

Exploring the role of different intensities of physical activity on fitness parameters in 9–11-year-old children: a framework for potential innovation of the physical education curriculum

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim Although physical activity (PA) is an important determinant of physical fitness (PF) in children, studies have rarely examined the associations between PA and PF in early school-age children within narrow age spans. The aim of this study was to evaluate the associations between different intensities of PA and various indices of PF in children aged 9–11 years.

Material and Methods The participants were 121 children aged 9–11 years (49 girls) who were tested for PF (anthropometrics, aerobic endurance, upper body and abdominal strength, jumping power, mobility and flexibility), and the PA was directly measured via GeneActiv triaxial accelerometers. A t test was used to define differences between sexes, while Pearson's correlations between PA variables and PF indices and multiple regressions for PF criteria were used to calculate sex stratification.

Results Compared with girls, boys achieved better results in terms of jumping power capacity, upper body strength, and aerobic endurance, and they had a higher number of steps taken per day, and a higher amount of vigorous PA per day (all $p < 0.05$). The girls achieved better results in terms of flexibility and mobility. Correlations between PA-intensities and PF were weak to moderate. Multiple regression calculations revealed that vigorous PA was a significant predictor of jumping power, upper body strength, and aerobic endurance in boys (16%, 20%, and 13% of the explained variance, respectively) and jumping power in girls (18% of the explained variance). Moderate PA was a significant partial regressor of aerobic endurance in girls (13% of the explained variance).

Conclusions Tailoring physical-education curricula to gender-specific PA responses and expanding PF assessments can enhance student engagement, optimize fitness outcomes, and improve the overall effectiveness of physical education programs.

Keywords: motor performance, aerobic capacity, preadolescence, multiple regression, accelerometry

Introduction

Physical fitness (PF) can be defined as the ability to perform daily activities with vigor, alertness, and without excessive fatigue, and with ample energy to enjoy leisure-time pursuits and to meet unforeseen emergencies [1]. It encompasses a range of components, including cardiorespiratory fitness, muscular strength and endurance, flexibility, and body composition [2]. Adequate PF in children and youth includes an appropriate level of strength, cardiorespiratory fitness, and body composition and is directly associated with lower cardiovascular risk factors. Importantly, proper PF in children is associated with better bone health, psychological well-being, cognition, and school performance, and may decrease the risk of sports injury [2]. Therefore,

promoting PF in children is crucial for their overall health and well-being, both in the present and future.

Physical activity (PA) is intrinsically linked to PF, and engaging in regular PA directly contributes to the development of various aspects of PF [3]. Regular PA strengthens various components of PF, including cardiovascular status, power capacity, muscular strength, and endurance. Regular PA promotes flexibility, improves bone health, helps maintain a healthy weight, and plays a crucial role in cognitive development by stimulating brain function and improving concentration, thereby influencing academic performance [4, 5]. Regular PA during childhood can establish healthy habits that continue into adulthood, reducing the risk of chronic diseases and promoting long-term health. Therefore, encouraging children to participate in a variety of PA activities is essential for their overall health and well-being, fostering not only PF but also

mental and emotional development [6].

Measuring PA in children is crucial for several reasons. First, it helps determine the effectiveness of interventions aimed at increasing PA levels and promoting healthy lifestyles [7]. By tracking PA, healthcare professionals can identify children who are not meeting recommended activity levels and provide targeted support. Furthermore, measuring PA allows for the assessment of its impact on various PF indices. This information can be used to develop effective and targeted public health strategies and interventions to promote PA among children. Additionally, measuring PA can help raise awareness among parents, educators, and policymakers about the importance of PA for children's overall health and well-being. Collectively, by accurately assessing PA levels, valuable insights into the relationship between physical activity and various aspects of child development can be gained, leading to better strategies for promoting healthy habits and preventing chronic diseases.

Modern lifestyles have contributed to a concerning decline in PA among children [8]. Increased screen time, readily available processed foods, and a decrease in active transportation and outdoor play have created a more sedentary environment for children, and the decrease in PA is particularly evident at the beginning of elementary school education [9]. This trend has resulted in a rise in childhood obesity and a decline in overall PF. Studies indicate that children today are less fit than their counterparts from previous generations, with reduced cardiovascular health and lower levels of muscular strength and endurance [10]. This decline in PA and PF has significant implications for children's long-term health, increasing their risk of developing chronic diseases such as type 2 diabetes and cardiovascular disease. Therefore, it is not surprising that studies have attempted to evaluate the degree of association between PA and PF in children.

