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# Unraveling Age-Driven Shifts in Adolescent Cardiorespiratory Fitness: A Comprehensive Analysis Using the Yo-Yo Intermittent Endurance Test

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ABSTRACT

**Objective:** This study aimed to examine cardiorespiratory responses during the Yo-Yo Intermittent Endurance Test in adolescents aged 14–18 years.
**Methods and Materials:** A total of 80 male high school students participated, with 20 from each grade (9–12) at Pendik Vocational and Technical Anatolian High School in Istanbul. Anthropometric measurements, including height and weight, were recorded. Body composition was assessed using a Tanita body impedance analyzer, and aerobic capacity was evaluated using the Yo-Yo IR1 test. Statistical analyses, including ANOVA and Pearson correlation, were performed using SPSS v25.
**Findings:** Significant differences were observed in height, distance covered, and VO2max across age groups. ANOVA revealed significant variations in height and distance covered, with older students performing better. Pearson correlation indicated strong positive relationships between Yo-Yo test levels, VO2max, and distance covered.
**Conclusion:** The findings underscore the need for age-specific fitness assessments in physical education programs to optimize athletic performance during adolescence.
**Keywords:** *Adolescents, Maturity, Endurance, Aerobic Capacity, Yo-Yo Test, Physical Education*

## 1. Introduction

Cardiorespiratory fitness (CRF) is a crucial indicator of overall health, particularly during adolescence, a period marked by rapid growth, hormonal fluctuations, and significant physical development. The importance of assessing CRF in adolescents is well-established, given its far-reaching implications for both immediate and long-term health outcomes. Adolescents with higher levels of CRF are more likely to exhibit better cardiovascular health, reduced risk of obesity, and enhanced cognitive function, which can lead to improved academic performance (1, 2). In recent

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years, the significance of physical fitness assessments, particularly aerobic capacity, has gained increasing attention within both educational and clinical settings as a key predictor of health outcomes and future lifestyle habits (3).

Despite the importance of understanding CRF, much of the research to date has either focused on broader age groups or predominantly explored adult populations, often overlooking the unique physiological and developmental characteristics of adolescents aged 14–18 years (4-8). This age group experiences considerable changes in body composition, hormonal levels, and physical abilities, all of which can influence CRF (9). For example, during adolescence, there is an increase in muscle mass, particularly in boys, which enhances aerobic capacity and endurance performance (10). These developmental changes necessitate age-specific assessments of CRF, as the physical capabilities of adolescents can vary significantly depending on their stage of maturation (2). Therefore, a tailored approach to evaluating and promoting CRF in adolescents is essential for optimizing both health outcomes and athletic performance during this critical developmental period.

The Yo-Yo Intermittent Endurance Test-Level 1 (Yo-Yo IE1) has emerged as a widely recognized and utilized fitness test in sports science, particularly for measuring an individual's ability to perform repeated high-intensity exercise (9). This test, which involves a series of 20-meter shuttle runs with intermittent recovery periods, has been extensively used across various team sports to assess endurance performance (11, 12). Its reliability and validity as a measure of CRF are well-established, making it a valuable tool for assessing physical fitness in both professional athletes and school-aged individuals (13, 14). One of the key advantages of the Yo-Yo IE1 test is its applicability in school settings. It is relatively easy to administer, cost-effective, and provides comprehensive insights into an individual's CRF, making it a practical option for educators and trainers looking to assess and improve the fitness levels of adolescents (3).

However, despite its widespread use, there remains a significant gap in the literature regarding the assessment of age-related differences in CRF among adolescents aged 14–18 years (1, 5, 15). Previous studies have largely focused on either younger children or broader adolescent populations without isolating this specific age group. For example, studies examining the CRF of children often include participants as young as six years old, while research on adolescents frequently groups individuals aged 10 to 18 together, overlooking the significant developmental differences within this range (5, 6). As a result, there is limited research on how age influences CRF within the 14-18 age demographic, particularly in the context of high school settings where physical education programs and athletic opportunities can vary significantly (11, 16).

