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RELATIONSHIP BETWEEN BODY COMPOSITION AND PHYSICAL FITNESS AMONG 13-YEAR-OLD ADOLESCENTS

Darko Stojanović[1], Vladimir Momčilović[1]

[1]Pedagogical Faculty in Vranje, University of Niš, Serbia

ABSTRACT

This study aimed to examine sex differences in physical fitness and body composition, and to explore the relationship between body composition and physical fitness among 13-year-old adolescents. A cross-sectional study was conducted on 80 adolescents (42 girls, 38 boys; mean age 13.47 ± 0.28 years) from an urban primary school in Niš, Serbia. Physical fitness was assessed using the Eurofit battery: Sit-and-Reach, Standing Long Jump, Handgrip Strength, 30-Second Sit-Ups, 10×5 m Shuttle Run, and the 20-Meter Shuttle Run. Body composition was measured via bioelectrical impedance (body fat percentage - BF%) and skinfold caliper (sum of five skinfolds - Σ5SF). Independent t-tests, Pearson correlations, and multiple regressions were performed separately by sex. Boys significantly outperformed girls in muscular strength, explosive power, speed, and aerobic capacity ($p < .001$), while girls had higher flexibility ($p = 0.035$) and BF% ($p < .001$). Σ5SF and BF% were negatively correlated with most fitness tests, especially shuttle run, long jump, and sit-ups. BMI showed weaker and inconsistent associations but was positively linked to handgrip strength, particularly in boys. Regression analyses identified Σ5SF and BF% as stronger predictors of physical fitness outcomes than BMI, with sex-specific patterns. Excess adiposity adversely affects physical fitness in adolescents, with stronger predictive value for BF% and skinfolds than for BMI. These findings support the use of direct body composition measures and emphasize the need for sex-sensitive approaches in adolescent fitness monitoring and physical education.

Key words: adiposity, association, Eurofit test battery, body fat mass, cardiorespiratory fitness

Corresponding author
Darko Stojanović
darko89_nish@hotmail.com

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INTRODUCTION

Globally, the combination of increasing physical inactivity and rising adiposity poses a significant and escalating threat to the health of children and adolescents. According to the World Health Organization (WHO), approximately 81% of adolescents aged 11 to 17 fail to meet the daily recommendation of 60 minutes of moderate-to-vigorous physical activity (Guthold et al., 2020; WHO, 2022). These trends have serious long-term implications, as poor physical fitness during youth is increasingly associated with cardiometabolic diseases, mental health disorders, and early mortality. In response, major cardiology organizations now recognize cardiorespiratory fitness as a critical clinical 'vital sign' (Raghuveer et al., 2020). Unfortunately, youth fitness is declining. A meta-analysis of international data showed that 20-meter shuttle run performance among children and adolescents declined by approximately 0.43 standard deviations between 1980 and 2000, indicating a significant reduction in cardiorespiratory fitness over two decades (Tomkinson et al., 2003). More recently, a population-based study from neighboring Croatia reported further declines in cardiorespiratory fitness and flexibility among 11–14-year-olds tested between 1999 and 2014 (Kasović et al., 2021).

Adolescence represents a crucial developmental phase marked by rapid growth, hormonal shifts, and evolving body composition, all of which significantly affect physical fitness outcomes (Joensuu et al., 2021). During this period, the balance between fat mass and lean tissue becomes especially important, as elevated adiposity has been consistently linked to poorer performance in cardiorespiratory fitness (Dewi et al., 2021). Indeed, multiple studies have demonstrated that adolescents with higher levels of body fat, whether measured through percentage body fat or skinfold thickness, tend to underperform in shuttle runs, strength tests, and agility-based tasks (Agata & Monyeki, 2018; Mendoza-Muñoz et al., 2020). These associations are not merely physiological but also sex-specific. Boys generally exhibit superior muscular strength, explosive power, and cardiorespiratory fitness, while girls often demonstrate greater flexibility and higher adiposity during early adolescence (Tomkinson et al., 2018; Ferreira et al., 2024). Biological maturation between the ages of 12 and 14 amplifies these sex-based performance differences. A recent meta-analysis further confirmed that female superiority in sit-and-reach tests peaks around age 12 (Nuzzo, 2024), underscoring the importance of recognizing sex-specific developmental trajectories in physical education and talent identification.

