ORIGINAL ARTICLE

The Association Between Health-related Physical Fitness and BMI Among Secondary School Students: A Cross-sectional Study

Zarizi Ab Rahman[1], Nurul Farahisya Ahmad Mazlan[1], Azlan Ahmad Kamal[1], Suthagar Narasuman[1], Mohd Izwan Shahril[2]

[1] Department of Physical & Health Education, Faculty of Education, Universiti Teknologi MARA,Puncak Alam Campus, 42300 Puncak Alam, Selangor, Malaysia
[2] Department of Sport Science, Faculty of Sport Science and Coaching, Universiti Pendidikan, Sultan Idris, 35900 Tanong Malim, Perak, Malaysia

ABSTRACT

Introduction: Childhood obesity is a growing global health concern, driven by poor diet and insufficient physical activity. Health-related fitness is linked to obesity, and Body Mass Index (BMI) is a key indicator of overweight and obesity. Overweight, obesity, and low physical fitness are interconnected issues; changes in one factor can influence the others. This study, which focuses on critical health-related fitness components, aims to explore the correlation between BMI and physical fitness. **Materials and methods:** A simple random sampling method was used to select 150 participants (62 boys and 88 girls) aged 13 to 16 from three schools in Shah Alam, Selangor. BMI, sit-ups, push-ups, modified push-ups, the YMCA Bench Step Test (YMCA 3MST), and sit and reach were used to measure all the variables. Descriptive statistics were used to analyse the demographic data, while stepwise multiple regression was employed to carry out the inferential analysis. **Results:** The analysis of multiple regression shows cardiovascular fitness (CF) positively significantly (ß = .315, P < .05) and contributes 0.9 % (r=.315) toward variance changes in BMI score [F (1,149) = 16.451, P< .05]. Meanwhile, the combination of cardiovascular fitness and muscle strength (MS) contributes 13 % (r=.36), and regression model 2 demonstrates two components are the predictors of BMI [F (1,148) = 11.035, P< .05]. **Conclusion:** CF and MS should be emphasized in any intervention programs targeting obesity among adolescents. These two components are crucial for achieving an ideal BMI and reducing obesity in this age group.
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Corresponding Author:
Zarizi Ab Rahman, PhD
Email: zarizi@uitm.edu.my
Tel : +60132291393

INTRODUCTION

Childhood obesity, a significant public health issue worldwide, demands our immediate attention. A report on overweight and obesity revealed an overall prevalence of 5.0% for childhood obesity, with 107.7 million children affected globally in 2015 (1). Projections suggest that 158 million children and adolescents aged 5 to 19 will be obese in 2020, 206 million in 2025, and 254 million in 2030, indicating a worrying trend that has not yet been halted (2). Furthermore, Malaysia's National Health and Morbidity Survey shows a rise in childhood obesity from 6.1% in 2011 to 14.8% in 2019 (3). This upward trajectory is a cause for immediate concern and action.

Childhood obesity leads to poor health in both children and adults, such as type 2 diabetes, dyslipidemia, and cardiovascular diseases (4). The issue also impacts psychological health, potentially harming children and adolescents. Overweight children often face bullying, ridicule, and various forms of psychological stress, which can severely affect their overall health and well-being. (5). Childhood obesity is an increased risk of developing emotional and behavioural issues, including cognitive impairment, poor social performance, abuse from peers, depression, and feelings of victimisation in society (6,7). The fundamental cause of obesity is an energy imbalance resulting from excessive energy intake compared to energy expenditure.

The worldwide prevalence of obesity among adolescents is on the rise because of the issue of poor diet and

insufficient physical activity in this population (8). Over the past several years, there has been a significant decline in physical activity among adolescents globally. In 2008, approximately 31% of adolescents aged 15 and above did not engage in enough physical activity (9). More recent data from 2016 shows that 81% of students between the ages of 11 and 17 had insufficient physical activity (8). These results align with a study conducted in Malaysia, which revealed that 35.5% of adolescents in Kuantan, Pahang (10), 87.1% in Hulu Langat, Selangor (11), and 50% nationwide had inadequate physical activity (12). Another recent study (13) showed that 52.9% of adolescents aged 13 and 14 in Terengganu had insufficient physical activity. These results indicated that adolescents in Malaysia were physically inactive and led sedentary lifestyles. Moreover, these issues contribute to low physical fitness in this age group, increasing the risk of becoming overweight or obese (14). Physical fitness includes health and skill-related attributes. It means being able to perform daily tasks with energy and alertness, without excessive fatigue, and having the ability to engage in leisure activities and respond to emergencies. (15)

Body mass index (BMI) is recognised worldwide as an indicator of health and is extensively utilised to assess malnutrition, overweight, and obesity (16-18). Likewise, BMI is a suitable measurement method for populations without participating in frequent high-intensity physical activity (19). Based on Asian classification, there are four categories for BMI which are: Underweight (<18.5 kg/m2), average weight (18.5–22.9 kg/m2), overweight (23–24.9 kg/m2), and obese 1 (≥25–29.9 kg/m2) (20). Previous studies have discovered a negative correlation between BMI and physical fitness relevant to health among adolescents and obese individuals (21).

