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Original Research Article

Association between exercise capacity and health markers in adolescents

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ABSTRACT

Background: Adolescent physical fitness is a crucial determinant of current and future health, influencing susceptibility to chronic diseases such as cardiovascular conditions and diabetes. The American Heart Association highlights cardiorespiratory endurance as a vital health metric, emphasizing the need for regular physical activity to mitigate long-term health risks.
Methods: A cross-sectional observational study was conducted from 24 March 2023 to 20 March 2024 in the Lucknow city, India. Total 411 adolescents recruited from local school camps and adolescent clinics. Participants underwent a series of assessments, including the 6-minute walk test (6-MWT) to evaluate functional capacity and endurance, body fat analysis using the body stat 1500 MDD machine, and anthropometric measurements. Tabulated data were statistically analysed to find any relationships between BMI, body fat composition, and physical performance.
Results: The study revealed significant correlations between BMI and body fat percentage ($p<0.0001$) and between BMI and body fat in kilograms ($p<0.0001$). Increased body fat percentage and fat mass was associated with higher BMI. The mean distance covered in the 6-MWT was 918.85 meters, with significant variability across gender. Body composition metrics indicated that higher BMI categories were associated with increased fat-free mass ($p<0.0001$).
Conclusions: This study underscores the critical need for targeted interventions to address physical inactivity and obesity in adolescents. By improving physical fitness and body composition, it is possible to mitigate health risks and promote better long-term health outcomes.

Keywords: Adolescent physical fitness, BMI and health risks, Body fat composition, Cardiorespiratory endurance, 6-minute walk test, Obesity

INTRODUCTION

Adolescent physical fitness acts not only as a real-time gauge of well-being but also as a significant predictor of future health trajectories. Amidst the dynamic shifts in socioeconomic landscapes and profound lifestyle alterations sweeping the globe, there's an escalating need to comprehensively grasp the current terrain of adolescent physical fitness. The physical well-being of the emerging young generation extends its influence beyond personal realms, resonating in academic achievements and contributing to national advancement and holistic upliftment. Physical fitness parameters- especially cardiorespiratory capacity and muscular strength- in shaping susceptibility to chronic ailments like cardiovascular diseases, diabetes, and hypertension, even in adolescence.[1,2] The risks associated with these conditions manifest early in life, underscoring the significance of cardiorespiratory health during adolescent, which can improve health benefits into adulthood.[3] Recognizing this, the American Heart Association underscored cardiorespiratory endurance as a vital health metric in 2016, positioning it alongside conventional indicators like pulse and blood pressure.

Indeed, a positive nexus exists between physical fitness and overall adolescent health.[4-6]

Low physical exercise and excessive use of electronic devices, and dwindling physical activity levels, adolescent health has emerged as a pressing public health concern.[7-9] Globally, the prevalence of overweight and obesity among young demographics has surged since 1980, signalling alarming rates across both developed and developing nations. Obesity is a multifaceted condition with significant health implications. It is associated with various risk factors, including diabetes, asthma, arthritis, hypertension, adverse lipid levels, and reduced life expectancy. Childhood overweight and obesity often persist into adulthood, magnifying health risks.[10] Physical activity is crucial as it influences the balance between calorie intake and expenditure. Aerobic fitness, linked with physical activity, contributes to reducing the risk of chronic diseases and metabolic syndrome. Studies indicate that low physical activity levels, coupled with high body fat, especially in the abdomen, correlate with increased cardiovascular disease risk in children. Encouraging regular moderate-to-vigorous physical activity can improve cardiorespiratory fitness across all age groups, leading to better overall health outcomes.

Physical activity (PA) assumes a pivotal role in determining both physical and mental health statuses.[11] The relationship between physical activity and aerobic fitness in healthy children has been examined in a number of earlier studies. It is recommended to use a 6-minute walk test (6MWT).