Despite this growing body of research, relatively few studies have combined comprehensive measures of body composition and physical fitness across sexes using standardized test batteries in narrowly defined age groups. This study aims to address this gap by (1) examining sex differences in physical fitness performance and body composition, and (2) investigating the relationships between body composition indicators and physical fitness outcomes among 13-year-old adolescents. By focusing on a single age cohort and validated fitness tools, the study seeks to offer precise insights relevant for health monitoring, school-based intervention design, and future longitudinal surveillance.

METHODS

Study Design

This study employed a cross-sectional design conducted at a large urban primary school located in Niš, Serbia.

Participants

The study sample consisted of 80 adolescents (mean age = 13.47 ± 0.28 years) recruited from four classes within a large primary school in Niš, Serbia. The cohort included 42 girls and 38 boys. Given the study's focus on physical fitness and body composition, inclusion criteria required participants to be free from any chronic health conditions that could interfere with their ability to perform physical tasks, to attend physical education classes regularly, and to provide signed informed consent from a parent or guardian. Participants who were absent on the day of testing or did not complete the full testing battery were excluded from the analysis. The study followed the Declaration of Helsinki and was approved by the Ethics Committee of the University of Niš, Faculty of Sport and Physical Education.

Procedures

All procedures were conducted in March 2016, during the second semester of the 2015/2016 academic year. Testing took place during regular physical education classes over two non-consecutive school mornings, separated by 48 hours, within the school's gymnasium. One week prior, a familiarization session was held to introduce participants with the testing protocols. On testing days, participants were instructed to abstain from vigorous physical activity since the previous afternoon and to refrain from food or caloric beverages for at least two hours prior to assessment.

Each session began with a standardized 10-minute warm-up consisting of five minutes of light jogging followed by dynamic mobility drills and test-specific movements. On Day 1, students completed a series of health-related physical fitness tests. On Day 2, measurements of body height, body mass, skinfolds, and body fat percentage, along with the 20-meter shuttle run test, were performed. A minimum two-minute passive rest was provided between each test station. To ensure consistency and minimize inter-rater variability, the same trained assessor administered each specific test throughout the study.

Body Composition

Body mass, body mass index (BMI), and body fat percentage (BF%) were assessed using a bioelectrical impedance analyzer (SOEHNLE Body Balance Chicago, Soehnle GmbH, Germany). Participants followed the pre-measurement preparation protocol recommended by Kyle et al. (2004). In addition, five skinfold thicknesses, namely the calf, suprailiac, subscapular, triceps, and biceps, were measured on the right side of the body using a calibrated GPM skinfold caliper (Switzerland, 0.2 mm resolution), following the standardized procedure described by Eston and Reilly (2009). The sum of the five skinfolds (Σ5SF) was calculated as an additional proxy for total subcutaneous fat.

Physical Fitness Assessment

Physical fitness was assessed using the standardized **Eurofit test battery**, developed by the Council of Europe to evaluate key components such as flexibility, muscular strength, endurance, speed, and agility in school-aged children (Adam et al., 1988). The following tests were administered:

- Sit-and-Reach Test: Assesses flexibility of the lower back and hamstring muscles.
- Standing Long Jump: Measures explosive leg power.
- Handgrip Strength Test: Evaluates maximal isometric strength of the hand and forearm muscles.
- 30-Second Sit-Ups: Assesses abdominal muscular endurance.
- 10×5 Meter Shuttle Run: Measures speed and agility.
- 20-Meter Shuttle Run Test: Evaluates cardiorespiratory fitness.

All tests were conducted in accordance with the official guidelines outlined in the Eurofit Handbook (Adam et al., 1988). The Eurofit test battery has demonstrated acceptable test-retest reliability in adolescent populations. For instance, Donncha et al. (1999) reported intraclass correlation coefficients (ICCs) ranging from 0.85 to 0.99 for various Eurofit tests in adolescent males. Similarly, Grgic (2022) conducted a systematic review and found that most Eurofit tests exhibit moderate to excellent reliability, with ICCs typically above 0.70. These findings support the use of the Eurofit battery as a reliable tool for assessing physical fitness in adolescents.

