which is organized in such a way that menu creation and food control are carried out by authorized experts. Parents have a high level of control over their children's diet, which can be useful for creating healthy habits and a proper, balanced diet for early and preschool children.

Conclusion

Based on the findings of the results of this research, it can be concluded that parents play a key role in creating healthy lifestyle habits and encouraging physical activity of preschool children. There was no statistically significant difference between girls and boys in the level of nutrition according to BMI results, but it was confirmed that more physically active children had lower BMI, while children who spent more time in sedentary activities had higher BMI. A significant correlation was found between children and parents' BMI, and children's BMI and the level of physical activity of parents. Parents' BMI is statistically significantly correlated with the PA and PI in girls and boys, which confirms previous findings that children of active parents were less likely to be overweight and obese. The results show that parents decide on the size of meals and the choice of foods included in the daily nutrition of children and are satisfied with the quality and size of meals that children consume during their stay in kindergartens.

The main limitation of this study is that physical activity and sedentary behavior were estimated using questionnaires filled out by the parents of preschool children. Children spend part of weekdays in kindergarten and parents are not present during that time in daycare, so there is a possibility of under- or overestimation of physical activity assessment by parents.

References

Benassi, L., Blažević, I., & Janković, D. (2021). Physical activity and nutrition of children in primary education. *Economic Research, 34* (1), 1–14. https://doi.org/10.1080/1331677X.2021.1962384

Brown, R., & Ogden, J. (2004). Children's eating attitudes and behavior: A study of the modeling and control theories of parental influence. *Health Education Research, 19* (3), 261–271. https://doi.org/10.1093/her/cyg040

Bučan Nenadić, D., Štrkalj, L., Zloić, K., Matana, A., Selak, M., Smoljo, M., Vlašić, A., Peričić, VI, & Kolak Gaurina, E. (2025). Laying the groundwork for health: Eating behavior and physical activity in preschoolers in Split-Dalmatia County, Croatia. *Children, 12* (6), 699. https://doi.org/10.3390/children12060699

Buratta, L., Delvecchio, E., Germani, A., & Mazzeschi, C. (2021). Parental feeding practices across child's weight status: Evidence of the Italian validation of the Child Feeding Questionnaire. *Public Health Nutrition, 24* (6), 1256–1264. https://doi.org/10.1017/S136898002000381X

Carson, V., Hunter, S., Kuzik, N., Wiebe, SA, Spence, JC, Friedman, A., Tremblay, MS, Slater, L., & Hinkley, T. (2016). Systematic review of physical activity and cognitive development in early childhood. *Journal of Science and Medicine in Sport, 19* (7), 573–580. https://doi.org/10.1016/j.jPIms.2015.07.011

Caspersen, CJ, Powell, KE, & Christenson, GM (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports, 100* (2), 126–131. PMID: 3920711; PMCID: PMC1424733.

Cleven, L., Syrjanen, JA, Geda, YE, ... & Kremers, S. (2023). Association between physical activity and longitudinal change in body mass index in middle-aged and older adults. *BMC Public Health, 23* , 202. https://doi.org/10.1186/s12889-023-15119-7

Erkelenz, N., Kobel, S., Kettner, S., Drenow atz, C., & Steinacker,

JM (2014). Parental activity as influence on children's BMI percentiles and physical activity. *Journal of Sports Science and Medicine, 13* (3), 645–650. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4126304/

Farkaš, K., Tomac, A., Petrić, V., & Novak, A. (2015). Anthropometric characteristics and obesity indicators among preschool children in an urban area in Croatia. *Collegium Antropologicum, 39* (2), 419–424.

Finn, K., Johannsen, N., & Specker, B. (2002). Factors associated with physical activity in preschool children. *Journal of Pediatrics, 140* (1), 81–85. https://doi.org/10.1067/mpd.2002.120693

Garrido-Miguel, M., Oliveira, A., Cavero-Redondo, I., Alvarez-Bueno, C., Pozuelo-Carrascosa, DP, Soriano-Cano, A., & Martinez-Vizcaino, V. (2019). Prevalence of overweight and obesity among European preschool children: A systematic review and meta-regression by food group consumption. *Nutrients*, 11 (7), 1698. https://doi.org/10.3390/nu11071698

Grant, VM, Tomayko, EJ, Prince, RJ, Cronin, K., & Adams, A. (2018). Understanding correlates of physical activity in American Indian families: The Healthy Children Strong Families-2 study. *Journal of Physical Activity & Health, 15* (11), 866–873. https://doi.org/10.1123/jpah.2017-0584

Klarin, M. (2017). *Psychology of Children's Play.* Zadar: University of Zadar.

Ma, FF, & Luo, DM (2023). Relationships between physical activity, fundamental motor skills, and body mass index in preschool children. *Frontiers in Public Health, 11* , 1094168. https://doi.org/10.3389/fpubh.2023.1094168

Maltarić, M., Kolak, M., Kolarić, B., Vranešić Bender, D., & Gajdoš Kljusurić, J. (2025). Cross-European patterns of obesity: Where does Croatia stand? Descriptive analysis of waves 2015–2022 of the Survey of Health, Aging and Retirement in Europe (SHARE) including adults aged over 50. *Obesity, 5* (3), 66. https://doi.org/10.3390/obesities5030066

Milanović, SM, Morović, ML, Bukal, D., Križan, H., Buoncristiano, M., & Breda, J. (2020). Regional and sociodemographic determinants of the prevalence of overweight and obesity in children aged 7–9 years in Croatia. *Acta Clinica Croatica, 59* (3), 303–311.

Muti, M., Ware, LJ, Micklesfield, LK, Ramsay, M., Agongo, G., Boua, PR, Kisiangani, I., Cook, I., Gómez-Olivé, FX, Crowther, NJ, Kabudula, C., Norris, SA, & Chikowore, T. (2023). Physical activity and its association with body mass index: A cross-sectional analysis in middle-aged adults from 4 Sub-Saharan African countries. *Journal of Physical Activity & Health, 20* (3), 217–225. https://doi.org/10.1123/jpah.2022-0539

Pedišić, Ž., Strika, M., Matolić, T., … & Jurakić, D. (2023). Physical Activity of Children and Adolescents in Croatia: A Global Matrix 4.0 Systematic Review of Its Prevalence and Associated Personal, Social, Environmental, and Policy Factors. *Journal of Physical Activity and Health*, 20(6), 487-499. https://journals.humankinetics.com/view/journals/jpah/20/6/article-p487.xml

Power, TG, Johnson, SL, Beck, AD, ... & Hughes, SO (2019). The Food Parenting Inventory: Factor structure, reliability, and validity in a low-income, Latina sample. *Appetite, 134* , 111–119. https://doi.org/10.1016/j.appet.2018.12.032

Rico-González, M., Ardigò, LP, Ramírez-Arroyo, AP, & Gómez-Carmona, CD (2024). Anthropometric influence on preschool children's physical fitness and motor skills: A systematic review. *Journal of Functional Morphology and Kinesiology, 9* (2), 95. https://doi.org/10.3390/jfmk9020095

Serrano-Gallén, G., Arias-Palencia, NM, González-Víllora, S., Gil-López, V., & Solera-Martínez, M. (2022). The relationship between physical activity, physical fitness and fatness in 3–6 year old boys and girls: A cross-sectional study. *Translational Pediatrics, 11* (7), 1095–1104. https://doi.org/10.21037/tp-22-30

Sunda, M., Brkic, M., & Blazevic, I. (2025). Association Between Body Morphology and Motor and Functional Abilities in Preschool Children. Sport Mont, 23(3), Ahead of Print. doi: 10.26773/smj.251003

Taylor, LJ, Gallagher, M., & McCullough, FSW (2004). The role of parental influence and additional factors in the determination of food choices for pre-school children. *International Journal of Consumer Studies, 28* (4), 337–346. https://doi.org/10.1111/j.1470-6431.2004.00391.x

Tiusanen, R., Saltychev, M., Ervasti, J., Kivimäki, M., Pentti, J., Stenholm, S., & Vahtera, J. (2022). Concurrent changes in physical activity and body mass index among 66,852 public sector employees over a 16-year follow-up: Multitrajectory analysis of a cohort study in Finland. *BMJ Open, 12* (2), e057692. https://doi.org/10.1136/bmjopen-2021-057692

Tomac, Z., Vidranski, T., & Ciglar, J. (2015). Physical activity of children during regular stay in preschool institution. *Medical Jadertina, 45* (3–4), 97–104. https://hrcak.srce.hr/clanak/393265

Vukelja, M., Milanović, D., & Salaj, S. (2022). Physical activity and sedentary behavior in Croatian preschool children: A population-based study. *Montenegrin Journal of Sports Science and Medicine, 11* (1), 37–42. https://doi.org/10.26773/mjssm.220304

World Health Organization. (2018). *Global action plan on physical activity 2018–2030: More active people for a healthier world.* Geneva: World Health Organization.

World Health Organization. (2019). *Guidelines on physical activity, sedentary behavior and sleep for children under 5 years of age.* Geneva: World Health Organization.

WHO Regional Office for Europe. (2022). *Report on the fifth round of data collection, 2018–2020: WHO European Childhood Obesity Surveillance Initiative (COSI).* Copenhagen, Denmark: WHO Regional Office for Europe.

Xu, S., & Xue, Y. (2016). Pediatric obesity: Causes, symptoms, prevention and treatment. *Experimental and Therapeutic Medicine, 11* (1), 15–20. https://doi.org/10.3892/etm.2015.2853

DOI 10.56886/itspa.251201

ORIGINAL SCIENTIFIC PAPER

Eccentric Training Effects on Hamstring Strength in Elite Pole Vaulters: A Case Study

Danijela Kuna[1], Ivan Paravac[1], Nikolina Uznik[1]

Affiliations: [1]Josip Juraj Strossmayer University, Faculty of Kinesiology Osijek, Osijek, Croatia

Correspondence: D. Kuna. Faculty of Kinesiology Osijek, Drinska 16a, 31000 Osijek, Hrvatska. E-mail: dkuna@kifos.hr

Abstract

Hamstring muscle injuries are among the most frequent injuries in sport and have a significant impact on performance and continuity of the training process. Their occurrence is particularly pronounced in sports involving sprinting and explosive movements, while the recurrence rate within the first year after injury is extremely high. Eccentric training is recognized as a key method in prevention and rehabilitation because it leads to specific adaptations such as increased eccentric strength, lengthening of biceps femoris muscle fascicles, and improved neuromuscular control. This study, conducted as a case study on a homogeneous group of elite pole vaulters, aimed to examine the effects of an eleven-week eccentric program on isometric strength of hamstring muscles at knee flexion angles of 10°, 45° and 90°. The sample included five senior-level athletes, multiple participants in national and international competitions. The training program included Nordic hamstring exercise, Romanian deadlift, single-leg Romanian deadlift, and isolation exercises on machines with emphasis on the eccentric phase of movement. Results showed that although differences between initial and final measurements were not statistically significant ($p > .05$), effect sizes indicated moderate-to-large effects. The greatest increase was recorded at the 10° angle ($r = .78$). These findings are in line with previous research confirming that eccentric training increases muscle strength and reduces injury risk, thus further emphasizing its importance in planning and implementing training programs.

Keywords: *eccentric training, injury prevention, isometric strength, sprint, the hamstring muscles*

Introduction

Hamstring muscle injuries are among the most common sports injuries, particularly in disciplines requiring sprinting, rapid changes of direction, and explosive jumps. Epidemiological data show that hamstring injuries account for 12-16% of all sports injuries in elite sports (Ekstrand et al., 2011; van Dyk et al., 2019), being particularly common in soccer, athletics, and rugby. In soccer, the incidence can reach 1.2 injuries per 1,000 exposure hours (Ekstrand et al., 2016). These injuries are characterized by prolonged recovery, high recurrence rates up to 30% within the first 12 months (Opar et al., 2012), and negative impact on sports performance and training continuity. Prevention and rehabilitation of the hamstring injuries therefore remain major challenges in modern sports training.

The biomechanical role of the hamstring muscles further explains their vulnerability. During the late swing phase in sprinting, the hamstring muscles are simultaneously maximally stretched and strongly activated in eccentric mode to decelerate the lower leg and prepare the foot for ground contact (Chumanov et al., 2007; Schache et al., 2013). At that moment, forces acting on the muscles can exceed eight times body weight (Bramah et al., 2024), creating conditions for acute strains and ruptures. Additional risk arises from muscle asymmetries, shorter fascicles of the biceps femoris muscle, and reduced eccentric strength, which are factors identified in prospective studies as injury predictors (Timmins et al., 2016). Furthermore, specific knee flexion angles during sprinting and swing phase are crucial for hamstring loading, where the greatest biomechanical load and injury risk occur at positions close to knee extension and an angle of approximately 10° (Kellis & Blazevich, 2022).

Eccentric training in recent decades has been recognized

Received: 30 October 2025 | Accepted after revision: 09 December 2025 | Early access publication date: 15 December 2025 | Final publication date: 15 December 2025

Conflict of interest: None declared.

as an effective method for reducing hamstring injury risk. Its effectiveness is based on adaptations such as increased eccentric strength, fascicle lengthening, and improved neuromuscular coordination (Franchi et al., 2017). Additionally, eccentric contraction enable generation of greater forces with lower metabolic cost compared to concentric contractions (Roig et al., 2009), making them particularly suitable for high-intensity sports. Specific muscle adaptations, including changes in fascicle architecture and increased isometric strength at different knee angles, are key for maintaining functional stability and reducing injury risk during intensive sprint phases.

The preventive value of eccentric training has been proven in numerous studies. The Nordic Hamstring Exercise (NHE) shows significant reduction in hamstring injury risk and recurrences (Petersen et al., 2011; van Dyk et al., 2019). Systematic reviews and meta-analyses confirm that regular implementation of NHE in training programs reduces injury incidence regardless of competition level (Al Attar et al., 2017). Furthermore, eccentric training contributes to increased strength, sprint speed, and jumping ability (de Keijzer et al., 2022). Despite strong evidence, practice shows that eccentric training is still insufficiently applied or used in insufficient volume and intensity, particularly during the competitive period (Bahr et al., 2015). This emphasizes the need for additional research on optimal protocols, particularly in athlete populations where hamstring injuries are common and can have serious impact on performance.

Therefore, the aim of this study was to examine the effect of an eleven-week eccentric training program on isometric strength of the hamstring muscles at different knee flexion angles (10°, 45° and 90°) in elite athletes specialized in pole vault.

Methods

Participants

Five elite athletes specialized in pole vault participated in the study, with a mean age of 26 years, national-level medals, and experience competing in international competitions. All participants were in the senior category and had no current hamstring injuries at the time of the study. Given the small sample and specificity of participants, the study was designed as a case study. During the preparation process, special attention was directed to eccentric training applied to selected muscle groups, including hamstring muscles.

Variables and Instruments

Isometric strength of the posterior thigh was assessed at three knee flexion positions: 90° (JAK90), 45° (JAK45) and 10° (JAK10). For assessing isometric strength, a K-Pull dynamometer (Kinvent®, Montpellier, France) was used, and a goniometer (Baseline®, Fabrication Enterprises Inc., White Plains, NY, USA) was used for precise adjustment of knee flexion angle. Measurements were performed exclusively on the take-off leg of participants in initial and final testing. For analysis, the maximum achieved force value expressed in kilograms (kg) was used. Intrarater reliability of measurements was high (ICC > .90) for all three flexion angles.