Overweight, obesity, and low physical fitness are interconnected elements that influence each other. Changes in one component might lead to changes in the other. While numerous research studies have examined the link between BMI and physical activity, only a limited number have explored the correlation between BMI status and physical fitness, especially among school-age individuals in Shah Alam, Selangor. Most previous studies have utilised one or two fitness components. Additionally, the predictors of health-related physical fitness toward BMI need to be established to gain better knowledge about the variables and to provide insightful information for any intervention related to overweight and obesity. Hence, the current study tries to determine the contribution of health-related physical fitness to BMI.

MATERIALS AND METHODS

Samples

We collected data from secondary school students in Shah Alam, Selangor. The study had 150 participants (Boys = 63, Girls = 88) between the ages of 13 and 16. The inclusion criteria for this study are participants aged 13 to 16 years, both boys and girls, who are in good health, capable of performing physical activity, and able to understand and follow verbal instructions for completing physical tasks. The exclusion criteria include individuals with any chronic medical conditions, recent injuries, or acute illnesses that could impair their ability to safely perform physical tasks. The participants and their guardians have signed the consent form and agreed to participate in this study because the respondents are underage, which is below age 18.

The number of participants, which is considered sufficient for stepwise multiple regression based on the formula suggested, provides a strong foundation for our findings. (22). According to the equation "50 + 8m," where "m" represents the number of components, the minimum number of participants in the present study is at least 82, with the variables being CF, muscle endurance (ME), MS, and flexibility. Stepwise multiple regression is a useful method for identifying the most significant predictors among a set of variables. Moreover, this method provides clear statistical criteria for adding or removing variables, ensuring that the process is both transparent and reproducible.

We selected participants using the simple random sampling method because it reduces bias, ensures representativeness, and enhances the generalizability of the results to the broader population. Three schools were chosen, and the participants were identified using a random number table. Three experienced Physical Education (PE) teachers, each with ten years of experience and assisted by PE students from Universiti Teknologi MARA, conducted the test of the health-related physical fitness components. Five test batteries were used to measure health-related fitness: BMI, sit up, push up, sit and reach, and step test. These tests are standardized measurement for *Standard Kecergasan Fizikal Kebangsaan Untuk Murid Sekolah Malaysia* (National Physical Fitness Standards for Malaysian School Students) which is apply for all students age 10 to 17 twice a year.

Standardised training was given to all raters on conducting tests and measurements for all fitness components. The training aimed to improve the objectivity among raters and enhance the reliability of the tests. This study was approved by the UiTM Research Ethics Committee ED/REC/F/10956.

Pilot Study

The pilot study aims to assess the validity and reliability of the test batteries. Validity and reliability are crucial for ensuring meaningful data. It is recommended to establish validity and reliability before conducting the study, as they may be influenced by differences in the population and the experience of test raters. The inter-rater reliability, test-retest and known method group will

be employed to determine the reliability and validity of the raters and test batteries. Inter-rater reliability was evaluated by inter-class correlation to ensure consistency among the three raters (two males, one female) administering the tests. Test-retest analysis with time intervals and Pearson Correlation was employed to assess the reliability of the physical fitness test battery. Each test was conducted twice, with a 7-day interval between the test and retest (23) to account for fatigue effects, except for the BMI and sit-and-reach tests, where a 24-hour interval was used since no fatigue effects were observed. A shorter time interval was chosen to enhance the reliability of the test batteries, as shorter intervals are known to improve reliability (24). Meanwhile, a known method group was employed to determine the validity of the test batteries. It involves comparing mean differences between elite and non-elite performers to assess a test's ability to distinguish between groups with known differences. A group of 30 participants, not representing their schools in sports, will be randomly selected from schools in Shah Alam. Meanwhile, another group of 30 participants will be chosen randomly to represent their state in multi-sport events.

Table I: Inter-rater reliability and test-retest reliability of the physical fitness test batteries

Test Batteries	Inter-rater reliability			Test-Retest		Correlation Coefficient
	ICC	95% CI Low	95% CI High	Mean	SD	
BMI	.984	.971	.992	20.43	1.99	.983
				20.51	1.93	
Sit-ups	.975	.955	.987	21.66	2.26	.891
				21.63	2.14	
Push-ups	.981	.966	.990	21.50	2.19	.984
				21.40	2.26	
YMCA 3MST	.979	.961	.989	99.50	15.00	.977
				100.23	16.00	
Sit and reach	.985	.972	.992	37.04	6.34	.982
				37.31	6.29	

Inter-rater reliability

The intraclass correlation coefficient (ICC) using a 2-way mixed model with absolute agreement was employed to evaluate inter-rater reliability. The findings revealed very high ICCs (≥ 0.75), aligning with the suggestion that ICCs between 0.75 and 0.9 indicate good reliability, while values above 0.90 indicate excellent reliability (31). The inter-rater reliability results for the three raters (n = 30) are presented in Table I.

Test-Retest Reliability

Test-retest analysis with time intervals and Pearson Correlation was employed to assess the reliability of the physical fitness test battery. Reliability refers to the consistency of scores achieved by the same individuals when re-tested with the same test on different occasions. The test-retest results demonstrated high reliability across all tests, with correlation coefficients ranging from r = .891 to .984

Construct Validity

We compared state athletes and non-athletes using an independent sample t-test to determine the validity of the National Physical Fitness Standard for Malaysian students. Table II indicates that the independent sample t-test findings for BMI showed a t value (40.1) = -3.928, p = 0.01, which was significant. Findings showed significant differences between state athletes (M = 20.436, SD = 1.821) and non-athletes (M = 23.636, SD = 4.072).

