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Body Mass Index and Muscular Fitness in Relation to Estimated Aerobic Capacity in Adolescents: An Exploratory Cross-Sectional Study

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ABSTRACT

Introduction. Aerobic capacity is a key marker of cardiorespiratory fitness in adolescents, while body mass index (BMI) and muscular fitness may be related to interindividual variation in maximal oxygen uptake (VO_2max). This exploratory study examined the joint association of BMI and muscular fitness with estimated aerobic capacity among junior high school students aged 14-16 years. Methods. An analytical observational cross-sectional design was used. All eligible students in the study setting (N = 20) were included by total sampling. BMI was calculated from measured body mass and stature; muscular fitness was assessed using squat, sit-up, and push-up tests and combined into a composite score; VO_2max was estimated from the Cooper 12-minute run test. Descriptive statistics, Spearman correlations, and multiple linear regression were used ($\alpha = .05$). Results. Mean estimated VO_2max was 53.16 ± 3.45 $mL \cdot kg^{-1} \cdot min^{-1}$. BMI ($r_s = -.064$, 95% CI −.49 to .39) and muscular fitness ($r_s = .012$, 95% CI −.43 to .45) showed very weak correlations with VO_2max, and the regression model explained 0.9% of its variance ($F(2, 17) = 0.077$, $p = .926$; adjusted $R^2 = -.108$). Confidence intervals were wide and compatible with no association as well as with moderate associations in either direction. Conclusion. In this small sample, no association of BMI or muscular fitness with estimated aerobic capacity was detected, but the estimates are imprecise and do not establish that the variables are unrelated. Larger samples with sex-specific analysis and measures of physical activity, body composition, and maturation are needed.

1. Introduction

Physical fitness during adolescence is a meaningful marker of current and future health. Cardiorespiratory fitness (CRF), commonly expressed as maximal or peak oxygen uptake, integrates cardiovascular, respiratory, and skeletal-muscle function and is strongly associated with cardiometabolic health in youth (Ortega et al., 2008; Raghuveer et al., 2020). International evidence also supports CRF as a useful population-health indicator in children and adolescents (Tomkinson et al., 2019). School-based physical-activity interventions can improve CRF, reinforcing the importance of aerobic fitness assessment in educational settings (Minatto et al., 2016; Wang et al., 2026).

Body mass index (BMI) is widely used in school and population settings because it is inexpensive and practical, and it provides a useful proxy of body size and weight status. Nevertheless, BMI cannot distinguish fat mass from fat-free mass, which limits its physiological interpretation when aerobic performance is expressed relative to body mass (Ortega et al., 2008; Dykstra et al., 2024). Evidence in youth indicates that lower CRF commonly coexists with higher adiposity and cardiometabolic risk, although the strength of the relationship depends on age, sex, maturation, physical activity, and the method used to estimate aerobic fitness (Raghuveer et al., 2020; Tomkinson et al., 2019).

Muscular fitness is another major component of health-related fitness. It includes strength, power, and local muscular endurance and is independently associated with important health indicators in young people (García-Hermoso et al., 2019). A systematic review further indicates meaningful associations between muscular-fitness phenotypes and cardiometabolic variables in children and adolescents (de Lima et al., 2022). Recent large-scale evidence suggests that cardiorespiratory and muscular fitness have partly distinct behavioral, contextual, and health-related correlates, supporting their assessment as complementary rather than interchangeable dimensions of fitness (Rosa et al., 2024).