Training Program

Participants regularly performed eccentric exercises targeting hamstring muscles during the eleven-week period. The main component was the Nordic hamstring exercise (NHE) which they performed in three sets of 5-8 repetitions, with emphasis on controlled forward lowering with ankle fixation by a partner; the eccentric phase lasted less than one second, and load was progressively increased by adding weight or increasing movement amplitude. In addition to NHE, participants performed Romanian deadlift (RDL) in 3-4 sets of 6-10 repetitions, using body weight or additional load of 20-40 kg, where the slow eccentric phase during barbell lowering activated gluteal muscles and trunk stabilization. Single-leg Romanian deadlift was performed in 2-3 sets of 6-8 repetitions per leg, aiming to reduce asymmetries and improve unilateral control. Additionally, eccentric isolation exercises – seated and lying hamstring curl – were performed in exclusively eccentric regime, in 2-3 sets of 8-12 repetitions, where each eccentric phase was shorter than one second; load was increased when the participant could control the movement longer than prescribed time. The program was supplemented with a two-week maximal sprint training, recognized as an important factor in hamstring injury prevention (Gómez-Piqueras et al., 2024). Throughout the entire period, researchers continuously provided demonstrations, corrections, and individual instructions, and exercise intensity was adjusted based on subjective feeling of fatigue and progress assessment.

Research Protocol

Initial testing was conducted in the second week after a training break, on condition that participants arrived rested. All participants performed standardized warm-up including three isometric contractions (50%, 75% and 90% of maximal voluntary contraction). After warm-up, maximal isometric strength was measured at three knee flexion angles (10°, 45° and 90°). Participants were in prone position, and the tested leg was positioned at the desired angle using a goniometer. The dynamometer was attached to the distal part of the lower leg. On verbal command, participants performed maximal isometric contraction lasting 1-2 seconds. Two measurements were taken for each angle, and the better value was included in analysis. Rest between measurements was one minute. After initial testing, an eleven-week eccentric training program was conducted, which included Nordic hamstring exercise, Romanian deadlift, single-leg Romanian deadlift, and eccentric isolation exercises for hamstring muscles. All exercises were performed with eccentric phase shorter than 1 second, with load increase when participant could control movement longer than prescribed time. The program included two weeks of maximal sprint training, recognized as an important factor in hamstring injury prevention. During the program, continuous demonstrations, corrections, and instructions were provided, and intensity was adjusted according to subjective feeling of fatigue and researcher assessment. Final testing was conducted one week before the start of the competitive season, applying the same protocol as at the beginning of the study. The study was conducted in accordance with the Helsinki Declaration and approved by the Ethics Committee of the Faculty of Kinesiology Osijek (CLASS: 029-01/25-01/05, NUMBER: 2158-110-01-25-33).

Statistical Analysis

Statistical analysis included descriptive statistics including mean, standard deviation, minimum and maximum values. To examine differences between initial and final test variables, Wilcoxon test for paired samples was applied due to small sample size and potential deviation from normal distribution.

DOI 10.56886/itspa.251202

Effect size was estimated using Cohen's r coefficient, where values of .30, .50 and .80 were interpreted as small, medium, and large effect sizes (Cohen, 1988). Collected data were statistically processed using "IBM SPSS Statistics 20.0". Significance level was set at $p < .05$.

Results

Descriptive indicators of isometric strength at three knee flexion angles (10°, 45° and 90°) are presented in Table 1. In initial measurement, mean values ranged from 31.46 kg (JAK90) to 67.40 kg (JAK10), with relatively low standard deviations, indicating a homogeneous group of participants. In final testing, strength increase was recorded at all angles. The greatest increase was observed for JAK10 (from 67.40 to 79.62 kg), followed by JAK45 (from 53.96 to 58.06 kg), while moderate increase was recorded for JAK90 (from 31.46 to 34.86 kg), with somewhat greater variability of results.

Table 1. Descriptive indicators of initial and final measurement of examined variables

Variable	Measurement	Min	Max	M	SD	Median
JAK90	I	27.8	33.6	31.46	2.3	31.9
	F	22.7	39.6	34.86	6.89	37.3
JAK45	I	43.6	62.8	53.96	7.07	54.2
	F	40.1	69.2	58.06	11.14	60.8
JAK10	I	60.6	73.6	67.4	5.65	65.5
	F	69.2	90.1	79.62	6.84	78.6

Note: M = mean; SD = standard deviation; Max = achieved maximum; Min = achieved minimum; I = initial measurement; F = final measurement; JAK10 = isometric strength at knee angle of 10°, JAK45 = isometric strength at knee angle of 45°, JAK90 = isometric strength at knee angle of 90°

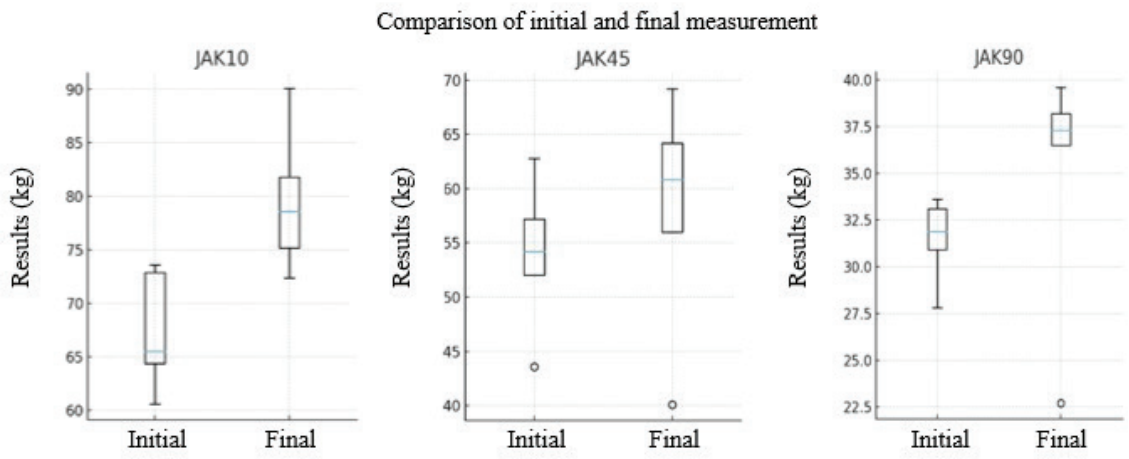
To examine differences between initial and final measurements, Wilcoxon nonparametric test for dependent samples was performed (Table 2). None of the analyzed variables showed statistically significant differences ($p > .05$). However, effect size values indicated moderate to large effects: JAK90 ($r = 0.42$), JAK45 ($r = 0.54$) and JAK10 ($r = 0.78$). The most pronounced effect was recorded for JAK10, indicating a potentially important practical shift in isometric strength at the 10° angle, although the difference was not statistically confirmed due to small sample size ($N = 5$).

Table 2. Results of Wilcoxon nonparametric test for observed variables

Variable	p	Z	Effect size (r)
JAK90	.345	-.94	0.42
JAK45	.225	-1.21	0.54
JAK10	.80	-1.75	0.78

Note. * $p < 0.05$; ** $p < 0.01$*

Graphical presentation (Graph 1) enables visual comparison of initial and final values for each observed variable. For variable JAK10, a clear shift of result distribution toward higher values in final measurement is visible, confirming the observed large effect ($r = 0.78$). For variable JAK45, a mild increase in mean values is present, but also greater variability with one lower result in final testing, explaining the absence of statistical significance. For variable JAK90, results also showed tendency of increase, although greater dispersion of obtained values appeared in final measurement compared to initial measurement. The presented graphical patterns further support the finding that despite lack of statistical significance, changes can be practically relevant, particularly for JAK10.



GRAPH 1. Graphical presentation of differences between initial and final testing of isometric strength at angles of 10°, 45° and 90°

Discussion

Study results show that although no statistically significant difference in isometric knee flexor strength (JAK10, JAK45, JAK90) was determined between initial and final testing, recorded growth trends and effect size values indicate moderate-to-large effects, particularly at the 10° angle. This finding is crucial as it suggests that absence of statistical significance is not necessarily a consequence of lack of real effect, but is more likely the result of small number of participants (N = 5), which inherently reduces statistical power and makes detection of differences difficult despite objectively existing adaptations – a phenomenon well known in statistical literature as type II error (Button et al., 2013). Strength increase at all examined angles, albeit non-significant, is consistent with previous research confirming effectiveness of eccentric training in hamstring muscle strength development. Numerous studies in sports kinesiology show that eccentric training programs, including Nordic hamstring exercise and various Romanian deadlift (RDL) variations, consistently result in significant increase in eccentric strength and favorable architectural changes in muscles (Mjølsnes et al., 2004; Roig et al., 2009). A meta-analysis including 20 studies with total of 433 participants clearly showed that eccentric training results in on average 35% greater increase in muscle strength compared to concentric contraction, while changes in muscle mass were comparable between both contraction (Roig et al., 2009). These results emphasize that eccentric training is superior for muscle strength development, which is particularly important in sports where high eccentric forces are decisive for performance, such as sprinting and jumping.

The finding of strength increase at small flexion angles (10°) is particularly interesting and important, as this position is biomechanically most loaded precisely in the late swing phase during sprinting and is strongly associated with hamstring injury risk (Chumanov et al., 2007). Previous research has shown that greater eccentric strength and favorable architectural adaptations in muscle, particularly fascicle length, contribute to injury risk reduction (Guex et al., 2016; Maroto-Izquierdo et al., 2023). One prospective cohort study on 152 elite soccer players showed that players with shorter fascicles and lower eccentric strength had significantly higher hamstring injury incidence during the season, directly confirming that increased fascicle length, systematically achieved through eccentric training, represents a key protective mechanism against injuries (Timmins et al., 2016). Although this study did not directly measure fascicle length, significant increase in isometric strength at small angles can be interpreted as an indirect indicator of favorable architectural adaptations in muscle, particularly considering that eccentric training promotes the process of sarcomerogenesis, i.e., addition of new sarcomeres in series within muscle fibers, thereby lengthening the optimal fiber length for force generation (Butterfield & Herzog, 2006). This adaptation not only reduces injury risk but also increases muscle's ability to generate high force in very short time and at great length, which is crucial in sprinting at maximal speeds. In contrast, concentric training primarily promotes transverse hypertrophy but has lesser effect on increasing muscle working range and ability to generate force at high shortening speeds (Franchi et al., 2017).

An important role in these adaptations is played by titin protein, which acts as a molecular spring within the sarcomere and enables muscles to withstand large mechanical stresses during eccentric contractions (Hessel et al., 2017). Titin contributes to both passive muscle elasticity and active force transmission during contraction, making it crucial for muscle protection from damage at extreme loads. High-velocity eccentric training – such as downhill sprinting, Nordic hamstring curls, or plyometric jumps with emphasized eccentric phase – is particularly effective for developing this adaptation (Douglas et al., 2017). Clinical applicability of these findings is reflected in prevention and rehabilitation of hamstring injuries. Petersen et al. (2011) in a cluster-randomized controlled trial on male soccer players determined that introducing Nordic hamstring exercise during the season reduces risk of acute hamstring injuries by more than 50%. Meta-analysis by van Dyk et al. (2019) including 8,459 athletes confirmed that including NHE in prevention programs halves injury rate and significantly reduces recurrences. In rehabilitation context, Askling et al. (2014) showed that athletes performing lengthening exercises under load (L-protocol) return to training and competition significantly faster, with lower recurrence rate, confirming the advantage of eccentric approach also in post-injury rehabilitation.

Comparisons of eccentric and concentric methods in terms of sports performance also show benefit of eccentric approach. Wagle et al. (2017) highlighted that protocols with emphasized or supramaximal eccentric loading result in greater gains in maximal strength, rate of force development, and explosive abilities such as sprinting and jumping, compared to classic concentric protocols. Supramaximal eccentric contraction, including eccentric loading above 100% of concentric 1RM, have proven useful not only for injury prevention and rehabilitation but also for enhancing sports performance, because they induce very large forces and mechanical stresses that more faithfully replicate conditions in the field. Similarly, de Keijzer et al. (2022) in a systematic review of flywheel training showed that this form of eccentric overload significantly improves strength, power, and performance in sports tasks.

As main limitations of this study should be noted the small sample of participants (N = 5), which inherently reduces statistical power and prevents broader generalization of results, although case studies can provide valuable clinical insights, particularly in athlete populations with high demands and rare available samples (Yin, 2014). Furthermore, only isometric measurements were used, while architectural changes such as fascicle length or changes in neuromuscular activity (EMG) were not monitored, preventing more direct conclusions about structural adaptations. Also, the intervention duration of 11 weeks is relatively short compared to long-term adaptations recorded in longitudinal studies, and introduction of a two-week sprint training, although potentially beneficial, can be a confounding variable affecting results. Future research should include larger samples, longer follow-up periods, and broader spectrum of measurement instruments such as ultrasound sonography for fascicle evaluation and EMG for neuromuscular activity assessment, along with continuous monitoring of injury incidence during the competitive season, to obtain a more comprehensive picture of adaptations. Despite mentioned limitations, results of this study provide clear support for the claim that eccentric training is an essential component of the training process for athletes exposed to high demands of sprinting and jumping, with potential for injury reduction, accelerated rehabilitation, and enhanced sports performance when applied in progressive and individualized manner.

DOI 10.56886/itspa.251202

Conclusion

The conducted study indicates that eccentric training leads to functionally significant increase in isometric knee flexor strength, with the most pronounced effect at 10° flexion angle, which is biomechanically critical during the late swing phase of sprinting. Obtained results suggest improvement in eccentric strength, neuromuscular control, and potentially favorable adaptations in muscle structure, indicating practical effectiveness of eccentric training and injury risk reduction. The practical implication for coaches and athletes is that eccentric exercises should be systematically included in preparatory and competitive cycles, with gradual and progressive dosing, and individualized adaptation for athletes of different levels and specific sport demands. Future research should include larger samples, longer follow-up periods, and combination of biomechanical, architectural, and clinical measures to obtain a more comprehensive picture of eccentric training effects.