Table II: Independent Sample T-Test for Construct Validity Evidence for National Physical Fitness Standard for Malaysian Students

Test Batteries	N		Mean	SD	t	Sig Level
BMI	State athletes	30	20.436	1.821	-3.928	.001
	Non-athletes	30	23.636	4.072		
Sit-ups	State athletes	30	3.866	.819	6.002	.001
	Non-athletes	30	2.533	.899		
Push Ups.	State athletes	30	4.333	.660	6.117	.001
	Non-athletes	30	3.100	.884		
YMCA 3MST	State athletes	30	2.533	.899	4.781	.001
	Non-athletes	30	4.000	.694		
Sit and reach	State athletes	30	3.400	.932	3.372	.001
	Non-athletes	30	2.466	1.195		

The findings for sit-ups also showed that the t value (58) = 6.002 and p = 0.01 were significant. Findings showed significant differences between state athletes (M = 3.866, SD =.819) and non-athletes (M = 2.533, SD =.899). In addition, findings for push-ups showed that the t value (58) = 6.117 and p = 0.01 were significant. Findings showed significant differences between state athletes (M = 4.333, SD =.660) and non-athletes (M = 3.100, SD =.884). The YMCA 3MST also showed that the t value (46.8) = 4.781 and p = 0.01 were significant. The findings indicated significant differences between state athletes (M = 2.533, SD =.899) and non-athletes (M = 4.000, SD = 6.94).

Meanwhile, the sit and reach also showed that the t value (58) = 3.372 and p = 0.01 were significant. The findings indicated significant differences between state athletes (M = 3.400, SD =.932) and non-athletes (M = 2.466, SD =1.195). Therefore, the results revealed that all the test batteries for the National Physical Fitness Standard for Malaysian students are valid in the target population because all the test batteries can discriminate the subjects' abilities, characteristics, and performance, as suggested one of the characteristics of a good test should discriminate students' abilities (25).

Measurements

The physical fitness assessment will use the National Physical Fitness Standard for Malaysian students. National Physical Fitness Standards for Malaysian School Students which is apply for all students age 10 to 17 twice a year. Although all the test batteries are field tests, which are less e less accurate than lab tests, the use of lab tests is limited due to their high cost, the requirement for skilled technicians, the need to conduct them in a highly controlled environment, the use of standardised protocols, and their inappropriateness for large populations. Therefore, the field test is more suitable for the current situation. Furthermore, field tests typically occur naturally with minimal equipment as the participants carry out the activity. The tests were conducted at school by three raters (two male and one female) in the morning. Participants were divided into two groups: male and female. The testing process was completed over two days. On the first day, participants had their BMI measured and performed the YMCA Bench Step Test (YMCA 3MST), push-ups, or modified push-ups. On the second day, sit-ups and flexibility were assessed.

Body Mass Index

The Body Mass Index (BMI) is an accepted metric for determining an individual's body weight relative to height. BMI is a valuable measure for evaluating the general health of individuals and identifying trends in weight distribution among various populations (26). BMI is calculated by dividing the weight in kilograms by the square of the height in meters. The World Health Organization (WHO) categorised BMI values into four groups according to the following criteria: < 18.5 kg/m2 for low weight, 18.5~23.9 kg/m2 for average weight, 24~27.9 kg/m^2 for overweight, and ≥ 28 kg/m2 for obesity.

Sit Ups

The sit-ups (SU) test was conducted to assess the endurance and strength of the abdominal muscles, with the participant completing the test within 60 seconds (27). The test protocol requires the participant to be in a lying down position with knees bent and feet resting on the floor, positioned no more than 1 foot away from the buttocks. The knee angle must exceed or equal 90 degrees. The fingers are placed behind the neck or shoulder. The partner securely holds the feet as the subject turns into a sitting position and touches their elbows to their knees. This activity is performed continuously for maximum repetitions within 60 seconds. One point is given for every accurate sit-up. The score is the most significant number of sit-ups that can be completed within a time (28).

The YMCA Bench Step Test (YMCA 3MST)

The YMCA Bench Step Test (YMCA 3MST) was conducted to evaluate the cardiovascular fitness of individuals (29). The YMCA 3MST protocol involved repeatedly stepping on and off a 12-inch bench (30 cm) for 3 minutes, without using handles, to maximise the number of steps taken. The metronome will be adjusted to a tempo of 96 beats per minute, and the volume will be increased to ensure that each beat is heard. Once the participant gets ready, the tester will start the stopwatch, and the participant will begin stepping on and off the step according to the rhythmic beat of the metronome, following a pattern of up, up, down, and down for 3 minutes. The procedure ends once it reaches 3 minutes. The pulse reading will be recorded for 60 seconds.

Push Ups

The push-up test assesses the endurance of the arm and shoulder muscles (30). A test of push-ups was conducted specifically for boys. The participants will be prone on the floor, with their bodies aligned, arms flexed, and hands resting flat on the floor beneath their shoulders. Place the hands on either side of the chest and maintain an upright stance on the back. The participants must perform a repetition of lowering their body till their chest contacts the floor, and then repeat this exercise as many times as possible within one minute, without taking any breaks. The tester will record occurrences of repetition. The scores of the participants who failed to finish the task within one minute will be recorded when they stop their efforts.

