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Differences in Physical Fitness Between 10- and 14-Year-Old Students

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Abstract

This study sought to determine the differences in physical fitness between students aged 10 and 14 years, clarify the impact of maturation on physical fitness and examine whether fitness levels decline with age. The cross-sectional study included 117 primary school students (64 fourth-grade and 53 eighth-grade students). The mean age was 12.05 ± 2.03 years. Measurements comprised anthropometric variables (body height and mass, body composition, waist-to-hip ratio [WHR], waist-to-height ratio [WHtR]), motor tests (standing long jump, sit-ups, sit-and-reach, 4 × 10 m shuttle run), and an indirect assessment of maximal oxygen uptake (VO_2max) using the 20 m multistage shuttle run test. ANOVA and Welch tests showed significant between-group differences. Fourteen-year-olds were taller and heavier and performed better in explosive leg power and repetitive trunk strength tests. Ten-year-olds demonstrated better agility, greater flexibility and higher cardiorespiratory endurance. Despite higher BMI in older students, WHtR did not differ significantly, which suggests proportional growth without marked changes in central fat distribution. Biological growth and increased muscle mass during adolescence are not sufficient to maintain cardiorespiratory capacity, flexibility, or speed and agility. The decline in aerobic endurance among older students indicates more sedentary habits and supports the need for targeted physical activity programs within the Physical Education curriculum to preserve cardiorespiratory health and motor competencies.

Keywords: *adolescence; cardiorespiratory capacity; motor skills; physical fitness*

Introduction

Regular physical activity is key to the prevention and treatment of childhood obesity as it contributes to maintaining a healthy body mass, improves metabolic health and encourages the adoption of healthy lifestyle habits. According to the World Health

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Organization recommendations, children should participate in at least 60 minutes of moderate to high-intensity physical activity daily (WHO, 2018). It is extremely important for children and youth to engage in sufficient levels of physical activity to support their health status in both the present and the future (Ha et al., 2019). Although consistent evidence links physical activity with positive health benefits, more than scientific evidence will be required to advance policy implementation. Successes in promoting physical activity often involves connecting major social trends and cultural shifts (Alamilla et al., 2023). The importance of physical activity in children is reflected in the fact that it is closely linked to motor development (Badrić & Roca, 2024). Furthermore, physical activity in childhood plays a crucial role in preventing excessive body mass; children who engage in more regular physical activity have less fat tissue than those with lower levels of physical activity (Wyszyńska et al., 2020). Physical fitness is a multidimensional construct encompassing both health-related and performance/skill-related components. Health-related fitness includes cardiovascular endurance, muscular strength, flexibility and body composition, all of which are important indicators of general health and predictors of future chronic disease risk in children and adolescents (Ortega et al., 2023).

Physical fitness is a comprehensive health indicator reflecting the functional state of multiple body systems, including the skeletal-muscular, cardiorespiratory, hemocirculatory, psychoneurological and endocrine-metabolic systems (Tomkinson et al., 2018). Changes in modern lifestyles have led to a marked reduction in human physical activity. Numerous studies have shown that the reduced amount of physical activity among students is the most significant reason for the decline in physical fitness (Lu et al., 2023). Due to significant changes in body composition, hormonal status and social interactions, puberty appears to be a critical period for physical fitness development (Greier et al., 2019).

Physical fitness generally increases with age, showing a significant aging-related effect for all fitness measures (Thomas & Palma, 2018). Research on German schoolchildren showed a significant age influence observed across various physical fitness tests (Golle et al., 2015). Significant improvements in various physical fitness components were observed between ages 11 and 15, with more pronounced gains in strength and endurance in boys compared to girls. In girls, improvements in physical fitness occurred primarily during early adolescence, followed by stagnation or even a decline after puberty. The minimum weekly increase in physical activity can produce significant changes in the level of motor skills in 14-year-old girls (Badrić et al., 2015). Besides growth-related aspects, hormonal changes appear to be key factors and often place boys at an advantage over girls (Greier et al., 2019; Thomas & Palma, 2018).

Childhood and teenage years are critical periods for developing motor skills such as speed, agility, coordination and strength. The greatest progress in speed and agility occurs between ages seven and twelve, while strength develops more significantly during puberty due to increased muscle mass (Alvares et al., 2020; Sheehan & Lienhard, 2018). Coordination is typically well developed by age ten, although it may temporarily

weaken during rapid growth spurts (Sheehan & Lienhard, 2018). The period from age 10 to 14 involves changes in physical appearance, hormones and motivation for movement, which can cause test results to vary (Sember et al., 2020).

Body composition, including height, mass, body fat percentage and waist circumference, plays an important role in children's physical capacity. Increased body fat percentage is associated with poorer results in agility, endurance and strength tests, while higher muscle mass leads to better results (Almeida, 2025; Gericke et al., 2025; Radin et al., 2023). The waist-to-height ratio (WHtR) is a reliable indicator of central abdominal obesity and a better predictor of cardiovascular disease risk compared to BMI (Sharma et al., 2015; Lee et al., 2022). Elevated WHtR values indicate lower VO2max, poorer agility test results and reduced strength (Dong et al., 2024; Eslami et al., 2023).

The age range from 10 to 14 years is a critical phase in children's development. This period involves strong changes in their body structure and motor skills. The development of motor and functional skills is not linear. It depends on sensitive phases of human development and the biological rules of growth. The younger school age, around 10 years, is a time of high spontaneous activity. This period is great for developing aerobic endurance. However, early adolescence, at about 14 years, brings specific challenges that can affect this growth. In addition to biological factors, at this age it is crucial to consider psychosocial factors such as motivation to engage in sports and changes in physical activity habits, which have a direct impact on achievements in standardized kinesiology tests (Sekulić & Metikoš, 2007). The significance of this study lies in its public health implications, as the results show a decline in cardiorespiratory capacity, agility and flexibility with the onset of adolescence due to a more sedentary lifestyle. This highlights the need for adaptations in Physical Education classes to specifically develop and preserve aerobic capacity and maintain motor skills in older students. When interpreting the results, it should be taken into account that performance in endurance tests largely depends on students' current motivation and subjective perception of effort, which may have influenced their final outcomes.

As the global problem of childhood obesity and declining aerobic capacity grows, researching the differences between younger and older school ages becomes increasingly important for understanding developmental trends and intervention needs. The aim of this study was to determine the differences in physical fitness between students aged 10 and 14 to gain a clear insight into the impact of maturation on motor, functional and morphological indicators.

Methodology

Research procedures and participant sample

A cross-sectional study was conducted involving 117 primary school students from two schools in the continental part of the Republic of Croatia. The sample consisted of 64 fourth-grade students and 53 eighth-grade students. In terms of gender distribution, there were 63 girls (54%) and 54 boys (46%) in total. Specifically, the eighth-grade

group included 30 girls and 23 boys, while the fourth-grade group included 33 girls and 31 boys. The mean age of the participants was 12.05 ± 2.03 years. The sample of respondents was divided by age and gender to ensure a more detailed analysis. To ensure maximum personal engagement, the tests took place with the subject's PE teacher and the researcher present. They focused on each individual's maximum effort during the functional tests.

Before the study commenced, school principals were contacted via telephone or email to obtain official approval. Written consent forms were distributed to the students; inclusion required signed parental or guardian consent and the students' own informed assent appropriate for their age. Inclusion criteria were: good health without physical or psychological impairments, regular attendance of Physical Education classes and successful completion of all morphological and motor tests. All procedures were conducted anonymously, respecting the ethical standards of the Declaration of Helsinki. The study was approved by the Ethics Committee of the Faculty of Teacher Education, University of Zagreb.

Anthropometric measurements

Body height was measured using a portable stadiometer (Seca® 213, Hamburg, Germany), following standardized anthropometric recommendations (Fredriksen et al., 2025; Kim et al., 2024; Agbaje, 2024). Body mass and composition were assessed using a dual-frequency bioelectrical impedance analysis (BIA) (TANITA DC-360P) (Thajer et al., 2025; Nahorna & Baur, 2025), which is a validated method for evaluating body composition in children and adolescents (Lee et al., 2017; de Castro et al., 2017).

Waist and hip circumferences were measured with a flexible tape measure. Waist circumference was measured at the midpoint between the lowest rib and the upper limit of the iliac crest at the end of a normal expiration (Fredriksen et al., 2025; Nahorna & Baur, 2025; WHO, 1995). Hip circumference was measured at the widest part of the hips, at the level of the greater trochanter. Based on these measurements, the waist-to-hip ratio (WHR) was calculated. Additionally, the waist-to-height ratio (WHtR) was derived from the measured waist circumference and body height using the following formula:

$$\text{WHtR} = \text{waist circumference (cm)} / \text{body height (cm)}$$

A WHtR threshold of 0.50 was identified as a universal risk indicator for children and adolescents (Ashwell et al., 2005), while WHtR values above 0.50 indicated an increased risk of abdominal obesity and cardiometabolic complications (Browning et al., 2010)

Measurement of motor skills

Motor abilities were assessed using four standardized tests encompassing explosive power, repetitive strength, flexibility, and agility and coordination. Explosive power of the lower extremities was measured using the standing long jump. During the test, the student performs a two-legged take-off and jumps as far as possible. The distance

is measured from the take-off line to the point where the heels touch the ground. Each student performed three attempts, with the best result recorded. The standing long jump is considered a reliable indicator of explosive leg power in children and adolescents (Tabacchi et al., 2019; Bianco et al., 2015; Ruiz et al., 2010).