Understanding how CRF changes during adolescence is crucial for designing effective health promotion strategies and interventions tailored to this developmental stage (17). As adolescents progress through high school, they experience substantial physical changes, including increases in height, weight, and muscle mass, which can significantly affect their aerobic capacity and endurance performance (9). These changes are influenced not only by biological factors such as growth spurts and hormonal fluctuations but also by external factors such as physical activity levels, nutrition, and participation in sports (Shahidi et al., 2023). For example, adolescents who engage in regular physical activity, particularly endurance-based sports, are likely to experience greater improvements in CRF compared to their less active peers (3, 18). Therefore, it is important to consider both intrinsic and extrinsic factors when evaluating CRF in this age group.

The Yo-Yo IE1 test provides a useful framework for assessing the impact of these developmental changes on CRF. By measuring an individual's ability to perform repeated high-intensity exercise with intermittent recovery periods, the test offers insights into both aerobic and anaerobic capacity, which are critical components of overall fitness (10, 19, 20). Aerobic capacity, typically measured as VO2max, refers to the maximum amount of oxygen the body can utilize during exercise, and it is a key indicator of endurance performance (18-20). Anaerobic capacity, on the other hand, refers to the body's ability to perform short bursts of high-intensity activity without relying on oxygen, and it is particularly important for sports that require quick, repeated efforts (3, 20). The Yo-Yo IE1 test captures both of these fitness components, making it a comprehensive tool for evaluating CRF in adolescents.

Given the importance of CRF for overall health and athletic performance, it is essential to understand how it varies across different age groups during adolescence. Research has shown that older adolescents typically perform better on fitness tests such as the Yo-Yo IE1, as they tend to have higher VO2max levels and greater endurance capacity compared to younger adolescents (13). These improvements are largely due to the physiological changes that occur during puberty, including increases in muscle mass, lung capacity, and cardiovascular efficiency (14). However, the extent of these changes can vary significantly between individuals, depending on factors such as genetic predisposition, physical activity levels, and overall health status (3).

In addition to the physical changes that occur during adolescence, psychological factors can also influence CRF. For example, motivation, self-efficacy, and perceived competence in physical activities have been shown to affect an individual's performance on fitness tests (11). Adolescents who are more confident in their physical abilities are more likely to engage in regular physical activity and perform better on tests such as the Yo-Yo IE1 (3, 13). Conversely, those with lower self-efficacy may be less inclined to participate in physical activities, leading to lower fitness levels and poorer performance on fitness assessments (11). Therefore, it is important to consider both physical and psychological factors when evaluating CRF in adolescents.

This study aims to address the gaps in the existing literature by investigating age-related differences in CRF among high school students aged 14–18 using the Yo-Yo IE1 test. Specifically, the study seeks to: (1) measure endurance performance using the Yo-Yo IE1 test to assess physical capabilities; (2) evaluate age-related differences in cardiorespiratory responses, such as heart rate variability and recovery rates post-test; and (3) analyze how age affects CRF levels to inform targeted health interventions and educational strategies. By focusing on the distinct age-related differences in CRF among high school adolescents, this study provides valuable insights that can guide future educational strategies and health interventions aimed at improving health outcomes for adolescents. The novelty of this work lies in its emphasis on the 14-18 age range, a demographic that has been underrepresented in previous research (Shahidi et al., 2023).

In summary, the assessment of CRF during adolescence is critical for promoting long-term health and optimizing athletic performance. The Yo-Yo IE1 test offers a practical and reliable method for evaluating CRF in high school students, and understanding how CRF varies across different age groups can inform the development of age-specific fitness programs and interventions. This study contributes to the growing body of literature on adolescent fitness by providing comprehensive data on the cardiorespiratory fitness of high school students and exploring the impact of age on endurance performance.

## 2. Methods and Materials

### *2.1 Study Design and Participants*

This study was conducted at Pendik Vocational and Technical Anatolian High School, located in the Pendik district of Istanbul. The participants consisted of 80 male students, with 20 students from each grade level, all of whom volunteered for the study. The eligibility criteria included the absence of injuries and the non-use of medication prior to or during the test period. Informed consent was obtained from all participants after explaining the experimental risks. Written informed consent was also obtained from the parents of each participant, and ethical approval for this study was granted by the local Research Ethics Committee (E-73487232-44-92609026). Additionally, written informed consent was obtained from the Istanbul District National Education Directorate (E-56365223-050.02.04-2023.137548.19). The tests were administered at the same time each day (between 09:00 and 16:00) at the same location by the same researcher, ensuring consistent environmental conditions. Participants first attended a familiarization session, followed by the Yo-Yo Intermittent Recovery Level 1 Test (Yo-Yo IR1) on a separate day. Before each test session, participants completed a 15-minute standardized warm-up, which included 5 minutes of submaximal running and a 5-minute dynamic stretching routine (hip flexion/extension, hip abduction/adduction).