Modified Push Ups

The modified push-up test aims to assess girls' arm and shoulder endurance (30). The test subject will be prone on the floor, with the body aligned in a straight line, knees flexed at a 90-degree angle, arms bent, and hands

resting flat on the floor below the shoulders. Participants must use their knees as the pivot and exert upward force to achieve a fully extended arm position. They should then lower their body until the chest contacts the floor and repeat this exercise as often as possible within one minute without taking any breaks. It is imperative to maintain a straight posture of the body trunk during the test. The evaluator will record occurrences of repetition. The participants' scores who did not complete the activity within one minute will be recorded when they stopped their efforts.

Sit and Reach Test

The sit and reach test measured the flexibility of the lower back and posterior thighs (30). The test apparatus should be prevented from slippering, and the test participants should not wear shoes. The performer will sit at the test apparatus with the knee fully extended and the feet shoulder-width apart, flat against the end of the board. The palms should be down, and hands should be placed on each other. Extend the arms forward and directly reach four times, and hold the position of maximum reach on the fourth trial for one second. The score is the most distant point on the fourth trial, measured to the nearest centimetre.

RESULTS

The current study aims to identify the key components of health-related physical fitness that contribute to the variability of BMI among 13 to 16-year-old adolescents. Data analysis was conducted using SPSS version 28, employing descriptive statistics and stepwise multiple regression to identify significant predictors of BMI while excluding less influential factors. This approach streamlines the model, making it particularly useful for exploratory research involving multiple potential predictors.

Table III: Descriptive Analysis of Demographic and Health-Related Physical Fitness Data

Variable	Frequency	Percentage	Min	Max	Mean	SD
Boy	62	41.3				
Girl	88	58.7				
age						
13	44	29.3				
14	49	32.7				
15	27	18.0				
16	30	20.0				
Body Mass Index			18.50	26	21.716	2.239
Cardiovascular Endurance			70.0	149	107.400	22.923
Muscle Endurance			7	76	21.513	8.123
Muscle strength			8	27	19.713	4.251
Flexibility			15	48	26.960	7.084

Table III presents the demographic distribution of respondents and descriptive statistics for the study variables. Of the 150 participants, 58.7% are female (88 respondents) and 41.3% are male (62 respondents). The age distribution shows that the largest group consists of 14-year-olds (32.7%, 49 participants), followed by 13-year-olds (29.3%, 44 participants), 16-year-olds (20.0%, 30 participants), and 15-year-olds (18.0%, 27 participants). In terms of the health-related physical fitness variables, the mean Body Mass Index (BMI) is 21.71 (SD = 2.23), indicating low variability in BMI. The mean score for cardiovascular fitness is 107.49 (SD = 22.87), reflecting moderate variability in fitness levels. Muscle endurance has a mean of 21.54 (SD = 8.10), showing some variability, while muscle strength has a mean of 19.73 (SD = 4.24), indicating consistent strength levels. Flexibility scores have a mean of 26.96 (SD = 7.06), demonstrating moderate variability across participants. Overall, the data provides an overview of the demographic characteristics and physical fitness levels of the sample, highlighting varying degrees of variability across different fitness components.

Table IV: The results of Multicollinearity

Independent variable	Tolerance	VIF
Cardiovascular fitness	.934	1.07
Muscle Endurance	.833	1.20
Muscle strength	.840	1.19
Flexibility	.954	1.04

Dependent Variable: Body Mass Index

Multicollinearity was assessed using tolerance and VIF. In multiple linear regression, unchecked multicollinearity can lead to inaccurate estimates and affect model validity. The results from Table IV show that the data is free from multicollinearity, with tolerance values above 0.2 and VIF values below 10 for all variables. Tolerance values under 0.2 or VIF values exceeding 10 would indicate potential multicollinearity, which could compromise the analysis. (31).

Table V: Analysis of the Impact of Health-Related Physical Fitness Components on BMI

Model	R	R^2	Adjusted R^2
Cardiovascular Fitness	.315[a]	.099	.099
Cardiovascular Fitness, Muscle Strength	.360[b]	.130	.030

a. Predictors: (Constant), Cardiovascular Fitness
b. Predictors: (Constant), Cardiovascular Fitness, Muscle Strength

Table V presents the results of the stepwise multiple regression analysis. The regression value (R) for the two health-based physical fitness components, cardiovascular fitness and muscle strength, is 0.130, indicating that together they explain 13% of the variability in BMI. When assessed separately, cardiovascular fitness accounts for an R value of 0.099. However, when both cardiovascular fitness and muscle strength are included in the model, the R increases to 0.130, demonstrating that their combined contribution explains 13% of the variability in BMI. It is important to note, however, that other factors account for the remaining 87% of the variability in adolescent BMI within the studied population.

Table VI: Relationship Between Health-Related Physical Fitness Components and BMI

Model	df	F	Sig.
Regression	2	11.035	<.001[c]
Residual	148		
Total	150		

a. Dependent Variable: Body Mass Index
b. Predictors: (Constant), Cardiovascular Male, Muscle Strength Male

Table VI presents the results of an ANOVA analysis, showing an F-value of (2, 148) = 11.035, with $p < 0.05$. The coefficient values for the two health-based physical fitness components are significant at the 0.05 level. These results indicate that the stepwise multiple regression model, consisting of the dependent variable and the predictor variables, is statistically significant. Specifically, the ANOVA analysis reveals that the two health-based physical fitness components, cardiovascular fitness and muscle strength, are significant predictors of changes in BMI.