For example, several studies have reported an association between greater PA and better fitness performance in preschoolers [11, 12]. A Belgian study of 241 early adolescents from 30 schools reported a low-to-moderate association between directly measured PA and body fatness, somewhat stronger associations between PA and cardiovascular fitness, and low-to-moderate associations between PA and muscular fitness [13]. In a recent study, the authors reported significant correlations between indirectly measured PA and different facets of PF in Chinese children [14]. This finding is in accordance with findings among Spanish adolescents, where the authors confirmed a positive association between questionnaire-based PA and cardiorespiratory fitness (aerobic endurance) [15]. However, a recent study did not find a significant correlation between indirectly measured PA and PF indices in preadolescents from Croatia [16].

From the previous brief literature overview, it is evident that studies performed thus far have either reported total PA (and not specific PA intensities), observed specific segments of PF (i.e., cardiovascular fitness, anthropometrics), or observed children of different ages and from different environments (schools). Moreover, it is unlikely that different segments of PF are equally influenced by different PA intensities, especially considering age-, sex-, and environment-specific factors. Additionally, in studies of this type, it is important to include the direct measurement of PA, not only because of its validity but also because of its accuracy in the evaluation of different PA intensities [14, 16]. Finally, given the specifics of different sociocultural environments, the associations between PA and PF should be studied in different regions, but studies that examine this issue in southeastern Europe, including Croatia, are lacking [16].

An analysis of previous studies allows for the assumption that different intensities of PA are differentially associated with PF components in boys and girls. This assumption is based on the fact that sex-specific physiological differences may lead to distinct responses to varying PA intensities. Additionally, considering that preadolescent children from southern Croatia, specifically 3rd- and 4th-grade students, have already experienced a decline in PA since the beginning of their formal education, the potential impact of reduced PA on PF may have already emerged. Understanding these associations can provide valuable insights for refining physical education (PE) curricula, ensuring that PE is more student-oriented and designed to enhance specific PF components in this age group. Therefore, the aim of this study was to evaluate the sex-specific associations between different PA intensities and various components of PF in this population.

Materials and Methods

Participants

The participants in this study were children aged 9–11 years ($n = 128$; 49 girls). All participants were elementary school students from Split-Dalmatia County in southern Croatia. All children regularly attended elementary school in their community and participated in physical education classes, while some were also involved in out-of-school sports programs. The study was initially approved by the Ethical Committee of the Faculty of Kinesiology, University of Zagreb (approval number 93/2004, issued on 09 September 2024). Before the study, the authors informed school authorities about the study aims, and school principals organized meetings with the parents. During these meetings, investigators provided information about the study's objectives, protocol, risks, and benefits and asked parents to

sign consent forms for their children's participation. Eighty-six percent of the parents who attended the meetings provided written consent for their children's participation in the study.

The inclusion criteria were regular participation in physical education, no illness or injury one week before the study, and no illness during the course of the study. The exclusion criteria included motor and functional impairments, health conditions preventing participation in physical education, as well as injury or illness one week prior to or during the measurement period. At baseline, 162 children were included, but due to technical issues (e.g., accelerometer measurement errors, excessive non-wear time), inconsistent data, injury, or illness, the final sample consisted of 128 children.

Research Design

In addition to age and gender (collected from school records), this study obtained data on PA and fitness variables.