Statistical Analyses

All statistical analyses were performed using IBM SPSS Statistics (Version 27). Descriptive statistics (mean ± standard deviation) were calculated for all continuous variables. The Shapiro–Wilk test was used to assess normality. To examine gender differences in body composition and physical fitness variables, independent samples t-tests were used. Effect sizes were calculated using Cohen's d for t-tests. Effect size magnitudes were interpreted according to Cohen's conventions: small ($d \approx 0.2$), medium ($d \approx 0.5$), and large ($d \geq 0.8$) (Cohen, 1988). Pearson's correlation coefficients (r) were used to assess relationships between body composition indicators (BMI, BF%, Σ5SF) and physical fitness outcomes, overall and by sex. Correlation coefficients were categorized using Hopkins' thresholds: trivial ($r < 0.1$), small (0.1–0.3), moderate (0.3–0.5), large (0.5–0.7), very large (0.7–0.9), and extremely large (> 0.9) (Hopkins et al., 2009). Additionally, multiple linear regression models were performed separately for boys and girls to explore whether body composition predicts key fitness outcomes (e.g., 20-m shuttle run, handgrip strength, standing long jump). A two-tailed p-value < 0.05 was considered statistically significant.

RESULTS

Preliminary analyses using the Shapiro-Wilk test and visual inspection of Q–Q plots indicated that the data were approximately normally distributed, justifying the use of parametric statistical methods. Sample characteristics are shown in Table 1.

Table 1. Sample Characteristics by Gender and Total (M ± SD)

Variable	Boys (n = 38)	Girls (n = 42)	Total (N = 80)
Age (years)	13.45 ± 0.27	13.49 ± 0.29	13.47 ± 0.28
Body Height (cm)	165.26 ± 10.28	161.11 ± 6.23	163.08 ± 8.60
Body Mass (kg)	57.42 ± 12.79	53.28 ± 9.01	55.25 ± 11.10

Note. Values are presented as mean ± standard deviation.

Statistically significant gender differences were observed in nearly all physical fitness components and body composition measures (Table 2). Boys exhibited superior strength, endurance, agility, and aerobic capacity, with large effect sizes (Cohen's d > 0.80). Girls had higher body fat percentages and greater sum of five skinfolds. Notably, flexibility (sit-and-reach) favored girls moderately (d = -0.48), while the largest effect sizes were observed in the 10×5 shuttle run (d = -1.73) and body fat percentage (d = -2.26), indicating strong sex-based performance and composition disparities.

Table 2. Gender Differences in Physical Fitness and Body Composition

Variable	Boys (n = 38)	Girls (n = 42)	t	p	d
Sit-and-Reach (cm)	19.79 ± 7.62	23.59 ± 8.21	-2.15	**.035**	-0.48
Standing Long Jump (cm)	177.53 ± 24.48	141.58 ± 23.35	6.70	**<.001**	1.50
Handgrip Strength (kg)	39.22 ± 9.20	30.17 ± 6.57	5.02	**<.001**	1.14
30-s Sit-Ups (reps)	23.76 ± 3.70	18.39 ± 3.45	6.69	**<.001**	1.50
10×5 Shuttle Run (s)	21.10 ± 1.35	24.18 ± 2.10	-7.88	**<.001**	-1.73
20-m Shuttle Run (stages)	5.91 ± 1.81	4.23 ± 1.17	4.93	**<.001**	1.09
Body Mass Index (kg/m^2)	20.87 ± 3.59	20.51 ± 3.18	0.48	.636	0.11
Body Fat Percentage (%)	14.33 ± 6.67	28.31 ± 5.77	-9.94	**<.001**	-2.26
Σ5SF (mm)	62.03 ±(25.92	78.30 ± 16.12	-3.53	**.001**	-0.79

Note. Values are presented as mean ± standard deviation; t = Student's t-statistic; d= Cohen's effect size); Σ5SF = sum of five skinfolds (calf, suprailiac, subscapular, biceps, triceps); p = probability value, significant at p < 0.05.