Table VII: Coefficients of Health-Based Physical Fitness Components in Relation to BMI

Variable	Unstandardized Coefficients β	Standardized Coefficients β	Sig.
Constant	20.437		<.001
Cardiovascular Male	.029	0.295	<.001
Muscle Strength Male	-.092	-0.175	.025

a. Dependent Variable: Body Mass Index

The multiple regression analysis yielded a significant model (BMI = 20.437 + 0.029 [CF] - 0.092 [MS]), indicating that the relationship between the dependent variable (BMI) and the predictor variables can be generalized to the population. Table VII shows that the Beta coefficient for CF is significant ($\beta = 0.295$, $p < 0.05$), as is the Beta coefficient for MS ($\beta = -0.175$, $p < 0.05$), identifying them as significant predictors of BMI. In contrast, the other two components, flexibility and muscle endurance, were not found to be significant predictors of BMI. These results highlight that among the health-based physical fitness components, only CF and MS significantly influence BMI in this adolescent population. This finding emphasizes the role of these two components in determining BMI within the studied population.

DISCUSSION

We have examined the influence of health-related physical fitness on BMI among adolescents aged 13 to 16. Our results show that CF and MS significantly influence the level of BMI among the target population. Our findings are in line with other similar studies that these components influence obesity among adolescents

(32-34). However, a recent study conducted on children in India showed differing results (35). It indicated that MS has a strong correlation with BMI, while CF has only a modest correlation with BMI among this population. Different populations may yield distinct results that challenge the findings of the current study. A separate study showed that overweight or obese students with high MS and CF displayed healthier anthropometric indicators than their peers with low muscle strength (36). These findings highlight the importance of both fitness components in relation to obesity in adolescents. Many studies examining the relationship between metabolic syndrome and obesity have reached a consensus on the impact and connection between MS and obesity across all age groups.

In another recent study (37) found that as body fat increases, muscle strength decreases, which aligns with earlier research indicating that the level of BMI is linked to lower muscle quality (38). Recent reviews show that overweight or obese individuals often have poor muscle performance in repetitive movement tests, such as sit-ups, and bodyweight support tests like planks and push-ups. Our findings align with previous studies indicating that MS affects BMI levels in adolescents. Moreover, a separate study conducted among adolescents in Spain found a significant indirect relationship between VO2 max, handgrip strength, and BMI (39). Similarly, another study (40) conducted among adolescents in China identified sprint, coordination, and CF as the most significant factors influencing BMI and obesity. These studies clearly demonstrate that components of health-related physical fitness, such as CF, MS, sprint, and coordination, negatively impact BMI and obesity. An increase in fitness levels leads to a reduction in BMI and obesity by decreasing body fat. Unlike the present study, which examined a broader range of physical fitness components, these studies specifically focused on CF, MS, flexibility, speed, and coordination using different test batteries. Nevertheless, they support our findings, confirming that CF and MS are important for achieving an ideal BMI and reducing obesity among adolescents.

Individuals with elevated BMI levels usually have higher levels of the proinflammatory biomarkers C-reactive protein (CRP) and interleukin 6 (41). When individuals are obese, macrophages and T cells reach the adipose tissue and generate proinflammatory cytokines (42). These cytokines then promote the synthesis of the acute phase proteins CRP and serum amyloid A (SAA) (43). Previous research has indicated that PA can reduce systemic inflammation by preventing the infiltration of macrophages into the adipose tissue and promoting the release of anti-inflammatory cytokines, which can aid in weight loss (44). In addition, individuals with higher CF tend to have lower levels of CRP compared to those who are unfit (45). People who have low levels of CRP and high levels of CF tend to lose weight by counteracting the inflammatory effects of being overweight. According to prior research, those who are obese and those with low CF exhibited the highest levels of inflammatory markers. Levels CRP and high levels of CF tend to lose weight by trying to counteract the inflammatory effects of being overweight (43). Therefore, those who are obese and those with low CF exhibited the highest levels of inflammatory markers.

Likewise, a recent study has discovered that sarcopenic obesity is already prevalent among children and adolescents. Children have been found to have decreased MS, and the presence of abdominal obesity suggests the possibility of sarcopenic obesity in both children (46). A recent systematic review also revealed a variation in the prevalence of sarcopenic obesity between 6% and 70% in girls and between 7% and 81% in boys (46). Sarcopenic obesity is when there is a simultaneous decrease in muscle mass and function, accompanied by an increase in adipose tissue. This condition typically occurs in adults. Consequently, MS is crucial in predicting the level of BMI. Those with greater muscular fitness tend to have lower inflammatory markers such as C-reactive protein, fibrinogen, leptin, and the homeostasis model assessment of the insulin resistance index. (47,48).