For the purpose of evaluating PF, we used body mass, body height, body mass index, and tests included in the FitnessGram battery [17], with the addition of one test of power capacity. Body height was measured with stadiometer, and body mass was measured with a digital diagnostic scale (Tanita BC 418 scale; serial number 15010067, 2015), both following standardized procedures. Body mass index (BMI) was calculated by dividing body mass (in kg) by the squared body height (in meters). The 15-m Pacer test (Pacer test) was used to assess aerobic endurance (cardiovascular endurance). The test consists of 21 or more levels of seven or more intervals of running segments of 15 m. Participants run from one end to the other of a segment marked with cones and must touch the line when the buzzer sounds. At the sound of the beep, they turn and run back to the other end. The participants continue to do this until they fail to reach the line twice in a row. The goal is to cross as many levels as possible, and the result is expressed numerically in levels. The sit-up test (Sit-ups) was used to assess abdominal muscular strength and endurance. The test is performed by having the participant lift the torso as many times as possible, up to a maximum of 75 repetitions. The result is the maximum number of correctly performed sit-ups. The torso lift test (Torso-lift) was used to assess torso extensor strength and flexibility (mobility). On cue, the participant independently raises the cervical and thoracic parts of the spine in a controlled manner to their maximum, with the head in a neutral position in line with the spine. The push-up test (Push-ups) was used to assess upper body strength and endurance. The test is performed with the participant assuming a prone position on the mat with the palms under the shoulders, fingers extended, legs extended and parallel, and feet slightly apart, resting on the toes. The participant

pushes off the mat with their hands until their arms are extended, keeping their legs and back straight. The participant then lowers their body using their arms until their elbows are bent at 90 degrees and their upper arms are parallel to the floor. The result is the maximum number of correctly performed push-ups. The Sit-and-Reach test was used to assess the flexibility of the lower back and hamstring muscles. The participant sits on the floor with their legs extended straight ahead, feet shoulder-width apart, and positioned against the box or measuring device. With their palms down and fingers pointing forward, the individual reaches forward along the measuring device as far as possible, holding the position for at least two seconds. Three trials are performed, and the average score is used as the final result. The standing broad jump (Broad jump) was used to assess jumping performance/power capacity. The test is performed with the participant standing behind the starting mark and jumping from a stationary position with bare feet as far as possible. A standardized measurement mat was used (ELAN, Begunje, Slovenia). The result was measured in centimeters, with the best of three attempts recorded. GeneActiv triaxial accelerometers were used for direct measurement of the PA of the participants over a seven-day period (Activinsights Ltd., Cambs, United Kingdom).

The GeneActiv is a small (43 × 40 × 13 mm), lightweight (16 g), waterproof device that collects raw acceleration data in the range of ±8 g. The device was validated for children aged 7–14 years. The devices were set to record at 30 Hz and were worn on the wrist [18]. The participants were instructed that the devices were waterproof and should be worn continuously, including while sleeping, swimming, and showering, allowing for a complete picture of their activity patterns. After the wearing period, the devices were connected to a computer, and raw acceleration data were downloaded via dedicated software. Using the same software, the data were cleaned, and non-wear time periods were removed. The PA variables observed in this study were based on accelerometer records and included the number of steps taken (steps), sedentary time, light PA, moderate PA, and vigorous PA.

Statistical Analysis

The Kolmogorov–Smirnov test was used to confirm that the data followed a normal distribution, a key assumption for many statistical tests. Means and standard deviations were calculated to provide a basic overview of the data characteristics. Independent samples t-tests were used to explore potential differences in study variables between boys and girls.

Pearson's correlation coefficients were calculated to assess the relationships between variables, and correlations were interpreted on a scale ranging

from 0.00 to 0.19 (very weak), 0.20 to 0.39 (weak), 0.40 to 0.69 (moderate), 0.70 to 0.89 (strong), and 0.90 to 1.00 (very strong), providing a clear indication of the strength of the associations. The correlations were calculated for the total sample and stratified by sex.

Multiple regression analyses were conducted to examine the relationships between PA variables (observed as predictors) and each PF variable (observed as a criterion). A forward stepwise approach was employed to address potential collinearity among the predictors. Since analyses of differences revealed significant differences in study variables between sexes (see the Results section for details), multiple regression calculations were stratified by sex.

Statistica (Tibco, Inc., Palo Alto, CA, USA) was used for all calculations, and a p-value of ≤ 0.05 was considered statistically significant.

Results

The descriptive statistics and differences in the study variables according to sex are presented in Table 1. Compared with girls, boys achieved better results in the power capacity test (broad jump, t-test = 2.33, $p < 0.05$), upper body strength test (push-ups, t-test = 2.22, $p < 0.05$), and cardiovascular endurance test (Pacer test, t-test = 3.96, $p < 0.001$). Boys also had a higher number of steps per day (t-test = 2.54, $p < 0.01$) and engaged in more vigorous PA per day (t-test = 5.15, $p < 0.001$). Girls achieved better results in the sit-and-reach test of flexibility (t-test = 4.41, $p < 0.001$).