Regular physical activity during these formative years is indispensable for healthy growth and development, contributing to cardiovascular health, weight management, musculoskeletal integrity, respiratory function, and mental well-being. Moreover, inadequate PA during adolescence can precipitate chronic health issues such as cancer, cardiovascular diseases, respiratory ailments, and obesity later in life.[12-14]

Despite ongoing debates concerning the quantum and nature of PA requisite for health dividends, the World Health Organization (WHO) advocates for a minimum of 60 minutes per day of moderate-to-vigorous PA for children and adolescents aged 5-17 years.[15] Majority of children and adolescents worldwide fall short of meeting these recommended PAL (physical activity level) thresholds. We can reframe this issue by emphasizing meeting these recommended PAL (physical activity level) thresholds. For instance, a global study revealed that merely 20% of adolescents aged 12 to 18 yrs engage in PA at WHO-recommended levels.[16-18]

Adolescence epitomizes a pivotal juncture in individual development, where foundational attitudes towards numerous critical life domains- including health and educational habits- are forged. The habits and attitudes imbibed during this phase often endure into adulthood.[18]

Despite the well-documented significance of attaining appropriate PALs in youth, studies have consistently shown a marked decline in PALs during adolescence.[19] Cross-sectional investigations across North America and Europe have consistently highlighted a downward trajectory in PA levels during adolescence.[20] Similarly, longitudinal studies corroborate this trend, documenting dwindling PALs among adolescents over time.[21]

For instance, a five-year longitudinal study observed a substantial decrease in weekly hours dedicated to PA among adolescents, juxtaposed against a surge in sedentary computer usage, especially among boys.[22] Another study spanning eight years in Norway demonstrated a progressive decline in PA levels from 13 to 19 years of age.[23,24] Similarly, recent research on older adolescents from Bosnia and Herzegovina discerned a significant reduction in PALs between the ages of 12 and 18, irrespective of gender.[25]

The interplay between exercise capacity and health markers in adolescents not only sheds light on their present health status but also furnishes invaluable insights into devising targeted interventions aimed at bolstering youth health outcomes.

This study endeavours to elucidate the intricate relationship between exercise capacity and health indicators in adolescents, bridging critical knowledge gaps and informing evidence-based interventions geared towards promoting physical activity and overall well-being in this demographic.

METHODS

A cross-sectional observational study was conducted from 24 March 2023 to 20 March 2024, in the Lucknow city, India.

Study recruitment and ethical considerations

The study recruited 411 participants from school camps, adolescent health clinics, and fitness awareness camps, adhering to well-defined inclusion and exclusion criteria. Each participant provided informed consent before engaging in the study to ensure ethical compliance and respect for participant rights.

6-minute walk test (6-MWT)

The 6-minute walk test (6-MWT) was conducted to assess participants functional capacity and endurance. A digital countdown timer was used to precisely measure the duration of the walk. The test took place on a flat, unobstructed 30-meter course. Subjects were educating to walk as distant as conceivable inside the six-minute time period. The digital countdown timer started as soon as the participant began walking and automatically stopped after six minutes, signaling the end of the test. This precise timing ensured the accuracy and standardization of the test. The distance covered by each participant was measured and recorded in meters using a measuring tape or a marked track. Additional observations regarding the participant's physical state and any deviations from the standard walking protocol were documented.

Mechanical lap counter

A mechanical lap counter was employed to track the number of laps completed during repetitive physical activities such as running or swimming. Before initiating the activity, the lap counter was calibrated and tested to ensure its accuracy and reliability. Participants used the mechanical lap counter throughout the activity to record each lap completed. The total number of laps completed was systematically documented, along with observations on participant performance and any anomalies encountered during the activity. This device provided a straightforward and reliable method for quantifying repetitive movements, which was crucial for analysing performance and endurance.