### *2.2 Body Composition Measurements*

Participants' height (cm) and body weight (kg) were measured while they were barefoot and wearing only shorts and a t-shirt. Body mass was measured using an electronic scale, height was measured with a portable stadiometer (SECA Leicester, UK), and body fat percentage was assessed using a Tanita impedance device (Tanita Corporation, Japan) as previously described.

### *2.3 Yo-Yo Intermittent Recovery Level 1 Test (Yo-Yo IR1)*

The Yo-Yo Intermittent Recovery Level 1 Test measures aerobic capacity through a series of 20-meter shuttle runs with a 5-meter end zone. Participants start from the middle line and run to the far cone upon hearing an auditory cue. They turn before reaching the cone and return to the starting line when a beep sounds. After each shuttle run, participants have a 10-second passive recovery period during which they stand still. The test continues until a participant fails to maintain the required pace or does not reach the finish line twice. Warnings are issued for false starts or incomplete shuttle runs, and two warnings result in elimination. The total distance covered, including any incomplete shuttle runs, is recorded in meters. Based on the performance in the Yo-Yo IR1 test, VO2max can be estimated using the following formula provided by Bangsbo et al. (2016): VO2max (ml/kg/min) = IR1 performance (meters) × 0.0084 + 36.4. This formula uses the total distance covered during the test to estimate the maximum oxygen uptake, which is a key indicator of aerobic fitness (9).

### *2.4 Data Analysis*

Descriptive statistics were calculated for each variable, including the mean, standard deviation, and 95% confidence interval. Analysis of variance (ANOVA) was used to determine if there were statistically significant differences in each variable across different age groups. Following ANOVA, Tukey's Honest Significant Difference (HSD) test was performed to identify which specific groups differed from each other for variables with significant ANOVA results. Pearson correlation analysis was used to examine the relationship between Yo-Yo IR1 level and other performance variables, such as VO2 max and total distance covered. Pearson correlation measures the linear relationship between two variables, providing a correlation coefficient (r) and a significance level (p-value). All statistical analyses were performed using SPSS version 26 (SPSS v.26, Armonk, NY, USA). A significance level of alpha = 0.05 was predetermined for all analyses.

## 3. Results

The descriptive data of the participants are presented in Table 1.

**Table 1.** Descriptive Statistics

| Variable | Mean ± SD | 95% CI |
|---|---|---|
| Height (cm) | 163.79 ± 8.56 | 161.58 - 166.00 |
| Weight (kg) | 64.21 ± 10.73 | 61.12 - 67.30 |
| Fat Percentage | 18.35 ± 5.32 | 17.00 - 19.71 |
| Distance (m) | 1051.58 ± 627.20 | 874.19 - 1228.98 |
| VO2max (ml/kg/min) | 45.77 ± 9.42 | 42.98 - 48.56 |

The ANOVA results indicated a significant difference in height across different age groups (Table 2)

**Table 2.** ANOVA Results

| Variable | F-value | P-value |
|---|---|---|
| Height (cm) | 10.14 | 0.001* |
| Weight (kg) | 1.01 | 0.409 |
| Fat Percentage | 0.28 | 0.891 |
| Distance (m) | 6.23 | 0.001* |
| VO2max (ml/kg/min) | 6.86 | 0.001* |

*Significant at alpha = 0.05

Tukey's HSD test further revealed specific age group differences, showing significant differences between younger and older age groups (Figure 1). The graph provides a visual representation of how physical measurements such as height, weight, and body fat percentage change with age among male high school students. The fluctuations and trends observed can be useful for understanding the physical development patterns in this age group, which could inform health and fitness programs tailored to adolescents. For example, there was a significant difference between ages 14 and 18 (mean difference = 8.72 cm, P < 0.0001).