Despite this evidence, the joint association of BMI and field-based muscular endurance with aerobic capacity remains insufficiently characterized in junior high school students, particularly in Indonesian school settings. Earlier work has examined muscular fitness as a predictor of cardiorespiratory fitness

in adolescents, for example in a three-year follow-up of adolescent girls that used squat and sit-up tests (Kasović et al., 2024), whereas BMI and muscular fitness are more often discussed separately in relation to CRF (Dykstra et al., 2024; Rosa et al., 2024). The present study differs in that it enters BMI and a composite of three equipment-free muscular-endurance tests into one model with a field-estimated VO_2max outcome, in a single school cohort in which simple physical-fitness assessments are relevant to routine physical education practice. In Indonesia, physical fitness assessment in schools has traditionally been associated with the Tes Kebugaran Jasmani Indonesia (TKJI). However, practical challenges, including limited facilities, procedural complexity, and the time required to assess large groups of students, have been reported among physical education teachers. These challenges have encouraged the development of alternative school-based assessment instruments, including the Tes Kebugaran Siswa Indonesia (TKSI). Therefore, simple field-based muscular-endurance tests may provide complementary information for preliminary physical fitness monitoring in school settings. Because CRF is influenced by multiple anthropometric, behavioral, physiological, and maturational factors, a multivariable approach may be more informative than isolated bivariate relationships (Raghuveer et al., 2020; Rosa et al., 2024). Because the Cooper test was developed in adults and its reliability and validity in adolescents remain uncertain (Martínez-Lemos et al., 2024), the study is framed as exploratory.

The objective of this exploratory study was to examine the association of BMI and muscular fitness with estimated aerobic capacity (VO_2max) among junior high school students aged 14–16 years. It was hypothesized that BMI would be negatively associated with VO_2max, that muscular fitness would be positively associated with VO_2max, and that the two variables jointly would explain a meaningful proportion of VO_2max variance.

2. Methods

Study Design

This quantitative study used an analytical observational cross-sectional design, in which predictor and outcome variables were measured at the same time. Cross-sectional designs are appropriate for estimating associations among variables within a defined population, while causal inference remains limited because temporal ordering cannot be established (Setia, 2016). The study is exploratory and was not designed to build a stable prediction model.

Participants

The participants were 20 junior high school students aged 14–16 years selected using total sample. Inclusion criteria were being healthy, actively participating in physical education, having no musculoskeletal injury, and agreeing to complete all measurements. Students with a history of cardiovascular disease, respiratory disorders, or other medical conditions that could interfere with fitness testing were excluded. The small sample reflects the complete eligible population available in the study setting. No a priori sample-size calculation was performed; the resulting limits on precision and power are addressed in the Statistical Analysis and Discussion sections.

Measurements and Instruments

Body mass was measured using a digital scale to the nearest 0.1 kg and stature using a stadiometer to the nearest 0.1 cm. BMI was calculated as body mass in kilograms divided by height in meters squared (kg/m^2). Although BMI is practical for field surveillance, it should be interpreted as an anthropometric proxy rather than a direct measure of body composition (Ortega et al., 2008; Dykstra et al., 2024).

Muscular fitness was assessed using three field tests of muscular endurance: squat repetitions (lower limb), sit-up repetitions (abdominal), and push-up repetitions (upper body and shoulder girdle). Protocols were as follows. higher scores indicate greater muscular endurance. Using multiple indicators is consistent with the multidimensional nature of muscular fitness described in youth research (de Lima et al., 2022).

Aerobic capacity was estimated using the Cooper 12-minute run test (Cooper, 1968). Participants were instructed to run or jog as far as possible for 12 minutes on a predetermined track, and VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$) was estimated from the distance covered using VO_2max = (distance in m − 504.9) / 44.73 (Cooper, 1968). Because this equation is a function of running distance alone, estimated VO_2max does not include body mass directly. Field running tests provide a practical alternative when laboratory

gas analysis is not feasible, but prediction error and population-specific validity should be acknowledged; the test was originally developed in adults, and its reliability and criterion validity in adolescents vary across studies (Bandyopadhyay, 2015; Martínez-Lemos et al., 2024). Estimated VO_2max should therefore be interpreted as an indirect indicator rather than a direct physiological measurement, and similar cautions apply to other field tests such as the 20-m shuttle run (Mayorga-Vega et al., 2015).