The linear correlations between the PA variables and PF are presented in Table 2. For the total

sample, vigorous PA was negatively correlated with body height (weak correlation), body mass (weak correlation), BMI (weak correlation), and sit-and-reach test flexibility (weak correlation). Moreover, in the total sample, vigorous PA was positively correlated with broad jump performance (weak correlation), push-up test results for upper body strength (moderate correlation), and Pacer test results for aerobic endurance (moderate correlation). Additionally, when the total sample of participants was considered, the number of steps performed daily was positively correlated with broad jump performance and Pacer test results (weak correlations). When correlations were calculated specifically for girls, broad jump performance was significantly positively correlated with the number of steps performed daily (weak correlation), moderate PA (weak correlation), and vigorous PA (moderate correlation), whereas Pacer test results were positively correlated with moderate PA (weak correlation). In boys, vigorous PA was negatively correlated with body height (moderate correlation), body mass (moderate correlation), and BMI (weak correlation) and positively associated with broad jump performance (weak correlation), push-up test results (moderate correlation), and Pacer test results for aerobic endurance (weak correlation).

Multiple regression calculations (forward stepwise model) for PF variables observed as criteria and PA indices as predictors for girls are presented in Table 3. The selected predictors explained 18% of BMI ($p < 0.05$), with no significant partial regressors. When predicting broad jump performance, vigorous PA was retained as a significant partial predictor ($\beta = 0.42$, 95% CI: 0.03–0.81), explaining 18% of

Table 1. Descriptive statistics and differences between genders in study variables (t test for independent samples)

Variables	Girls		Boys		t test	
	Mean	Std.Dev.	Mean	Std.Dev.	t value	p
Body height (cm)	142.4	7.16	144.0	7.71	-1.29	0.20
Body mass (kg)	37.2	12.72	37.3	9.13	-0.08	0.94
BMI (kg/m ²)	17.6	3.53	17.8	3.29	-0.41	0.68
Broad jump (cm)	131.9	34.76	142.6	22.46	-2.33	0.02
Push-ups (reps)	9.7	9.53	13.1	9.36	-2.22	0.03
Sit-ups (reps)	17.4	13.00	15.0	12.09	1.15	0.25
Torso lift (cm)	20.6	11.05	19.3	9.82	0.75	0.45
Sit-and-reach (cm)	48.5	15.01	39.8	9.47	4.41	0.001
Pacer (levels)	6.7	2.49	8.4	2.52	-3.96	0.001
Steps (count)	12016	3507	13921	4540	-2.54	0.01
Sedentary time (min/day)	436.6	98.77	431.5	107.12	0.27	0.79
Light physical activity (min/day)	343.3	89.46	338.4	114.51	0.26	0.79
Moderate physical activity (min/day)	180.0	45.87	179.8	49.39	0.02	0.98
Vigorous physical activity (min/day)	24.8	14.55	48.1	30.37	-5.15	0.001

Table 2. Pearson’s correlations between physical activity data and physical fitness variables in the total sample and separately for boys and girls

Variables		Steps	Sedentary time	Light physical activity	Moderate physical activity	Vigorous physical activity
Body height	Total	-0.03	0.08	-0.06	-0.06	-0.31*
	Girls	-0.15	0.10	-0.20	-0.02	-0.19
	Boys	0.01	0.06	0.00	-0.09	-0.43*
Body mass	Total	-0.12	0.09	-0.04	-0.11	-0.36*
	Girls	-0.14	0.09	0.04	-0.10	-0.33*
	Boys	-0.11	0.09	-0.10	-0.12	-0.49*
BMI	Total	-0.14	0.07	-0.03	-0.13	-0.32*
	Girls	-0.23	0.05	0.14	-0.18	-0.35*
	Boys	-0.10	0.09	-0.10	-0.09	-0.39*
Broad jump	Total	0.25*	0.03	-0.09	0.12	0.33*
	Girls	0.31*	-0.13	-0.07	0.29*	0.43*
	Boys	0.19	0.11	-0.09	0.04	0.29*
Push-ups	Total	0.15	-0.02	0.04	0.07	0.43*
	Girls	0.20	0.04	-0.02	0.00	0.25
	Boys	0.08	-0.05	0.08	0.12	0.45*
Sit-ups	Total	0.01	0.16	-0.05	0.06	0.02
	Girls	0.00	0.15	-0.01	-0.03	0.13
	Boys	0.04	0.18	-0.07	0.12	0.04
Torso lift	Total	-0.03	0.14	-0.01	0.00	-0.02
	Girls	0.01	0.08	0.13	-0.03	0.11
	Boys	-0.03	0.17	-0.09	0.01	-0.02
Sit-and-reach	Total	-0.04	0.03	0.01	-0.06	-0.29*
	Girls	-0.05	0.04	-0.05	0.06	0.04
	Boys	0.14	0.04	0.03	-0.17	-0.18
Pacer test	Total	0.26*	-0.01	0.00	0.17	0.42*
	Girls	0.23	0.01	0.03	0.34*	0.18
	Boys	0.20	-0.03	0.01	0.18	0.33*