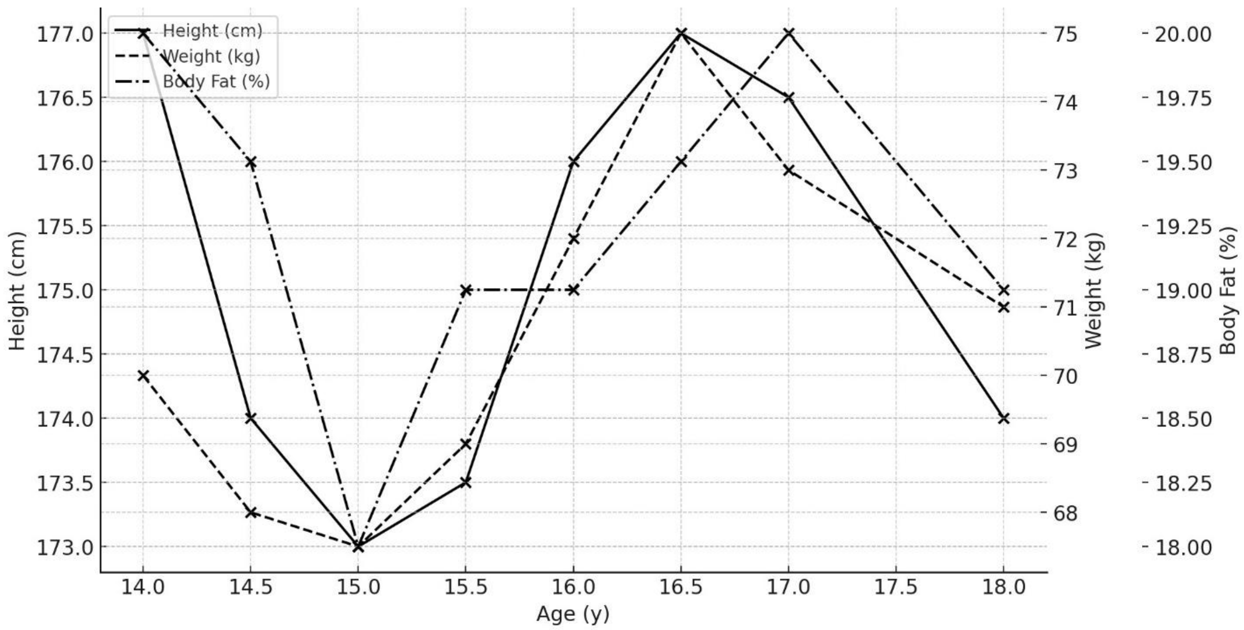


**Figure 1.** Age-Related Trends in Height, Weight, and Body Fat Percentage

The distance covered in the Yo-Yo IR1 test also showed significant differences across age groups. Tukey's HSD test indicated that younger age groups (14 and 15) performed significantly differently compared to older age groups (17 and 18) as shown in Figure 2.