References

Al Attar, W. S. A., Soomro, N., Sinclair, P. J., Pappas, E., & Sanders, R. H. (2017). Effect of injury prevention programs that include the Nordic hamstring exercise on hamstring injury rates in soccer players: A systematic review and meta-analysis. *Sports Medicine*, *47*(5), 907–916. https://doi.org/10.1007/s40279-016-0638-2

Askling, C. M., Tengvar, M., Tarassova, O., & Thorstensson, A. (2014). Acute hamstring injuries in Swedish elite sprinters and jumpers: a prospective randomised controlled clinical trial comparing two rehabilitation protocols. *British Journal of Sports Medicine*, *48*(7), 532–539. https://doi.org/10.1136/bjsports-2013-093214

Bahr, R., Thorborg, K., & Ekstrand, J. (2015). Evidence-based hamstring injury prevention is not adopted by the majority of Champions League or Norwegian Premier League football teams: The Nordic Hamstring survey. *British Journal of Sports Medicine*, *49*(22), 1466–1471. https://doi.org/10.1136/bjsports-2015-094826

de Keijzer, K. L., Gonzalez, J. R., & Beato, M. (2022). The effect of flywheel training on strength and physical capacities in sporting and healthy populations: An umbrella review. *PloS one*, *17*(2), e0264375. https://doi.org/10.1371/journal.pone.0264375

Bramah, C., Mendiguchia, J., Dos'Santos, T., & Morin, J. B. (2024). Exploring the Role of Sprint Biomechanics in Hamstring Strain Injuries: A Current Opinion on Existing Concepts and Evidence. *Sports medicine (Auckland, N.Z.)*, *54*(4), 783–793. https://doi.org/10.1007/s40279-023-01925-x

Button, K. S., Ioannidis, J. P. A., Mokrysz, C., Nosek, B. A., Flint, J., Robinson, E. S. J., & Munafò, M. R. (2013). Power failure: Why small sample size undermines the reliability of neuroscience. *Nature Reviews Neuroscience*, *14*(5), 365–376. https://doi.org/10.1038/nrn3475

Butterfield, T. A., & Herzog, W. (2006). The magnitude of muscle strain does not influence serial sarcomere number adaptations following eccentric exercise. *Pflügers Archiv: European Journal of Physiology*, *451*(5), 688–700. https://doi.org/10.1007/s00424-005-1503-6

Chumanov, E. S., Heiderscheit, B. C., & Thelen, D. G. (2007). The effect of speed and influence of individual muscles on hamstring mechanics during the swing phase of sprinting. *Journal of biomechanics*, *40*(16), 3555–3562. https://doi.org/10.1016/j.jbiomech.2007.05.026

Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences (2nd ed.). Routledge. https://doi.org/10.4324/9780203771587

Douglas, J., Pearson, S., Ross, A., & McGuigan, M. (2017). Eccentric exercise: Physiological characteristics and acute responses. *Sports Medicine*, *47*(4), 663–675. https://doi.org/10.1007/s40279-016-0624-8

Ekstrand, J., Hägglund, M., & Waldén, M. (2011). Epidemiology of muscle injuries in professional football (soccer). *American Journal of Sports Medicine*, *39*(6), 1226–1232. https://doi.org/10.1177/0363546510395879

Ekstrand, J., Waldén, M., & Hägglund, M. (2016). Hamstring injuries have increased by 4% annually in men's professional football, since 2001: A 13-year longitudinal analysis of the UEFA Elite Club injury study. *British Journal of Sports Medicine*, *50*(12), 731–737. https://doi.org/10.1136/bjsports-2015-095359

Franchi, M. V., Reeves, N. D., & Narici, M. V. (2017). Skeletal muscle remodeling in response to eccentric vs. concentric loading: Morphological, molecular, and metabolic adaptations. *Frontiers in Physiology*, *8*, 447. https://doi.org/10.3389/fphys.2017.00447

Gómez-Piqueras, P., González-García, J., & Sánchez-Sánchez, J. (2024). If You Want to Prevent Hamstring Injuries in Soccer, Run Fast: A Narrative Review about Practical Considerations of Sprint Training. *Sports*, *12*(3), 77. https://doi.org/10.3390/sports12050134

Hessel, A. L., Lindstedt, S. L., & Nishikawa, K. C. (2017). Physiological Mechanisms of Eccentric Contraction and Its Applications: A Role for the Giant Titin Protein. *Frontiers in physiology*, *8*, 70. https://doi.org/10.3389/fphys.2017.00070

Kellis, E., & Blazevich, A. J. (2022). Hamstrings force-length relationships and their implications for angle-specific joint torques: a narrative review. *BMC sports science, medicine & rehabilitation*, *14*(1), 166. https://doi.org/10.1186/s13102-022-00555-6

Maroto-Izquierdo, S., Martín-Rivera, F., Nosaka, K., Beato, M., González-Gallego, J., & de Paz, J. A. (2023). Effects of submaximal and supramaximal accentuated eccentric loading on mass and function. *Frontiers in physiology*, *14*, 1176835. https://doi.org/10.3389/fphys.2023.1176835

Guex, K., Degache, F., Morisod, C., Sailly, M., & Millet, G. P. (2016). Hamstring Architectural and Functional Adaptations Following Long vs. Short Muscle Length Eccentric Training. *Frontiers in physiology*, *7*, 340. https://doi.org/10.3389/fphys.2016.00340

Mjølsnes, R., Arnason, A., Østhagen, T., Raastad, T., & Bahr, R. (2004). A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scandinavian Journal of Medicine & Science in Sports*, *14*(5), 311–317.

Opar, D. A., Williams, M. D., & Shield, A. J. (2012). Hamstring strain injuries: Factors that lead to injury and re-injury. *Sports Medicine*, *42*(3), 209–226. https://doi.org/10.2165/11594800-000000000-00000

Petersen, J., Thorborg, K., Nielsen, M. B., Budtz-Jørgensen, E., & Hölmich, P. (2011). Preventive effect of eccentric training on acute hamstring injuries in men's soccer: A cluster-randomized controlled trial. *American Journal of Sports Medicine*, *39*(11), 2296–2303. https://doi.org/10.1177/0363546511419277

Roig, M., O'Brien, K., Kirk, G., Murray, R., McKinnon, P., Shadgan, B., & Reid, W. D. (2009). The effects of eccentric versus concentric resistance training on muscle strength and mass in healthy adults: A systematic review with meta-analysis. *British Journal of Sports Medicine*, *43*(8), 556–564. https://doi.org/10.1136/bjsm.2008.051417

Schache, A. G., Dorn, T. W., Wrigley, T. V., Brown, N. A., & Pandy, M. G. (2013). Stretch and activation of the human biarticular hamstrings across a range of running speeds. *European journal of applied physiology*, *113*(11), 2813–2828. https://doi.org/10.1007/s00421-013-2713-9

Timmins, R. G., Bourne, M. N., Shield, A. J., Williams, M. D., Lorenzen, C., & Opar, D. A. (2016). Short biceps femoris fascicles and eccentric knee flexor weakness increase the risk of hamstring injury in elite football (soccer): a prospective cohort study. *British journal of sports medicine*, *50*(24), 1524–1535. https://doi.org/10.1136/bjsports-2015-095362

van Dyk, N., Behan, F. P., & Whiteley, R. (2019). Including the Nordic hamstring exercise in injury prevention programmes halves the rate of hamstring injuries: a systematic review and meta-analysis of 8459 athletes. *British Journal of Sports Medicine*, *53(21), 1362–1370. https://doi.org/10.1136/bjsports-2018-100045*

Wagle, J. P., Cunanan, A. J., Carroll, K. M., Sams, M. L., Wetmore, A., Bingham, G. E., ... Stone, M. H. (2017). Accentuated eccentric loading for training and performance: A review. *Sports Medicine*, *47*(12), 2473–2495. https://doi.org/10.1007/s40279-017-0755-6

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Thousand Oaks, CA: Sage Publications, Inc.

DOI 10.56886/itspa.251202

OPEN ACCESS

REVIEW PAPER

Gambling Prevention Strategies in Adolescents

Dusan Stupar[1]

Affiliations: [1]University Educons, Faculty of Sport and Psychology, TIMS, Novi Sad, Serbia

Correspondence: D. Stupar. Educons University, Faculty for Sport and Psychology, Radnicka 30 A, 21 000 Novi Sad, Serbia. E-mail: dusan.stupar@tims.edu.rs

Abstract

One of the global social problems that is becoming increasingly noticeable is betting, or different forms of gambling. The increasing availability of online platforms, aggressive media marketing, and the advertising of such products by well-known public figures, such as actors and athletes, certainly contribute to this. All of that together created an image of the normality of such actions, which also affects the increase in the number of young people involved in gambling. Qualitative analysis and synthesis of results obtained from existing works on the topic of betting prevention strategy is actually the main goal of this review paper. For this purpose, the following relevant databases, PubMed, Google Scholar, Scopus, DOAJ, and COBISS, were reviewed during October and November 2025. Keywords were used, both in Serbian and in English (betting, adolescents, prevention, strategy, sports activities, institutions). Based on the reviewed literature, it can be concluded that the most effective strategies are those based on education, the development of social skills, including sports activities, family engagement, and collaboration with relevant institutions. Special emphasis is put on the role of sport in the prevention of gambling, as a healthy model of competitiveness, development of self-confidence, and team spirit, which can act as a protective factor regarding pathological gambling, but unfortunately, also the possibility of promoting gambling. Different prevention strategies are compared, including school education programs, nationwide campaigns, and good practices from European countries.

Keywords: *youth gambling addiction, sports betting, youth gambling prevalence, strategy, adolescents*

Introduction

Gambling is defined as an activity in which an individual invests something of value, usually money, on the outcome of an event that is uncertain and depends on luck or chance, with the expectation of a potential gain, where there is always a risk and the possibility of loss. This understanding includes three basic elements: stake, uncertain outcome, and hope of gain (National Research Council, 1999). Gambling has become one of the most commonly reported addictive behaviors among young people. Recognizing and understanding the factors responsible for this behavior is crucial in the prevention and treatment of these addictive diseases (Secades-Villa et al., 2016). When it comes to the European continent, a study by the European Addiction Network (Andrie et al, 2019) states that the youth participation rate is very high, 28.1% of adolescents regularly engage in gambling activities. Researchers Livazović and Bojčić (2019) point to an important connection between adolescent gambling behavior and very serious psychological, social, and financial consequences. Several risk factors likely put certain individuals at high risk for problem gambling. A group of researchers (Monreal-Bartolome et al., 2023) unequivocally indicates that new technologies, easy access to the Internet, which implies new ways of gambling, are reasons for even greater concern in this matter. By researching this problem, scientists managed to identify several biological factors that can contribute to the development of gambling in adolescents. These are, above all, specific brain states, neurochemical levels, physiological tendencies of excitement, and genetic predispositions. In addition to them, several psychological processes were also discovered, including the need to escape from psychological stress, certain cognitive errors, and the creation of wrong rules about the gambling event itself (Nastally & Dixon, 2010).

According to recent research, Tran, Wardle et al (2024) report that the global prevalence of gambling among adolescents is about 17.9% in the last 12 months. Also, European

Received: 04 November 2025 | Accepted after revision: 09 December 2025 | Early access publication date: 15 December 2025 | Final publication date: 15 December 2025

Conflict of interest: None declared.

School Survey Project on Alcohol and Other Drugs (ESPAD, data from the European ESPAD Study (2024) shows that 23% of students (15 16 years) reported betting in the past year, while participation in online betting increased to 14% — and potentially harmful betting increased from 4.7% (2019) to 8.5% (2024) (European School Survey Project on Alcohol and Other Drugs, 2025). The research results also showed that Italy has the highest prevalence of gambling among students (45%), followed by Iceland (41%) and Greece (36%), while the lowest rate was recorded in Georgia (9.5%). According to the same ESPAD source, 2 in 3 (65%) students who reported gambling for money over the past year did so on the internet, either exclusively or as a combination with physical locations. The highest percentages for gambling were reported in Sweden (81%), Slovenia (77%), Iceland (75%), Montenegro (75%), with Bulgaria and Slovakia tied at 74%. The lowest represented Italy (28%) and Spain (44%). Among boys (20%), online gambling was more than double the rate of girls (8.7%).

The situation is not any better in the area of the Western Balkans either. According to data from the Institute for Public Health "Batuta" in the ESPAD survey from the 2018/2019 school year, 15.2% of first-grade high school students in Serbia gambled in the last 12 months, while 11.2% gambled online; with the Lie/Bet test, 1.3% of students (2.3% of boys and 0.3% of girls) showed signs of pathological gambling, while according to the CSPG test, 4.1% of students (7.2% of boys, 1.2% of girls) had excessive gambling (AGOS, 2022). Research in Croatia showed that as many as 72.9% of high school students gambled at least once in their lives, and 12.9% already have serious consequences related to gambling (Ricijaš, Dodig, Hundrić, Huić&Kranželić, 2016). A research study that included 1036 high school students from urban areas of Bosnia and Herzegovina showed that almost 70% of high school students had gambled at least once in their lives. Young people most often play sports betting, gamble on the Internet for money, and play TV bingo, while less than a tenth of students go to a casino weekly, which tells us about the seriousness of gambling in this population (Bijedić et al., 2015). According to the Institute for Public Health of Montenegro (2020), every third student, at the level of the total sample, gambled for money in the previous 12 months (32%). There is a significant difference between boys and girls – 46% of boys gambled for money in the specified time period (almost every second), compared to 18% of girls (almost every fifth). As many as 35% of students were found to have an excessive gambling pattern. Among boys, the share of excessive gambling behavior is 39%, while among girls, one out of four girls gambled for money, according to this pattern. Problem gambling was identified by 8% of students among those who gambled in the previous 12 months – 8% of boys and 7% of girls.

Method

This work is a literature review (review paper) based on the analysis of domestic and foreign scientific articles, reports, strategies, and recommendations of relevant institutions. For this purpose, the following relevant databases, PubMed, Google Scholar, Scopus, DOAJ, and COBISS, were reviewed during October and November 2025. Keywords were used, both in Serbian and in English (betting, adolescents, prevention, strategy, sports activities, institutions). The inclusion criterion was: research dealing with the adolescent and youth population; studies that analyze the prevention of gambling; papers containing empirical or theoretical data on the effects of preventive programs.

Risk Factors that May Contribute to Gambling Addiction

According to scientifically proven claims, the factors that encourage the development of adolescent gambling problems can be divided into several categories: psychological, cognitive, social, and structural (Calado et al., 2017; Derevensky & Gupta, 2011). By this, they mean the impulsivity of young people, wrong beliefs about potential gains, risky social threats, and little or no knowledge of probability. What drives young people in this direction is curiosity, the need to prove themselves to their peers and their influence, quick and easy earnings, and the illusion of some kind of knowledge that can lead them to victory (sports betting) (Derevensky & Gupta, 2011).

Impulsivity

It is a personality construct frequently employed to explain and predict important human behaviors (Huang et al, 2024). "Impulsivity is defined as the failure to resist cues or stimuli, or as a personality dimension that denotes the inability to resist a desire that may be harmful." (Kisa et al., 2005). Impulsivity is the tendency of a person to satisfy their own urges without the involvement of rational thinking and consideration of potential consequences. It is especially characteristic of children and adolescents and is due to neurological immaturity.

The factor most consistent in most research and linked to a possible cause is gambling impulsivity. During the growth and development of adolescents, the part of the brain called the prefrontal cortex is not yet sufficiently developed. Considering that he is responsible for making decisions, inhibiting impulses, and assessing risks, his insufficient development can cause a tendency towards impulsive decisions. It is precisely this behavior that is linked as a key cause of addiction or gambling (Chambers & Potenza, 2003). Based on the results of a longitudinal study, Liu et al. (2013) concluded that adolescents who showed a high level of impulsivity have a significantly higher chance of developing an addiction problem that involves gambling in the later period of adolescence. According to them, such adolescents were at a much higher risk. Estevez et al. (2015) examined the connection between impulsivity and the so-called search for sensation. The results showed that sensation seeking did not mediate the emergence of dysfunctional symptomatology and that impulsivity partially mediated the emergence of anxiety, phobic anxiety disorder, depression, and psychosis, and perfectly mediated somatization, obsessive-compulsive behavior, interpersonal sensitivity, paranoid ideas, and hostility. These results have implications for the development of treatment and prevention programs for pathological gambling in adolescents.

In their study, Nigro et al. (2017) set two goals. The main goal of this study was to investigate the mutual influence of functional and dysfunctional impulsivity, delay discounting, time perspective, and emotionally negative states on the severity of gambling in Italian adolescents. Another aim of the study was to analyze the developmental trajectories of gambling participation, functional and dysfunctional impulsivity, delay discounting, consideration of future consequences, and negative affectivity in a cross-sectional perspective. The results of the research showed that the greater the involvement in gambling, the greater the tendency to devalue delayed re-

DOI 10.56886/itspa.251203

wards and focus on the immediate consequences of one's own behavior, as well as that the severity of gambling contributes more than age in shaping the developmental trajectories of functional and dysfunctional impulsivity, delay discounting, time perspective, and negative affective states.

Peer influence

One of the leading factors influencing the development of gambling among adolescents is certainly the influence of peers. Research has shown (Smith et al) that adolescents are ready to make riskier decisions in the presence of peers. Similar claims in the region are also made by Tomašič, Kovačič Petrovič (2021), while Tankosić and Čvorović (2024) believe that the intensive social contacts of young people actually represent a crucial factor for the development of betting among adolescents. The general behavior and norms of a peer group in any context can influence the attitudes and behaviors of an individual as a member of that group. In this context, adolescents who identify with their peer group and who accept gambling activities as normal behavior are certainly at a greater risk of becoming addicted. Specifically, to reduce the initiation of gambling, preventative programs should focus on helping adolescents to find strategies for resisting peer influences (Parrado-González et al., 2023).