Repetitive core muscle strength was assessed via the 60-second sit-up test. The student lies in a supine position with knees bent at a 90-degree angle, feet fixed and arms crossed over the chest. The participant must rise to a sitting position and return to the starting supine position. The number of correctly performed repetitions within 60 seconds was recorded (Bianco et al., 2015; Häcker et al., 2017).

Flexibility was measured using the sit-and-reach test. The student sits with legs extended, feet placed against the measuring box and arms stretched forward. By performing a slow forward reach, the student attempts to touch the furthest possible point and hold the position for two seconds. The best result was recorded in centimeters. The sit-and-reach test is a reliable assessment of hamstring and lower back flexibility in children and adolescents (Bianco et al., 2015; Ruiz et al., 2010; Castro-Piñero et al., 2009).

Agility and coordination were evaluated using the 4 × 10-meter shuttle run test. The student runs between two parallel lines 10 meters apart, touching each line before turning. The test was performed in two attempts, with the time measured in hundredths of a second and the fastest result recorded. The 4x10 m shuttle run test is considered a reliable tool for testing school and sports populations (Bianco et al., 2015; Ruiz et al., 2010; Ramírez-Vélez et al., 2015).

Measurement of cardiorespiratory capacity

Cardiorespiratory capacity was assessed using the 20-metre multistage shuttle run test (Léger & Lambert, 1982). All measurements were conducted in the school setting on a flat, clearly marked 20-metre surface at the same time of day to ensure consistent conditions (Brito et al., 2022; Amedro et al., 2023). Before testing, the protocol was thoroughly explained and demonstrated to the students. The test session began with a ten-minute warm-up and stretching exercises (Brito et al., 2022). Students were tested in groups of eight, with each participant given one attempt. The research team understood that results in endurance tests depend on perceived effort and psychological strain (Sekulić & Metikoš, 2007). To prevent boredom and premature withdrawal, they provided continuous encouragement throughout the test.

Participants in this field test run back and forth between two lines 20 meters apart, marked by a measuring line and cones. The running pace is regulated by acoustic signals, starting at 8.5 km/h and increasing by 0.5 km/h every minute. Each level lasts approximately 60 seconds, with the speed (duration of each interval) dictated by the frequency of the beeps.

Students must reach the marked line before the beep; if they arrive early, they must wait for the next signal before returning (Bok et al., 2023). The test concluded for each student when they failed to reach the line on time for two consecutive intervals or

when they withdrew due to fatigue and exhaustion. The result recorded was the last successfully completed stage (Léger & Lambert, 1982; Brito et al., 2022).

VO_2max (mL/kg/min) values were calculated using the standard equation:

$$VO_2max=31{,}025+3{,}238\times S-3{,}248\times A+0{,}1536\times(A\times S),$$

where S represents the speed (km/h) achieved at the end of the test, and A represents the student's age in years (Léger et al., 1988; Menezes Júnior et al., 2019). Testing was conducted in school sports halls.

Statistical analysis

Descriptive statistics included the calculation of arithmetic means (M), standard deviations (SD), minimum (Min) and maximum (Max) values, as well as skewness and kurtosis coefficients. These indicators provide insight into central tendency, dispersion and distribution's shape, which are the standard for presenting and interpreting numerical results (Fulk, 2023; Mishra et al., 2019). The normality of variables' distribution was verified using the Shapiro–Wilk test.

When researchers determined gender differences in the variables of morphological characteristics and physical fitness by age, they used the Mann-Whitney U test due to the small number of subjects in the defined subsamples by gender and age.

Significance of differences in physical fitness levels between age groups was examined using one-way analysis of variance (ANOVA), traditionally used to compare means between two or more groups (Silva de Souza & Borges, 2023; Delacre et al., 2019). Homogeneity of variances was checked with Levene's test, recommended as a prerequisite for ANOVA, given that the classic F-test is sensitive to variance inequalities (Müller et al., 2024; Odoi et al., 2025; Delacre et al., 2019). For variables where statistically significant differences in variances were found, the Welch ANOVA test was applied, as it does not require homogeneity of variances and is considered a more robust choice in such cases (Delacre et al., 2019; Silva de Souza & Borges, 2023).

Statistical analysis was performed using the IBM SPSS Statistics software package, version 29.0, which is a standard tool for data processing and analysis in the social and biomedical sciences. The level of statistical significance was set at $p < 0.05$, the conventional threshold in scientific research.

Results

The results in Table 1 present the descriptive statistics for the observed variables. The average age of the students was M = 12.05 ± 2.03 years. Body height and body mass values follow the biological laws of growth and development, with a few participants exhibiting higher body mass, reaching a maximum result of M = 129.00 ± 12.34. Regarding body composition variables, it is evident that the variables are normally distributed, with a few results deviating significantly from the mean values. Motor tests showed satisfactory variability without significant deviations from normality.

Table 1
Descriptive statistics results for fourth- and eighth-grade students (Total N=117)

Variable	Total (N=117)					
	Mean	SD	Min	Max	Skew	Kurt
Age (years)	12.05	2.03	10.00	15.00	0.19	-1.82
BH (cm)	157.72	12.34	128.90	185.00	-0.01	-0.68
BM (kg)	52.33	16.18	25.90	129.00	1.15	3.21
FAT %	20.93	8.17	5.90	46.10	0.67	0.09
BMI	20.95	4.98	14.40	45.20	2.05	3.21
WC (cm)	70.09	10.19	52.00	110.00	1.03	1.66
HC (cm)	86.93	10.96	65.00	126.00	0.41	0.50
WHR	0.81	0.09	0.60	1.08	0.71	1.40
WHtR	0.44	0.05	0.35	0.63	0.75	1.04
SPEED	9.65	0.55	9.00	11.50	1.04	1.11
SLJ	149.19	38.39	90.00	240.00	0.61	-0.80
SIT-UPS	54.79	20.67	25.00	98.00	0.27	-1.23
4X10M	11.75	1.08	10.20	15.23	0.98	0.39
SAR	58.51	14.12	20.00	87.00	-0.43	-0.44

Note: BH = Body height; BM = Body mass; FAT % = Body fat percentage; BMI = Body mass index; WC = Waist circumference; HC = Hip circumference; WHR = Waist-to-hip ratio; WHtR = Waist-to-height ratio; SPEED = Running speed in km/h at the last completed stage; SLJ = Standing long jump; SIT-UPS = Sit-ups in 60 seconds; 4X10M = 4x10 meters shuttle run; SAR = Sit-and-reach; SD = Standard deviation; Skew = Skewness; Kurt = Kurtosis

Analysis of the results by gender (Table 2) shows that eighth-grade boys performed better in strength and agility tests than girls. In fourth grade, boys were better at explosive strength, repetitive strength and agility. In contrast, girls excelled in flexibility. There were no significant differences in body composition in fourth-grade students, but differences appeared in eighth-grade students. Boys had higher body height and body mass scores, and significantly lower body fat percentage values than girls. In the aerobic endurance test (VO2 max), a decrease in scores is visible in both gender groups. In eighth grade, scores are similar for both genders. However, in fourth grade, boys scored much higher than girls in cardiorespiratory capacity. Similar results were obtained in a study by Kovač et al. (2013).

It is also evident that nominal differences appear between the sexes in fourth- and eighth- grade students. These data suggest that the decrease in aerobic capacity is not just a trend for one gender; it's a general pattern at this stage of development.

The normality of distribution was tested using the Shapiro–Wilk test (Table 3). In some variables (body mass, BMI, WHR, speed and agility), deviations from normal distribution were found, which were expected in this population given the pubertal developmental phase of the sample. Levene's test results indicate non-homogeneity of variances for a portion of the investigated variables. Such results are somewhat expected given the age difference between the groups. It is also important to note that

Table 2
The Mann-Whitney U test results show gender differences. These differences are in students' physical traits and fitness levels.