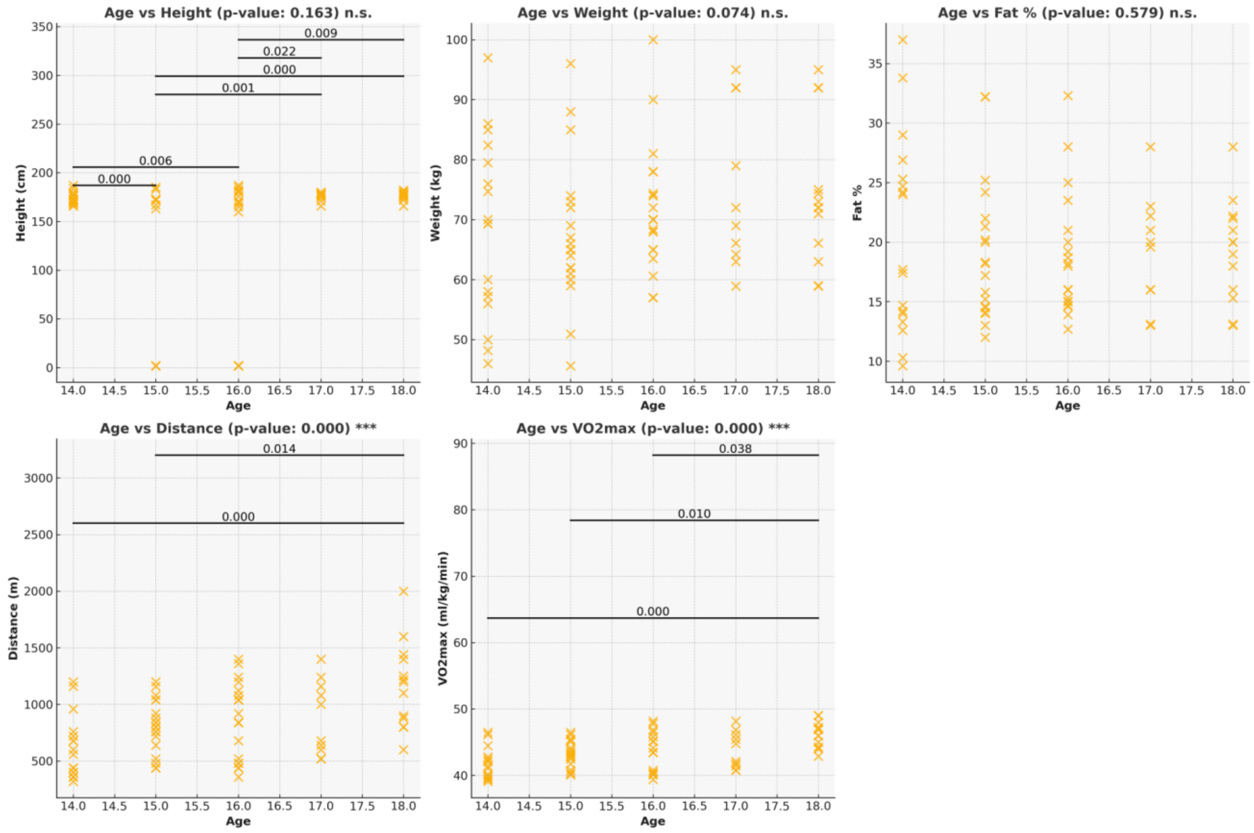


**Figure 2.** Age-Related Differences in Anthropometric and Cardiorespiratory Fitness Variables

VO2max, an indicator of aerobic fitness, also showed significant differences across age groups, with post-hoc tests revealing significant differences between younger and older age groups. For example, there was a significant difference between ages 14 and 18 (mean difference = 3.73 ml/kg/min, $P < 0.0001$) as shown in Table 3.

**Table 3.** Tukey's HSD Results

| Variable | Group Comparison | Mean Difference | P-value |
|---|---|---|---|
| Height (cm) | 13 vs 15 | 4.96 | 0.016* |
| | 13 vs 16 | 6.13 | 0.004** |
| | 13 vs 17 | 8.72 | 0.000*** |
| | 14 vs 15 | 6.17 | 0.004** |
| | 14 vs 16 | 7.34 | 0.001*** |
| | 14 vs 17 | 9.94 | 0.001*** |
| | 15 vs 17 | 3.76 | 0.082 |
| | 16 vs 17 | 2.59 | 0.399 |
| Distance (m) | 13 vs 15 | 165.88 | 0.004** |
| | 13 vs 16 | 150.66 | 0.007** |
| | 13 vs 17 | 231.43 | 0.001*** |
| | 14 vs 15 | 113.03 | 0.082 |
| | 14 vs 16 | 197.8 | 0.001*** |
| | 14 vs 17 | 278.57 | 0.001*** |
| | 15 vs 17 | 165.55 | 0.004** |
| VO2max (ml/kg/min) | 13 vs 16 | 3.01 | 0.003** |
| | 13 vs 17 | 3.73 | 0.001*** |
| | 14 vs 15 | 2.92 | 0.003** |
| | 14 vs 16 | 3.82 | 0.001*** |
| | 14 vs 17 | 4.53 | 0.001*** |

*Significant at alpha = 0.01 **Significant at alpha = 0.001 ***Significant at alpha = 0.0001

No significant differences were found in weight and body fat percentage across different age groups. This might indicate that weight and body composition do not vary significantly among the participants or could suggest that these variables are more influenced by factors other than age, such as diet, genetics, and overall lifestyle.