When examined separately by gender, the correlation patterns between body composition and physical fitness showed distinct trends.

In girls (Table 3), the relationship between adiposity and physical fitness was particularly evident in the 20-m shuttle run, where BMI, BF% and Σ5SF all showed significant negative association, with correlation magnitudes ranging from moderate to large. A similar, though slightly weaker, trend was observed in the standing long jump, where Σ5SF showed a moderate negative correlation (r = –0.36), while BMI and BF% were not statistically significant. Flexibility (sit-and-reach) and muscular endurance (sit-ups) showed trivial to small associations with adiposity, while handgrip strength was moderately associated with BMI.

Table 3. Correlations Between Body Composition Indicators and Physical Fitness Outcomes in Girls

Variable	BMI (r)	BF% (r)	Σ5SF (r)
Sit-and-Reach (cm)	0.06	–0.01	–0.05
Standing Long Jump (cm)	–0.19	–0.12	–0.36*
Handgrip Strength (kg)	0.35*	0.22	0.16
30-s Sit-Ups (reps)	–0.10	–0.10	–0.15
10×5 Shuttle Run (s)	0.02	0.05	0.16
20-m Shuttle Run (stages)	–0.39*	–0.37*	–0.53**

Note. BF% = body fat percentage; BMI = Body mass index; Σ5SF = sum of five skinfolds (calf, suprailiac, subscapular, biceps, triceps);

** = significant correlation at 0.05 level (two-tailed); ** = significant correlation at 0.01 level (two-tailed).*

In boys (Table 4), adiposity measures were more broadly and consistently related to physical fitness performance. Significant negative correlations were observed between Σ5SF and standing long jump, sit-ups, and 20-m shuttle run, with moderate to large effect sizes. Both BMI and BF% were also significantly negatively correlated with 20-m shuttle run (r = –0.39 and –0.48, respectively), showing moderate effects. These findings suggest that in boys, higher fat mass is consistently associated with lower performance in explosive power, muscular endurance, and cardiorespiratory fitness. The positive correlation between Σ5SF and 10×5 shuttle time, with moderate magnitude, further indicates that increased adiposity may be linked to reduced agility and coordination.

Table 4. Correlations Between Body Composition Indicators and Physical Fitness Outcomes in Boys

Variable	BMI (r)	BF% (r)	Σ5SF (r)
Sit-and-Reach (cm)	0.12	0.15	–0.02
Standing Long Jump (cm)	–0.24	–0.24	–0.43**
Handgrip Strength (kg)	0.36*	0.09	0.09
30-s Sit-Ups (reps)	–0.21	–0.25	–0.38*
10×5 Shuttle Run (s)	0.08	0.28	0.39*
20-m Shuttle Run (stages)	–0.39*	–0.48**	–0.62**

Note. BF% = body fat percentage; BMI = Body mass index; Σ5SF = sum of five skinfolds (calf, suprailiac, subscapular, biceps, triceps);

** = significant correlation at 0.05 level (two-tailed); ** = significant correlation at 0.01 level (two-tailed).*

In Table 5 the regression analysis revealed that all models significantly predicted physical fitness outcomes, with R^2 values ranging from 0.40 to 0.56, indicating that a moderate proportion of variance in fitness performance could be explained by the body composition indicators. BMI emerged as a consistent positive predictor across several models, suggesting that adolescents with higher BMI, potentially reflecting a combination of fat-free and fat mass, tended to perform better in strength-oriented tests such as handgrip and standing long jump. In contrast, both body fat percentage (BF%) and the sum of five skinfolds (Σ5SF) showed negative associations with fitness outcomes, highlighting the potential adverse effects of higher adiposity on physical performance. This was particularly evident in the standing long jump, where both BF% and Σ5SF were significantly associated with reduced performance, and in aerobic capacity (20MS), where Σ5SF negatively predicted endurance levels. These findings underscore the importance of differentiating between fat-free and fat mass when interpreting BMI in youth fitness research, and they support the use of skinfold-based measurements as more precise indicators for assessing fitness-related health risks.