Note. * - indicates a significance of $p < 0.05$

Table 3. Multiple regression results (forward stepwise model) predicting physical fitness variables by physical activity variables in girls

Regressors	Broad jump		Push-ups		Sit-ups		Pacer	
	β	b	β	b	β	b	β	b
Intercept		124.33*		8.26		0.27		4.95*
Steps			0.27	0.001				
Sedentary time					0.19	0.001		
Light physical activity								
Moderate physical activity			-0.31	0.001			0.35*	0.001*
Vigorous physical activity	0.42*	0.001*	0.24	0.001	0.18	0.001		
Multiple R	0.42*		0.34		0.23		0.35*	
Multiple R ²	0.18*		0.11		0.05		0.13*	

Note. * - indicates significance of $p < 0.05$

Table 4. Multiple regression results (forward stepwise model) predicting physical fitness variables by physical activity intensity in boys

Regressors	Broad jump		Push-ups		Sit-ups		Torso lift		Sit-and-reach		Pacer	
	β	b	β	b	β	b	β	b	β	b	β	b
Intercept		113.47*		6.59*		0.15		12.79*		42.94*		6.11*
Steps									0.20	0.00	0.15	0.00
Sedentary time					0.18	0.00	0.17	0.00				
Light physical activity												
Moderate physical activity					0.13	0.00			-0.27	0.00		
Vigorous physical activity	0.34*	0.00*	0.45*	0.00*					-0.13	0.00	0.32*	0.00*
Multiple R	0.41*		0.44*		0.21		0.17		0.25		0.36*	
Multiple R ²	0.16*		0.20*		0.04		0.02		0.06		0.13*	

Note. * - indicates significance of $p < 0.05$

the criterion variance ($p < 0.05$). Moderate PA was significantly partially associated with Pacer test results ($\beta = 0.35$, 95% CI: 0.01–0.69), explaining 13% of the variance ($p < 0.05$).

When multiple regressions were performed for boys, PA predictors were significantly correlated with three of the seven PF criteria. Specifically, vigorous PA was a significant regressor of broad jump performance ($\beta = 0.34$, 95% CI: 0.03–0.65), push-ups ($\beta = 0.45$, 95% CI: 0.10–0.75), and Pacer test results ($\beta = 0.32$, 95% CI: 0.06–0.58), explaining 15%, 16%, and 13% of the criterion variance, respectively (Table 4).

Discussion

There are several important findings related to the study aims. First, vigorous PA is significantly associated with PF in boys, whereas both moderate and vigorous PA are associated with PF in girls, influencing power and cardiovascular endurance. Therefore, our initial study hypothesis can be partially confirmed. Finally, PA appears to be a stronger determinant of PF in boys than in girls.

Vigorous physical activity and physical fitness in boys

Studies have frequently, but not consistently, confirmed that PA plays a vital role in shaping the fitness status of children and adolescents [14, 15, 16]. However, our results support the idea that different PA intensities contribute differently to fitness outcomes. It is generally accepted that light-intensity activities, such as walking or casual play, have limited effects on improving PF. These activities primarily support basic mobility and energy expenditure but do not significantly challenge the cardiovascular or musculoskeletal systems. Therefore, light PA is not expected to be significantly associated with PF [18]. On the other hand, moderate-intensity activities

promote cardiovascular endurance and improve muscle strength and, therefore, could contribute to improvements in PF [19]. However, in the boys studied herein, moderate PA did not appear to be associated with better PF. The possible reasons for this are briefly discussed.