Body fat analysis

Body fat composition was assessed using a BodyStat 1500 MDD Machine. This analysis helped in understanding participants body fat percentage and overall body composition. Prior to the test, participants were instructed to follow specific pre-test guidelines, such as fasting for a certain period or avoiding strenuous exercise, to ensure the accuracy of the measurements. The BodyStat machine was calibrated according to the manufacturer's instructions to maintain precision. Participants then used the machine as directed, which involved either standing on a platform or holding a handheld device, depending on the model. The machine provided readings on body fat percentage and total body fat, which were recorded for subsequent analysis. Additional metrics provided by the machine, such as muscle mass and hydration levels, were also noted if relevant to the study's objectives.

Data analysis

Data collected from the 6-MWT were statistically analysed (descriptive statistics) to determine average distances covered and to compare performance across different participant groups. The accuracy and reliability of lap counts from the mechanical lap counter were assessed by comparing recorded lap counts to expected values, ensuring consistency and validity. Body fat analysis results were evaluated for patterns and correlations with other study variables, such as distance covered in the 6-MWT and lap counts.

Statistical techniques, including correlation analysis and regression modelling, were employed to explore relationships between body fat composition and physical performance metrics.

Ethical considerations

Throughout the consider, moral contemplations were vital. Educated assent was gotten from all members, guaranteeing they were completely mindful of the study's reason, methods, and potential dangers. Confidentiality of participant data was strictly maintained, with all personal identifiers removed from data reports. The study adhered to relevant ethical guidelines and regulations, including those outlined by institutional review boards or ethics committees, to ensure the highest standards of research integrity and participant welfare.

By employing these detailed methodologies and adhering to ethical standards, the study aimed to generate reliable and meaningful data, contributing to a deeper understanding of functional capacity, endurance, and body composition among the participants.

Cross-sectional observational study

This cross-sectional observational study was designed to investigate the relationship between adolescent obesity and exercise capacity and was conducted at the Physiology Department of King George Medical University, Lucknow, Uttar Pradesh. The ponder included 411 young people who were enrolled from different neighbourhood schools and open awareness/fitness camps in Lucknow. Participants were selected based on voluntary consent, and both written informed consent and assent were obtained from the adolescents and their guardians, respectively.

Baseline measurements

For baseline measurements, a series of assessments were conducted to evaluate various health parameters. Blood pressure (BP) was measured using a Dr. Morapen digital sphygmomanometer. Subjects were seated comfortably with their arms positioned at heart level. To ensure accurate readings, participants were instructed to avoid consuming tea, coffee, or any other caffeinated beverages before the measurement, and they were required to rest for at least 5 minutes before BP was recorded. The measurement was performed according to standard procedures to avoid any external influences on the results.

Body fat composition was assessed using the BodyStat machine, which employed bioelectrical impedance analysis (BIA) technology. This device worked by passing a small electrical current through the body and measuring resistance to determine body fat percentage. The assessment was carried out with the subject lying supine, ensuring that four electrodes (two on each hand and foot) were properly placed. The BodyStat machine, connected to a bluetooth-enabled cordless printer, provided real-time data on body fat percentage. Measurements were adjusted for the subject's height, weight, age, and gender to ensure accuracy.

Height was measured with a wall stadiometer, a device that featured a vertical measuring rod mounted securely to a wall. Participants stood barefoot with their heels together and their backs straight. Their heads were aligned in the Frankfurt plane, which ensured that the ear canal and the lower margin of the eye socket were in the same horizontal plane. The headpiece of the stadiometer was balanced to softly touch the beat of the subject's head, and tallness was recorded to the closest centimeter.

Body weight was measured with the help of calibrated digital weighing machine. Subjects were instructed to remove their shoes, sandals, and any excessive clothing to ensure an accurate weight reading. The machine was calibrated before each use to ensure precision, and the weight was recorded to the nearest kilogram.

BMI was calculated by formula. This measurement was used to classify participants into different BMI categories, including underweight, normal weight, overweight, and obese. These categories helped to assess the degree of obesity and its potential impact on exercise capacity.