Data Collection Procedure

Before testing, participants received standardized explanations of the study purpose and testing procedures. Anthropometric measurements were completed first, followed by squat, sit-up, and push-up tests with sufficient recovery between tests to reduce fatigue carryover. The Cooper 12-minute run test was administered last. All measurements were conducted by the research team with assistance from the physical education teacher using uniform procedures.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 26. Descriptive statistics included mean, standard deviation, minimum, and maximum values. Distributional assumptions were assessed using the Shapiro–Wilk test (Shapiro & Wilk, 1965). Because BMI and VO_2max were not normally distributed, bivariate associations were examined using Spearman rank-order correlation; 95% confidence intervals for r_s were obtained with the Fisher z transformation using the Bonett–Wright standard error. Multiple linear regression was used to estimate the joint association of BMI and muscular fitness with VO_2max. Multicollinearity was evaluated using tolerance and variance inflation factor (VIF), residual normality was examined, and heteroskedasticity was assessed using the Breusch–Pagan test. Regression results are reported with unstandardized coefficients, standardized coefficients, 95% confidence intervals, R^2, adjusted R^2, F statistics, and p values. Results are interpreted mainly through effect estimates and their confidence intervals rather than through statistical significance alone ($\alpha = .05$). Because the sample comprised all eligible students, no a priori power analysis was performed; instead, a post hoc sensitivity analysis (noncentral F distribution, $\alpha = .05$, power = .80, two predictors, N = 20) was computed to indicate the smallest overall effect the regression model could reliably detect.

3. Results

Participant Characteristics

The study involved 20 students aged 14–16 years 12 girls and 8 boys. Mean age was 15.05 ± 0.51 years, mean stature was 155.45 ± 5.19 cm, mean body mass was 48.00 ± 9.83 kg, and mean BMI was 19.79 ± 3.45 kg/m^2. Mean squat, sit-up, and push-up performance was 44.80 ± 9.93, 29.80 ± 8.91, and 30.50 ± 8.82 repetitions, respectively. The composite muscular-fitness score averaged 31.40 ± 6.92 (range 20.00–47.00). Mean estimated VO_2max was 53.16 ± 3.45 mL·kg^{-1}·min^{-1} (range 49.25–60.58).

Table 1. Participant anthropometric and physical-fitness characteristics

Variable	Mean ± SD	Minimum	Maximum
Age (years)	15.05 ± 0.51	14.00	16.00
Stature (cm)	155.45 ± 5.19	147.00	163.00
Body mass (kg)	48.00 ± 9.83	35.20	68.40
BMI (kg/m^2)	19.79 ± 3.45	16.05	27.41
Squat (repetitions)	44.80 ± 9.93	24.00	59.00
Sit-up (repetitions)	29.80 ± 8.91	15.00	48.00
Push-up (repetitions)	30.50 ± 8.82	17.00	47.00
Composite muscular fitness	31.40 ± 6.92	20.00	47.00
VO_2max (mL·kg^{-1}·min^{-1})	53.16 ± 3.45	49.25	60.58

Note. N = 20. SD = standard deviation; BMI = body mass index

Assumption Testing and Bivariate Associations

The Shapiro–Wilk test indicated normality for the composite muscular-fitness score (p = .363), whereas BMI (p = .008) and VO_2max (p = .031) were non-normal. Regression residuals were normally distributed (p = .075). VIF was 1.009 for both predictors, indicating no multicollinearity, and the Breusch–Pagan test did not indicate heteroskedasticity (p = .939). Spearman analysis showed a very weak negative

association between BMI and VO_2max (r_s = −.064, 95% CI −.49 to .39, p = .789) and a very weak positive association between muscular fitness and VO_2max (r_s = .012, 95% CI −.43 to .45, p = .959). Both intervals are wide and include moderate associations in either direction.

Table 2. Correlations of BMI and muscular fitness with VO_2max

Variable	Spearman r_s	p	Interpretation
BMI	−.064	.789	Very weak negative; 95% CI −.49 to .39; not significant
Muscular fitness	.012	.959	Very weak positive; 95% CI −.43 to .45; not significant

Note. N = 20. r_s = Spearman rank-order correlation; CI = confidence interval (Fisher z transformation, Bonett–Wright standard error).