One explanation is that moderate-intensity PA does not provide the physiological stress necessary to drive substantial cardiovascular and musculoskeletal adaptations in preadolescent boys. While moderate-intensity PA is beneficial for maintaining general health, it may lack the intensity required to challenge and enhance aerobic capacity or muscular strength at this developmental stage [20]. Additionally, the energy expenditure and heart rate achieved during moderate-intensity PA might not meet the threshold needed to elicit meaningful changes in the fitness metrics used in this study, such as aerobic endurance, power, or strength, in healthy preadolescent boys [20]. Finally, it is also possible that the fitness improvements attributed to moderate-intensity PA occur over longer durations or require higher cumulative weekly volumes. Consequently, eventual associations between moderate-intensity PA and PF could become evident later in adolescence.

Moreover, our results revealed that vigorous PA was the most influential intensity for enhancing PF in boys. Indeed, high-intensity activities such as running, sprinting, jumping, or competitive sports induce substantial stress on the cardiovascular, respiratory, and musculoskeletal systems, leading to marked improvements in aerobic capacity, muscle strength, and overall endurance [20, 21]. The association between vigorous PA and fitness is especially pronounced because such activities push the body closer to its physiological limits, stimulating greater adaptations. Compared to lower-

intensity activities, vigorous PA yields higher levels of metabolic stimulation, supports fat metabolism and lean muscle development, and plays a critical role in preadolescent growth, benefiting boys during this developmental stage [20].

All of these findings are supported by the fact that vigorous PA is positively correlated with strength, power, and cardiovascular endurance but not with flexibility. Specifically, vigorous PA involves repeated bursts of effort that heavily engage both the cardiovascular system and large muscle groups. These activities promote significant improvements in aerobic capacity (cardiovascular endurance), muscular strength, and explosive power due to the high levels of oxygen consumption and mechanical load placed on the muscles, tendons, and joints [22]. In contrast, flexibility is largely determined by the extensibility of muscles and connective tissues, which is not a primary focus during vigorous activities [23]. Flexibility improvements are typically achieved through activities that involve sustained stretching or movements that increase the range of motion, and vigorous PA does not inherently emphasize the slow, controlled, and prolonged movements required to improve joint and muscle flexibility. On the contrary, the fast-paced and repetitive nature of vigorous PA may actually limit opportunities for stretching or lengthening muscle fibers during exercise. This may explain the lack of a significant correlation between vigorous PA and flexibility in preadolescent boys.

Moderate physical activity and physical fitness in girls

While only vigorous PA was positively associated with PF indices in boys, both vigorous and moderate PA were positively correlated with PF in girls. These findings can be explained by a combination of physiological, hormonal, psychological, and sociocultural factors, as well as sex differences. Some of these factors will be briefly discussed below.

Two important physiological differences between boys and girls should be highlighted in relation to our findings. First, girls tend to have a greater proportion of slow-twitch muscle fibers than boys [20]. Slow-twitch fibers are optimized for low-intensity activities of prolonged duration and, therefore, respond better to lower-intensity activities. Additionally, girls typically have a higher percentage of body fat and a different fat distribution pattern than boys. Since moderate-intensity PA preferentially targets fat metabolism and aerobic capacity, these activities may be more effective at improving fitness in girls. For example, it has been empirically confirmed that women exhibit greater fat oxidation at moderate exercise intensities than men [24, 25]. Therefore, moderate-intensity exercise has been suggested to be particularly effective for targeting fat oxidation and improving fitness in women.

Hormonal specificity also plays a role in the sex-specific association between PA intensity and PF. Higher levels of testosterone in boys promote greater muscle mass and anabolic capacity, which are better developed through vigorous activities (e.g., sprinting, jumping, plyometrics, high-intensity interval training) [26]. On the other hand, higher levels of estrogen in girls directly contribute to fat metabolism and cardiovascular function, as estrogen enhances fat metabolism by facilitating free fatty acid oxidation and mitochondrial biogenesis during moderate-intensity exercise [27]. Moderate-intensity activities, such as brisk walking or cycling, align well with these hormonal profiles and are more likely to enhance cardiovascular and metabolic fitness in girls than in boys, which could at least partially explain our findings.