Exercise capacity evaluation

The 6-minute walk test (6MWT) was employed to evaluate exercise capacity. Prior to the test, participants were given a thorough explanation of the procedure, including its purpose and what to expect. The test was conducted in an open area or hallway where a 30-meter straight course was marked with clear start and end points using cones. Subjects were instructed to walk back and forth along the course for a duration of 6 minutes at their usual pace. They were encouraged to cover as much distance as possible without rushing or slowing down excessively.

During the test, a stopwatch was used to time the 6 minutes. Verbal encouragement was provided to maintain motivation, and the time was announced at the halfway mark (3 minutes) to inform participants of their progress. Throughout the test, oxygen saturation (SpO_2) was monitored to assess the subjects' respiratory function, and any symptoms such as shortness of breath or fatigue were recorded.

Immediately after the test, post-exercise measurements of oxygen saturation and heart rate were taken. Subjects were then allowed to rest and recover for a few minutes, during which any post-exertional symptoms or signs of distress were noted. The total distance covered during the 6MWT was measured and recorded.

Data collection and analysis

All collected data, including baseline parameters (BP, body fat composition, height, weight, BMI), 6MWT performance (distance walked, SpO_2, heart rate), and post-test observations, were meticulously documented. The data analysis included descriptive statistics to summarize average distances covered and performance across different participant groups. The accuracy and reliability of lap counts from the mechanical lap counter were assessed by comparing recorded lap counts to expected values, ensuring consistency and validity. Body fat analysis results were evaluated for patterns and correlations with other study variables, such as distance covered in the 6MWT and lap counts. Statistical techniques, including correlation analysis and regression modelling, were employed to explore relationships between body fat composition and physical performance metrics.

This comprehensive approach allowed for a detailed examination of the relationships between adolescent obesity, body composition, and exercise capacity, providing insights that contribute to a better understanding of these factors in the context of adolescent health and fitness.

RESULTS

Age distribution

The study encompassed 411 participants categorized into three age groups: 12-13 years, 14-15 years, and 16-18 years. The distribution was as follows: 110 participants (26.76%) were in the 12-13 years group, another 110 participants (26.76%) were in the 14-15 years group, and the largest group, 191 participants (46.47%), were in the 16-18 years range. The mean age of the participants was 15.20 years with a standard deviation of 2.10 years. This distribution indicates that the majority of the participants were older adolescents, which may influence the study's findings related to physical performance and body composition, given the significant physiological changes that occur during these years (Table 1).

Table 1: Age groups and their counts.

Age distribution	N	%
12-13	110	26.76
14-15	110	26.76
16-18	191	46.47
Mean±SD	15.20±2.10	

Table 2: Gender comparison.

Gender	N	%
Female	158	38.44
Male	253	61.56

Gender distribution

The study included 158 females, making up 38.44% of the total sample, and 253 males, constituting 61.56% of the participants. This gender imbalance indicates a predominance of males in the sample, which could potentially skew the results related to physical performance and body composition metrics, given that males and females can have different physiological characteristics and fitness levels (Table 2).

Anthropometric measurements

The anthropometric data showed an average height of 154.78 cm with a standard deviation of 16.68 cm, indicating considerable variation in height among participants. The average weight was 58.88 kg with a standard deviation of 19.22 kg, reflecting a range of body weights within the group. The average body mass index (BMI) was 22.61 kg/m^2 with a standard deviation of 5.70 kg/m^2, falling within the normal range but exhibiting substantial variability (Table 3).

Table 3: Anthropometry parameters.

Antropometry parameters	Mean	SD
Height (cm)	154.78	16.68
Weight (kg)	58.88	19.22
BMI (kg/m^2)	22.61	5.70

6-minute walk test (6MWT) performance

The results of the 6-minute walk test (6MWT) showed that the overall mean distance covered was 918.85 meters with a standard deviation of 364.73 meters. After adjusting for total mean, the distance was 721.17 meters with a standard deviation of 112.67 meters. Performance differences by gender indicated that females walked an average of 905.13 meters (SD=230.46 meters), while males walked an average of 927.43 meters (SD=427.97 meters). The substantial standard deviation, especially among males, suggests considerable variability in endurance levels, which might be due to individual differences in fitness or external factors affecting performance (Table 4).