Variable	N= 33	N= 31		N= 30	N= 23	
	Mean ± SD 4. GIRL	Mean ± SD 4. MEN	MW U-test	Mean ± SD 8. GIRL	Mean ± SD 8. MEN	MW U-test
BH (cm)	149.19 ± 9.12	149.70 ± 8.47	0,89	163.92 ± 6.77	172,67 ± 6,19*	0,00
BM (kg)	42.99 ± 11.27	42.92 ± 10.61	0,80	59,29 ± 9,91	69,34 ± 17,00*	0,02
FAT %	22.04 ± 8.26	18.26 ± 6.52	0,07	25,06 ± 7,74	17,54 ± 8,26*	0,00
BMI	19.73 ± 5.91	18.92 ± 2.90	0,70	22,42 ± 4,32	23,53 ± 5,09	0,42
WC (cm)	64.76 ± 7.17	66.16 ± 6.63	0,36	71,95 ± 8,72	80,61 ± 11,28*	0,00
HC (cm)	79.97 ± 8.78	80.87 ± 7.94	0,60	93,37 ± 7,54	96,70 ± 8,94	0,17
WHR	0.81 ± 0.06	0.82 ± 0.06	0,50	0.77±0.10*	0,84 ± 0,12	0,03
WHtR	0.43 ± 0.04	0.44 ± 0.03	0,47	0.44±0.06	0,47 ± 0,06	0,10
SPEED	9.66 ± 0.69	10.08 ± 0.52*	0,01	9.38 ±0.22	9.39 ±0.21	0,82
SLJ	117.76 ± 14.04	122.74 ± 12.35*	0,04	171,13 ± 22,67	201,30 ± 25,19*	0,00
SIT-UPS	36.03 ± 9.25	40.55 ± 7.52*	0,01	73,77 ± 9,29	76,17 ± 12,40	0,12
4X10M	11.73 ± 0.92	11.25 ± 0.79*	0,00	12,48 ± 1,21	11,49 ± 0,96*	0,00
SAR	72.03 ± 6.78*	64.61 ± 5.95	0,00	44,60 ± 10,68	49,04 ± 10,04	0,18

Note: BH = Body height; BM = Body mass; FAT % = Body fat percentage; BMI = Body mass index; WC = Waist circumference; HC = Hip circumference; WHR = Waist-to-hip ratio; WHtR = Waist-to-height ratio; SPEED = Running speed in km/h at the last completed stage; SLJ = Standing long jump; SIT-UPS = Sit-ups in 60 seconds; 4X10M = 4x10 meters shuttle run; SAR = Sit-and-reach; SD = Standard deviation; * denotes significant differences $p < 0.05$

the age difference reflects the biological heterogeneity of the investigated groups. Given the approximately equal group sizes and moderate deviations, a one-way analysis of variance (ANOVA) was applied to variables that did not show statistical significance in variance difference, while the robust Welch's ANOVA was applied to variables where the homogeneity of variance was violated, ensuring a reliable interpretation of the results.

Based on the results in Table 4, it is evident that in terms of body height (TV), eighth-grade students are expectedly taller than fourth-grade students, with a statistically significant difference (ANOVA $F = 139.49$, $p < 0.00$) and a large effect size ($Eta^2 = 0.548$). Similarly, in terms of body mass (TM), eighth-grade students (63.65 kg) are significantly heavier than fourth-grade students (42.96 kg), with a statistically significant difference (ANOVA $F = 79.50$, $p < 0.00$) and a large effect size ($Eta^2 = 0.409$). Consistent with these findings, eighth-grade students have a significantly higher BMI (22.90) compared to fourth-grade students (19.34), which shows a statistically significant difference (ANOVA $F = 16.87$, $p < 0.00$) with a moderate effect size ($Eta^2 = 0.128$). At the same time, body fat percentage and body proportion ratios (WHR and WHtR) revealed no significant differences or relevant effect sizes, which suggests proportional growth without an increase in relative adiposity.

Table 3

Results of Levene's test for homogeneity of variances and normality of distribution (Shapiro-Wilk) for fourth- and eighth-grade students

Variable	N= 64		N= 53				
	Mean 4.	SD 4.	Mean 8.	SD 8.	Leven p	Shapiro-Wilk 4.	Shapiro-Wilk 8.
BH (cm)	149.44	8.74	167.72	7.81	0.39	0.98	0.91
BM (kg)	42.96	10.87	63.65	14.22	0.49	0.00	0.00
FAT %	20.21	7.65	21.80	8.74	0.55	0.01	0.20
BMI	19.34	4.68	22.90	4.65	0.86	0.00	0.00
WC (cm)	65.44	6.90	75.71	10.72	0.01	0.35	0.01
HC (cm)	80.41	8.33	94.81	8.26	0.35	0.23	0.00
WHR	0.81	0.06	0.80	0.11	0.00	0.00	0.04
WHtR	0.44	0.04	0.45	0.06	0.01	0.55	0.06
SPEED	9.87	0.64	9.39	0.21	0.00	0.00	0.00
SLJ	120.17	13.39	184.23	27.98	0.00	0.71	0.23
SIT-UPS	38.22	8.69	74.81	10.71	0.23	0.03	0.47
4X10M	11.50	0.89	12.05	1.21	0.03	0.00	0.04
SAR	68.44	7.36	46.53	10.55	0.00	0.25	0.43

Note: BH = Body height; BM = Body mass; FAT % = Body fat percentage; BMI = Body mass index; WC = Waist circumference; HC = Hip circumference; WHR = Waist-to-hip ratio; WHtR = Waist-to-height ratio; SPEED = Running speed in km/h at the last completed stage; SLJ = Standing long jump; SIT-UPS = Sit-ups in 60 seconds; 4X10M = 4x10 meters shuttle run; SAR = Sit-and-reach; SD = Standard deviation

Functional endurance, tested via the 20-metre shuttle run test (with the result expressed as the running speed in km/h at the last completed stage), showed significantly poorer results in older students compared to younger ones. This indicates that aerobic fitness declines with age, which is a clear indicator of lower activity levels. A highly significant difference was found between the grades (Welch $F = 30.28$, $p < 0.001$) with a moderate effect size ($Eta^2 = 0.19$).

The largest differences between groups in motor skills were observed in repetitive trunk strength and explosive leg power. The sit-up test showed a very large effect size ($\eta^2 = 0.78$) with ANOVA $F = 416.33$, $p < 0.001$, and the standing long jump test showed high significance (Welch $F = 233.52$, $p < 0.001$) with a large effect size ($\eta^2 = 0.70$), both indicating distinct dominance in the area of strength among older students. Conversely, flexibility test results point out the statistical significance in favor of younger students (Welch $F = 162.99$, $p < 0.001$), with a very large effect size ($\eta^2 = 0.60$). Furthermore, results in the 4x10 metre shuttle run test show that younger students possess significantly better agility and speed (Welch $F = 7.64$, $p = 0.01$).

Table 4

Results of one-way ANOVA and Welch's ANOVA for morphological, functional and motor variables between fourth- and eighth-grade students

Variable	4th Grade (N=64) Mean ± SD	8th Grade (N=53) Mean ± SD	ANOVA F	ANOVA p	WELCH F	WELCH p	Partial Eta Squared(η2)
BH (cm)	149.44±8.74	167.72±7.81*	139.49	0.00	/	/	0.55
BM (kg)	42.96±10.87	63.65±14.22*	79.50	0.00	/	/	0.41
FAT %	20.21±7.65	21.80±8.74	1.10	0.30	/	/	0.01
BMI	19.34±4.68	22.90±4.65*	16.87	0.00	/	/	0.13
WC (cm)	65.44±6.90	75.71±10.72*	/	/	36.21	0.00	0.25
HC (cm)	80.41±8.33	94.81±8.26*	87.33	0.00	/	/	0.43
WHR	0.81±0.06	0.80±0.11	/	/	0.60	0.44	0.01
WHtR	0.44±0.04	0.45±0.06	/	/	1.94	0.17	0.02
SPEED	9.87±0.64*	9.39±0.21	/	/	30.28	0.00	0.19
SLJ	120.17±13.39	184.23±27.98*	/	/	233.52	0.00	0,70
SIT-UPS	38.22±8.69	74.81±10.71*	416.33	0.00	/	/	0,78
4X10M	11.50±0.89*	12.05±1.21	/	/	7.64	0.01	0,07
SAR	68.44±7.36*	46.53±10.55	/	/	162.99	0.00	0,60

*Note: BH = Body height; BM = Body mass; FAT % = Body fat percentage; BMI = Body mass index; WC = Waist circumference; HC = Hip circumference; WHR = Waist-to-hip ratio; WHtR = Waist-to-height ratio; SPEED = Running speed in km/h at the last completed stage; SLJ = Standing long jump; SIT-UPS = Sit-ups in 60 seconds; 4X10M = 4x10 meters shuttle run; SAR = Sit-and-reach; SD = Standard deviation; ** denotes significant differences $p < 0.05$

Discussion

In line with the primary objective of this study, differences in physical fitness were established between students aged 10 and 14. The results indicate complex developmental dynamics during adolescence, where an increase in strength occurs alongside biological maturation, accompanied by a concerning trend of declining aerobic endurance, agility and flexibility in older students. In accordance with biological growth, 14-year-old students expectedly showed higher measured values for body height, body mass and Body Mass Index (BMI)—variables that define body composition—compared to younger students, thus confirming the natural processes of pubertal development (Caprio et al., 2020; Cesare et al., 2019).

A key result regarding morphological characteristics relates to the waist-to-height ratio (WHtR). While BMI was significantly higher in older students, the differences in WHtR were not statistically significant. This is a vital piece of data as WHtR is considered a more reliable indicator of abdominal obesity and cardiometabolic risk (Sharma et al., 2015; Lee et al., 2022; Lopes et al., 2014). The stability of this ratio suggests that fat distribution is not drastically disrupted by the onset of puberty. Nevertheless, given that Croatia ranks among the top European countries in terms of childhood obesity prevalence (Cesare et al., 2019), the increase in BMI among older students must not be ignored and requires continuous monitoring.