Some psychological and behavioral factors also deserve attention in explaining the sex-specific correlations between PA intensity and PF in our participants. First, due to social and cultural norms, boys more often than girls engage in sports and games that involve higher intensities [28]. Moreover, girls may prefer activities that are less intense but more sustained, such as dance, yoga, or walking [29]. These activities align with moderate-intensity PA and may contribute significantly to overall fitness because of the previously explained physiological and hormonal characteristics of girls. This is confirmed by our results, as boys engaged in more vigorous PA than girls, whereas differences in moderate PA were not statistically significant (see the Results section for more details). Additionally, studies have confirmed that female gender roles often lead to decreased participation in high-intensity sports, aligning women's fitness goals with moderate-intensity PA [30].

Stronger correlation between physical activity and physical fitness in boys than in girls

Our results suggest that PA is more strongly correlated with PF in boys than in girls. However, previous studies on this topic have shown inconsistent findings. While some authors reported higher correlations in boys, others observed stronger associations in girls [13, 31, 32]. Some possible explanations for our findings are discussed below.

The first explanation is contextual and relates to differences in PA habits between boys and girls. Due to social tendencies, boys typically engage in more vigorous-intensity PA, which has a stronger impact on PF metrics. On the other hand, girls often participate in moderate-intensity PA, which is beneficial (see previous discussion) but may not produce pronounced fitness outcomes. This is particularly relevant given the previously discussed hormonal differences and higher estrogen levels in girls, which promote fat deposition [20]. This factor is especially important because most PF tests are

performed relative to body weight (e.g., push-ups, Pacer test, and broad jump). The results of these tests depend on body mass, where higher body fat negatively impacts PF outcomes.

Another set of reasons is related to measurement and assessment. First, accelerometers may not capture the full spectrum of PA in girls (e.g., casual play, dance, or household chores). This could lead to an underestimation of their PA levels and weaken the correlation with PF. Additionally, the PF tests used in this study assessed strength, power, flexibility, and cardiovascular endurance. These tests are more sensitive to the effects of PA types that are more characteristic of boys (e.g., vigorous PA). On the other hand, aspects of PF that are more typical for girls and naturally associated with moderate-intensity PA (e.g., balance, coordination) were not included in the test battery used in this study. One could argue that flexibility is one of the PF components more characteristic of girls and that this fitness capacity was covered in our research. However, in the case of the correlation between PA and flexibility, the issue previously discussed is the “inadequacy of the influence.” Briefly, PA intensity is not a factor that can directly influence flexibility, as PA measurement does not emphasize the types of movements required to improve joint and muscle flexibility [23].

Practical applications and pedagogical relevance in physical education settings

The previously discussed mechanisms of how different PA intensities influence PF in boys and girls could be practically applied in the physical education (PE) pedagogical process, particularly in modifying PE curricula and PF assessment. First, given the established association between vigorous PA and PF in boys, PE programs for boys should prioritize high-intensity activities, including sprinting, plyometrics, interval training, and team sports. These activities have been confirmed as highly efficient in developing cardiovascular endurance and muscular strength. Additionally, such activities align with boys’ natural preference for competitive and dynamic movements and could therefore maximize PF gains during critical developmental periods [33, 34]. For girls, since both moderate and vigorous PA were found to be associated with PF, PE teachers should balance endurance-based activities (e.g., brisk walking, cycling, aerobics) with more intense exercises (e.g., circuit training, dance-based interval workouts, structured sports participation). While being more accepted among girls, these activities have been found to be effective in increasing PA levels and improving PF [35, 36]. This differentiated approach will ensure that both sexes engage in activities that best support their physiological and metabolic adaptations, ultimately enhancing overall PF outcomes in PE settings.

Beyond PE curriculum design, our findings underscore the need to rethink PF assessment as a strategic approach to encouraging sustained student engagement in PA. In the studied country and region, traditional PF assessments primarily measure strength, power, and cardiovascular endurance [16]. While these are important determinants of PF status, focusing solely on these aspects overlooks PF components that are directly influenced by moderate-intensity PA, which is particularly important for girls. To address this, PE authorities could expand PF assessment methods by incorporating balance and coordination into PF testing batteries, offering a more comprehensive evaluation of PF. Importantly, the potential benefits of such an approach extend beyond PF evaluation itself. Objective PF assessment is a fundamental prerequisite for active and motivated participation in any exercise program, including PE lessons, as it provides participants with clear benchmarks for progress and goal setting. In other words, when PF assessment accurately reflects an individual’s status (e.g., strengths and areas for improvement), it fosters a sense of achievement and intrinsic motivation. This, in turn, encourages students to engage more consistently in exercise, including PE lessons [37].