Table 5. Multiple Regression Models Predicting Physical Fitness Outcomes

Outcome	**R^2**	**F**	**Model p-value**	**Significant Predictors (Direction)**
Standing Long Jump (cm)	0.465	22.03	< .001	BMI (+), Σ5SF (−)
Handgrip Strength (kg)	0.478	23.19	< .001	BMI (+), BF% (−), Σ5SF (−)
30-s Sit-Ups (reps)	0.402	17.02	< .001	BMI (+), BF% (−), Σ5SF (−)
10×5 Shuttle Run (s)	0.518	27.24	< .001	BMI (−), BF% (+), Σ5SF (+)
20-m Shuttle Run (stages)	0.560	32.24	< .001	BMI (+), Σ5SF (−)

Note. R^2 = coefficient of determination; F = F-statistic from regression analysis; p-value indicates overall model significance. Positive (+) or negative (−) signs in the "Significant Predictors" column denote the direction of association between each body composition variable and the physical fitness outcome. BMI = body mass index; BF% = body fat percentage; Σ5SF = sum of five skinfolds. All predictors listed were statistically significant at p < .05.

As shown in Table 6, the regression models indicated that among boys, the sum of five skinfolds (Σ5SF) consistently served as a negative predictor across several fitness outcomes, particularly for the 20-m shuttle run and 10×5 shuttle run (R^2 > 0.53). BMI demonstrated mixed associations: it positively predicted performance in the 20-m shuttle run and handgrip strength, possibly reflecting contributions from fat-free mass, while negatively predicting agility in the 10×5 shuttle run. Among girls, only three regression models reached statistical significance. The sum of five skinfolds (Σ5SF) was negatively associated with performance in both the standing long jump and the 20-m shuttle run, while BMI positively predicted handgrip strength. Interestingly, a positive association between BF% and standing long jump was observed, which may reflect underlying maturational differences. Overall, adiposity appeared to be a more consistent predictor of fitness outcomes in boys, whereas its influence among girls was more selective. These findings underscore the value of sex-specific assessments when evaluating the relationship between body composition and physical fitness in adolescents.

Table 6. Sex-Specific Regression Models for Physical Fitness Outcomes

Sex	Outcome	R^2	F	Model p-value	Significant Predictors (Direction)
Boys	Standing Long Jump (cm)	0.348	6.05	.002	Σ5SF (−)
	Handgrip Strength (kg)	0.432	8.60	<.001	BMI (+), Σ5SF (−)
	Sit-ups (30 s)	0.237	3.53	.025	Σ5SF (−)
	10x5 (s)	0.535	13.06	<.001	BMI (−), Σ5SF (+)
	20-m Shuttle Run (stages)	0.536	13.10	<.001	BMI (+), Σ5SF (−)
Girls	Standing Long Jump (cm)	0.285	5.06	.005	BF% (+), Σ5SF (−)
	Handgrip Strength (kg)	0.204	3.25	0.032	BMI (+)
	20-m Shuttle Run (stages)	0.313	5.76	.002	Σ5SF (−)

Note. R^2 = coefficient of determination; F = F-statistic from regression analysis; p-value indicates overall model significance. Positive (+) or negative (−) signs in the "Significant Predictors" column denote the direction of association between each body composition variable and the physical fitness outcome. BMI = body mass index; BF% = body fat percentage; Σ5SF = sum of five skinfolds. All predictors listed were statistically significant at $p < .05$.

DISCUSSION

This study aimed to assess gender differences in physical fitness and body composition and to explore the predictive value of adiposity indicators such as body fat percentage (BF%), sum of five skinfolds (Σ5SF), and body mass index (BMI), on performance outcomes among Serbian adolescents. As anticipated, boys demonstrated significantly higher values in strength, endurance, and aerobic capacity, while girls exhibited superior flexibility and elevated levels of body fat. Among the three adiposity measures, Σ5SF and BF% showed stronger associations, tipically in the moderate to large range, with reduced physical fitness performance than BMI, highlighting their relevance in evaluating functional health in youth.