The main result of this study is a significant decrease of cardiorespiratory fitness for fourteen-year-olds (M±SD=9.39±0.21) compared to ten-year-olds (M±SD=9.87±0.64). This contrasts with the study by Pojskic and Eslami (2018), which showed that boys had significantly better fitness as they got older. However, this improvement was not seen in girls. Other studies (Ramírez-Vélez et al., 2019; Badrić et al., 2016) found a significant difference in cardiorespiratory fitness among girls. Younger girls had notably higher fitness levels than older girls. Such differences were not observed in boys.

The fact that cardiorespiratory capacity declines despite biological growth—and thus the growth of the heart and lungs—means that physiological development is insufficient to compensate for the reduction in physical activity and the increase in sedentary lifestyles in the higher grades of primary school (Hardy et al., 2018; Dong et al., 2025). It is concerning that low cardiorespiratory capacity in childhood is associated with a twofold higher risk of developing obesity and metabolic diseases (Tetteh et al., 2020). However, it is also important to note that interventions aimed at improving aerobic fitness have been proven to reduce body mass and improve metabolic health, thereby reducing the risk of metabolic diseases (Liu et al., 2024; Chen et al., 2021).

Analysis of motor skills results primarily revealed an increase in strength among older students. They achieved statistically significantly better results in explosive power (standing long jump) and repetitive strength (sit-ups), which are consistent with results of intensive strength development during puberty, primarily due to increased muscle mass and hormonal changes (Alvares et al., 2020; Sheehan & Lienhard, 2018). In contrast, younger students achieved significantly better results in agility (4x10 m) and flexibility (sit-and-reach). Lower flexibility values in older students can be explained by bone growth during puberty, when muscles and tendons do not grow at the same rate (Bianco et al., 2015). Meanwhile, the poorer agility result could be a consequence of disrupted coordination due to changes in body proportions and a decrease in spontaneous play, which is prevalent among younger children and abounds in diverse movements (Sember et al., 2020; Barnett et al., 2016).

The results indicate that the school system cannot rely solely on natural biological development in older students to correct all irregularities without significant engagement. While this development holds true for the increase in strength, there is a decline in aerobic endurance and flexibility, which are key health indicators. These results point to the necessity of redefining Physical Education classes in higher primary school grades. Curricula should place a greater emphasis on high-intensity aerobic activities and flexibility exercises, rather than relying exclusively on sports games that do not provide a sufficient stimulus for all students (Goran et al., 1999; Wyszyńska et al., 2020). If the trend of declining cardiorespiratory endurance is not halted during school age, today's generations will face an increased risk of chronic diseases later in life. The psychosocial development of adolescents, particularly eighth-grade girls, leads to changes in how they perceive their bodies and their public performance. The level of effort in tests depends on the psychological profile and motivation. Some older

female students might have put in less effort because they felt uncomfortable around their peers. However, eighth-grade boys also had lower relative VO2 max values. This suggests that body mass and the repetitive nature of the running protocol are more important than any gender-related demotivation (Sekulić & Metikoš, 2007).

The strength of this study lies in the fact that there is very little research comparing differences in physical fitness components between prepubertal and pubertal participants. The results have practical implications in the field of public health, as well as for the implementation of actions aimed at increasing physical fitness levels in students and reducing obesity, which is a massive health problem in the Republic of Croatia.

When interpreting the results, realistic limitations of this study must be considered. The research is cross-sectional, which precludes tracking individual changes in the same participants over time. Furthermore, the sample is convenient and limited to one geographical region, which reduces the possibility of generalizing the results to the entire territory of the Republic of Croatia. Additionally, the relatively small number of participants limits generalizability. Future research should utilize larger samples to confirm these results. Another limitation of this study is that it lacks data on the subjects' extracurricular sports activities. This data would help clarify the difference between the effects of biological growth and training. The study assessed the level of motivation during the shuttle run test by observation, while future studies should include subjective effort scales or heart rate monitoring to further confirm whether the subjects truly reached their physiological limit. The lack of precise data on nutritional habits and extracurricular activities of students leaves room for further studies that could explain the causes of the differences observed in this research.

Biological growth and increased muscle mass in adolescence are not sufficient to maintain cardiorespiratory capacity and flexibility. These results serve as a foundation for introducing targeted intervention programs in Physical Education classes aimed at preserving and increasing aerobic endurance and preventing a sedentary lifestyle. The results of this study can serve as a starting point for future longitudinal research focused on monitoring changes in physical fitness and children's health, as well as the development of intervention programs to improve the quality of life for children and adolescents. Preserving cardiorespiratory health and motor competence should, therefore, be a priority for the school system and public health strategies.

Conclusion

This study aimed to compare the physical fitness of students aged 10 and 14 in the Republic of Croatia. The results clearly indicate the existence of age-related differences in most of the analyzed variables. Older students, as expected, showed higher values in body height and body composition components, while the waist-to-height ratio (WHtR) and waist-to-hip ratio (WHR) did not differ with statistical significance between the age groups. One of the more significant results was lower cardiorespiratory capacity in older students, which confirms the trend of the negative impact of a sedentary lifestyle during adolescence.

Students aged 14 were, as expected, better in strength tests, while 10-year-old students showed greater agility, speed and flexibility. These differences point to the complexity of development, which involves biological maturation, changes in body composition and shifts in physical activity patterns during growth. The results indicate that biological growth and increased muscle mass are not sufficient to maintain cardiorespiratory capacity. The decrease in maximal oxygen uptake (VO2max), along with a simultaneous decline in agility and flexibility, reveals that a reduction in spontaneous movement and an increase in sedentary behaviour occur during adolescence. This trend emphasizes the need for systematic and targeted physical activity programs in higher grades of primary school, with an emphasis on developing and maintaining aerobic capacity as well as motor skills such as speed, agility and flexibility.

The results have important public health implications aimed at reducing the sedentary behaviour of school-aged children and increasing physical activity. Physical Education classes should be planned to respond to the specific needs of different age groups, with an increase in aerobic and high-intensity activities for older students, which is one of the key factors for health preservation and obesity prevention.

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Razlike u tjelesnoj spremnosti između učenika u dobi od 10 i 14 godina

Sažetak

Cilj istraživanja jest utvrditi razlike u tjelesnoj spremnosti između učenika u dobi od 10 do 14 godina. Istraživanjem se želi dobiti jasan uvid utjecaja odrastanja na tjelesnu spremnost i smanjuje li se s porastom dobi razina tjelesne spremnosti. U presječnom istraživanju sudjelovalo je 117 učenika osnovnih škola (64 učenika četvrtoga razreda i 53 učenika osmoga razreda). Prosječna dob ispitanika iznosila je 12,05 ± 2,03 godine. Mjerenja su obuhvatila antropometrijske varijable (tjelesna visina i masa, komponente sastava tijela, omjeri WHR i WHtR), motoričke testove (skok u dalj s mjesta, podizanje trupa, pretklon, trčanje 4 x 10 m) te funkcionalnu procjenu maksimalnoga primitka kisika (VO2 max) putem Shuttle run testa. ANOVA i Welchov test pokazali su značajne razlike između dobnih skupina. Stariji učenici u dobi od 14 godina očekivano su viši i teži te postižu značajno bolje rezultate u testovima eksplozivne snage nogu i repetitivne snage trupa. S druge strane, mlađi učenici u dobi od 10 godina pokazali su statistički značajno bolju agilnost, veću fleksibilnost te višu razinu kardiorespiratorne izdržljivosti u usporedbi sa starijom skupinom. Zanimljivo je da unatoč porastu BMI-a, omjer struka i visine (WHtR) nije pokazao značajne razlike, što ukazuje na proporcionalan rast bez drastičnoga narušavanja distribucije masnoga tkiva. Istraživanje potvrđuje da biološki rast i povećanje mišićne mase u adolescenciji nisu dovoljni za održavanje kardiorespiratornoga kapaciteta, fleksibilnosti te brzine i agilnosti. Pad aerobne izdržljivosti među starijiim učenicima ukazuje na povećanje sjedilačkoga načina života, što naglašava potrebu za uvođenjem specifičnih intervencijskih programa u nastavu tjelesne i zdravstvene kulture usmjerenih na razvoj kardiorespiratornoga zdravlja i motoričkih kompetencija.