The results of Pearson correlation analysis showed a high positive correlation between Yo-Yo IR1 test performance and VO2max ($r = 0.83$, $P < 0.001$) and total distance covered ($r = 0.91$, $P < 0.001$). These results indicate a strong linear relationship between these variables, suggesting that higher performance in the Yo-Yo IR1 test is associated with higher VO2max and greater total distance covered (Figure 3).

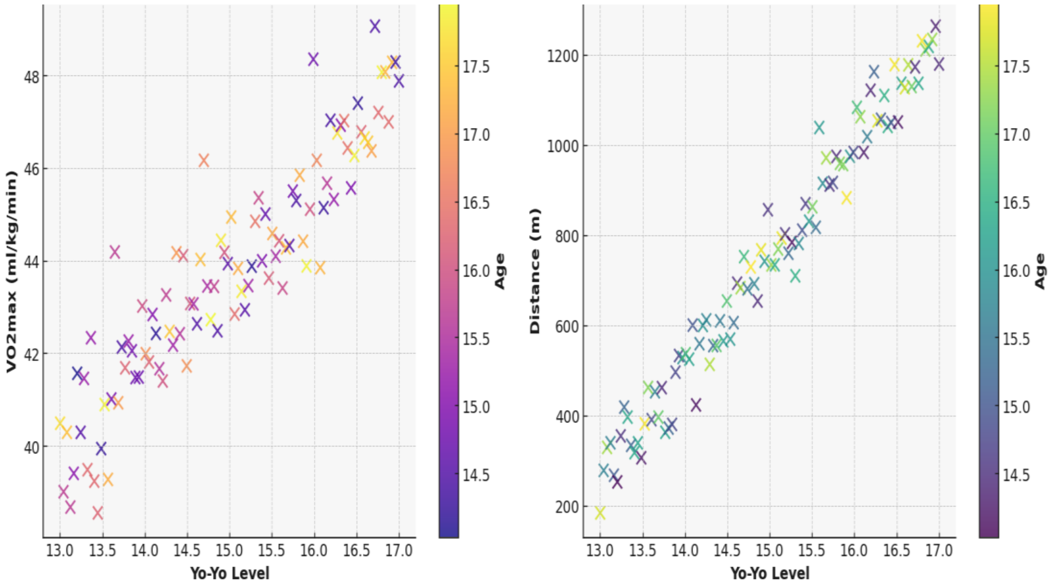


**Figure 3.** Relationship Between Yo-Yo Level and VO2max/Distance Covered for Age Groups 14-18

## 4. Discussion and Conclusion

This study aimed to explore age-related differences in cardiorespiratory fitness (CRF) among adolescents aged 14–18 years using the Yo-Yo Intermittent Endurance Test Level 1 (Yo-Yo IE1). The results demonstrated significant variations in height, distance covered, and VO2max across different age groups, indicating that older adolescents tend to have superior aerobic endurance and cardiorespiratory performance compared to their younger counterparts. These findings align with the existing literature, which suggests that CRF improves with age during adolescence due to physiological and developmental factors (1, 2).

The significant difference in VO2max between younger and older adolescents reflects the expected developmental changes that occur during adolescence. Older adolescents, particularly those aged 17 and 18, exhibited higher VO2max levels compared to younger participants, which is consistent with the physiological adaptations that occur during puberty, such as increased muscle mass, lung capacity, and cardiovascular efficiency (9). These findings align with those of previous studies that have reported enhanced aerobic capacity and endurance performance in older adolescents compared to younger peers. Additionally, the Yo-Yo IE1 test has been shown to be a reliable indicator of aerobic capacity, as the test measures both endurance and recovery abilities, providing a comprehensive assessment of CRF (11).

The observed age-related differences in distance covered during the Yo-Yo IE1 test further support the notion that physical maturation significantly influences endurance performance. Adolescents in the 17- and 18-year-old age groups were able to cover greater distances compared to their younger counterparts, a finding that is in line with previous research demonstrating improved performance in endurance tests as adolescents age (3, 9, 11-14). This increase in endurance can be attributed to the natural development of the cardiovascular and muscular systems during adolescence, as well as the greater experience and physical conditioning that older adolescents may possess due to increased participation in physical activities and sports. Furthermore, studies on adolescent athletes have shown similar trends, where older participants consistently outperformed younger ones in aerobic endurance tasks (12, 20).