Table 4: The 6-minute walk test (6MWT) reference values were as follows.

	6MWT (meter)		Reference	
	Mean	SD	Mean	SD
Female	905.13	230.46	772.10	56.34
Male	927.43	427.97	689.36	126.63
Total	918.85	364.73	721.17	112.67

Body fat composition

The average total body fat percentage was 21.82% with a standard deviation of 5.86%. The average body fat in kilograms was 12.78 kg with a standard deviation of 5.75 kg, and the average fat-free mass was 46.10 kg with a standard deviation of 19.28 kg. These figures highlight the diversity in body fat and fat-free mass among the participants, reflecting a wide range of body compositions (Table 5).

Table 5: Total body fat %, body fat (kg) and fat free mass.

	N	%
Total body fat (%)	21.82	5.86
body fat (kg)	12.78	5.75
Fat free mass	46.10	19.28

Total body fat percentage and BMI

The relationship between total body fat percentage and body mass index (BMI) categories revealed that participants with a BMI of less than 18.5 had a mean body fat percentage of 21.32% with a standard deviation of 5.5%. Those with a BMI between 18.5 and 24.9 had a mean body fat percentage of 23.29% with a standard deviation of 6.2%. Participants with a BMI between 25.0 and 29.9 had a mean body fat percentage of 28.2% with a standard deviation of 5.66%, and those with a BMI over 30.0 had a mean body fat percentage of 38.37% with a standard deviation of 7.21%. The measurable investigation affirmed a noteworthy relationship between BMI and body fat rate (p<0.0001), showing that higher BMI is unequivocally related with expanded body fat rate (Table 6).

Table 6: The total body fat percentages related to body mass index (BMI) categories.

		Total body fat (%)		P value
		Mean	SD	
BMI	<18.5	21.32	5.5	χ^2=625.2 p<0.0001*
	18.5-24.9	23.29	6.2	
	25.0-29.9	28.2	5.66	
	>30.0	38.37	7.21	

*Statistically significant

Body fat in kilograms and BMI

The data on mean body fat in kilograms across different BMI categories showed that participants with a BMI of less than 18.5 had an average body fat of 10.89 kg with a standard deviation of 4.34 kg. Those with a BMI of 18.5-24.9 had an average body fat of 20.4 kg with a standard deviation of 1.19 kg.

Table 7: The mean body fat in kilograms varied according to the body mass index (BMI) categories.

		Body fat (kg)		P value
		Mean	SD	
BMI	<18.5	10.89	4.34	χ^2=2238 p<0.0001*
	18.5-24.9	20.4	1.19	
	25.0-29.9	25.8	0.14	
	>30.0	34.57	7.21	

*Statistically significant

For participants with a BMI of 25.0-29.9, the average body fat was 25.8 kg with a standard deviation of 0.14

kg, and those with a BMI over 30.0 had an average body fat of 34.57 kg with a standard deviation of 7.21 kg. The significant correlation between BMI and body fat in kilograms (p<0.0001) underscores the relationship between higher BMI and increased body fat (Table 7).

Fat-free mass and BMI

The data on fat-free mass, illustrated in Figure 1, showed that participants with a BMI of less than 18.5 had a mean fat-free mass of 38.13 kg with a standard deviation of 19.9 kg. Those with a BMI between 18.5 and 24.9 had a mean fat-free mass of 42.05 kg with a standard deviation of 19.72 kg. Participants with a BMI of 25.0-29.9 had a mean fat-free mass of 46.88 kg with a standard deviation of 19.12 kg, while those with a BMI over 30.0 had a mean fat-free mass of 67.45 kg with a standard deviation of 18.17 kg. The significant increase in fat-free mass with higher BMI categories (p<0.0001) suggests that higher BMI is associated with increased fat-free mass, reflecting greater muscle or bone mass (Figure 1).