Psychological and Emotional Problems

Key factors that also influence the development of gambling problems are certainly psychological and emotional problems. In the period of adolescence, this type of problem can be more pronounced because at that age, young people do not yet have enough experience to overcome them. In this sense, adolescents who have problems with expressing their feelings, that is, have difficulties in regulating their emotions, are at a greater risk of accepting gambling as a solution to their problems. Alexithymia, difficulties in emotion regulation, and negative affect play an important role in adolescents who present pathological gambling (Estévez et al., 2022). People with gambling disorder (GD) exhibit distorted cognitions and superstitious beliefs more often than the general population. Similarly, difficulties in coping and emotion dysregulation are more prevalent among those with GD, and could determine the onset of GD in particularly vulnerable groups such as adolescents (Estévez et al., 2021).

Availability of Online and Offline Gambling

The fact that it is available and facilitated at any time, through online platforms that are "open" 24 hours a day or physically through a large number of betting shops that are increasingly being offered, contributes to the growth of gambling. Although in some countries it is not legally possible to open such facilities in the immediate vicinity of schools and places where young people gather, it makes the problem more dangerous. Apart from the fact that it leads to more frequent gambling, it also results in the so-called normality, that is, the situation in society, which implies that such situations are normal. New technology is changing the nature of gambling, with interactive modes of gambling becoming putatively associated with higher rates of problem gambling (Gainsbury et al., 2014). Moreover, with the emergence of new technologies, gambling has become increasingly accessible and appealing to this population (Roquer at al., 2025). A study by the group of authors Andrie et al. (2019) was conducted in seven European countries (Germany, Greece, Iceland, the Netherlands, Poland, Romania, and Spain. A sample of 13,824 schoolchildren showed that 12.5% of the participants reported last year's gambling activities either online or offline. 3.6% of the study participants and 28.1% of gamblers (either online or offline) were at risk or had a gambling problem.

Gambling Prevention Strategies in Adolescents

There are various strategies in the world aimed at preventing gambling among adolescents. The most frequently mentioned ones are:

Educational interventions: programs in schools that include workshops and lectures on the risks of gambling

Research indicates that school-based programs can yield positive results in terms of gambling prevention. For example, according to a meta-analysis (Talebi & Bazrafshan, 2025). which included 15 studies with a total sample of 4,201 adolescents, the results obtained showed a statistically significant reduction in gambling behavior among adolescents. However, the certainty of the evidence was very low, according to the GRADE profile assessment, which indicates potential limitations in the study's quality.

Another study (Walther et al., 2013) showed that even 90 minutes of lectures on the harms of gambling by trained teachers in regular classes can influence students' perceptions of the harms of gambling and reduce their frequency. A 90-minute gambling lesson can improve gambling knowledge and change attitudes toward gambling and gambling behavior among adolescents.

In the research conducted for the first time in Portugal (Calado et al., 2020), which concerned the prevention of gambling among adolescents, a specific intervention was applied. It consisted of didactic units to increase accurate knowledge and reduce misconceptions about gambling, but also to target other factors associated with risky behavior in adolescents in general. The program consisted of five didactic units, each consisting of one session, which were held in the classroom during regular school hours. The intervention was implemented weekly, and each session lasted approximately 1 hour. The results showed that among students in the experimental group, there was a significant decrease in the percentage of gamblers at risk/problem from pre-test to follow-up.

A systematic review by a group of authors (Giménez et al., 2022) investigated all gambling addiction prevention programs implemented in schools, with the aim of highlighting their effectiveness and encouraging the creation of more such programs. In the period until the end of 2021, a total of 15 articles that dealt with the mentioned issue showed that the analyzed programs show effective results. Effective programs should focus more on long-term results and the emotional aspects of gambling. The authors also conclude that there is a need for adequate experts who can convey the causal nature of the problems faced by young people.

Probability and Statistics Education: Demonstrating the Concepts of Expected Value, Randomness, and House Edge

These types of strategies aim to educate young people about how gambling works. In this context, it should be further explained to young people that the probability of winning is very small and that it is in favor of the organizers of the games. In this way, young people get a broader picture of

games of chance, where it is completely clear that they cannot beat that system in the long run.

Furthermore, a systematic review (Keen, 2017) of dozens of school-based educational programs has shown that programs that improve knowledge about gambling (including probabilistic concepts) are associated with significant reductions in problematic beliefs in adolescents, although evidence of long-term behavioral changes is still limited.

Through statistics education, young people acquire more accurate beliefs that games of chance are not "fair" on their terms — that the expected value is negative in the long run and that the advantage always goes to the house. This reduces their cognitive distortions (illusions of control, overly optimistic expectations), which is directly related to a reduced risk of developing problem gambling. Analyses carried out on a sample of 447 Italian adolescents (Donati et al., 2024) showed that "accurate knowledge about gambling" has an indirect protective effect — it reduces cognitive distortions and the frequency of gambling, which indirectly reduces the symptoms of gambling problems.

One of the more well-known programs aimed at educating adolescents on the issue of probability and statistics of games of chance is the program called "Who Really Wins?", which was implemented in Croatian secondary schools through a series of short educational workshops. The research was conducted on 629 high school students from 18 Croatian cities. The results showed significant effects in terms of increased knowledge about gambling, cognitive distortions, and frequency of sports betting and lottery playing. The program had no detrimental effects on any of the measured variables (Dodig et al., 2021).

Some researchers have also investigated the effectiveness of education-based problem gambling prevention programs. To this end, they conducted a systematic review of 17 papers and attempted to identify key characteristics of such programs to provide appropriate guidance for future programs. The authors concluded that two main strategies can be observed in most of the examined programs. One is the targeting of risk factors in the sense of correcting wrong beliefs about the possibility of obtaining or increasing knowledge about probability. The second is based on the strengthening of protective factors, e.g., social and emotional skills, and resilience (Oh et al., 2017).

Family and Social Support: Involvement of Parents and Peers in Prevention

The family certainly plays a key role in the prevention of gambling among adolescents. If the quality of family relationships is good and if there is support and understanding from family members, the probability of gambling problems is less. It is this involvement of the family that is the basic factor in treatment and prevention, which encourages efforts to better integrate it into therapeutic processes. A generally greater awareness of family influence may improve prevention, treatment, and support for gambling-related harm (Smith et al., 2025).

In research conducted by Savolainen et al. (2019) with the aim of establish how social identification with online and offline social groups is related to problem gambling among young people. 1,212 American and 1,200 Finnish youth aged 15 to 25 participated in the research. The obtained results lead to the conclusion that young people who were more involved in offline peer groups were less prone to problem gambling, in contrast to young people who had a strong relationship with offline peer groups. Focusing on offline peer groups and increasing social support may have significant potential in preventing youth gambling.

Active and open communication in the family — parents should regularly talk to their children about the risks of betting, show the attitude that betting is not acceptable, and explain the possible consequences. Research on Peer and Parental Social Norms as Determinants of Gambling Initiation shows that the perception of parental reluctance to gamble, i.e., injunctive norms, reduces the likelihood that an adolescent will start betting (Parrado-González et al., 2023). Monitoring and awareness of parents about children's activities - parents who know that their children participate, even in simulated games of chance, have a greater chance of "resolving" their children or taking preventive measures. Study Sure they Gamble -, But At Least They're Not Being Bullied! shows that many parents are aware when their adolescents participate in simulated betting, and this provides an opportunity for parents to get involved and talk about the risks (Dittman et al., 2025). Training young people in social and emotional skills includes assertiveness, the ability to resist peer pressure, and decision-making. Given that high "peer suggestibility" among adolescents is a significant risk factor for the initiation of betting, it is important to implement preventive measures (Parrado-González et al., 2023).

Sports and Physical Education as a Strategy to Prevent Adolescent Gambling

At first glance, sports and physical education could be an excellent choice for the prevention of gambling among adolescents. In this sense, sport should be a synonym for a healthy life, a good social environment managed by adequately educated persons (coaches), and a place where adolescents can spend quality time. On the other hand, physical education, which should develop healthy lifestyles in children and young people, develop morally willing characteristics, discipline, and a sense of belonging, certainly contributes to the aforementioned provenance. Also, sports and physical education teach children that the path to achieving a result is usually long and not at all easy, which develops in them the ability to wait, or delayed rewards, which is exactly the opposite in gambling, the reward now and immediately. Through sports activities, they learn self-control and make different decisions in different situations, which again lead them to rational thinking. In addition, these activities have a positive effect on the physical and mental development of adolescents, happy hormones are secreted, and this affects their and their better mood. This directly opposes one of the leading factors that push children towards risky behavior, which is a poor mental and emotional state. Some research confirms that this study provides cross-sectional evidence supporting the positive association between sports participation and the resilience of children and adolescents, underscoring the potential of encouraging sports participation as a strategy for promoting mental health resilience and the ability to resist risky behaviors such as alcohol, drugs, and gambling (Sheng et al., 2024). On the other hand, some research conducted on the population of 18- to 20-year-old males in Ireland confirms the theory that the social norms that develop within the young male adult sports team environment may play a role in generating increased gambling

DOI 10.56886/itspa.251203

behavior, in both online and traditional modes, among team members (Duggan &Mohan, 2023).

Institutional and Regulatory Measures: Restriction of Access to Online Betting, Legal Regulations

According to Gooda (2024) and on the example of the Western Balkans, Croatia, similar to Serbia, has clearly defined regulations and strictly regulates the market through the Law on Games of Chance, while Bosnia and Herzegovina does not have a single regulation at the state level, but the entities have their own regulations. North Macedonia and Montenegro have separate laws regulating online gambling, but licensing and market control procedures are somewhat less detailed than in Serbia. Although there are certain legal regulations governing this matter, a significant issue is their practical application. Researchers suggest that the increase in gambling, especially online, increases the risk of exposure to that behavior. The most frequently mentioned measures are measures such as operator licensing, restricting access to unlicensed sites, verifying the identity of users, limiting deposits, and implementing self-exclusion. Researchers Fisher et al. (2025) emphasize that legal and regulatory responses are key to reducing harms associated with online gambling. In their research, a systematic review of legal regulations for online gambling, they concluded that adequate resources to ensure compliance with legal interventions are a key priority. Furthermore, when adopting legal regulations, it is necessary to remove industry influence on their adoption. And thirdly, they state that. Finally, several included studies indicate the importance of stricter, more robust definitional boundaries around terms that are particularly crucial for effective legal control of online gambling. In general, it has been shown that legal regulations in practice are not able to eliminate the harmfulness of gambling. Partially good results were observed in Norway. Norway's gambling policy is an exceptional case due to the state monopoly and strict regulation that restricts access to gambling (Rossow & BangHansen, 2016). Specifically, when a ban on the availability of slot machines was introduced in that country, the policy restrictions have led to reductions in gambling expenditures and problem gambling. Even in countries with strong regulation (such as Australia), addiction problems persist — especially as people may switch to "legal" or "semi-legal" alternatives, or illegal offshore operators (Grattan Institute, 2018; Wikipedia, 2025; The International Association of Gaming Advisors, n.d.).

Conclusion

The increase in the number of people participating in gambling activities is obvious, as confirmed by numerous studies. What is worrying is the fact that there is an increasing number of teenagers. There are many reasons for this, starting with the social environment in which they grow up, peer influence, insufficient experience and maturity in making decisions, inadequate family support and understanding, and all the way to psychological and emotional problems that can also contribute to risky behavior. When you add to that the great physical availability of gambling facilities, which are located in almost all parts of the city in the Western Balkans, even right next to schools and kindergartens, then it is clear that the challenges faced by young people are very serious. Additionally, the situation is worsened by so-called online betting, which is available 24 hours a day and requires nothing more than a smartphone, which almost every adolescent owns. Top sportsmen, actors, and public figures who advertise gambling give a boost to this problem in some countries. It is also a fact that advertisements are increasingly aggressive and frequent, even on television, with a national frequency. Research (McGrane et al., 2025) has shown that exposure to sports-related gambling advertising appears to be associated with increased gambling behavior for a wide range of advertising media. This association may be more pronounced in higher-risk gamblers who are already at increased risk of harm.The absence of adequate institutional activities to tighten the law and its application in practice leads to the assumption that it is an impossible mission to prevent such risky behavior among adolescents. Nevertheless, which was the goal of this paper, certain strategies that can give positive results in terms of the prevention of risky gambling behavior among adolescents. In this paper, those that succeeded in this are identified, such as educational interventions, programs in schools that include workshops and lectures on the risks of gambling; Probability and Statistics Education: Demonstrating the concepts of expected value, randomness, and house edge; Family and social support: involvement of parents and peers in prevention; Institutional and regulatory measures: restriction of access to online betting, legal regulations. As for the strategy of prevention through sports and physical education, the evidence is not completely explicit, because sports can even, in some circumstances, encourage betting. For example, adolescents who think that they know the sport they are playing may mistakenly conclude that this knowledge will help them specifically in sports climbing. In addition, their sports idols often advertise betting shops, which may mislead them into believing that this is a normal phenomenon. The environment in which children and young people train (halls, pubs) is increasingly contaminated with advertisements for betting shops, which become their "normal" environment. Therefore, when it comes to sports, one should be careful and use them in such a way that they really give children the healthy entertainment they need. Other researchers dealing with this issue also agree that to achieve better results or reduce the increase in youth gambling activities, it is necessary to develop preventive interventions in the future that will encompass all aspects of addiction development - from individual development, family and social environment to legislation, with multidisciplinary and interdisciplinary cooperation between various experts and political support (Tomašić et al., 2021).

References

Andrie, E. K., Tzavara, C. K., Tzavela, E., Richardson, C., Greydanus, D., Tsolia, M., & Tsitsika, A. K. (2019). Gambling involvement and problem gambling correlate among European adolescents: Results from the European Network for Addictive Behavior study. *Social psychiatry and psychiatric epidemiology*, *54*(11), 1429-1441.