It is well known that exercise programs, including PE classes, yield significantly better results when they align with the preferences and needs of the target group [38, 39]. Pedagogically speaking, the appropriateness of a training program enhances engagement and adherence and, therefore, improves overall effectiveness [40]. Regrettably, traditional PE often emphasizes generalized activity participation without considering how specific PA intensities contribute to fitness outcomes across different populations. Meanwhile, our findings clearly challenge the one-size-fits-all approach, highlighting sex-specific responses to PA and suggesting that PE curricula should be adapted to accommodate these differences. Therefore, the discussed sex-specific associations between PA intensities and PF could enable PE teachers to make more informed decisions about PE curricula and, consequently, to enhance the overall pedagogical process in this area. More specifically, by integrating our findings into PE pedagogy, teachers can develop more personalized and inclusive programs that align with students’ developmental needs and long-term health goals.

Limitations and strengths

This study has certain limitations. First, the cross-sectional design limits our ability to infer causality between PA and PF. While PA could be a cause of PF, it is also possible that PA should be considered a consequence of better PF. Therefore, future prospective studies are needed to clearly evaluate these relationships. Second, the geographical

specificity of our sample (a Mediterranean region with a mild climate) may limit the generalizability of our findings to other populations. Despite these limitations, this study has notable strengths. It is among the first to investigate this issue in southeastern Europe using objective measures of PA and a comprehensive battery of fitness tests. Furthermore, by having the same investigators conduct all assessments in the same region and season, we minimized potential biases and enhanced the reliability of our findings.

Conclusions

Our findings highlight the importance of vigorous PA for boys, as it contributes significantly to their strength, power, and cardiovascular endurance. In girls, both moderate and vigorous PA play crucial roles in enhancing PF. The study also revealed a stronger correlation between PA and PF in boys than in girls, suggesting that the impact of PA on fitness may be more pronounced in boys during this developmental stage.

These differences could be attributed to various factors, including hormonal profiles, PA preferences, and the sensitivity of PF tests to different types of activities. Additionally, the observed sex-specific associations between PA intensity and PF emphasize the need for tailored interventions to promote PA and enhance PF in preadolescent youth. While encouraging vigorous PA is crucial for boys, promoting both moderate and vigorous PA appears essential for girls.

Most importantly, the results emphasize the need to tailor PE to sex-specific responses to PA

intensities, ensuring that boys engage in high-intensity activities while girls benefit from a balance of moderate and vigorous PA. Additionally, expanding PF assessment methods beyond traditional measures of strength and endurance to include balance and coordination can provide a more comprehensive evaluation and enhance student motivation. By integrating these insights into PE curricula, educators can create more inclusive and effective programs that promote long-term engagement and optimal PF outcomes for all students.

Investigating the influence of diverse PA types, including those more commonly preferred by girls (e.g., dance, yoga), would provide a more complete picture of the relationship between PA and PF. Moreover, exploring the role of other lifestyle factors, such as living environment, nutrition, and sleep, in conjunction with PA, will contribute to a more holistic understanding of child health and development. By addressing these research gaps, we can develop more effective strategies to promote healthy lifestyles and enhance the well-being of future generations.

Acknowledgement

The authors are particularly grateful to the school authorities and parents for their support. Special thanks go to the children for their voluntary participation in the study.

Conflict of Interest

The authors report that there are no competing interests to declare.

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Cite this article as:

Sekulic D, Volaric T, Pehar M, Pranjić T, Rajkovic Vuletic P. Exploring the role of different intensities of physical activity on fitness parameters in 9–11-year-old children: a framework for potential innovation of the physical education curriculum. *Pedagogy of Physical Culture and Sports*, 2025;29(2):112–122. <https://doi.org/10.15561/26649837.2025.0205>

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Received: 15.02.2025

Accepted: 20.03.2025; Published: 30.04.2025