Physical education and sport through the centuries
2026, 13(1), 101-111
ISSN 2335-0598
https:// phedss.fsfv-pr.rs

Original research article DOI:

SEX-RELATED DIFFERENCES IN PHYSICAL FITNESS COMPONENTS AMONG YOUNG SCHOOL-AGE CHILDREN: A CROSS-SECTIONAL STUDY

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ABSTRACT

The aim of this study was to examine sex-related differences in fitness components among young school-age children. A total of 138 children (72 boys and 66 girls; mean age 9.08 ± 0.67 years) participated in this cross-sectional study. Body composition, motor abilities, and cardiorespiratory parameters were assessed using standardized field-based tests. Differences between boys and girls were analyzed using the independent samples Student's t-test or Mann–Whitney U tests, depending on data distribution. The results revealed that boys had significantly higher muscle mass percentage, faster sprint times, better agility, greater explosive power of both the lower and upper limbs, higher aerobic capacity, and lower resting heart rate compared to girls ($p < 0.05$). No significant differences were observed in body height, body mass, body mass index, body fat percentage or blood pressure parameters. These findings indicate that sex-related differences in multiple fitness components are evident already in early school age, providing important insight into the early emergence of distinct physical fitness profiles between boys and girls.

Key words: Body composition, motor abilities, aerobic capacity, primary school children

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INTRODUCTION

Physical fitness represents one of the most important indicators of health and overall physical development in children, as it reflects the body's ability to efficiently perform everyday activities without excessive fatigue and to successfully adapt to various physical demands (Ortega, Ruiz, Castillo, & Sjöström, 2008; Ament & Verkerke, 2009). It encompasses the integration of several interrelated components—morphological, motor and cardiorespiratory—which together form the basis of functional and motor performance (Vandendriessche et al., 2011; Kukic, Dopsaj, Dawes, Orr, & Cvorovic, 2018; Mijalković et al., 2022). The development of these components affects not only sports achievements but also general health, proper growth and development, postural status, and the psychosocial well-being of the child (Hinkley et al., 2014). The assessment of physical fitness includes measurements of morphological characteristics (body height, body mass, body mass index, percentage of body fat and muscle mass, etc.) (Kukic et al., 2018), motor abilities (speed, agility, coordination, strength, flexibility, balance, and precision) (Vanhees et al., 2005), as well as cardiorespiratory parameters (maximal oxygen uptake, systolic and diastolic blood pressure, resting and exercise heart rate, etc.) (Lang et al., 2018). The period of young school age is characterized by intensive growth and maturation, which makes the monitoring of these parameters particularly important for the early detection of potential deviations in physical and health status and for guiding further proper development (Beunen & Malina, 2008; Scherdel et al., 2016). Also, it can be said that physical fitness has multiple implications for a child's health and development, and therefore it is important to understand how its individual components differ between boys and girls (Boreham & Riddoch, 2001; Thompson, Baxter-Jones, Mirwald, & Bailey, 2003).

Previous studies examining differences in physical fitness components between boys and girls indicate the presence of pronounced sex-related differences even during young school age (Dencker et al., 2007; Marta, Marinho, Barbosa, Izquierdo, & Marques, 2012; Flanagan et al., 2015; Racette, Uhrich, White, Yu, & Clark, 2017). Marta et al. (2012) showed that boys generally achieve better results in power, speed and aerobic endurance, while girls exhibit greater abilities in areas requiring flexibility and balance. Similarly, Dencker et al. (2007) found that boys have higher levels of aerobic capacity compared to girls, which can partly be explained by differences in body composition and levels of physical activity. Flanagan et al. (2015) emphasized that developmental differences between sexes become more pronounced during the transition from fourth to fifth grade, when physiological and motor characteristics of boys and girls begin to differentiate more rapidly. Furthermore, Racette et al. (2017) analyzed health risks based on aerobic capacity and body composition, concluding that boys are generally more likely to meet the criteria for healthy cardiorespiratory fitness, while girls show more favorable values for body mass index and body fat percentage.