AGOS. (2022). *Koliko se mladi kockaju u Srbiji – istraživanje*. https://agos.rs/istrazivanja/koliko-se-mladi-kockaju-u-srbiji-istrazivanje-750

Bijedić, M., Kuralić-Ćosić, L., Kovačević, R. i Vardo, E. (2015). Navike kockanja srednjoškolaca u dvije urbane sredine u Bosni i Hercegovini. *Socijalne teme, 1* (2), 44-44. Preuzeto s https://hrcak.srce.hr/177306

Calado, F., Alexandre, J., & Griffiths, M. D. (2017). Prevalence of adolescent problem gambling: A systematic review of recent research. Journal of Gambling Studies, 33(2), 397–424. https://doi.org/10.1007/s10899-016-9627-5

Calado, F., Alexandre, J., Rosenfeld, L., & Griffiths, M. D. (2020). The efficacy of a gambling prevention program among high-school students. Journal of Gambling Studies, 36(2), 573–595. https://doi.org/10.1007/s10899-019-09908-2

Chambers, R. A., & Potenza, M. N. (2003). Neurodevelopment, impulsivity, and adolescent gambling. *Journal of Gambling Studies*, *19*(1), 53–84. https://doi.org/10.1023/a:1021275130071

Donati, M. A., Vehkalahti, K., Capitanucci, D., & Primi, C. (2024). A Structural Equation Model to Explain Gambling Problem Severity in Adolescents with an Integrated Perspective. *Journal of Gambling Studies*, *40*(2), 971–983. https://doi.org/10.1007/s10899-023-10266-3

Derevensky, J. & Gupta, R. (2011). 16. The International Centre for Youth Gambling Problems and High-Risk Behaviors (Centre International d'étude sur le jeu et les comportements à risque chez les jeunes). In J. Derevensky, D. Shek & J. Merrick (Ed.), *Youth Gambling: The Hidden Addiction* (pp. 249-254). Berlin, Boston: De Gruyter. https://doi.org/10.1515/9783110255690.249

Dodig Hundric, D., Mandic, S., & Ricijas, N. (2021). Short-Term Effectiveness of the Youth Gambling Prevention Program "Who Really Wins?"-Results from the First National Implementation. *International journal of environmental research and public health*, *18*(19), 10100. https://doi.org/10.3390/ijerph181910100

Dittman, C. K., Gossner, M., Browne, M., *et al.* (2025). *Sure they gamble – but at least they're not being bullied! A survey of parental perspectives of adolescent gambling. International Journal of Mental Health and Addiction*. https://doi.org/10.1007/s11469-025-01444-y

Duggan, B., & Mohan, G. (2023). *A Longitudinal Examination of Young People's Gambling Behaviours and Participation in Team Sports. Journal of Gambling Studies, 39*(2), 541–557. https://doi.org/10.1007/s10899-022-10175-x

Estevez, A., Herrero-Fernández, D., Sarabia, I., & Jauregui, P. (2015). The impulsivity and sensation-seeking mediators of the psychological consequences of pathological gambling in adolescence. *Journal of Gambling Studies*, *31*(1), 91–103. https://doi.org/10.1007/s10899-013-9419-0

Estévez, A., Jáuregui, P., Lopez-Gonzalez, H., Mena-Moreno, T., Lozano-Madrid, M., Macia, L., Granero, R., Mestre-Bach, G., Steward, T., Fernández-Aranda, F., Gómez-Peña, M., Moragas, L., Del Pino-Gutierrez, A., Codina, E., Testa, G., Vintró-Alcaraz, C., Agüera, Z., Munguía, L., Baenas, I., Valenciano-Mendoza, E., … Jiménez-Murcia, S. (2021). The Severity of Gambling and Gambling Related Cognitions as Predictors of Emotional Regulation and Coping Strategies in Adolescents. *Journal of Gambling Studies*, *37*(2), 483–495. https://doi.org/10.1007/s10899-020-09953-2

Estévez, A., Jauregui, P., Macía, L., & Martín-Pérez, C. (2022). Alexithymia and emotion regulation strategies in adolescent gamblers with and without at-risk profiles. *Journal of Gambling Studies*, *38*(1), 15-29. https://doi.org/10.1007/s10899-021-10057-8

European School Survey Project on Alcohol and Other Drugs (ESPAD). (2025). *ESPAD 2024 Key Findings*. European Union Drugs Agency. https://doi.org/10.2810/5746644

Fisher, M. L., Piper, T., Fitzpatrick, M., Mavi, S., Retzer, A., Bradbury-Jones, C., Montgomery, P., Melendez-Torres, G. J., Kirby, J., Chandan, J. S., & Bedford, K. (2025). Legal and regulatory responses to online gambling harms: A scoping review of evidence. *Harm Reduction Journal, 22*, Article 163. https://doi.org/10.1186/s12954-025-01292-y

Gainsbury, S. M., Russell, A., Hing, N., Wood, R., Lubman, D. I., & Blaszczynski, A. (2014). The prevalence and determinants of problem gambling in Australia: Assessing the impact of interactive gambling and new technologies. *Psychology of Addictive Behaviors, 28*(3), 769–779. https://doi.org/10.1037/a0036207

Grattan Institute. (2018). *A better bet: How Australia should prevent gambling harm*. Grattan Institute. https://grattan.edu.au/report/a-better-bet-how-australia-should-prevent-gambling-harm/?utm_source=chatgpt.com

Giménez Lozano, J. M., & Morales Rodríguez, F. M. (2022). Systematic Review: Preventive Intervention to Curb the Youth Online Gambling Problem. *Sustainability*, *14*(11), 6402. https://doi.org/10.3390/su14116402

Gooda. (2024). *Kako zakon reguliše online kockanje u Srbiji i regionu*. https://gooda.rs/kako-zakon-regulise-online-kockanje-u-srbiji-i-regionu/

Huang, Y., Luan, S., Wu, B., Li, Y., Wu, J., Chen, W., & Hertwig, R. (2024). Impulsivity is a stable, measurable, and predictive psychological trait. *Proceedings of the National Academy of Sciences of the United States of America*, *121*(24), e2321758121. https://doi.org/10.1073/pnas.2321758121

Institut za javno zdravlje Crne Gore. (2020). *Evropsko istraživanje o upotrebi psihoaktivnih supstanci i nehemijskih sredstava zavisnosti među mladima: ESPAD 2019 Crna Gora.* Podgorica: Institut za javno zdravlje Crne Gore. Preuzeto sa https://s3.eu-central-1.amazonaws.com/web.repository/ijzcg-media/files/1593458554-espad-2019-nacionalni-izvjestaj-web.pdf

Kisa, C., Yildirim, S. G., & Göka, E. (2005). Ataklik ve Ruhsal Bozukluklar [Impulsivity and mental disorders]. *Turk psikiyatri dergisi = Turkish journal of psychiatry*, *16*(1), 46–54.

Keen, B., Blaszczynski, A., & Anjoul, F. (2017). Systematic Review of Empirically Evaluated School-Based Gambling Education Programs. *Journal of gambling studies*, *33*(1), 301–325. https://doi.org/10.1007/s10899-016-9641-7

Livazović, G., & Bojčić, K. (2019). Problem gambling in adolescents: what are the psychological, social and financial consequences?. *BMC psychiatry*, *19*(1), 308. https://doi.org/10.1186/s12888-019-2293-2

Liu, W., Lee, G. P., Goldweber, A., Petras, H., Storr, C. L., Ialongo, N. S., & Martins, S. S. (2013). Impulsivity trajectories and gambling in adolescence among urban male youth. *Addiction (Abingdon, England)*, *108*(4), 780–788. https://doi.org/10.1111/add.12049

McGrane, E., Pryce, R., Field, M., Gu, S., Moore, E. C., & Goyder, E. (2025). What is the impact of sports-related gambling advertising on gambling behaviour? A systematic review. *Addiction (Abingdon, England)*, *120*(4), 589–607. https://doi.org/10.1111/add.16761

Monreal-Bartolomé, A., Barceló-Soler, A., García-Campayo, J., Bartolomé-Moreno, C., Cortés-Montávez, P., Acon, E., Huertes, M., Lacasa, V., Crespo, S., Lloret-Irles, D., Sordo, L., Clotas Bote, C., Puigcorbé, S., & López-Del-Hoyo, Y. (2023). Preventive Gambling Programs for Adolescents and Young Adults: A Systematic Review. *International Journal of Environmental Research and Public Health*, *20*(6), 4691. https://doi.org/10.3390/ijerph20064691

DOI 10.56886/itspa.251203

Nastally, B. L., & Dixon, M. R. (2010). Adolescent gambling: current trends in treatment and future directions. *International Journal of Adolescent Medicine and Health*, *22*(1), 95-111. https://doi.org/10.1007/BF03395828

National Research Council. (1999). *Pathological Gambling: A Critical Review*. Washington, DC: The National Academies Press. https://doi.org/10.17226/6329

Nigro, G., Cosenza, M., & Ciccarelli, M. (2017). The Blurred Future of Adolescent Gamblers: Impulsivity, Time Horizon, and Emotional Distress. *Frontiers in psychology*, *8*, 486. https://doi.org/10.3389/fpsyg.2017.00486

Oh, B. C., Ong, Y. J., & Loo, J. M. Y. (2017). A review of educational-based gambling prevention programs for adolescents. *Asian Journal of Gambling Issues and Public Health, 7*(1), 4. https://doi.org/10.1186/s40405-017-0024-5

Parrado-González, A., Fernández-Calderón, F., Newall, P. W. S., & León-Jariego, J. C. (2023). Peer and Parental Social Norms as Determinants of Gambling Initiation: A Prospective Study. *The Journal of adolescent health : official publication of the Society for Adolescent Medicine*, *73*(2), 296–301. https://doi.org/10.1016/j.jadohealth.2023.02.033

Roquer, M., Clotas, C., & Bartroli, M. (2025). Online Gambling and At-Risk Gambling Behaviour in a Cross-Sectional Survey Among 13-19 Year-Old Adolescents in Barcelona. *Journal of Gambling Studies*, *41*(1), 167–185. https://doi.org/10.1007/s10899-024-10341-3

Rossow, I., & Bang Hansen, M. (2016). *Gambling and gambling policy in Norway — an exceptional case*. *Addiction, 111*(4), 593–598. https://doi.org/10.1111/add.13172

Ricijaš, N., Dodig Hundrić, D., Huić, A., & Kranželić, V. (2016). *Youth Gambling in Croatia – Frequency of Gambling and the Occurrence of Problem Gambling.* Kriminologija & socijalna integracija, 24(2), 48–72. https://doi.org/10.31299/ksi.24.2.3

Savolainen, I., Sirola, A., Kaakinen, M., & Oksanen, A. (2019). Peer group identification as a determinant of youth behavior and the role of perceived social support in problem gambling. Journal of Gambling Studies, 35(1), 15–30. https://doi.org/10.1007/s10899-018-9813-8

Secades-Villa, R., Martínez-Loredo, V., Grande-Gosende, A., & Fernández-Hermida, J. R. (2016). The relationship between impulsivity and problem gambling in adolescence. *Frontiers in Psychology*, *7*, 1931. https://doi.org/10.3389/fpsyg.2016.01931

Smith, A. R., Chein, J., & Steinberg, L. (2014). Peers increase adolescent risk-taking even when the probabilities of negative outcomes are known. *Developmental Psychology, 50*(5), 1564–1568. https://doi.org/10.1037/a0035696

Smith, J., Wright, S., Dighton, G., Dymond, S., & Torrance, J. (2025). *The influence of family on gambling behaviours: A rapid review of emergent literature. International Journal of Mental Health and Addiction.* Advance online publication. https://doi.org/10.1007/s11469-025-01505-2

Sheng, X., Liang, K., Li, K., Chi, X., & Fan, H. (2024). Association between sports participation and resilience in school-attending students: a cross-sectional study. Frontiers in Psychology, 15, 1365310. https://doi.org/10.3389/fpsyg.2024.1365310

Tankosić, B., & Čvorović, A. (2024). Faktori rizika adolescentnog klađenja. *Pedagoška stvarnost*, *70*(2), 213-230. https://doi.org/10.19090/ps.2024.2.213-230

Talebi, F., & Bazrafshan, F. (2025). Effectiveness of preventive gambling interventions in adolescents: a systematic review and meta-analysis. *Addictive behaviors*, *170*, 108436. https://doi.org/10.1016/j.addbeh.2025.108436

The International Association of Gaming Advisors. (n.d.). *Australia: Playing whack-a-mole with online gambling shutdowns*. The IAGA. https://www.theiaga.org/australia--playing-whack-a-mole-with-online-gambling-shutdowns?utm_source=chatgpt.com

Tomašić, L., & Kovačić Petrović, Z. (2021). *Poremećaj kockanja – prevencija među adolescentima*. *Socijalna Psihijatrija*, 49(3), 179–201. https://doi.org/10.24869/spsih.2021.179

Tran, L. T., Wardle, H., Colledge-Frisby, S., Taylor, S., Lynch, M., Rehm, J., … Degenhardt, L. (2024). *The prevalence of gambling and problematic gambling: A systematic review and meta-analysis*. *The Lancet Public Health, 9*(8), e594–e613. https://doi.org/10.1016/S2468-2667(24)00126-9

Walther, B., Hanewinkel, R., & Morgenstern, M. (2013). Short-term effects of a school-based program on gambling prevention in adolescents. *The Journal of adolescent health: official publication of the Society for Adolescent Medicine*, *52*(5), 599–605. https://doi.org/10.1016/j.jadohealth.2012.11.009

Wikipedia. (2025, November 29). *Gambling in Australia*. Wikipedia. https://en.wikipedia.org/wiki/Gambling_in_Australia?utm_source=chatgpt.com

OPEN ACCESS

ORIGINAL SCIENTIFIC PAPER

Trends in Changes of Short-Distance Running Speed in Four-Year-Old Children (2020–2025)

Ivica Scepanovic[1], Aleksandar Vlahovic[1]

Affiliations: [1]University of Montenegro, Faculty for Sport and Physical Education, Niksic, Montenegro

Correspondence: I. Scepanovic. University of Montenegro, Faculty for Sport and Physical Education, Narodne omladine bb, 84000 Niksic, Montenegro. E-mail: ivicascepanovic@gmail.com

Abstract

The aim of this study was to analyze short-distance running times in four-year-old children across a six-year period (2020–2025), as well as to determine if a gradual generational quality decline can be identified. Total number of 981 participants was divided into subgroups related to the testing year and gender. All subjects were enrolled in Smart Gym sport school program in Podgorica, Montenegro. Short-distance running speed was assessed using two variables - time of 5m and 10m sprint. All results were subjected to basic descriptive statistical analysis, and linear regression analysis was used to determine changes in running speed over time. Results show that it is evident that in both gender groups there were clear evidence of generational running speed deterioration over six-year period. Also using testing year as categorical factor, regression analysis confirmed a statistically significant effects on sprint performance in six years. These findings emphasize the greater need for more structured and unstructured physical activity during the preschool period, especially given that this developmental stage represents a critical period for acquiring most of fundamental motor abilities.

Keywords: *sprint performance, short distance running, preschool children, generational trends*

Introduction

Everyday life for many preschool-aged children has increasingly shifted toward lower levels of physical activity and more time in sedentary lifestyle. These changes should not be ignored. They can directly influence early motor development and overall physical competence of children (Christian et al., 2024; Tomkinson et al., 2019; Tremblay et al., 2015). Growing evidence of this suggests that levels of fundamental motor abilities are declining faster than previously assumed, with some reports that indicate this negative trend becoming even more pronounced following the COVID-19 pandemic (Kotzsch et al., 2025). Among motor abilities, running speed stands out as a particularly sensitive indicator of neuromuscular development, because it has high level of genetic predominance, develops within a short time period and cannot be significantly altered later in childhood (Bowerman et al., 2009).

A large number of studies have explored the factors that shape and influence running speed performance in young children. Although body composition can influence motor abilities outcomes (Graf et al., 2004; D'Hondt et al., 2009; Kakebeeke et al., 2017; Martins et al., 2024; Yip et al., 2024), sprinting speed is typically more closely linked to neuromuscular development and early movement experiences. Research shows that in the preschool period, boys and girls perform similarly in short-distance running tasks, with improvements largely attributed to developmental progression rather than sex differences (Babić et al., 2010; Latorre-Román et al., 2017). Additional insights provide information that explosive strength plays an important role in sprint performance, as standing long jump outcomes have been identified as significant predictors of short distance running speed in children aged four and five (Bertozzi et al., 2024).

Despite extensive research, year-to-year trend analysis in younger children's motor abilities remains limited. This fact is particularly evident for four-year-olds, a crucial age when neuromotor development is progressing rapidly and

Received: 06 November 2025 | Accepted after revision: 09 December 2025 | Early access publication date: 15 December 2025 | Final publication date: 15 December 2025

Conflict of interest: None declared.

foundational motor learning becomes more stable. Long-term practical work with children of this age provides subtle information about generational differences. Many experts report that today's children may be slightly slower, less coordinated, and less proficient during basic tasks compared to their peers from earlier periods. Although those are subjective observations, they certainly raise important questions about the possibility of a gradual decline in motor abilities.