Ključne riječi: *tjelesna spremnost; kardiorespiratorni kapacitet; motoričke sposobnosti; pubertet*

Uvod

Redovitost tjelesne aktivnosti ključna je u prevenciji i liječenju pretilosti u dječjoj dobi jer doprinosi održavanju zdrave tjelesne mase, poboljšava metaboličko zdravlje i potiče usvajanje zdravih životnih navika. Djeca bi prema preporukama Svjetske zdravstvene

organizacije trebala sudjelovati u najmanje 60 minuta umjerene do visokointenzivne tjelesne aktivnosti dnevno (WHO, 2018). Izuzetno je važno da se djeca i mladi angažiraju i potrebno im je osigurati u dovoljnoj mjeri tjelesne aktivnosti za podršku njihova sadašnjega I budućega zdravstvenoga statusa (Ha i sur., 2019). Iako postoje dosljedni dokazi koji povezuju tjelesnu aktivnost s pozitivnim zdravstvenim dobrobitima, bit će potrebno više od znanstvenih dokaza da bi napredovala provedba javnozdravstvene politike. Uspjesi u promicanju tjelesne aktivnosti često uključuju povezivanje glavnih društvenih trendova i kulturnih promjena (Alamilla i sur., 2023). Važnost tjelesnoga aktiviteta djece i učenika ogleda se u činjenici da je ono usko povezano s motoričkim razvojem (Badrić i Roca, 2024). Tjelesna aktivnost u dječjoj dobi ima ključnu ulogu u prevenciji prekomjerne tjelesne mase. Djeca koja se više bave redovitom tjelesnom aktivnošću imaju manje masnoga tkiva od one s manjom razinom tjelesnoga aktiviteta (Wyszyńska i sur., 2020).

Tjelesna spremnost višedimenzionalni je konstrukt koji obuhvaća i komponente povezane sa zdravljem i komponente povezane s performansama/vještinama. Kondicija povezana sa zdravljem obuhvaća kardiovaskularnu izdržljivost, mišićnu snagu, fleksibilnost i sastav tijela, pri čemu su svi navedeni aspekti važni pokazatelji općega zdravlja i prediktori mogućega rizika od kroničnih bolesti u djece i adolescenata (Ortega i sur., 2023). Tjelesna spremnost je sveobuhvatan pokazatelj zdravlja koji odražava funkcionalno stanje više tjelesnih sustava, uključujući skeletomuskularni, kardiorespiratorni, hematocirkulacijski, psihoneurološki i endokrino-metabolički sustav (Tomkinson i sur., 2018). Promjene u modernom načinu života dovele su do izraženoga smanjenja ljudske tjelesne aktivnosti. Brojne studije pokazale su da je smanjena količina tjelesne aktivnosti među učenicima najvažniji razlog pada tjelesne spremnosti (Lu i sur., 2023). Zbog značajnih promjena u sastavu tijela, hormonalnom statusu i društvenim interakcijama, pubertet se čini kritičnim razdobljem za razvoj tjelesne spremnosti (Greier i sur., 2019). Značajan broj istraživanja naglasio je pozitivnu korelaciju između tjelesne spremnosti i općega zdravlja mladih (Yi i sur., 2019) što je potaknulo globalne inicijative za poboljšanje razine tjelesne spremnosti (Gao i sur., 2023).

Tjelesna spremnost raste s dobi, stoga postoji značajan učinak povezan sa starenjem za sve mjere tjelesne spremnosti (Thomas i Palma 2018). Istraživanje na uzorku njemačke školske djece pokazalo je značajan utjecaj dobi koji je uočen među različitim testovima tjelesne spremnosti (Golle i sur., 2015). Meinel i Schnabel (2014) navode da se značajna poboljšanja u različitim komponentama tjelesne spremnosti uočavaju između 11. i 15. godine, pri čemu su povećanja snage i izdržljivosti izraženija među dječacima u usporedbi s djevojčicama. Među djevojčicama poboljšanja tjelesne spremnosti događaju se samo tijekom rane adolescencije, dok nakon puberteta dolazi do stagnacije ili čak pada. Minimalno tjedno povećanje tjelesne aktivnosti može proizvesti značajne promjene u razini motoričkih sposobnosti među 14-godišnjim djevojčicama (Badrić

i sur., 2015). Osim aspekata povezanih s rastom, čini se da su hormonalne promjene ključni faktori promjena u tjelesnoj spremnosti i stavljaju dječake u prednost nad djevojčicama (Greier i sur., 2019; Thomas i Palma 2018).

Djetinjstvo i tinejdžerske godine ključno su razdoblje za razvoj motoričkih sposobnosti poput brzine, agilnosti, koordinacije i snage. Najveći napredak u brzini i agilnosti događa se između sedme i dvanaeste godine života, dok se snaga radi povećanja mišićne mase razvija u pubertetu (Alvares I sur., 2020; Sheehan i Lienhard, 2018). Koordinacija je obično dobro razvijena već oko desete godine iako može privremeno oslabljeti tijekom nagloga rasta (Sheehan i Lienhard, 2018; Alvares i sur., 2020). Razdoblje od 10. do 14. godine uključuje promjene u izgledu tijela, hormonima i motivaciji za kretanje zbog čega rezultati testiranja i u ovoj dobi mogu varirati (Sember i sur., 2020).

Tjelesna građa poput tjelesne visine, mase, udjela masnoga tkiva i opsega struka ima važnu ulogu u tjelesnoj spremnosti djece. Povećani udio masnoga tkiva kod djece povezan je sa slabijim rezultatima u testovima agilnosti, izdržljivosti i snage, a veći udio mišićne mase donosi bolje rezultate (Almeida, 2025; Gericke i sur., 2025; Radin i sur., 2023). Indikatori pretilosti koji čine postotak masti, indeks tjeslne mase (BMI), omjer struka i visine (WHtR) i opseg struka (WC) kao zajednička cjelina mogu utjecati na razinu kardiorespiratornoga kapaciteta (Badrić i sur., 2024). Omjer struka i visine (WHtR) pouzdan je pokazatelj centralne abdominalne pretilosti i bolji prediktor rizika od bolesti srca i krvnih žila u odnosu na BMI (Sharma i sur., 2015; Lee i sur., 2022; Lopes i sur., 2014). Povišene vrijednosti WHtR-a ukazuju na slabiji VO_2max, lošije rezultate u testovima agilnosti i smanjenu snagu. Optimalne vrijednosti WHtR za predviđanje abdominalne pretilosti u djece kreću se između 0,49 i 0,50 (Dong i sur., 2024, Eslami i sur., 2023; Zong i sur., 2023; Sharma i sur., 2015). Uz rastući globalni problem dječje pretilosti i pada aerobnoga kapaciteta, istraživanje razlika između mlađe i starije školske dobi dobiva sve veću važnost za razumijevanje razvojnih trendova, rizika i potreba za intervencijama.

Razdoblje između desete i četrnaeste godine jest doba velikih promjena građe tijela i motoričkih sposobnosti te je ključno u razvoju djece. Danas je sve više pretile djece loše kondicije i potrebno je istražiti ovo razdoblje velikih promjena između mlađih i starijih osnovnoškolaca kako bi se pravodobno otkrili i razumjeli rizici ove razvojne faze i na vrijeme interveniralo. Dob od 10. do 14. godine predstavlja kritičnu fazu u razvoju djece s obzirom na snažne promjene u tjelesnoj građi i motoričkim sposobnostima. Razvoj motoričkih i funkcionalnih sposobnosti nije linearan proces, već je podložan senzibilnim fazama i biološkim zakonitostima rasta. Dok mlađa školska dob (10 godina) predstavlja razdoblje visoke spontane aktivnosti i povoljnih uvjeta za razvoj aerobne izdržljivosti, faza rane adolescencije (14 godina) donosi specifične izazove. Osim bioloških faktora, u ovoj je dobi ključno razmotriti i psihosocijalne čimbenike poput motivacije za bavljenje sportom i promjena u navikama tjelesne aktivnosti, što izravno utječe na postignuća u standardiziranim kineziološkim testovima (Sekulić i Metikoš,

2007). Važnost ove studije jest u njezinim javnozdravstvenim implikacijama jer rezultati pokazuju da ulaskom u adolescenciju opadaju kardiorespiratorni kapacitet, agilnost i fleksibilnost što se događa zbog sjedilačkoga oblika života što naglašava potrebu za prilagodbama nastave tjelesne i zdravstvene kulture kako bi se među starijim učenicima ciljano razvijao i očuvao aerobni kapacitet te održale motoričke sposobnosti.Prilikom interpretacije rezultata treba uzeti u obzir da rezultati u testovima izdržljivosti uvelike ovise o trenutačnoj motivaciji i subjektivnom osjećaju učenika, što je moglo utjecati na njihov konačni rezultat.

Cilj istraživanja jest utvrditi razlike u tjelesnoj spremnosti između učenika u dobi od 10. do 14. godine. Istraživanjem se želi dobiti jasan uvid utjecaja odrastanja na tjelesnu spremnost i smanjuje li se s porastom dobi razina tjelesne spremnosti uzimajući u obzir promjene u motoričkim, funkcionalnim i morfološkim pokazateljima između mlađe i starije dobne skupine.