Understanding sex-related differences in physical fitness components is important for gaining insight into the biological and developmental mechanisms that influence

2026, 13(1), 101-111
ISSN 2335-0598

children's physical growth and performance. Identifying these differences at a young age provides valuable information about how boys and girls develop distinct physical profiles, which can help explain variations in functional abilities, health indicators, and overall physical potential during growth and maturation. Therefore, the aim of this study was to examine sex-related differences in fitness components among young school-age children

METHOD

Participants:

The sample consisted of 138 children with a mean chronological age of 9.08 ± 0.67 years, including 72 boys (9.10 ± 0.61 years) and 66 girls (9.06 ± 0.74 years), attending the third and fourth grades of primary schools in Niš, Serbia. All children were healthy, free from injuries or medical conditions that could affect performance, able to understand and follow testing instructions, and regularly attended school and physical education classes. Parents or guardians provided written informed consent for participation. The study was approved by the Ethics Committee of the Faculty of Sport and Physical Education, University of Niš (approval number 04-1409/2).

Testing procedures:

The testing was conducted in the school gymnasium during the morning hours. The facility was well-lit and adequately heated. Participants were divided into smaller groups to enable the most efficient implementation of the circuit testing method. The fitness components included the assessment of body height, body mass, body mass index, body fat percentage, muscle mass percentage, speed, agility, explosive power of both lower and upper limbs, maximal oxygen uptake, systolic and diastolic blood pressure, as well as resting heart rate.

Body height was measured with a Martin anthropometer GPM 101 (GPM GmbH, Switzerland; accuracy 0.1 cm) (Flores et al., 2020). Body mass, BMI, body fat, and muscle percentage were assessed using a bioelectrical impedance device, Omron BF511 (Omron Healthcare Co., Kyoto, Japan; accuracy 0.1 kg), with established validity and reliability (Dehghan & Merchant, 2008).

Speed was assessed over 5 m and 10 m using Witty photocell gates (Microgate, Italy; accuracy 0.01 s) (Madić, Nikolić, & Stojiljković, 2015). Participants started from a standing position behind the start line and completed three trials for each distance, with the best result retained for analysis. The validity and reliability of these tests have been previously confirmed (Rumpf, Cronin, Oliver, & Hughes, 2011).

Agility was assessed using the slalom and T-tests, with Witty photocell gates (Microgate, Italy; accuracy 0.01 s) (Madić, Nikolić, & Stojiljković, 2015). In the slalom test, participants started from a standing position behind the start line and ran through a course of five cones. The first cone was positioned 1 m from the start line, with 2 m between subsequent cones. Participants weaved between the cones, reached the final cone, performed a 180° turn, and returned along the same path. The validity and reliability of this test have been previously confirmed (Artero et al., 2011). For the T-test, participants began from a standing start and ran straight to a cone 9.14 m away, touching it. They then shuffled sideways to a cone 4.57 m to the side, touched it, and continued sideways to a second side cone 9.14 m away. After touching the second side cone, they returned to the central cone, touched it, and finished by running backward 9.14 m to cross the finish line. This test has also been validated and shown to be reliable (Negra et al., 2017).

Lower limb explosive power was assessed using the countermovement jump (CMJ) and countermovement jump with arm swing (CMJwAS), both measured with Optojump photocells. The validity and reliability of the device have been previously established (Glatthor et al., 2011). For the countermovement jump, participants began from a standing position with feet shoulder-width apart and hands on the hips, lowered into a semi-squat, and performed a maximal vertical jump, absorbing the landing by flexing the knees. The countermovement jump with arm swing followed the same procedure, with the addition of coordinated arm movement to enhance jump height. These tests have been validated and shown to be reliable (Meylan, Cronin, Oliver, Hughes, & McMaster, 2012).

Upper limb explosive power was evaluated using a 1 kg medicine ball throw from both standing and seated positions. In the standing throw, participants stood behind the throwing line with feet shoulder-width apart and knees slightly bent, holding the ball above the head with both hands, and then performed a forward throw for maximal distance. The validity and reliability of this test have been confirmed (Aertssen, Ferguson & Smits-Engelsman, 2016). In the seated throw, participants sat against a wall with legs extended and slightly apart, holding the ball at chest level with both hands, and threw it forward as far as possible without lifting the back from the wall or moving the torso. This test has also been validated and shown reliable (Beckham et al., 2019).