The study emphasizes the importance of PE in boosting CF and MS among adolescents, helping to lower BMI and obesity rates. It calls for schools to promote active participation in PE, especially physical fitness and regular exercise to enhance students' physical health and overall quality of life. The PE curriculum could be updated to include specific fitness goals focusing on CF and MS, not just on sports, games and exercises. Furthermore, PE lessons could broaden the scope by applying the health holistic approach while integrating the theory and practical of obesity prevention. The lesson should cover the science behind the importance of CF and MS in obesity prevention. The study's findings also may lead to the development of more specific physical activity guidelines for children, emphasizing the importance of both aerobic exercises and resistance activities in promoting healthy body composition and preventing obesity. Moreover, for the extracurricular activities, schools should encourage the students to participate in activities that can enhance CF and MS such as sport teams (e.g., soccer, netball), outdoor adventure program (e.g., rock climbing, jungle trekking, kayaking). Specific intervention for obese children also can be organized in school such as fitness boot camps which can focus and consist of aerobic and strength exercise such as brisk walk, resistance band exercise, aerobic dance, jump rope, individual and team sports. All the activities should incorporate fun element to ensure the participant remain active, engaged, enjoy, motivated, and stay consistent.

Comprehensive and practical guidance can be provided to parents, schools, and communities on the importance of engaging in activities that build CF and MS.

Additionally, the findings provide new insights into the biological processes involving CF and MS in preventing obesity among children. This contributes to a more comprehensive understanding of childhood obesity, moving beyond traditional risk factors such as diet and sedentary behaviour. Therefore, exercise programs for obese children should be specifically designed to enhance both CF and MS.

However, the study has limitations, including the use of field tests, which may lack the accuracy of laboratory tests. It also faces challenges in selecting valid and reliable test batteries for the population. Additionally, it only assesses abdominal strength, which does not fully represent overall muscular strength, including upper and lower body strength. Limitations in sample size may influence the outcomes of the current study, even though the sample size meets the requirements for statistical analysis. It is plausible that a larger sample with greater demographic diversity could yield different results. Furthermore, the regional focus of this study represents another significant limitation. Variations in cultural, economic, educational, and environmental factors across different populations and regions could lead to differing outcomes. For instance, a health intervention proven effective in one region might not achieve similar results in another due to disparities in healthcare systems and their efficacy. Consequently, the findings of this study should be interpreted within the context of the specific region under investigation. Future research should strive to address these limitations by incorporating larger and more diverse samples and expanding the geographic scope to enhance generalizability. Additionally, future studies should examine the precision of the test batteries employed and explore the role of overall muscle strength to optimize outcomes. By addressing these limitations, subsequent research can contribute meaningfully to the existing body of knowledge on this topic.

CONCLUSION

In conclusion, CF and MS significantly influence obesity levels in both males and females. These two components should therefore be prioritized in any intervention programs targeting adolescent obesity. Addressing CF and MS effectively has the potential to reduce body fat and lower body BM) levels among adolescents. Moreover, to enhance health-related physical fitness in this age group, greater emphasis should be placed on the PE curriculum. Structured PE classes should focus on physical fitness health related components. PE teachers should adopt creative approaches to organize physical activities, incorporating engaging initiatives like step-count challenges, relay races, and fitness tests to sustain student interest and motivation.

Furthermore, the teaching style employed in PE classes plays a critical role in influencing student participation. Teaching methods should be tailored to accommodate diverse student abilities, ensuring inclusivity and equal opportunities for all students to engage meaningfully in PE activities. By adopting these strategies, schools can create a supportive and effective framework to promote physical fitness and combat obesity among adolescents.

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REFERENCES

1. The GBD 2015 Obesity Collaborators. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. New England Journal of Medicine [Internet]. 2017 Jul 6;377(1):13–27. Available from: https://www.nejm.org/doi/full/10.1056/NEJMoa1614362
2. World Obesity Federation. Global Atlas on Childhood Obesity [Internet]. World Obesity Federation. 2019. Available from: https://www.worldobesity.org/membersarea/global-atlas-on-childhood-obesity
3. Institute for Public Health. National Health and Morbidity Survey (NHMS) 2019: Non-communicable diseases, healthcare demand, and health literacy. Selangor: Institute for Public Health National Institutes of Health; 2020.
4. Darnton-Hill I, Nishida C, James W. A life course approach to diet, nutrition and the prevention of chronic diseases. Public Health Nutrition. 2004 Feb;7(1a).
5. Hupparage V, Waman T, Waman P, Yadav P, Tare H, Dama G. A Review of the Psychological Aspects of Childhood Obesity: Causes, Consequences and Treatment. International Journal of Pharmaceutical Quality Assurance. 2023 Dec 25;14(4):1214–20.
6. Reeves GM, Postolache TT, Snitker S. Childhood Obesity and Depression: Connection between these Growing Problems in Growing Children. PubMed. 2008 Aug 1;1(2):103–14.
7. Mohajan D, Kumar Mohajan H. A Study on Body Fat Percentage for Physical Fitness and Prevention of Obesity: A Two Compartment Model . Journal of Innovations in Medical Research. 2023 Feb 4;2(4):1–10.
8. Guthold R, Stevens GA, Riley LM, Bull FC. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. The Lancet Child & Adolescent Health [Internet]. 2020 Nov;4(1):23–35. Available from: https://www.thelancet.com/journals/lanchi/article/PIIS2352-4642(19)30323-2/fulltext
9. Ahmad N, Asim HH, Juatan N, Hipni NE, Ithnain N, Ahmad Sanusi NH, et al. Contributing Factors to Decline in Physical Activity Among Adolescents:

A Scoping Review. Malaysian Journal of Social Sciences and Humanities (MJSSH). 2021 Sep 10;6(9):447–63.
10. Dan SP, Mohd NMT, Zalilah MS. Determination of factors associated with physical activity levels among adolescents attending school in Kuantan, Malaysia. PubMed. 2011 Aug 1;17(2):175–87.
11. Woon FC, Chin YS, Mohd Nasir MT. Association between behavioural factors and BMI-for-age among early adolescents in Hulu Langat district, Selangor, Malaysia. Obesity Research & Clinical Practice. 2015 Jul;9(4):346–56.
12. Tee ES, Nurliyana AR, Norimah AK, Mohamed HJBJ, Tan SY, Appukutty M, et al. Breakfast consumption among Malaysian primary and secondary school children and relationship with body weight status - Findings from the MyBreakfast Study. Asia Pacific Journal of Clinical Nutrition [Internet]. 2018;27(2):421–32. Available from: https://pubmed.ncbi.nlm.nih.gov/29384332/
13. Jaafar J, Shaaban J, Abdul Rahman R, Mohd Noor N. Physical Activity and Its Associated Factors among Adolescents in Secondary Schools in Northeast Peninsular Malaysia. Indian Journal of Public Health Research & Development. 2020 Jul;11(7):1278–84.
14. Dwyer T, Magnussen CG, Schmidt MD, Ukoumunne OC, Ponsonby AL ., Raitakari OT, et al. Decline in Physical Fitness From Childhood to Adulthood Associated With Increased Obesity and Insulin Resistance in Adults. Diabetes Care. 2008 Dec 23;32(4):683–7.
15. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. PubMed. 1985 Mar 1;100(2):126–31.
16. Zhang Y, Su F, Song Y, Lu J. Associations between Physical Fitness Index and Body Mass Index in Tibetan Children and Adolescents in Different High-Altitude Areas: Based on a Study in Tibet, China. International journal of environmental research and public health/International journal of environmental research and public health [Internet]. 2022 Aug 16;19(16):10155–5. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9408390/
17. Bi C, Yang J, Sun J, Song Y, Wu X, Zhang F. Benefits of normal body mass index on physical fitness: A cross-sectional study among children and adolescents in Xinjiang Uyghur Autonomous Region, China. Boullosa D, editor. PLOS ONE. 2019 Aug 15;14(8):e0220863.
18. Hashim A, Elumalai G, Rahman ZA. Reliability and validity for measurement of body composition: A field method. Journal of Fundamental and Applied Sciences. 2018 Feb 1;9(6S):1187.
19. Eather N, Morgan PJ, Lubans DR. Improving health-related fitness in adolescents: the CrossFit TeensTM randomised controlled trial. Journal of Sports Sciences. 2015 May 14;34(3):209–23.
20. Al-Ghamdi S, Shubair MM, Aldiab A, Al-Zahrani JM, Aldossari KK, Househ M, et al. Prevalence of overweight and obesity based on the body mass index; a cross-sectional study in Alkharj, Saudi Arabia. Lipids in Health and Disease [Internet]. 2018 Jun 5;17(1). Available from: https://lipidworld.biomedcentral.com/articles/10.1186/s12944-018-0778-5
21. Ding C, Jiang Y. The Relationship between Body Mass Index and Physical Fitness among Chinese University Students: Results of a Longitudinal Study. Healthcare [Internet]. 2020 Dec 17;8(4):570. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7765873/
22. Tabachnick BG, Fidell LS. Using multivariate statistics. 6th ed. Boston Pearson; 2013.
23. Henriques-Neto D, Minderico C, Peralta M, Marques A, Sardinha LB. Test-retest reliability of physical fitness tests among young athletes: The FITescola® battery. Clinical Physiology and Functional Imaging [Internet]. 2020 May 1;40(3):173–82. Available from: https://pubmed.ncbi.nlm.nih.gov/32056351/
24. Bishop PA. Measurement and Evaluation in Physical Activity Applications. Routledge; 2018.
25. Jacob B, Rothstein J. The Measurement of Student Ability in Modern Assessment Systems. Journal of Economic Perspectives. 2016 Aug 1;30(3):85–108.
26. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. JAMA [Internet]. 2006 [cited 2019 Feb 28];295(13):1549–55. Available from: https://www.ncbi.nlm.nih.gov/pubmed/16595758
27. Čvorović A, Kukić F, Orr RM, Dawes JJ, Jeknić V, Stojković M. Impact of a 12-Week Postgraduate Training Course on the Body Composition and Physical Abilities of Police Trainees. Journal of Strength and Conditioning Research. 2021 Mar;35(3):826–32.
28. Kansal K. A Textbook of Sports Science: Test, Evaluation, Accreditation, Measurements and Standards (TEAMS). K.K. Publications; 2021.
29. Santo AS, Golding LA. Predicting Maximum Oxygen Uptake from a Modified 3-Minute Step Test. Research Quarterly for Exercise and Sport. 2003 Mar;74(1):110–5.
30. Johnson BL, Nelson JK. Practical measurements for evaluation in physical education. Edina, Minn.: Burgess Pub; 1986
31. Ganesh Prasad Adhikari. Interpreting the Basic Results of Multiple Linear Regression. Scholars' Journal. 2022 Dec 31; 5:22–37.
32. Kaze AD, Agoons DD, Santhanam P, Erqou S, Ahima RS, Echouffo-Tcheugui JB. Correlates of cardiorespiratory fitness among overweight or obese individuals with type 2 diabetes. BMJ Open Diabetes Research & Care [Internet]. 2022