Metodologija

Istraživački postupci i uzorak ispitanika

U presječnom istraživanju sudjelovalo je 117 učenika osnovnih škola iz dvije osnovne škole kontinentalnoga dijela Republike Hrvatske. Od ukupnoga uzorka, 64 učenika pohađalo je četvrti razred, a 53 učenika osmi razred. Od ukupnoga uzorka prema spolnoj razlici bilo je 63 djevojčice (54 %) i 54 dječaka (46 %) ukupno, od toga 30 djevojčica i 23 dječaka osmoga razreda te 33 djevojčice i 31 dječak četvrtoga razreda. Prosječna dob ispitanika iznosila je 12,05 ± 2,03 godine. Uzorak ispitanika bio je podijeljen prema dobi i spolu kako bi analiza bila što detaljnija. Kako bi se osigurala maksimalna razina osobnoga angažmana, testiranja su provedena u nazočnosti predmetnoga nastavnika TZK-a i istraživača, pri čemu je naglasak stavljen na individualni maksimalni napor u funkcionalnim testovima

Prije provedbe istraživanja ravnatelji škola kontaktirani su telefonski ili putem elektroničke pošte te je zatraženo službeno odobrenje za sudjelovanje učenika u istraživanju. Nakon dobivenih odobrenja učenicima su podijeljeni pismeni pristanci za sudjelovanje u istraživanju. U istraživanje su uključeni učenici koji su imali potpisanu suglasnost roditelja ili skrbnika te oni koji su samostalno potpisali informirani pristanak primjeren njihovoj dobi. Kriteriji za uključivanje u istraživanje bili su: uredno zdravstveno stanje bez prisutnih tjelesnih ili psihičkih smetnji, redovito pohađanje nastave tjelesne i zdravstvene kulture te uspješno obavljena mjerenja u svim morfološkim i motoričkim testovima. Svi postupci provedeni su anonimno, uz poštivanje etičkih standarda i odredbi Helsinške deklaracije. Istraživanje je odobrilo od Etičko povjerenstvo Učiteljskog fakulteta Sveučilišta u Zagrebu.

Antropometrijska mjerenja

Tjelesna visina mjerena je prijenosnim visinomjerom (Seca® 213, Hamburg, Njemačka), prema standardiziranim antropometrijskim preporukama (Fredriksen i sur., 2025; Kim

i sur., 2024; Agbaje, 2024). Tjelesna masa procjenjivala se dvofrekventnim analizatorom sastava tijela TANITA DC-360P, koji se temelji na principu bioelektrične impedancije (BIA) (Thajer i sur., 2025; Nahorna i Baur, 2025) koja je validirana metoda za procjenu sastava tijela djece i adolescenata (Lee i sur., 2017; de Castro i sur., 2017). Opseg struka i bokova izmjeren je metarskom vrpcom. Opseg struka izmjeren je na sredini između najniže granice prsnog koša i gornje granice krista ilijake, na kraju normalnoga izdisaja (Fredriksen i sur., 2025; Nahorna i Baur, 2025; WHO, 1995). Opseg bokova izmjeren je na najširem dijelu kuka, na razini velikoga trohantera. Na temelju njihova omjera izračunat je omjer struka i bokova (WHR indeks), a temeljem izmjerenoga opsega struka i tjelesne visine izračunat je omjer struka i visine (WHtR);

WHtR=opseg abdomena (cm)/visina (cm)

Prag WHtR od 0,50 označen je kao univerzalni pokazatelj rizika za djecu i adolescente (Ashwell i sur.,2005) dok vrijednosti WHtR iznad 0,50 upućuju na povećan rizik od abdominalne pretilosti i kardiometaboličkih komplikacija ((Browning i sur.,2010).

Mjerenje motoričkih sposobnosti

Motoričke sposobnosti procijenjene su putem četiriju standardiziranih testova koja obuhvaćaju eksplozivnu snagu, repetitivnu snagu, fleksibilnost te agilnost i koordinaciju.

Eksplozivna snaga donjih ekstremiteta mjerena je skokom u dalj s mjesta. Pri skoku u dalj učenik se sunožno odražava i doskače što je dalje moguće i mjeri se udaljenost od odrazne linije do mjesta dodira pete s podlogom i izvodi se u tri pokušaja uz bilježenje najboljega rezultata. Skok u dalj smatra se pouzdanim pokazateljem eksplozivne snage nogu u djece i adolescenata (Tabacchi i sur., 2019; Bianco i sur., 2015; Ruiz i sur., 2010).

Repetitivna snaga mišića trupa mjerena je testom podizanja trupa u 60 sekundi. U izvođenju testa učenik leži na leđima sa savijenim koljenima pod kutom od 90 stupnjeva uz fiksirana stopala i ruke prekrižene na prsima. U izvedbi je potrebno podići se do sjedećega položaja i vratiti se u početni položaj ležanja na leđima. Mjere se pravilno izvedena ponavljanja u 60 sekundi (Bianco i sur., 2015; Häcker i sur., 2017).

Fleksibilnost je mjerena testom pretklona raznožno pri čemu učenik sjedi ispruženih nogu, stopala postavljenih uz mjernu kutiju i ruku ispruženih prema naprijed. Potrebno je polaganim pretklonom dosegnuti najudaljeniju moguću točku i zadržati položaj dvije sekunde. Najbolji rezultat bilježi se u centimetrima. Testiranje pretklona pouzdano je u procjeni fleksibilnosti stražnje strane natkoljenice i donjega dijela leđa u djece i adolescenata (Bianco i sur., 2015; Ruiz i sur., 2010; Castro-Piñero i sur., 2009).

Agilnost i koordinacija procijenjene su testom trčanja 4 × 10 metara pri čemu učenik trči između dviju paralelnih crta udaljenih 10 metara i svaku crtu mora dotaknuti prije okreta. Test trčanja izvodi se u dva pokušaja, a vrijeme se mjeri u stotinkama sekunde i bilježi se najbrži rezultat. Test trčanja 4 x 10 metara smatra se pouzdanim instrumentom za procjenu agilnosti u školskim i sportskim populacijama (Bianco i sur., 2015; Ruiz i sur., 2010; Ramírez-Vélez i sur., 2015).

Mjerenje kardiorespiratornoga kapaciteta

Kardiorespiratoni kapacitet procijenjen je višestupanjskim testom trčanja na 20 metara (Shuttle run test) (Léger i Lambert, 1982). Sva mjerenja odrađena su u školi, na ravnoj i jasno označenoj površini od 20 metara i u isto doba dana kako bi uvjeti bili što ujednačeniji (Brito i sur., 2022; Amedro i sur., 2023). Učenicima je prije početka testiranja detaljno objašnjen i demonstriran protokol izvođenja testa. Test je započinjao desetominutnim zagrijavanjem i vježbama istezanja (Brito i sur., 2022). Učenici su testirani u skupinama po 8 ispitanika, a svaki sudionik imao je jedan pokušaj. Budući da rezultati u testovima izdržljivosti ovise o razini opaženoga napora i psihološkom opterećenju, istraživački tim osigurao je kontinuirano bodrenje kako bi se spriječilo prerano odustajanje uzrokovano monotonošću testa (Sekulić i Metikoš, 2007).

Ispitanici u ovom terenskom testu trče naprijed-natrag između dvije postavljene linije na udaljenosti od 20 metara. Udaljenost od 20 metara označena je mjernom linijom i čunjevima. Brzina trčanja regulirana je pomoću zvučnih signala i započinje pri 8,5 km/h−1 te se povećava za 0,5 km/h−1 svake minute. Svaka razina traje približno 60 sekundi, pri čemu 'brzinu' (vrijeme trajanja svakog intervala) ispitaniku diktira interval zvučnih signala.

Učenici moraju stići do obilježene linije prije zvučnoga signala i ako stignu ranije, moraju čekati sljedeći signal za povratak (Bok i sur., 2023). Test je za svakog učenika završio kada učenik dvaput uzastopno ne stigne do linije na vrijeme ili kada sam odustane zbog umora i iscprljenosti. Kao rezultat testa bilježila se posljednja uspješno dovršena razina (Léger i Lambert, 1982; Brito i sur., 2022).

Vrijednost VO_2max (mL/kg/min) izračunata je pomoću standardne jednadžbe:

$$VO_2max = 31{,}025 + 3{,}238 \times S - 3{,}248 \times A + 0{,}1536 \times (A \times S)$$

pri čemu je S – brzina (km/h) postignuta na kraju testa, a A – dob učenika u godinama (Léger i sur., 1988; Menezes Júnior i sur., 2019). Testiranjeučenika provodilo se u sportskim školskim dvoranama.

Statističke analize

U deskriptivnoj statistici izračunane su aritmetičke sredine (AS), standardne devijacije (SD), minimalne (Min) i maksimalne (Max) vrijednosti te koeficijenti zakrivljenosti (Skewness) i spljoštenosti distribucije (Kurtosis). Ovi pokazatelji omogućuju uvid u centralnu tendenciju, raspršenost i oblik distribucije podataka, te predstavljaju standard u prikazu i interpretaciji numeričkih rezultata (Fulk, 2023; Mishra i sur., 2019). Normalnost distribucije varijabli provjerena je Shapiro–Wilkovim testom. U utvrđivanju spolnih razlika u varijablama morfoloških karakteristika i tjelesne spremnosti prema dobi korišten je Mann-Whitney U test zbog maloga broja ispitanika između definiranih poduzoraka prema spolu i dobi. Značajnost razlika između dobnih skupina u razini tjelesne spremnosti ispitana je jednosmjernom analizom varijance (ANOVA), koja se uobičajeno primjenjuje za usporedbu aritmetičkih sredina između

dvije ili više skupina (Silva de Souza i Borges, 2023; Delacre i sur., 2019). Homogenost varijanci provjerena je Levenovim testom, koji se preporučuje kao korak prije primjene ANOVA jer je klasični F-test osjetljiv na nejednakosti varijanci (Müller i sur., 2024; Odoi i sur., 2025; Delacre i sur., 2019). Za varijable kod kojih su utvrđene statistički značajne razlike u varijancama primijenjen je Welchov ANOVA test jer ne zahtijeva homogenost varijanci i smatra se robusnijim izborom u takvim situacijama (Delacre i sur., 2019; Silva de Souza i Borges, 2023).