Participants' maximal oxygen uptake (VO_2max) was estimated using a modified Yo-Yo Intermittent Recovery Level 1 (Yo–Yo IR1) test adapted for young school-age children. Cones were placed 16 m apart, with each participant assigned a personal cone to follow throughout the test. On the instructor's signal, participants ran to the opposite cone and back, completing a total distance of 32 m to successfully finish a level. The test was terminated if the participant chose to stop, with a maximum of two allowed delays before elimination. The validity and reliability of the test have been confirmed (Póvoas et al., 2016).

VO_2max was calculated using the following formula: $VO_2max = 0.0116 \times x + 42.3$ $ml \cdot min^{-1} \cdot kg^{-1}$ (Ahler, Bendiksen, Krustrup, & Wedderkopp, 2012).

Resting heart rate, as well as systolic and diastolic blood pressure, were measured prior to the warm-up using an automated monitor (M6 HEM-7223-E; Omron, Lake Forest, IL, USA) (Larsen et al., 2017; Larsen et al., 2021). Three measurements were taken on the left arm at one-minute intervals after an eight-minute rest, with additional measurements performed if differences between the first three readings exceeded 10 mmHg.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics 20. Descriptive statistics were calculated for the total sample as well as separately for boys and girls. The Kolmogorov–Smirnov test was used to assess the normality of data distribution. Among the 18 variables analyzed, 5 were found to deviate from normality. Accordingly, to determine sex differences in fitness components among young school-age children, both the independent samples Student's t-test and the nonparametric Mann-Whitney U test were applied. Cohen's d was used to assess the effect size for comparisons between sexes. Values were interpreted according to conventional guidelines: 0.2 = small effect, 0.5 = medium effect, 0.8 = large effect (Cohen, 2013).

RESULTS

Table 1 presents the descriptive statistics for the entire sample of participants, as well as the results of the Kolmogorov–Smirnov test used to assess the normality of data distribution.

Table 1. Descriptive statistics and Kolmogorov–Smirnov test results.

Variables	Mean	SD	K-S Test
BH (cm)	140.01	8.11	0.35
Body mass (kg)	37.39	10.60	0.03
BMI (kg/m^2)	18.95	3.84	0.08
Fat (%)	22.32	8.52	0.69
Muscle (%)	32.24	2.89	0.80
5 m (s)	1.48	0.14	0.01
10 m (s)	2.54	0.22	0.03
Slalom (s)	8.32	1.29	0.14
T-test (s)	16.14	2.49	0.73
CMJ (cm)	16.73	3.72	0.95
CMJwAS (cm)	19.91	4.24	0.70
SMBCP (m)	4.07	0.80	0.20
SeMBCP (m)	2.97	0.60	0.40
YO-YO (m)	256.00	121.41	0.02
VO_2max ($ml\cdot kg^{-1}\cdot min^{-1}$)	45.35	1.41	0.02
SBP (mmHg)	115.15	13.46	0.78
DBP (mmHg)	74.17	9.64	0.19
RHR	100.07	15.84	0.57

Legend: SD - standard deviation; K-S Test - Kolmogorov-Smirnov Test; BH - body height; BM – body mass; BMI – body mass index; Fat - body fat percentage; Muscle - muscle mass percentage; 5 m – 5-meter sprint; 10 m – 10-meter sprint; Slalom – agility test; T-test – agility test; CMJ - countermovement jump; CMJwAs - countermovement jump with arm swing; SMBCP - standing medicine ball chest pass; SeMBCP - seated MB chest pass; YO-YO - Yo-Yo Intermittent Recovery Test Level 1; VO_2max - maximal oxygen consumption; SBP - systolic blood pressure; DBP - diastolic blood pressure; RHR - resting heart rate.

Based on the results of the Kolmogorov–Smirnov test, five variables (body mass, 5- and 10-meter sprints, Yo–Yo IR1 and VO_2max) were found not to be normally distributed. Consequently, the Mann–Whitney U test was used for these variables, while the independent samples Student's t test was applied to the remaining variables to assess sex differences in fitness components among young school-age children. "Furthermore, Cohen's d was used to determine the effect size. Descriptive statistics by sex and the tests results are presented in Table 2.