Another important finding from this study is the strong positive correlation between VO2max, Yo-Yo test levels, and total distance covered. This suggests that adolescents with higher VO2max levels tend to perform better on the Yo-Yo IE1 test, which is consistent with previous studies that have identified VO2max as a key determinant of endurance performance. These results underscore the value of the Yo-Yo IE1 test as an effective tool for assessing aerobic capacity in adolescents, particularly in high school settings where resources and time constraints may limit the use of more sophisticated testing methods (5, 6, 13). Given its simplicity, reliability, and ability to capture both aerobic and anaerobic fitness components, the Yo-Yo IE1 test offers valuable insights into the cardiorespiratory health of adolescents (9).

Interestingly, the results of this study did not show significant differences in body fat percentage across age groups, which contrasts with some previous research suggesting that body fat composition typically changes during adolescence due to hormonal shifts and changes in physical activity levels (11, 15, 16, 19, 21). One possible explanation for this finding is that the participants in this study were relatively homogeneous in terms of body composition, with similar physical activity levels and dietary habits, as they were all from the same school and grade levels. Moreover, the use of the Tanita body impedance analyzer, while practical for school settings, may have limitations in accurately capturing subtle differences in body composition, which could have contributed to the lack of significant findings in this area (11, 13).

The lack of significant variation in weight across the age groups also suggests that body mass may not be as closely related to CRF as other factors such as height, muscle mass, and VO2max (9). This finding is consistent with research indicating that while body weight is an important factor in overall health, it is not necessarily a strong predictor of aerobic fitness or endurance performance, particularly when weight is not differentiated into lean muscle mass and fat mass. As such, future research should explore the relationships between different components of body composition, such as muscle mass and fat mass, and their effects on CRF in adolescents (3).

One limitation of this study is the relatively small and homogeneous sample size, which consisted of only male high school students from a single school in Istanbul. This limits the generalizability of the findings to other populations, including females, students from different socioeconomic backgrounds, and those from different geographical regions. Additionally, the study relied on the Tanita body impedance analyzer to assess body composition, which, while practical in a school setting, may not provide the same level of accuracy as more advanced methods such as dual-energy X-ray absorptiometry (DEXA). This may have affected the precision of the body composition data, particularly with regard to fat percentage. Furthermore, the cross-sectional design of the study limits the ability to establish causal relationships between age and CRF, as the study only captures data at a single point in time.

Future research should aim to include a larger and more diverse sample of adolescents, including both males and females from different socioeconomic and geographical backgrounds, to enhance the generalizability of the findings. Longitudinal studies would also be valuable to track changes in CRF over time and establish causal relationships between age, physical development, and fitness levels. Additionally, future studies should explore the effects of other variables such as nutrition, physical activity outside of school, and psychosocial factors on CRF to provide a more comprehensive understanding of the factors that influence fitness during adolescence. Using more advanced methods for assessing body composition, such as DEXA, would also help improve the accuracy of the data and provide deeper insights into the relationships between body composition and CRF.

In practice, physical education programs should consider implementing regular fitness assessments, such as the Yo-Yo IE1 test, to monitor the cardiorespiratory fitness of students. These assessments can help educators identify students who may benefit from additional fitness interventions and tailor programs to meet the specific needs of different age groups. Schools should also emphasize the importance of endurance and aerobic capacity training, particularly for older adolescents, to help improve overall health and fitness outcomes. Furthermore, providing students with opportunities for regular physical activity, both within and outside of the school setting, will be critical in supporting the development of CRF and promoting long-term health.

## Authors' Contributions

S. H. S., B. Ö., and A. S. contributed equally to the study. S. H. S. led the research design and coordinated the Yo-Yo Intermittent Endurance Test execution. B. Ö. assisted with data collection, including anthropometric measurements and body composition analysis. A. S. was responsible for statistical analysis using SPSS and contributed to data interpretation. All authors participated in writing and reviewing the manuscript and agreed on its final version.

## Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

## Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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## Declaration of Interest

The authors report no conflict of interest.

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## Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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