Statistička analiza provedena je pomoću softverskoga paketa IBM SPSS Statistics, verzija 29.0, koji predstavlja standardni alat za obradu i analizu podataka u društvenim i biomedicinskim znanostima. Razina statističke značajnosti postavljena je na $p < 0,05$, što je uobičajeni prag u znanstvenim istraživanjima.

Rezultati

Rezultati u Tablici 1 prikazuju vrijednosti deskriptivne statistike za promatrane varijable. Prosječna dob učenika iznosi (M = 12,05 ± 2,03) godina. Tjelesna visina i tjelesna masa pokazuju vrijednosti sukladno zakonitostima rasta i razvoja uz nekoliko ispitanika koji imaju višu tjelesnu masu s maksimalnim rezultatom (M = 129,00 ± 12,34). U varijablama sastava tijela vidljivo je da su one normalno distribuirane uz nekoliko rezultata koji značajno odstupaju od srednjih vrijednosti. Motorički testovi pokazali su zadovoljavajuću varijabilnost bez značajnih odstupanja od normalnosti.

Tablica 1

Analiza rezultata razvrstanih po spolu (Tablica 2) otkriva da su dječaci 8. razreda značajno superiorniji u testovima snage i testu agilnosti u odnosu na djevojčice. Među učenicima 4. razreda vidljivo je da su dječaci statistički značajno bolji u eksplozivnoj i repetitivnoj snazi te agilnosti, dok su djevojčice statistički značajno bolje u fleksibilnosti. U sastavu tijela nema značajnih razlika među učenicima 4. razreda, dok se razlike pojavljuju među učenika 8. razreda. Dječaci imaju više rezultate tjelesne visine i tjelesne mase, značajno manje vrijednosti postotka masti u organizmu od djevojčica.

U testu aerobne izdržljivosti (VO2 max) vidljiv je pad rezultata u obje spolne skupine. Razlike ne postoje u 8. razredu, ali se pojavljuju u 4. razredu jer dječaci imaju značajno bolje rezultate kardiorespiratornoga kapaciteta od djevojčica. Slične rezultate dobili su Kovač i sur. (2013). Također se uočavaju nominalne razlike između spolova među učenicima 4. i 8. razreda. Ovi podatci sugeriraju da pad relativnoga aerobnog kapaciteta nije izolirana pojava vezana uz jedan spol, već opći trend u ovoj fazi razvoja.

Tablica 2

Rezultati Mann- Whitney U test za utvrđivanje razlika prema spolu u morfološkim karakteristika i tjelesnoj spremnosti učenika

Normalnost distribucije varijabli provjerena je Shapiro–Wilkovim testom (Tablica 3). Za neke varijable (tjelesna masa, BMI, WHR, brzina i agilnost) utvrđeno je odstupanje

od normalnosti distribucije, što se i očekuje u ovoj populaciji ispitanika s obzirom na pubertetsku razvojnu fazu uzorka. Rezultati Leveneova testa ukazuju kod dijela istraživanih varijabli na nehomogenost varijanci. Ovakvi rezultati relativno su očekivani s obzirom na različitu dob između istraživanih učenika. Isto tako važno je napomenuti da se različitost dobi reflektira i na biološku heterogenost istraživanih skupina. S obzirom na približno jednake veličine skupina i umjerena odstupanja, za varijable koje ne pokazuje statističku značajnost u daljnjoj analizi primijenjena je jednosmjerna analiza varijance (ANOVA) dok se za varijable kojima je utvrđena narušenost homogenosti varijanci primjenjivala robusnija Welchova analiza varijance kojom se osigurala pouzdana interpretacija rezultata.

Tablica 3

Iz dobivenih rezultata u Tablici 4 vidljivo je da su u mjerenju tjelesne visine (TV) učenici 8. razreda očekivano viši od učenika 4. razreda uz statistički značajnu razliku (ANOVA $F = 139,49$, $p < 0,00$) s velikom veličinom učinka ($Eta^2 = 0,548$). Isto tako, u mjerenju tjelesne mase (TM) učenici 8. razreda (63,65 kg) značajno su teži od učenika 4. razreda (42,96 kg) uz statistički značajnu razliku (ANOVA $F = 79,50$, $p < 0,00$) s velikom veličinom učinka ($Eta^2 = 0,409$). Sukladno dvama prijašnjim mjerenjima tjelesne građe učenici 8. razreda imaju značajno viši BMI (22,90) u usporedbi s učenicima 4. razreda (19,34) uz statistički značajnu razliku (ANOVA $F = 16,87$, $p < 0,00$) s umjerenom veličinom učinka ($Eta^2 = 0,128$). Istodobno, postotak tjelesne masti te omjeri tjelesnih proporcija (WHR i WHtR) nisu pokazali značajne razlike ni relevantne veličine učinka, što upućuje na proporcionalan rast bez povećanja relativne adipoznosti.

Vrijednosti funkcionalne izdržljivosti koja je provjeravana 20 metarskim Shuttle run testom te je rezultat bio brzina trčanja u km/h na posljednjoj završenoj etapi, pokazali su značajno slabije rezultate među starijim učenicima u odnosu na mlađe što znači da s odrastanjem aerobna kondicija pada što je jasan pokazatelj da su manje aktivni. Pronađena je statistički vrlo značajna razlika između razreda (Welch $F = 25,67$, $p < 0,001$) s umjerenom veličinom učinka ($Eta^2 = 0,182$).

Najveće razlike između skupina u motoričkim sposobnostima uočene su u repetitivnoj snazi trupa i eksplozivnoj snazi nogu. Test podizanja trupa s vrlo velikom veličinom učinka ($\eta^2 = 0,78$) uz (ANOVA $F = 416,33$, $p < 0,001$) te test skok u dalj s mjesta uz značajnost (Welch $F = 263,08$, $p < 0,001$) i veliku snagu učinka ($\eta^2 = 0,70$) ukazuju na izrazitu dominaciju u području snage kod starijih učenika. Suprotno tome, rezultati testa fleksibilnosti pokazuju statističku značajnost među mlađim učenicima (Welch $F = 8,09$, $p = 0,01$) s vrlo velikom veličinom učinka ($\eta^2 = 0,60$). također, rezultati na testu trčanje 4 x 10 metara pokazuju da mlađi učenici imaju značajno bolju agilnost i brzinu.

Tablica 4

Rezultati jednosmjerne analize varijance i Welchove analize varijance za morfološke, funkcionalne i motoričke varijable između učenika 4. i 8. razreda

Diskusija

S obzirom na primaran cilj istraživanja utvrđene su razlike u tjelesnoj spremnosti kod učenika u dobi od 10 i 14 godina. Rezultati istraživanja ukazuju na složenu dinamiku razvoja tijekom adolescencije pri čemu dolazi do porasta snage uz biološko sazrijevanje te je prisutan zabrinjavajući trend pada aerobne izdržljivosti, agilnosti i fleksibilnosti kod starijih učenika.

U skladu s biološkim rastom očekivano su učenici u dobi od 14 godina pokazali veće izmjerene vrijednosti tjelesne visine, tjelesne mase i indeksa tjelesne mase (BMI) odnosno varijabli koji određuju sastav tijela u odnosu na mlađe učenike čime se potvrđuju prirodni procesi pubertetskog razvoja (Caprio i sur. 2020; Cesare i sur. ,2019).

Ključan nalaz istraživanja morfoloških karakteristika odnosi se na omjer struka i visine (WHtR) pri čemu je BMI bio značajno viši kod starijih učenika, ali razlike u WHtR-u nisu bile statistički značajne što je bitan podatak jer se WHtR smatra pouzdanijim pokazateljem abdominalne pretilosti i kardiometaboličkoga rizika (Sharma i sur., 2015; Lee i sur., 2022; Lopes i sur., 2014) i stabilnost ovog omjera govori kako distribucija masnoga tkiva nije drastično narušena ulaskom u pubertet. Unatoč tome, s obzirom na to da se Hrvatska nalazi u samom vrhu europskih zemalja po prevalenciji pretilosti djece (Cesare i sur., 2019), porast BMI-a kod starijih učenika se ne smije zanemariti i zahtijeva kontinuirano praćenje.