Table 2. Descriptive statistics by sex and group comparison tests.

	Boys		Girls				
Variables	**Mean**	**SD**	**Mean**	**SD**	**Ind. t test**	**M-W U test**	**Cohen's d**
BH (cm)	139.93	6.88	140.10	9.32	0.90		0.02
Body mass (kg)	37.38	10.04	37.41	11.27		0.83	0.00
BMI (kg/m²)	19.05	3.96	18.84	3.72	0.75		0.06
Fat (%)	21.63	9.03	23.06	7.92	0.32		0.17
Muscle (%)	32.86	2.85	31.56	2.80	0.01*		0.46
5 m (s)	1.45	0.12	1.52	0.16		0.00*	0.50
10 m (s)	2.49	0.19	2.59	0.24		0.01*	0.46
Slalom (s)	8.15	1.10	8.50	1.47	0.12		0.27
T-test (s)	15.52	2.34	16.82	2.48	0.00*		0.54
CMJ (cm)	17.53	4.03	15.85	3.15	0.01*		0.46
CMJwAS (cm)	20.71	4.27	19.02	4.06	0.02*		0.41
SMBCP (m)	4.37	0.81	3.74	0.65	0.00*		0.85
SeMBCP (m)	3.14	0.57	2.78	0.58	0.00*		0.63
YO-YO (m)	287.56	133.35	221.58	96.62		0.00*	0.56
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	45.64	1.55	44.87	1.12		0.00*	0.57
SBP (mmHg)	116.03	13.18	114.20	13.79	0.43		0.14
DBP (mmHg)	74.58	9.69	73.73	9.65	0.60		0.09
RHR	96.64	16.37	103.80	14.47	0.01*		0.46

*Legend: * - statistically significant differences ($p < 0.05$); SD - standard deviation; Ind. t test - Student's t test for independent samples; M-W U test - Mann-Whitney U test; BH - body height; BM – body mass; BMI – body mass index; Fat - body fat percentage; Muscle - muscle mass percentage; 5 m – 5-meter sprint; 10 m – 10-meter sprint; Slalom – agility test; T-test – agility test; CMJ - countermovement jump; CMJwAs - countermovement jump with arm swing; SMBCP - standing medicine ball chest pass; SeMBCP - seated MB chest pass; YO-YO - Yo-Yo Intermittent Recovery Test Level 1; VO_2max - maximal oxygen consumption; SBP - systolic blood pressure; DBP - diastolic blood pressure; RHR - resting heart rate.*

Based on the results of the Student's t test and Mann–Whitney U test, sex differences were observed in the fitness components of young school-age children. Statistically significant differences were found in muscle mass percentage ($p = 0.01$), speed tests (5 m ($p = 0.00$) and 10 m ($p = 0.01$) sprints), the agility T-test ($p = 0.00$), explosive power of the lower limbs (CMJ ($p = 0.01$) and CMwAS ($p = 0.02$)) and upper limbs (chest pass standing with a medicine ball ($p = 0.00$) and seated chest pass with a medicine ball ($p = 0.00$)), Yo-Yo IR1 ($p = 0.00$), VO_2max ($p = 0.00$) and resting heart rate ($p = 0.01$). In all variables showing significant differences, boys outperformed girls. All differences were considered statistically significant at $p < 0.05$. Effect sizes in this study ranged from negligible to large, with the largest effects observed in explosive strength tests and the smallest in anthropometric and cardiovascular variables.

DISCUSSION

The aim of this study was to examine sex-related differences in fitness components among young school-age children. The results revealed significant differences between boys and girls in several parameters, including muscle mass percentage, speed, agility, explosive power of both lower and upper limbs, aerobic capacity, and resting heart rate. Boys demonstrated superior performance in all measured variables. They achieved faster times in the 5 m and 10 m sprints and showed better coordination and agility in the T-test. In addition, boys exhibited greater explosive power in both the lower limbs, as indicated by higher CMJ and CMJwAS scores, and the upper limbs, as shown by superior results in the chest pass standing and seated chest pass tests with a medicine ball. Furthermore, boys reached higher levels in the Yo-Yo IR1 test and had higher estimated VO_2max values, reflecting better aerobic capacity. A lower resting heart rate in boys also indicated a more efficient cardiovascular response compared to girls. Overall, these findings demonstrate clear sex-based differences across multiple components of physical fitness even in early school age.