Given the absence of systematic monitoring of children motor abilities in Montenegro, examining short distance running performance trends has become both relevant and necessary. The aim of this study was to analyze short-distance running times in four-year-old children across a six-year period (2020–2025), as well as to determine if a gradual generational quality decline can be identified.

Methods

Participants

This study included children, age four at the time of testing, all enrolled in the Smart Gym sport school program in Podgorica. Annual testing was conducted consistently in September, at the start of the season. Written parental consent was obtained for every participant. A total sample of 981 children was divided into subsamples by testing year and gender. In 2020, the subsample consisted of 54 boys and 55 girls; in 2021, 80 boys and 75 girls took part; in 2022, the subsample included 81 boys and 77 girls; in 2023, 106 boys and 87 girls were assessed; in 2024, 90 boys and 78 girls; and in 2025, the study involved 107 boys and 91 girls. None of children participated in any systematic or structured sports training activities prior to testing, thus ensuring that no external training-related factors could influence their performance at the beginning of the season.

Procedure

Running speed in short distances every year was assessed in the last week of September, while ensuring consistent conditions across all testing protocols over the period of time. This was done annually, from 2020 to 2025, and time needed to finish assessment is five workdays. All assessments were conducted indoors on a flat, slippery free surface, ensuring natural and voluntarily movement execution.

Short warmup was conducted prior to the testing, which included slow-paced jogging, flexibility exercises, and dynamic age-appropriate explosive movements. All instructions and encouragement were conducted by physical education teacher, while two additional teachers kept track or results and observe testing procedure to be constant in every year.

Each child performed two sprint attempts, with one-minute break between trials. Better of two trials was used for further analysis. A trial was repeated if the child stumbled, stopped, initiated the start incorrectly, or failed to pass cleanly through the timing gates.

Measures

Running speed was recorded using an electronic timing system (Physical Ability Test 01, Uno-Lux NS, Belgrade) which was equipped with a start floor sensor and dual photocell gates placed at 5 m and 10 m from the starting line. Consistent height of photocells in every year was at 65cm, and gate was 1.5m wide. Starting floor sensor was placed 30cm behind the starting line, ensuring that only the rear foot was in the sensor area.

Children began each sprint from a high-start position, choosing on their own the starting leg. Timing was initiated automatically the moment the child's rear foot was lifted from the starting floor sensor, allowing a natural and child-friendly initiation of movement without auditory cues. Two times were recorded at two different spots:

- 5 m mark — split time (T5M);
- 10 m mark — final sprint time (T10M).

A valid trial is considered if the child passed directly through both photo-cell gates without running off the track. The measurement system and testing protocol was the same in every assessment year. With this, high reliability of results is guaranteed.

Data Analysis

Basic descriptive parameters were calculated for 5m and 10m sprint times. These parameters were consisted of mean (M), standard deviation (SD), minimum (Min), and maximum (Max) values. These were analyzed separately for subgroups boys and girls across all assessment years (2020–2025) to provide an overview of annual performance patterns.

To determine changes of running speed over time, a linear regression model was used. The testing year represented a continuous predictor and sprint time as the dependent variable. Separate analyses were done for subgroups boys and girls, allowing the trends within each subgroup of subjects to be analyzed. Statistical significance was determined at $p \leq .05$ level of statistical significance, and all analyses were conducted using Statistica 14 software package.

Results

In Table 1 (boys) and Table 2 (girls) descriptive statistics for 5 m and 10 m sprint times in 4-year-old children across the 2020–2025 period is shown. It is clear that across all testing years, both groups showed a clear pattern of gradual running speed performance deterioration.

Table 1. Descriptive statistics for 5m and 10m sprint performance in subgroup boys

	T5M					T10M			
	N	M	Min	Max	SD	M	Min	Max	SD
2025	107	2.05	1.53	2.95	0.25	3.67	2.80	5.93	0.51
2024	90	2.01	1.69	2.58	0.19	3.51	2.70	4.81	0.37
2023	106	1.97	1.53	3.09	0.28	3.48	2.52	5.23	0.56
2022	81	1.95	1.52	3.02	0.27	3.44	2.62	6.00	0.55
2021	80	1.86	1.43	2.92	0.27	3.43	2.56	6.05	0.56
2020	54	1.85	1.49	2.40	0.20	3.35	2.70	4.75	0.42

DOI 10.56886/itspa.251204

For subgroup boys, while inspecting Table 1, it is seen that mean values for the 5 m sprint time increased almost every year, accompanied by parallel increases in standard deviations. This is indication of not only slower average sprint times but also a slightly wider dispersion of individual results. This can be affected also by an increasing number of testing subjects in recent years. A similar pattern was also seen in the T10M variable, where the distribution of results is toward longer sprint times as the years progressed.

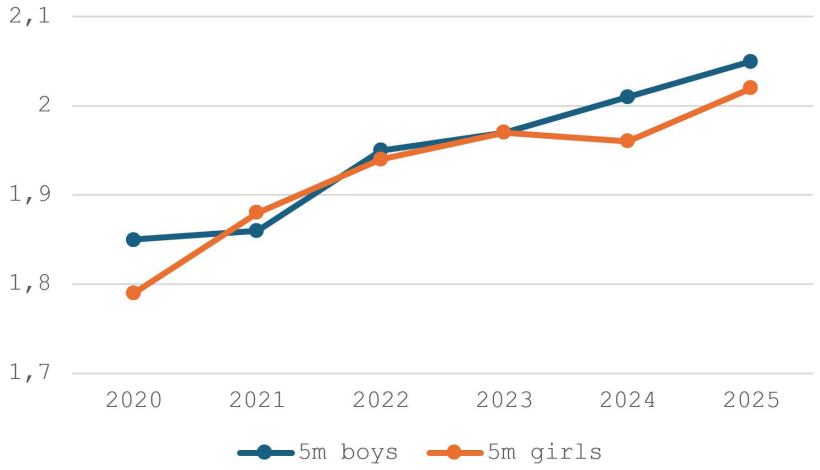


FIGURE 1. Boys vs Girls in 5m sprint (2020-2025)

Table 2. Descriptive statistics for 5m and 10m sprint performance in 4-year-old girls

	T5M					T10m			
	N	M	Min	Max	SD	M	Min	Max	SD
2025	91	2.02	1.47	2.88	0.28	3.50	2.55	5.17	0.50
2024	78	1.96	1.54	2.79	0.21	3.52	2.73	4.96	0.42
2023	87	1.97	1.42	2.90	0.31	3.48	2.53	5.40	0.58
2022	77	1.94	1.46	2.97	0.31	3.40	2.56	5.34	0.53
2021	75	1.88	1.37	2.90	0.32	3.38	2.55	5.36	0.56
2020	55	1.79	1.43	2.20	0.19	3.22	2.55	4.13	0.42

Inspecting Table 2, it is shown that subgroup girls had a similar slower running time results as the years progressed. Their mean values in T5M variable showed consistent increases across the six-year period. Again, SD and Min and Max values also reflect a gradual broadening of performance variability in recent years

Trends in the T10M variable mirrored these findings, which showed shorter running times at the beginning of the observed period and progressively higher running times toward year 2025. The alignment of trends between boys and girls suggests that the decline in short-distance running performance is not gender-specific but reflects a wider generational change in this motor ability.

These changes are visually emphasized in Figure 1 (T5M) and Figure 2 (T10M), which clearly illustrate the year-to-year progression of slower performance for both genders. Also, it is presented that in some cases girls demonstrated better average testing times in contrast to the boys.

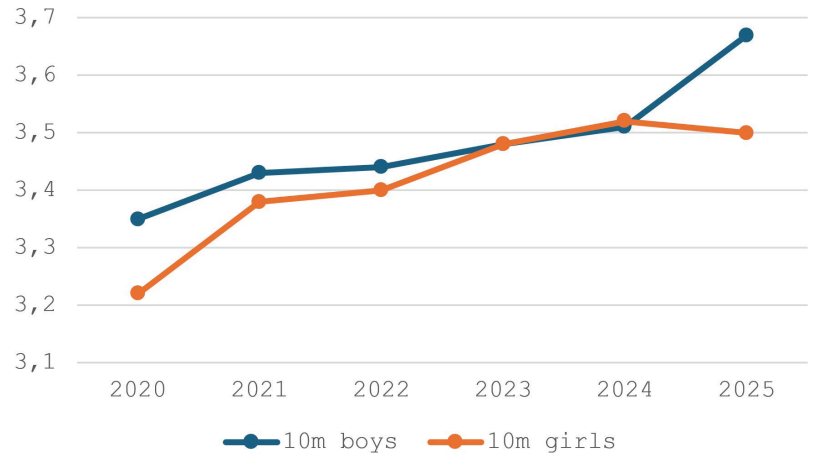


FIGURE 2. Boys vs Girls in 10m sprint (2020-2025)

Linear regression analysis confirmed a statistically significant effects on sprint performance in six-year period. Among boys, the year of testing was a significant predictor of 5 m sprint time (β=0.043, p < .001), as well as 10 m time (β=0.054, p< .001). Girls demonstrated the same pattern, with significant positive year effects for both 5 m (β=0.039, p< .001) and 10 m sprint time (β=0.051, p< .001). Positive β coefficients across all models indicate a consistent linear decline in running speed from 2020 to 2025 for both sexes.

Although year of testing is not a physiological predictor of sprint ability, the year-to-year progression clearly shows that more recent annual samples performed worse than earlier ones (R2 suggests 2.5% to 7.2% determination of running times). This confirms a generational decline in sprint speeds, particularly emphasized in the recent testing years. It would be interesting to address period prior to this.

Table 3. Linear regression for 5m and 10m sprint performance (2020-2025)

Group	Variable	β	Se	t	p	R2
Boys	T5M	0.043***	0.007	6.426	0.000	0.072
Boys	T10M	0.054***	0.014	3.937	0.000	0.027
Girls	T5M	0.039***	0.008	4.983	0.000	0.049
Girls	T10M	0.051***	0.014	3.560	0.000	0.025

*** β changes are significant at p <.001 level of statistical significance.

Discussion

The findings in this study show that sprint performance in 4-year-old children has decreased over the six-year period. The time progression across annual sample of subjects reveals a change in results, when subjects tested in recent years consistently ran slower than those who were tested earlier. This negative trend appeared in both boys and girls and was present in both sprint distances, indicating a stable pattern and not linked to gender differences.

Findings in this study are consistent with what recent articles have already suggested that today's preschool children generally show lower levels of motor abilities compared to children from previous generations. Greier et al. (2014) pointed out that declines in physical fitness among young children often reflect lifestyle changes, rather than developmental differences. Recent international findings, such as Tomkinson et al. (2019) and Tremblay et al. (2015), emphasize that reduced physical activity and increased sedentary lifestyle have become widespread concerns, with children motor abilities being especially sensitive to these changes.

Compared with the results of Babić et al. (2010), children within this sample demonstrated superior sprinting performance in short distances. Such differences may indicate the presence of genetic traits within this geographical area, alongside supporting factors of early motor abilities development.

The period after the COVID-19 pandemic brought notable changes in daily routines, with reduced time of the outdoor play, increased screen time, and less opportunities for spontaneous movement. Hedderson et al. (2023) report that the screen time in COVID-19 period was substantially higher than in pre COVID-19 period, and Ramirez et al. (2024) concluded that in post COVID-19 period physical activity is decreased in 89% articles that reported changes. These changes may have significant effects on how frequently and intensely young children engage in movement activities. Keeping in mind that all six testing years in this study were performed under identical conditions—with the same equipment, same testing protocols, it becomes clear that the observed differences reflect real changes in children's motor abilities.

Certain limitations should also be noted. The sample was drawn from a single geographic area, which may limit national viewpoint even though approximately 30% of nation lives in Podgorica. Additionally, factors such as physical activity habits, screen time, sleep quality, and body composition measurements were not assessed in this research but could significantly contribute to the interpretation of these trends.

Conclusion

These results emphasize the importance of systematic and leisure time for movement activities in early childhood as a developing crucial period of fundamental motor abilities such as running speed. Regular exposure to all types of basic movement and playful activities may help to counteract the negative trend observed in this study.

These findings emphasize the need for greater focus on structured physical activity during the preschool period, especially given that this developmental stage represents a critical period for acquiring fundamental motor abilities. Ensuring that young children have regular access to movement-rich environments may be essential for ensuring adequate further and healthy motor development. Monitoring of running speed will ensure proper selection of future athletes. With this, it is possible to believe that many children would be physically active in later years, and to be included in sports either in professional or recreational level and have a healthier lifestyle.

References

Babić, V., Blažević, S., & Vlašić, J. (2010). Karakteristike sprinterskog trčanja djece predškolske i mlađe školske dobi. *Hrvatski športskomedicinski vjesnik,* 25(1), 3–8.

Bertozzi, F., Camuncoli, F., Galli, M., & Tarabini, M. (2024). The relationship between jump and sprint performance in preschool children. *The Journal of sports medicine and physical fitness*, *64*(6), 526–531. https://doi.org/10.23736/S0022-4707.24.15628-9

Bowerman, W. J., Freeman, W. H., & Gambetta, V. (2009). *Athletic development: The art & science of functional sports conditioning.* Human Kinetics.

Christian, H., Adams, E. K., Moore, H. L., Nathan, A., Murray, K., Schipperijn, J., & Trost, S. G. (2024). *Developmental trends in young children's device-measured physical activity and sedentary behaviour. International Journal of Behavioral Nutrition and Physical Activity, 21*(97). https://doi.org/10.1186/s12966-024-01645-z

D'Hondt, E., Deforche, B., De Bourdeaudhuij, I., & Lenoir, M. (2009). Relationship between motor skill and body

 DOI 10.56886/itspa.251204

mass index in 5- to 10-year-old children. *Adapted Physical Activity Quarterly*, 26(1), 21–37. https://doi.org/10.1123/apaq.26.1.21

Graf, C., Koch, B., Kretschmann-Kandel, E., Falkowski, G., Christ, H., Coburger, S., Lechmacher, W., Bjarnason-Wehrens, B., Platen, P., Tokarski, W., Predel, H. G., & Dordel, S. (2004). Correlation between BMI, leisure habits and motor abilities in childhood (CHILT-project). *International journal of obesity*, *28*(1), 22-26. https://doi.org/10.1038/sj.ijo.0802428

Greier, K., Riechelmann, H., & Burtscher, M. (2014). Prevalence of obesity and motor performance capabilities in Tyrolean preschool children. *Wiener klinische Wochenschrift*, *126*. https://doi.org/10.1007/s00508-014-0553-1

Hedderson, M. M., Bekelman, T. A., Li, M., Knapp, E. A., Palmore, M., Dong, Y., … Ferrara, A. (2023). Trends in screen time use among children during the COVID-19 pandemic, July 2019 through August 2021. *JAMA Network Open, 6*(2), e2256157. https://doi.org/10.1001/jamanetworkopen.2022.56157

Kakebeeke, T. H., Lanzi, S., Zysset, A. E., Arhab, A., Messerli-Bürgy, N., Stuelb, K., Leeger-Aschmann, C. S.,Schmutz, E. A., Meyer, E. A., Kriemler, S., Munsch, S., Jenni, O. G., & Puder, J. J. (2017). Association between body composition and motor performance in preschool children. *Obesity facts*, *10*(5), 420-431. https://doi.org/10.1159/000477406

Kotzsch, A., Papke, A., Heine A. (2025). The Impact of the COVID-19 Pandemic on the Development of Motor Skills of German 5- to six-year-Old Children. *Behavioral Sciences*, 15(353). https://doi.org/10.3390/bs15030353