Najvažniji rezultat ovoga istraživanja jest značajan pad kardiorespiratorne izdržljivosti među četrnaestogodišnjacima ($M \pm SD = 9{,}39 \pm 0{,}21$) u usporedbi s desetogodišnjacima ($M \pm SD = 9{,}87 \pm 0{,}64$) što je suprotno od istraživanja Pojskic i Eslami (2018) u kojem su dječaci imali značajno bolje rezultate porastom dobi, dok se kod djevojčica ta razlika nije utvrdila. Također, istraživanje Ramírez-Vélez i sur. (2019) te Badrić i sur. (2016) pokazalo je da postoji statistički značajna razlika u kardiorespiratornom fitnesu kod djevojčica pri čemu mlađe djevojčice imaju značajno više vrijednosti u odnosu na starije. Takve razlike nisu uočene među dječacima.

Činjenica da kardiorespiratorni kapacitet opada unatoč biološkom rastu , a time rastu pluća i srce znači da fiziološki razvoj nije dovoljan da bi se nadoknadila razina smanjenja tjelesne aktivnosti i porasta sjedilačkoga načina života u višim razredima osnovne škole (Hardy i sur., 2018; Dong i sur., 2025). Zabrinjavajući je podatak kako je nizak kardiorespiratorni kapacitet u dječjoj dobi povezan s dvostruko većim rizikom od razvoja pretilosti i metaboličkih bolesti (Tetteh i sur., 2020), ali bitno je znati i kako intervencije usmjerene na poboljšanje aerobne kondicije dokazano smanjuju tjelesnu masu i poboljšavaju metaboličko zdravlje, a time i rizik od metaboličkih bolesti (Liu i sur., 2024; Chen i sur., 2021).

Analiza rezultata motoričkih sposobnosti otkrila je ponajprije porast snage starijih učenika. Oni su postigli statistički značajno bolje rezultate u eksplozivnoj snazi (skok u dalj) i repetitivnoj snazi (podizanje trupa) što je u skladu s nalazima intenzivnoga

razvoja snage tijekom puberteta primarno zbog povećanja mišićne mase i hormonalnih promjena (Alvaresa i sur., ,2020, Sheehan i sur., 2018). Suprotno tome, mlađi učenici postigli su značajno bolje rezultate u agilnost (4 x 10 m) i fleksibilnost (pretklon). Niže vrijednosti fleksibilnosti starijih učenika mogu se objasniti rastom kostiju tijekom puberteta, pri čemu mišići i tetive ne prate rast istom brzinom (Bianco i sur., 2015), dok je slabiji rezultat agilnosti posljedica narušene koordinacije zbog promjene tjelesnih proporcija i smanjenja spontane igre koja je među mlađom djecom prisutna i obiluje raznolikim kretanjima (Sember i sur., 2020; Barnett i sur., 2016).

Rezultati ukazuju na to da se školski sustav ne može oslanjati isključivo na biološki razvoj starijih učenika koji će ispraviti sve nepravilnosti bez prevelikoga angažmana jer premda dolazi do porasta snage, istodobno se bilježi pad aerobne izdržljivosti i fleksibilnosti, koji su ključni zdravstveni pokazatelji. Ovi rezultati ukazuju na nužnost redefiniranja nastave tjelesne i zdravstvene kulture u višim razredima osnovne škole, pri čemu bi se u kurikulima veći naglasak trebao staviti na aerobne aktivnosti visokoga intenziteta i vježbe fleksibilnosti, umjesto isključivoga oslanjanja na sportske igre koje ne pružaju dovoljan podražaj za sve učenike (Goran i sur., 1999; Wyszyńska i sur., 2020). Ako se trend pada kardiorespiratorne izdržljivosti ne zaustavi u školskoj dobi današnje generacije suočit će se s povećanim rizikom od kroničnih bolesti u kasnijoj životnoj dobi. Psihosocijalni razvoj adolescenata, posebno djevojčica u 8. razredu, donosi promjene u percepciji vlastitoga tijela i javnoga nastupa. Razina napora u testovima do otkaza ovisi o psihološkom profilu i motivaciji. S obzirom na to moguće je da je dio starijih učenica imao nižu razinu voljnoga napora zbog nelagode pred vršnjacima, ali kako su i dječaci 8. razreda pokazali niže vrijednosti relativnoga VO2 max-a, razvidno je da masa tijela i monotonost samoga protokola trčanja imaju dominantniju ulogu od isključivo spolno specifične demotivacije (Sekulić i Metikoš, 2007).

Vrijednost ovoga rada očituje se u činjenici da postoji vrlo malo istraživanja koja uspoređuju razlike među ispitanicima prije puberteta i tijekom puberteta u pogledu sastavnica tjelesne spremnosti. Rezultati imaju praktičnu primjenu u području javnoga zdravstva, kao i njihove akcije koje su usmjerene na povećanje razine tjelesne spremnosti učenika i smanjenje pretilosti koja je ogroman zdravstveni problem u Republici Hrvatskoj.

Pri interpretaciji rezultata treba uzeti u obzir i realna ograničenja ovoga rada. Istraživanje je presječnoga karaktera čime se onemogućuje praćenje individualnih promjena istih ispitanika tijekom vremena, također uzorak je prigodan i ograničen na jednu geografsku regiju što smanjuje mogućnost primjene na cijeli teritorij Republike Hrvatske. Osim toga, ograničenja ove studije odnose se i na nemogućnost generalizacije naših nalaza zbog relativno malog broja sudionika. Potrebno je koristiti više podataka iz većega uzorka da bi se potvrdili rezultati. Osim toga, ograničenje ovoga istraživanja jest nedostatak podataka o izvanškolskim sportskim aktivnostima ispitanika, što bi omogućilo jasniju identifikaciju razlike između utjecaja biološkoga rasta i treninga. Razina motivacije tijekom Shutlle run testa procijenjena je u istraživanju opservacijom, dok bi buduća istraživanja trebala uključiti subjektivne ljestvice napora ili praćenje srčane

frekvencije kako bi se dodatno potvrdilo jesu li ispitanici doista dosegnuli fiziološki limit. Nedostatak preciznih podataka o prehrambenim navikama i izvannastavnim aktivnostima učenika ostavlja prostor za daljnja istraživanja koja bi mogla objasniti uzroke uočenih razlika u ovome istraživanju.

Biološki rast i povećanje mišićne mase u adolescenciji nisu dovoljni za održavanje kardiorespiratornoga kapaciteta i fleksibilnosti te ovi rezultati služe kao jedan od temelja za uvođenje ciljanih intervencijskih programa u nastavu tjelesnoga odgoja usmjerenih na očuvanje i povećanje aerobne izdržljivosti i prevenciju sjedilačkoga načina života. Nalazi ovoga istraživanja mogu poslužiti kao polazište za buduća longitudinalna istraživanja usmjerena na praćenje promjena tjelesne spremnosti i zdravlja djece te razvoj intervencijskih programa za unaprjeđenje kvalitete života djece i adolescenata. Očuvanje kardiorespiratornoga zdravlja i motoričke kompetentnosti zato treba biti prioritet školskoga sustava i javnozdravstvenih strategija.

Zaključak

Ovo istraživanje imalo je cilj usporedbu tjelesne spremnosti učenika u dobi od 10 i 14 godina u Republici Hrvatskoj. Rezultati jasno ukazuju na postojanje dobnih razlika u većini analiziranih varijabli. Stariji učenici očekivano su imali veće vrijednosti tjelesne visine, komponenti sastava tijela dok se omjer struka i visine (WHtR) te omjer struka i bokova (WHR) nije statistički značajno razlikovao između dobnih skupina. Jedan od značajnijih nalaza pokazao je da je kardiorespiratorni kapacitet bio niži među starijim učenicima čime se potvrđuje trend negativnoga utjecaja sjedilačkoga načina života u adolescenciji.

Učenici u dobi od 14 godina bili su očekivano bolji u testovima snage, dok su učenici u dobi od 10 godina pokazali veću agilnost, brzinu i fleksibilnost. Ove razlike ukazuju na kompleksnost razvoja sadržanoga od biološkoga sazrijevanja, promjena u tjelesnom sastavu i promjena u obrascima tjelesne aktivnosti tijekom odrastanja. Dobiveni nalazi ukazuju da biološki rast i povećanje mišićne mase nisu dovoljni za održavanje kardiorespiratornoga kapaciteta. Smanjenje maksimalnoga primitka kisika (VO_2max), uz istodobni pad agilnosti i fleksibilnosti otkriva da tijekom adolescencije dolazi do smanjenja spontanoga kretanja i povećanja sedentarnoga ponašanja. Ovaj trend naglašava potrebu za sustavnim i ciljanim programima tjelesne aktivnosti u višim razredima osnovne škole, s naglaskom na razvoj i očuvanje aerobnoga kapaciteta i održavanje motoričkih sposobnosti brzine, agilnosti i fleksibilnosti.

Rezultati imaju važne javnozdravstvene implikacije s ciljem smanjivanja sedentarnoga ponašanja djece školske dobi i povećanja tjelesnoga aktiviteta. Nastavu tjelesne i zdravstvene kulture potrebno je planirati tako da odgovora specifičnim potrebama različitih dobnih skupina, uz povećanje udjela aerobnih aktivnosti i aktivnosti visokoga intenziteta među starijim učenicima što je jedan od ključnih čimbenika za očuvanje zdravlja i prevenciju pretilosti.