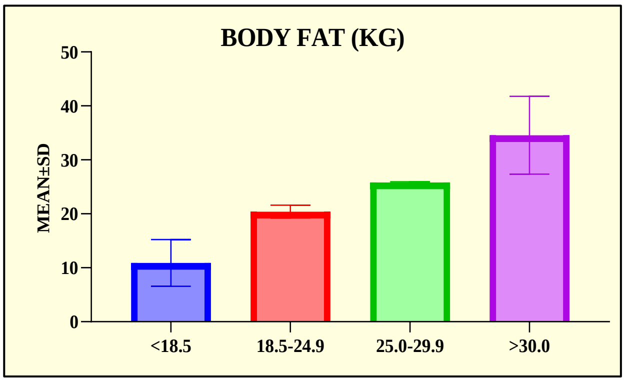

Figure 1: Influence of body mass index on mean fat-free mass.

DISCUSSION

The results of this study provide valuable insights into the physical characteristics, body composition, and cardiovascular fitness of adolescents, offering findings that are consistent with previous research in this field. The observed range of body sizes and compositions, along with the variability in physical performance and health metrics, aligns with existing literature that has reported similar diversity during adolescence, a time of rapid physical and physiological change.[26,27]

The significant correlations found between BMI and various health indicators, such as body fat percentage and cardiovascular endurance, are in line with earlier studies. For instance, it has been consistently demonstrated that a higher BMI is often associated with increased adiposity and poorer cardiovascular fitness in adolescents.[28,29] This is supported by research from Gutin et al and Aires et al, who also reported that adolescents with higher BMI exhibit lower aerobic capacity and physical performance, likely due to the increased burden of excess body fat.[30,31]

These findings reinforce the importance of addressing excess body fat during adolescence to prevent declines in fitness and potential future health risks.

Body composition metrics, such as total body fat, fat mass, and fat-free mass, are crucial for identifying individuals at risk of obesity-related health conditions, as has been noted in prior studies. For example, Daniels et al emphasized the role of fat-free mass in maintaining metabolic health, while high fat mass has been linked to greater risks for conditions like insulin resistance, hypertension, and dyslipidemia.[32] The results of this study echo these findings and underscore the need for routine monitoring of body composition in adolescence to better target interventions aimed at improving both fitness and metabolic health.

Regarding blood pressure, the study's results are consistent with those from previous research that has found most adolescents to fall within normal ranges, but with individual variations that warrant attention.[33] Prior studies by Sorof et al and Falkner have highlighted the growing concern of hypertension in youth, particularly in populations with elevated BMI, suggesting that regular blood pressure monitoring during adolescence is key to identifying early signs of cardiovascular risk.[34] The normal blood pressure values seen in this study, despite the BMI variability, may indicate that cardiovascular risks are not yet fully manifested but could emerge with continued weight gain and sedentary lifestyles.

This study has several limitations. The relatively small sample size and its focus on a specific geographic region may limit the generalizability of the findings to a broader population. Additionally, the cross-sectional design restricts the ability to establish causal relationships between body composition, cardiovascular fitness, and health outcomes. The study also did not account for other potential confounding factors, such as diet, physical activity levels, and socioeconomic status, which could influence the results.

Finally, although standard methods were used to assess body composition, more advanced techniques like dual-energy x-ray absorptiometry (DXA) could provide more precise measurements.

CONCLUSION

Our study findings support the hypothesis that individuals with low exercise capacity, often characterized by higher BMI and body fat percentages, may face elevated health risks. Addressing obesity and promoting physical activity among adolescents are crucial for mitigating these risks and improving overall health outcomes. These results underscore the importance of comprehensive strategies for obesity prevention and management in adolescent populations.

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