Gender differences observed in this study align with previous research documenting superior male performance in fitness tests requiring muscular strength, explosive power, and aerobic capacity (Tomkinson et al., 2018; Agata & Monyeki, 2018; Puszczałowska-Lizis et al., 2023), while girls had greater flexibility and higher adiposity (Joensuu et al., 2018; Agata & Monyeki, 2018; Galan-Lopez et al., 2018; Gjonbalaj et al., 2022). These disparities are largely attributable to hormonal changes during puberty, particularly testosterone-driven increases in fat-free mass in boys and estrogen-induced fat deposition in girls (Minasian et al., 2014; Szmodis et al., 2019). Higher flexibility in girls may reflect intrinsic sex-specific differences in musculoskeletal structure and connective tissue properties, such as lower musculotendinous stiffness and greater joint laxity (Yu et al., 2022). Additionally, sociocultural factors such as stronger encouragement and access to vigorous sports for boys from both school and family environments, likely contribute to observed sex differences in adolescent fitness (Telford et al., 2016).

Correlational and regression analyses further reinforced the inverse relationship between adiposity and physical fitness. Both body fat and sum of five skinfolds exhibited consistent and strong associations with diminished performance than BMI, especially in aerobic (20-m shuttle run) and dynamic strength (sit-ups, long jump) tests. These findings are in agreement with Joensuu et al. (2018) and Stojanović & Branković (2018), who reported similar patterns in adolescent cohorts. Notably, BMI was a weaker predictor overall but did exhibit a positive correlation with handgrip strength in boys, suggesting that in some cases, higher BMI may reflect greater fat-free mass rather than fat mass (Mendoza-Muñoz et al., 2020; Gjonbalaj et al., 2022). The current results echo observations by Mendoza-Muñoz et al. (2020) and Gjonbalaj et al. (2022), who noted that adolescents with higher fat mass may demonstrate stronger handgrip values, likely due to accompanying increases in absolute fat-free mass. Similarly, findings from Moliner-Urdiales et al. (2011) and Lohman et al. (2008) support the conclusion that fat-free mass promotes static strength while higher fat mass compromises movement-based fitness. These patterns also confirm the critique that BMI, as an indirect measure, fails to adequately distinguish between fat and lean mass (Galan-Lopez et al., 2018; Dewi et al., 2022).

From a practical perspective, these findings emphasize the need for sex-sensitive fitness assessments and interventions. School programs should incorporate direct measures of adiposity rather than rely solely on BMI, a pattern also advocated by Galan-Lopez et al. (2018) and Dewi et al. (2022). Given the observed differences, particularly the adverse impact of excess fat on girls' endurance and muscular outcomes, physical education curricula should tailor conditioning programs accordingly, emphasizing motor coordination, aerobic capacity, and body composition improvement, especially for female students.

Nevertheless, this study has several limitations. Its cross-sectional design restricts the ability to establish causal relationships between body composition and physical fitness. Additionally, the sample was drawn from a single urban school and a narrow age range, which may limit the generalizability of the findings to broader adolescent populations. Furthermore, the absence of pubertal staging or maturational indicators limits the biological interpretation of sex-related patterns. Future studies should pursue longitudinal designs incorporating a broader population base and psychosocial or maturational covariates to further elucidate the mechanisms underlying the body composition–fitness relationship in youth.

CONCLUSION

In summary, this study highlights the complex interplay between sex, body composition, and physical fitness in adolescents. Boys generally outperformed girls in strength and endurance tasks, while girls demonstrated superior flexibility. Importantly, girls also exhibited significantly higher levels of adiposity, as reflected in body fat percentage and skinfold thickness. Adiposity measures showed consistent negative associations with fitness, particularly in boys, underscoring the adverse impact of excess fat on physical performance. Among girls, these effects were more targeted, influencing cardiorespiratory and power-related tasks. While BMI offers a general estimate, skinfold-based assessments can provide more precise insight into fitness-related health risks. These findings underscore the importance of integrating precise body composition assessments into youth fitness monitoring programs and support the development of gender-specific interventions aimed at improving adolescent health outcomes through physical activity.

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