Latorre-Román, P. Á., Mora-López, D., Martínez-Redondo, M., & García-Pinillos, F. (2017). Reference values for running sprint field tests in preschool children: A population-based study. *Gait & Posture*, *54*, 76-79. https://doi.org/10.1016/j.gaitpost.2016.12.013

Martins, C., Romo-Perez, V., Webster, E. K., Duncan, M., Lemos, L. F., Staiano, A. E., ... & Barnett, L. M. (2024). Motor competence and body mass index in the preschool years: A pooled cross-sectional analysis of 5545 children from eight countries. *Sports medicine*, *54*(2), 505-516.
https://doi.org/10.1007/s40279-023-01929-7

Ramirez, A., Rapp, A. B., & Santarossa, S. (2024). Effects of the COVID-19 Pandemic on Physical Activity in Children: A Systematic Review. *International Journal of Medical Students*, *12*(3), 311–333. https://doi.org/10.5195/ijms.2024.1716

Tomkinson, G. R., Lang, J. J., & Tremblay, M. S. (2019). Temporal trends in the cardiorespiratory fitness of children and adolescents representing 19 high-income and upper middle-income countries between 1981 and 2014. *British journal of sports medicine*, *53*(8), 478-486. https://doi.org/10.1136/bjsports-2017-097982

Tremblay, M. S., Gray, C., Babcock, S., Barnes, J., Bradstreet, C. C., Carr, D., ... & Brussoni, M. (2015). Position statement on active outdoor play. *International journal of environmental research and public health*, *12*(6), 6475-6505. https://doi.org/10.3390/ijerph120606475

Yip, K. M., So, H. K., Tung, K. T., Wong, R. S., Tso, W. W., Wong, I. C., ... & Ip, P. (2024). Normative values of motor performance and their relationship with BMI status in Hong Kong preschoolers. *Scientific reports*, *14*(1), 6567. https://doi.org/10.1038/s41598-024-57121-y

OPEN ACCESS

STUDY PROTOCOL

Physical Literacy Assessment Protocol (PLAP): A Comprehensive Methodological Framework for Monitoring School-Based Physical Literacy in Children and Adolescents

Stevo Popovic[1,2,3], Jovan Gardasevic[1], Milena Mitrovic[1], Ivan Jovancevic[1], Ling Yan[4], Dong Wang[4], Yan Liang[4], Gang He[4]

Affiliations: [1]University of Montenegro, Faculty for Sport and Physical Education, Niksic, Montenegro,[2]Western Balkan Sport Innovation Lab, Podgorica, Montenegro, [3]Korea University, Seongbuk-gu, Seoul, Republic of Korea, [4]Capital University of Physical Education and Sports, School of Kinesiology and Health, Beijing, China

Correspondence: Stevo Popovic. Faculty for Sport and Physical Education, University of Montenegro, Narodne omladine bb, 81400 Niksic, Montenegro. E-mail: stevop@ucg.ac.me; Gang He. School of Kinesiology and Health, Capital University of Physical Education and Sports, No.11 West North Third Ring Road, Beijing, China. E-mail: hegang@cupes.edu.cn

Abstract

This protocol was developed to enable evaluators to collect up-to-date data and generate comprehensive annual assessments of physical literacy (PL) among school-aged children and adolescents, using a set of key measurable criteria. Its purpose is to establish a robust methodological framework for monitoring school-based PL in this population. The Physical Literacy Assessment Protocol (PLAP) offers a standardized framework for identifying relevant trends and barriers affecting the development of physical literacy within educational settings. The protocol proposes 18 sociodemographic indicators, sourced from publicly accessible global databases, to describe the demographic and contextual profiles of participating countries. In addition, four operational dimensions comprising 12 content indicators have been specifically designed to assess core elements of PL: motivation, confidence, physical competence, knowledge, and environmental support. Each content indicator is assessed independently through a ten-point grading scale, enabling the synthesis of results into an evidence-based Country Card. The PLAP will also serve as the foundation for annual evaluator meetings, where national research teams collaboratively analyze outcomes and develop tailored national reports. These outputs aim to bridge the gap between research and educational practice, and to support policy development and school-based interventions that foster lifelong physical activity through targeted PL enhancement.

Keywords: *physical literacy, school-based assessment, children and adolescents, monitoring protocol, health promotion*

Introduction

Physical literacy (PL) is increasingly recognized as a key component of a healthy, active lifestyle and a cornerstone of contemporary physical education. Defined as "the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for engaging in physical activities for life" (International Physical Literacy Association, 2017), PL encompasses more than physical fitness. It promotes lifelong well-being, social engagement, and cognitive development in children and adolescents.

Although rooted in philosophical traditions such as monism, phenomenology, and existentialism (Whitehead, 2010), the practical implementation of PL within school systems worldwide remains inconsistent and insufficiently monitored.

Received: 05 November 2025 | Accepted after revision: 09 December 2025 | Early access publication date: 15 December 2025 | Final publication date: 15 December 2025

Conflict of interest: None declared.

As the concept gains recognition across academic, policy, and health sectors, there is an increasing demand for standardized monitoring systems to assess and foster its development from early childhood through adolescence.

The importance of PL becomes even more apparent in light of increasing sedentary behavior, physical inactivity, and screen time among youth. These trends have profound implications for physical and mental health, academic performance, and social development. In many countries, students spend a significant portion of their day in passive environments, often without access to quality physical education or structured opportunities for movement. Although various initiatives aim to promote physical activity, few are grounded in comprehensive, standardized measures of PL at national or international levels (Cairney et al., 2019).

Despite various national and international efforts to monitor physical activity in the general population, there remains no internationally standardized framework for assessing PL within or related to school settings. While independent studies have examined different dimensions of PL, the absence of harmonized indicators and grading systems limits cross-study comparability and reduces the relevance of findings for policy development (Edwards et al., 2018).

To address this gap, the Physical Literacy Assessment Protocol (PLAP) was developed. Its primary aim is to establish a comprehensive methodological framework for monitoring school-based PL in children and adolescents. Grounded in best practices from previous health surveillance systems, the protocol introduces 18 clearly defined sociodemographic indicators and four operational dimensions, which are further divided into 12 content indicators. These indicators are specifically designed to assess core elements of physical literacy, including motivation, confidence, physical competence, knowledge, and environmental support.

The PLAP enables national evaluators and researchers to collect timely, relevant data, conduct standardized assessments, and publish comprehensive annual PL Country Cards. These cards compile key statistics, identify critical challenges and disparities, and serve as actionable resources for educators, policymakers, and professionals in sport and health sectors. By highlighting strengths and gaps in school-based PL development, these reports aim to inform evidence-based interventions, shape educational policies, and foster environments that support physically literate, active, and healthy youth.

More importantly, the PLAP is not merely a tool for data collection, it is also a catalyst for change. By fostering collaboration among stakeholders and advocating for structured, school-based PL programs, it calls for concrete actions to enhance the health, development, and long-term well-being of children and adolescents worldwide.

Materials and Methods

A multidisciplinary team of sport science researchers and health promotion experts from China and Montenegro developed the PLAP to provide a comprehensive methodological framework for monitoring school-based PL in children and adolescents. The protocol draws on best practices in physical activity surveillance and has been adapted to address the specific needs of school-based PL evaluation.

The PLAP also initiates a structured process in which national evaluators, including education researchers, policymakers, and sport and health professionals, convene annually to assess the latest evidence on school-based PL within their respective countries. These collaborative meetings result in the development of standardized national reports, known as PL Country Cards, which integrate both quantitative outcomes and qualitative insights from focus groups. These reports are intended to guide school policy, support educational reform, and inform national strategies aimed at enhancing PL among youth.

Table 1. Country's demographic profile

Questions
Country name:
Total population:
% of population aged 5–17:
Urban population (%):
GDP per capita (US$):
Government expenditure on education (%):
Government expenditure on sports and recreation (%):
Public health expenditure (% of GDP):
Life expectancy at birth:
Physical activity prevalence (%):
Youth sedentary behavior prevalence (Y/N or %):
% of schools with PE at least twice weekly:
% of schools with access to PA infrastructure:
Teacher-to-student ratio in PE:
National Physical Activity Plan (Y/N):
National Physical Literacy Policy/Guidelines (Y/N):
Gender parity in youth sports participation (%):
Family/community facility access (%):

DOI 10.56886/itspa.251205

This study protocol proposes 18 sociodemographic indicators, including country name, total population, percentage of the population within the official school-age range, as defined by national education systems , urban population, GDP per capita, government expenditure on education/sports and recreation/public health, life expectancy at birth, physical activity prevalence, youth sedentary behaviour prevalence, percentage of schools offering physical education at least twice weekly, percentage of schools with access to physical activity infrastructure, teacher-to-student ratio in physical education, national physical activity plan, national PL policy or guidelines, gender parity in youth sports participation, and access to family/community facilities. These publicly available indicators will be compiled to identify the characteristics of participating countries and to describe each country's demographic and contextual profile (Table 1).

This protocol also proposes four operational dimensions, divided into 12 content indicators, specifically designed to assess core elements of physical literacy. These dimensions are briefly described in Table 2. In addition, the authors of this study protocol will regularly gather feedback from stakeholders to refine and update the list of content indicators on an annual basis. External evaluations will also be conducted to assess the protocol's inputs, outputs, and its immediate, intermediate, and long-term outcomes.

Table 2. Physical literacy indicators and benchmarks used to guide the grade assignment process

Dimension	Indicator	Benchmark
Physical Competences	Agility and Movement Skills	% of children and adolescents who met the age- and gender-specific benchmarks from the Canadian Assessment of Physical Literacy (Longmuir et al., 2018). Agility and movement skills are assessed using the Canadian Agility and Movement Skill Assessment (CAMSA; Longmuir, 2017).
	Peak Aerobic Fitness	% of children and adolescents meeting age- and gender-specific benchmarks for peak aerobic fitness (Longmuir et al., 2018). Assessed using the Progressive Aerobic Cardiovascular Endurance Run (PACER; Scott et al., 2013) or similar tests.
	Torso Muscular Endurance	% of children and adolescents meeting age- and gender-specific benchmarks for torso muscular endurance (Longmuir et al., 2018). Assessed using the isometric plank test (Boyer et al., 2013).
Knowledge and Understanding	Health and Fitness Knowledge	% of children and adolescents who demonstrate understanding of physical activity guidelines, health benefits of exercise, and related concepts. This indicator evaluates awareness of how physical activity impacts the body and mind, including knowledge of endurance, strength, and flexibility.
	Safety, Risk, and Injury Prevention Knowledge	% of children and adolescents demonstrating knowledge of safe practices, injury prevention, and hazard recognition. This includes understanding warm-up routines, proper equipment use, hydration, and techniques to avoid injury.
Motivation and Confidence	Motivational Disposition	% of children and adolescents exhibiting enjoyment and interest in physical activity. This indicator reflects intrinsic motivation and predilection i.e., the desire to be active and enjoyment derived from participation.
	Perceived Competence and Confidence	% of children and adolescents displaying adequate self-efficacy for physical activity participation. Assesses a child's confidence and perceived competence in their physical abilities (self-efficacy).
	Attitudes and Beliefs about Physical Activity	% of children and adolescents aware of physical activity benefits and perceived barriers. This indicator measures belief in the importance of physical activity and recognition of potential barriers (e.g., lack of time, facilities, or support).
Daily Behaviour	Physical Activity Levels	% of children and adolescents achieving at least 60 minutes of moderate-to-vigorous physical activity (MVPA) daily, as recommended by the World Health Organization (WHO, 2019).
	Active Transportation	% of children and adolescents using active transportation (e.g., walking, biking) at least 3 days per week (Aubert et al., 2022; Tremblay et al., 2018).
	Sedentary Behaviour and Screen Time	% of children and adolescents spending no more than 2 hours per day on recreational screen time. This includes non-educational use of screens such as television, video games, and mobile devices (Tremblay et al., 2018, 2020; WHO, 2020).
	Sleep Duration	% of children and adolescents meeting age-specific recommended sleep durations (e.g., 9–11 hours for ages 5–13). Sleep is considered alongside physical activity and sedentary behaviour as part of the integrated movement behaviour cluster (Tremblay et al., 2020).

Each of the twelve indicators will be assessed using national datasets, peer-reviewed studies, government or NGO reports, and structured observations in school environments from the past ten years. Evaluation employs a 10-point grading scale, adapted from international surveillance protocols such as the Global Matrix 4.0 (Aubert et al., 2022) and the PEP Matrix 1.0 (Long et al., 2024). The scale ranges from 10 = Exceptional (≥90%) to 0 = Incomplete. Grades are determined through a synthesis of available evidence and consensus-based scoring among national evaluators. In cases of limited data or scoring disagreements, evaluations may be supported by external reviewers and expert panels to ensure transparency, consistency, and validity.

Table 3. Grading System and Evaluation

Grade	CI	Description
10	90% ≤	Exceptional
9	80%–89%	Excellent
8	70%–79%	Very Good
7	60%–69%	Good
6	50%–59%	Fairly Good
5	40%–49%	Satisfactory
4	30%–39%	Quite Satisfactory
3	20%–29%	Poor
2	10%–19%	Very Poor
1	≤10%	Failing
0	Insufficient or inadequate information to assign a grade	Incomplete

Note. CI – Class Intervals represent the difference between the upper and lower class limits of the available data.

The reliability of the content analysis in this protocol will be ensured through the operationalization of the PL concept for school-aged children and adolescents, the training of coders in applying standardized definitions of physical literacy domains, and the evaluation of annual cross-national coding audits (Riff et al., 2014).

To address potential subjectivity in data coding and grading, inter-rater agreement will be calculated using Cohen's kappa coefficient (κ), as recommended by McHugh (2012). This statistic offers a reliable measure of agreement between evaluators beyond chance, supporting the consistent and objective application of the PLAP framework.

Electronic databases (including Scopus, PubMed/MEDLINE, and Web of Science) will be systematically searched to identify relevant peer-reviewed articles. Additional sources such as the Open Access Theses and Dissertations (OATD) and the Networked Digital Library of Theses and Dissertations (NDLTD) will support the review of graduate-level research. Google Scholar and targeted web searches will also be used to locate grey literature, government reports, and educational policy documents essential for evaluating the content indicators.

The complete search syntax for each database is detailed in Table 4 and will be adapted to include the specific indicator and country of interest during each national assessment.

Table 4. Full search syntax used for each database

Database	Search Syntax
Scopus	(ALL (physical AND literacy OR indicator) AND ALL (kid* OR child* OR youth OR young OR adolescent* OR student*) AND ALL (school OR education OR curriculum) AND TITLE-ABS-KEY (country))
PubMed/MEDLINE	("physical literacy"[tw] OR "indicator"[tw]) AND (kid*[tw] OR child*[tw] OR youth[tw] OR young[tw] OR adolescent*[tw] OR student*[tw]) AND (school[tw] OR education[tw] OR curriculum[tw]) AND "country"[tiab]
Web of Science	TS=(("physical literacy" OR "indicator") AND (kid* OR child* OR youth OR young OR adolescent* OR student*) AND (school OR education OR curriculum) AND (country))
Open Access Theses and Dissertations (OATD), Networked Digital Library of Theses and Dissertations (NDLTD)	("physical literacy" OR "indicator") AND (kid* OR child* OR youth OR young OR adolescent* OR student*) AND (school OR education OR curriculum) AND (country)
Google Scholar and targeted web searches	"physical literacy" OR "indicator" AND kid* OR child* OR youth OR young OR adolescent* OR student* AND school OR education OR curriculum and country

Note. Replace the placeholders "indicator" and "country" with the specific term for each indicator being searched and the name of the country under investigation.

Discussion and Dissemination

The implementation of the PLAP is expected to drive meaningful progress in the monitoring, promotion, and development of PL among school-aged children and adolescents. By providing a comprehensive methodological framework, the protocol will bridges the knowledge-to-practice gap in physical education through translational science mechanisms.