Jan;10(1): e002446. Available from: https://drc.bmj.com/content/bmjdrc/10/1/e002446.full.pdf
33. Petrovics P, Sandor B, Palfi A, Szekeres Z, Atlasz T, Toth K, et al. Association between Obesity and Overweight and Cardiorespiratory and Muscle Performance in Adolescents. International Journal of Environmental Research and Public Health [Internet]. 2021 Jan 1;18(1):134. Available from: https://www.mdpi.com/938000
34. Leslie Gross Portney, Watkins MP. Foundations of clinical research: applications to pratice. Philadelphia: F.A. Davis; 2015.
35. Shetty NU, Chippala P. Influence of Body Mass Index on Health-Related Physical Fitness in School-Going Children of North and South Mangaluru. Journal of Health and Allied Sciences NU. 2024 Nov 7.
36. Albornoz-Guerrero J, Zapata-Lamana R, Reyes-Molina D, Cigarroa I, García Pérez de Sevilla G, García-Merino S. Overweight/Obese Schoolchildren with Low Muscle Strength Have a Lower Cardiorespiratory Capacity and Greater Cardiovascular Risk: Results of the School Health Survey of the Extreme South of Chile 2019. Children [Internet]. 2021 Sep 1;8(9):734. Available from: https://www.mdpi.com/2227-9067/8/9/734
37. Dipak Kumar Dhar, Brijesh Purwar. Effect of Body Fat and BMI on Muscle Strength and Endurance in Young Adults: A Cross-sectional Study. Journal of Clinical and Diagnostic Research. 2023 Jan 1.
38. Therkelsen KE, Pedley A, Hoffmann U, Fox CS, Murabito JM. Intramuscular fat and physical performance at the Framingham Heart Study. AGE. 2016 Feb 22;38(2).
39. González-Gálvez N, Vaquero-Cristobal R, Maciá-Andreu MJ, García-Tascon M, Soler-Marín A, Gallardo-Guerrero AM. Influence of physical fitness components on personality factors and risk perception of children and adolescents: a cross-sectional study. BMJ Open [Internet]. 2023 Dec 1 [cited 2024 Apr 1];13(12): e071995. Available from: https://bmjopen.bmj.com/content/13/12/e071995
40. Wang Q, Guo H, Chen S, Ma J, Kim H. The Association of Body Mass Index and Fat Mass with Health-Related Physical Fitness among Chinese Schoolchildren: A Study Using a Predictive Model. Int J Environ Res Public Health. 2022 Dec 26;20(1):355–5.
41. Pang Y, Kartsonaki C, Lv J, Fairhurst-Hunter Z, Millwood IY, Yu C, et al. Associations of Adiposity, Circulating Protein Biomarkers, and Risk of Major Vascular Diseases. JAMA Cardiology. 2021 Mar 1;6(3):276.
42. Chait A, den Hartigh LJ. Adipose Tissue Distribution, Inflammation and Its Metabolic Consequences, Including Diabetes and Cardiovascular Disease. Frontiers in Cardiovascular Medicine. 2020 Feb 25;7(22).
43. Midtbø H, Arve Ulvik, Cramariuc D, Meyer K, Ueland PM, Halland H, et al. Influence of cardiorespiratory fitness on obesity-associated inflammation in women and men: The FATCOR study. Nutrition Metabolism and Cardiovascular Diseases. 2024 Apr 1;34(8).
44. Lavie CJ, Milani RV. Weight Reduction and Improvements in Endothelial Function. Chest. 2011 Dec;140(6):1395–6.
45. Aronson D, Sella R, Muhammad Sheikh-Ahmad, Kerner A, Ophir Avizohar, Shmuel Rispler, et al. The association between cardiorespiratory fitness and C-reactive protein in subjects with the metabolic syndrome. Journal of the American College of Cardiology. 2004 Nov 16;44(10):2003–7.
46. Mai-Lis Hellénius, Andermo S, Nordenfelt A, Matthias Lidin, Nyberg L, Nyberg G. Negative associations between step-up height and waist circumference in 8-year-old children and their parents. Acta Paediatrica. 2024 May 16;113(8):1900–7.
47. Agostinis-Sobrinho C, García-Hermoso A, Ramнrez-Vélez R, Moreira C, Lopes L, Oliveira-Santos J, et al. Longitudinal association between ideal cardiovascular health status and muscular fitness in adolescents: The LabMed Physical Activity Study. Nutrition, Metabolism and Cardiovascular Diseases. 2018 Sep;28(9):892–9.
48. César Agostinis-Sobrinho, Robinson Ramírez-Vélez, García-Hermoso A, Moreira C, Lopes L, José Oliveira-Santos, et al. Low-grade inflammation and muscular fitness on insulin resistance in adolescents: Results from LabMed Physical Activity Study. Pediatric Diabetes. 2017 Nov 24;19(3):429–35.