The observed sex-related differences in muscle mass percentage and motor performance are consistent with findings from previous studies examining physical fitness in prepubescent children (Dencker et al., 2007; Manzano-Carrasco et al., 2022). Boys demonstrated a significantly higher muscle mass percentage, which likely contributed to their superior performance in speed, agility, and explosive power tests. Previous evidence suggests that even before puberty, boys tend to exhibit greater lean mass accumulation and neuromuscular efficiency, while girls generally show higher relative fat mass (Marta et al., 2012; Dencker et al., 2007). These morphological differences may partially explain the observed advantages of boys in tasks requiring rapid force production and high movement velocity, such as sprinting, jumping, and throwing.

The superior performance of boys in sprinting and agility tasks observed in this study aligns with earlier research reporting faster sprint times and better agility outcomes in boys during young school age (Flanagan et al., 2015; Negra et al., 2017). Speed and agility are highly dependent on neuromuscular coordination, stride frequency, and lower limb power, which appear to develop earlier or more prominently in boys (Živković et al., 2022). In contrast, although girls often demonstrate advantages in flexibility and balance (Marta et al., 2012; Smits-Engelsman, Coetzee, Valtr, & Verbecque, 2023), these components were not assessed in the present study, which may partly explain why no variables favored girls. The lack of significant differences in the slalom test, compared to the T-test, may reflect differences in task complexity and movement demands, suggesting that more multidirectional and cognitively demanding agility tasks may be more sensitive in detecting sex-related differences.

Significant differences were also found in measures of explosive power of both the lower and upper limbs, with boys achieving higher values in CMJ, CMJwAS, chest pass standing with a medicine ball and seated chest pass with a medicine ball. These findings are consistent with previous studies reporting higher explosive strength in boys even at prepubescent ages (Meylan et al., 2012; Aertssen et al., 2016). The inclusion of both standing and seated medicine ball throws allowed for a more comprehensive assessment of upper limb explosive power, minimizing the influence of lower body contribution. The consistent superiority of boys across both tests suggests that differences are not solely attributable to technique but may reflect underlying neuromuscular and morphological factors. These differences may be further influenced by early sex-related variations in neuromuscular coordination and motor unit recruitment efficiency, which are known to emerge prior to puberty and contribute to performance in explosive tasks (Meylan, Cronin, Oliver, & Rumpf, 2014).

Regarding cardiorespiratory fitness, boys achieved significantly better results in the Yo-Yo IR1 test and demonstrated higher estimated VO_2max values. These findings are in agreement with previous studies indicating higher aerobic capacity in boys compared to girls during childhood (Rowland, Goff, Martel, & Ferrone, 2000; Dencker et al., 2007; Racette et al., 2017). Potential explanations include differences in habitual physical activity levels, movement patterns during play, and cardiovascular adaptations. Additionally, the lower resting heart rate observed in boys may indicate more efficient autonomic regulation and cardiovascular function, which has been associated with higher cardiorespiratory fitness levels in children (Lang et al., 2018).

Several limitations of this study should be acknowledged. First, the cross-sectional design limits the ability to infer causal relationships or developmental trajectories of sex-related differences. Second, physical activity levels outside school were not assessed, which may have influenced fitness outcomes. Third, biological maturation was not directly evaluated, and although the sample consisted of young school-age children, individual differences in maturation status may still exist. Future studies should incorporate longitudinal designs, objective measures of physical activity, and indicators of biological maturation to provide a more comprehensive understanding of sex-related differences in physical fitness development.

CONCLUSION

This study demonstrated clear sex-related differences in several components of physical fitness among young school-age children. Boys outperformed girls in muscle mass percentage, speed, agility, explosive power of both the lower and upper limbs, aerobic capacity, and resting heart rate, while no differences were observed in basic anthropometric or blood pressure measures. These findings suggest that functional and neuromuscular factors, rather than body size alone, contribute to early fitness differences between sexes. Considering sex-specific characteristics in physical education may support balanced physical development and long-term health in children.

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Received on 12.05.2026.
Accepted on 21.05.2026.