In the short term, PLAP is expected to increase awareness among educators, policymakers, and stakeholders about the importance of PL and its current status across different regions. Research indicates that school-based assessments and targeted PL initiatives can enhance professional and institutional engagement in promoting physical activity among youth (Grauduszus et al., 2024). The standardized PL Country Cards produced through PLAP implementation will serve as advocacy and decision-support tools, enabling stakeholders to identify strengths and gaps within national education systems.

Over the medium term, the protocol is expected to inform education policy and drive curriculum reform by providing relevant, evidence-based insights. When governments are equipped with consistent and comparable data, they are more likely to adopt policies that enhance access

DOI 10.56886/itspa.251205

to quality physical education and physical activity opportunities for all children (Schmidt & Hanssen-Doose, 2023). This is particularly crucial for addressing disparities related to socioeconomic status, geographic location, and gender.

PLAP also supports the long-term goal through life-course intervention modeling by enhancing PL during childhood and adolescence. Research indicates that youth with higher levels of PL are more likely to engage in regular physical activity and experience improved physical, cognitive, and emotional well-being (Jerebine et al., 2024). Furthermore, the knowledge, motivation, and confidence developed through school-based PL initiatives are strongly associated with sustained physical activity into adulthood (Cornish et al., 2020).

An additional anticipated outcome is the reduction of health disparities through data-informed, inclusive policy and program design. By identifying underperforming populations and settings, PLAP promotes the development of tailored interventions that advance equity in both education and health promotion (Mayordomo-Pinilla et al., 2025). The PL Country Cards will function not only as informational tools but also as calls to action, urging institutions to support all students in developing PL.

Finally, on a global scale, PLAP is expected to make a significant contribution to the expanding body of research on PL. By generating standardized data across diverse educational contexts, the protocol facilitates international comparisons and cross-cultural studies, enhancing our understanding of how PL can be effectively promoted worldwide (Jerebine et al., 2024).

Ethics Declarations

This study protocol was developed in accordance with principles of integrity, fidelity, and honesty. Users of the protocol are expected to uphold these values by taking responsibility for their actions, honouring their commitments, and acting transparently. Furthermore, they are expected to refrain from engaging in any behaviour that could cause intentional harm to others, whether human or animal.

Funding

This bilateral project, titled "The National Reports on School-Based Physical Literacy among Children and Adolescents in China and Montenegro," was funded by "Fourth Session of the China-Montenegro Science and Technology Cooperation Committee Exchange Projects" co-supported by the governments of China and Montenegro. The project was coordinated by Professors Stevo Popovic and Gang He. The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Acknowledgements

This manuscript benefited from AI-assisted language editing using OpenAI's ChatGPT for clarity and grammar improvement.

Authors' Contributions

Conceptualization: Stevo Popovic, Gang He

Methodology: Stevo Popovic, Milena Mitrovic, Dong Wang, Ling Yan

Supervision: Stevo Popovic, Gang He

Validation: Stevo Popovic, Jovan Gardasevic, Yan Liang

Writing – original draft: Stevo Popovic

Writing – review & editing: Jovan Gardasevic, Milena Mitrovic, Ivan Jovancevic, Gang He

References

Aubert, S., Barnes, J. D., Abdeta, C., Abi Nader, P., Adeniyi, A. F., Aguilar-Farias, N., & Tremblay, M. S. (2022). Global Matrix 4.0 Physical Activity Report Card Grades for Children and Adolescents: Results and Analyses From 57 Countries. *Journal of Physical Activity and Health*, 19(11), 700–728. https://doi.org/10.1123/jpah.2022-0456

Boyer, C., Tremblay, M., Saunders, T. J., McFarlane, A., Borghese, M., Lloyd, M., & Longmuir, P. (2013). Feasibility, validity and reliability of the plank isometric hold as a field-based assessment of torso muscular endurance for children 8-12 years of age. *Pediatric exercise science*, 25(3), 407–422. https://doi.org/10.1123/pes.25.3.407

Cairney, J., Dudley, D., Kwan, M., Bulten, R., & Kriellaars, D. (2019). Physical literacy, physical activity and health: Toward an evidence-informed conceptual model. *Sports Medicine*, 49(3), 371–383. https://doi.org/10.1007/s40279-018-0988-y

Cornish, K., Fox, G., Fyfe, T., Koopmans, E., Pousette, A., & Pelletier, C. A. (2020). Understanding physical literacy in the context of health: A rapid scoping review. *BMC Public Health, 20*, 1569. https://doi.org/10.1186/s12889-020-09583-8

Edwards, L. C., Bryant, A. S., Keegan, R. J., Morgan, K., & Jones, A. M. (2018). Definitions, foundations and associations of physical literacy: A systematic review. *Sports Medicine*, 47(1), 113–126. https://doi.org/10.1007/s40279-016-0560-7

Grauduszus, M., Koch, L., Wessely, S., & Joisten, C. (2024). School-based promotion of physical literacy: A scoping review. *Frontiers in Public Health, 12*, 1322075. https://doi.org/10.3389/fpubh.2024.1322075

International Physical Literacy Association. (2017). *What is physical literacy?* https://www.physical-literacy.org.uk/

Jerebine, A., Arundell, L., Watson-Mackie, K., Keegan, R., Juric, P., Dudley, D., Ridgers, N. D., Salmon, J., & Barnett, L. M. (2024). Effects of holistically conceptualised school-based interventions on children's physical literacy, physical activity, and other outcomes: A systematic review. *Sports Medicine – Open, 10*(1), 32. https://doi.org/10.1186/s40798-024-00766-w

Long, B., Agudamu, Matic, R. M., Popovic, S., & Bu, T. (2024). Esports Physical Exercise/Performance Matrix 1.0 Country Factsheets: a protocol for national, regional, and global annual assessment study protocol. *Frontiers in public health*, *12*, 1497552. https://doi.org/10.3389/fpubh.2024.1497552

Longmuir, P. E., Boyer, C., Lloyd, M., Borghese, M. M., Knight, E., Saunders, T. J., Boiarskaia, E., Zhu, W., & Tremblay, M. S. (2017). Canadian Agility and Movement Skill Assessment (CAMSA): Validity, objectivity, and reliability evidence for children 8-12 years of age. *Journal of sport and health science*, 6(2), 231–240. https://doi.org/10.1016/j.jshs.2015.11.004

Longmuir, P. E., Gunnell, K. E., Barnes, J. D., Belanger, K., Leduc, G., Woodruff, S. J., & Tremblay, M. S. (2018). Canadian Assessment of Physical Literacy Second Edition:

A streamlined assessment of the capacity for physical activity among children 8 to 12 years of age. *BMC Public Health, 18*(Suppl 2), 1047. https://doi.org/10.1186/s12889-018-5902-y

Mayordomo-Pinilla, N., Sánchez-Miguel, P. A., Galán-Arroyo, C., Castillo-Paredes, A., & Rojo-Ramos, J. (2025). Physical literacy in school-aged children: A preliminary analysis relating health factors. *Frontiers in Public Health, 13*, 1424027. https://doi.org/10.3389/fpubh.2025.1424027

Riff, D., Lacy, S., & Fico, F. (2014). *Analyzing media messages: Using quantitative content analysis in research* (3rd ed.). Routledge.

Schmidt, M., & Hanssen-Doose, A. (2023). Definitions and assessments of physical literacy among children and adolescents: A scoping review. *BMC Public Health, 23*, 1460. https://doi.org/10.1186/s12889-023-16680-x

Scott, S. N., Thompson, D. L., & Coe, D. P. (2013). The ability of the PACER to elicit peak exercise response in the youth. *Medicine & Science in Sports & Exercise, 45*(6), 1139–1143. https://doi.org/10.1249/MSS.0b013e318281e4a8

Tremblay, M. S., Chaput, J. P., Adamo, K. B., Aubert, S., Barnes, J. D., Choquette, L., Faulkner, G., Goldfield, G. S., Gray, C. E., Gunnell, K. E., Janssen, I., Kolen, A. M., & Saunders, T. J. (2020). Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep. *Applied Physiology, Nutrition, and Metabolism*, 45(10), S57–S102. https://doi.org/10.1139/apnm-2020-0467

Tremblay, M. S., Longmuir, P. E., Barnes, J. D., Belanger, K., Bailey, D. A., & Chaput, J. P. (2018). Canadian Assessment of Physical Literacy Second Edition (CAPL-2): Rationale and development of the physical competence domain. *BMC Public Health, 18*, 1036. https://doi.org/10.1186/s12889-018-5933-4

Whitehead, M. (2010). *Physical literacy: Throughout the lifecourse*. Routledge.

World Health Organization. (2019). *Guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age*. https://iris.who.int/handle/10665/311664

World Health Organization. (2020). *Guidelines on physical activity and sedentary behaviour*. Geneva: World Health Organization. https://www.who.int/publications/i/item/9789240015128

DOI 10.56886/itspa.251205

Guidelines for Authors

May 2022

*** 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 *Innovative Technologies in Sport and Physical Activity* (IT-SPA) applies the Creative Commons Attribution (CC BY) license to articles and other works it publishes.

There is no charge for submissions and no page charge for accepted manuscripts. However, if the manuscript contains graphics in color, note that printing in color is charged.

IT-SPA 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.

IT-SPA honors a 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. English standard should be consistent throughout the manuscripts.

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

IT-SPA 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 IT-SPA.

☑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 IT-SPA editorial board. IT-SPA also publishes award papers selected by the scientific committee of the annual conference.

☐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.

Meeting Abstracts contain conference abstracts of the sports science papers presented at the annual conference and sponsored meetings. This publication offers a first look into the current research in the field of Sports Science.

☐Open Submissions ☑Indexed ☐Peer Reviewed

Meeting Abstracts should be:

- Restricted to 250 words (including title, authors and institutions) and must include the following separate sections: [1] purpose; [2] methods; [3] results; [4] conclusion;
- Without references;
- Without Tables/Figures.

1.3. Submission

IT-SPA only accepts electronic submission to the e-mail of the Journal Office: **journal@pastechl.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 IT-SPA, 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

An original 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 IT-SPA;
- 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 IT-SPA.

The editors-in-chief, executive editor 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.

IT-SPA 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, executive editor 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

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 IT-SPA 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, IT-SPA 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, IT-SPA 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. IT-SPA provides a form the author(s) can use to ask for and obtain permission from the owner.

In addition, the author(s) may freely use the content they previously published in a paper through another publisher and they own the rights to that content; however, that's not necessarily the case and it depends on the license that covers the other paper. Some publishers allow free and unrestricted reuse of article content they own, such as under the CC BY license. Other publishers use licenses that allow reuse only if the same license is applied by the person or publisher reusing the content. If the article was published under a CC BY license or another license that allows free and unrestricted use, the author(s) may use the content in the submitted manuscript provided that the author(s) give proper attribution, as explained above. If the content was published under a more restrictive license, the author(s) must ascertain what rights they have under that license. IT-SPA advices the author(s) not to include any content in the submitted manuscript which they do not have rights to use, and always give proper attribution.

The editors of IT-SPA 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 IT-SPA. 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.

IT-SPA 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 IT-SPA 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 IT-SPA. 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 journal@pastechl.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

IT-SPA 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:

Transfer of Learning on a Spatial Memory Task between the Blind and Sighted People Spatial Memory among Blind and Sighted

Original Scientific Paper

Transfer of learning on a spatial memory task

Selcuk Akpinar[1], Stevo Popović[1,2], Sadettin Kirazci[1]

[1]Middle East Technical University, Physical Education and Sports Department, Ankara, Turkey
[2]University of Montenegro, Faculty for Sport and Physical Education, Niksic, Montenegro

Corresponding author:
S. Popovic
University of Montenegro
Faculty for Sport and Physical Education
Narodne omladine bb, 84000 Niksic, Montenegro
E-mail: stevop@ac.me

Word count: 2,980

Abstract word count: 236

Number of Tables: 3

Number of Figures: 3

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), and Title and Abstract in Montenegrin (only for the authors from former Yugoslavia, excluding Macedonians and Slovenes). 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

MJSSM 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

IT-SPA adheres to the American Psychological Association 7th Edition reference style. Check the Publication Manual of the American Psychological Association (2019), Seventh Edition that is the official source for APA Style, 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 or more authors: cite only the name of the first author followed by et al. and the year

- ✓ Bangsbo et al. (2008) stated that…
- ✓ In one study (Bangsbo et al., 2008), soccer players…

Works by organization as an author: cite the source, just as you would an individual person

- ✓ According to the American Psychological Association (2000)…
- ✓ In the APA Manual (American Psychological Association, 2003), it is explained…

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); separated by a semi-colon

- ✓ Several studies (Bangsbo et al., 2008; Duffield & Marino, 2007; Reilly, 1997) suggest that…

2.4.3. Examples for Reference list

Works by one author
Borg, G. (1998). *Borg's perceived exertion and pain scales*: Human Kinetics.

Works by two authors
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. https://doi.org/10.1007/s00421-007-0468-x

Works by three to twenty authors
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. https://doi.org/10.26773/mjssm.2017.09.008

Works by more than twenty authors
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 & Science in Sports & Exercise, 35*(4), 697–705. https://doi.org/10.1249/01.mss.0000058441.94520.32

Works by group of authors
NCD-RisC. (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. *Lancet*, 390(10113), 2627-2642. https://doi.org/10.1016/s0140-6736(17)32129-3

Works by unknown authors
Merriam-Webster's collegiate dictionary (11th ed.). (2003). Merriam-Webster.

Journal article (print)
Scruton, R. (1996). The eclipse of listening. *The New Criterion, 15*(3), 5–13.

Journal article (electronic)
Aarnivala, H., Pokka, T., Soininen, R., Mottonen, M., Harila-Saari, A., & Niinimaki, R. (2020). Trends in age- and sex-adjusted body mass index and the prevalence of malnutrition in children with cancer over 42 months after diagnosis: a single-center cohort study. *European Journal of Pediatrics,* 179(1), 91-98. https://doi.org/10.1007/s00431-019-03482-w

Thesis and dissertation
Pyun, D. Y. (2006). *The proposed model of attitude toward advertising through sport*. [Unpublished Doctoral Dissertation]. The Florida State University.

Book
Borg, G. (1998). *Borg's perceived exertion and pain scales*: Human Kinetics.

Chapter of a book
Armstrong, D. (2019). Malory and character. In M. G. Leitch & C. J. Rushton (Eds.), *A new companion to Malory* (pp. 144-163). D. S. Brewer.

Reference to a Facebook profile
Little River Canyon National Preserve (n.d.). *Home* [Facebook page]. Facebook. Retrieved January 12, 2020 from https://www.facebook.com/lirinps/

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. IT-SPA 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 IT-SPA.

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*

CIP – Каталогизација у публикацији
Централна народна библиотека Црне Горе, Цетиње

INNOVATIVE Technologies in Sport and Physical Activity / urednik Bojan Mašanović. - Jun, (2022)- . - Podgorica : Tehnologija u sportu i tjelesnom vježbanju za zdrave stilove života, 2022- . - 21 cm
Два пута годишње

ISSN 2957-2525 = Innovative Technologies in Sport and Physical Activity
COBISS.CG-ID 22745092
ISSN 2957-2533 = Innovative Technologies in Sport and Physical Activity (Online)
COBISS.CG-ID 23352068

3rd Annual Scientific PASTECHL Sports & Health Conference

Sport, Science, and Technology for the Future of the Olympic Movement

https://pastechl.me/conference/

23 – 26 April 2026, Bar, Montenegro

Hosted by Physical Activity and Sports Tech for Healthy Lifestyles Lifestyles