Multiple Regression

The multiple linear regression model was not statistically significant, F(2, 17) = 0.077, p = .926, and explained only 0.9% of VO_2max variance (R^2 = .009; adjusted R^2 = −.108; the negative adjusted value indicates no explanatory gain beyond chance). BMI had B = −0.082 (95% CI [−0.593, 0.430], p = .741): each 1 kg/m^2 higher BMI was associated with 0.08 mL·kg^{-1}·min^{-1} lower estimated VO_2max, and the interval is compatible with differences from about −0.6 to +0.4 mL·kg^{-1}·min^{-1} per kg/m^2. Muscular fitness had B = −0.028 (95% CI [−0.283, 0.227], p = .820) per one-unit increase in the composite score. The resulting equation was VO_2max = 55.648 − 0.082(BMI) − 0.028(muscular fitness). With N = 20 and two predictors, the sensitivity analysis indicated 80% power only for effects of about R^2 = .37 (f^2 = 0.58); smaller associations could not be reliably detected, and the equation should not be used for prediction.

Table 3. Multiple linear regression predicting VO_2max

Predictor	B	SE	β	t	p	95% CI
Constant	55.648	6.437	–	8.645	< .001	42.068 to 69.229
BMI	−0.082	0.242	−.081	−0.336	.741	−0.593 to 0.430
Muscular fitness	−0.028	0.121	−.056	−0.232	.820	−0.283 to 0.227

Note. N = 20. B = unstandardized coefficient; SE = standard error; β = standardized coefficient; CI = confidence interval. Model: F(2, 17) = 0.077, p = .926; R^2 = .009; adjusted R^2 = −.108.

4. Discussion

This exploratory study examined whether BMI and muscular fitness are jointly associated with estimated aerobic capacity among junior high school students aged 14–16 years. Neither predictor was significantly associated with VO_2max, and the combined regression model explained 0.9% of its variance. However, the confidence intervals were wide, so the data are compatible with no association as well as with associations of moderate size in either direction; the results therefore do not show that BMI or muscular fitness are unrelated to aerobic capacity. They are consistent with the view that CRF in youth reflects interacting cardiovascular, respiratory, muscular, anthropometric, behavioral, and developmental influences (Raghuveer et al., 2020; Rosa et al., 2024).

The direction of the BMI–VO_2max association was negative, although extremely weak and imprecisely estimated. A negative association would be plausible if greater non-metabolically active mass lowered running performance, but this was not measured and the present data cannot confirm it. BMI does not distinguish adipose from lean tissue, so two adolescents with similar BMI may differ substantially in body composition and aerobic performance (Dykstra et al., 2024; Ortega et al., 2008). In addition, because VO_2max was estimated from running distance only, body mass entered the outcome only indirectly through running performance, which may further weaken any BMI association. The small sample and the modest BMI range (16.05–27.41 kg/m^2) may also have limited the ability to detect an association.

The weak association between muscular fitness and VO_2max is not unexpected. Squat, sit-up, and push-up tests predominantly reflect local muscular endurance, whereas maximal aerobic capacity depends strongly on oxygen delivery and utilization. The literature is not uniform: a three-year follow-up of adolescent girls reported that muscular fitness, including squat and sit-up performance, was associated with later cardiorespiratory fitness (Kasović et al., 2024), whereas a large study found that

cardiorespiratory and muscular fitness have partly distinct correlates (Rosa et al., 2024). Differences in sex composition, age, tests, and design may explain these differences, but the present sample was too small, and its sex composition too poorly characterized for a sex-stratified analysis, to address this. Muscular fitness nevertheless has independent health relevance and is associated with cardiometabolic outcomes in youth (de Lima et al., 2022).

The very low R^2 indicates that other determinants likely accounted for most interindividual differences in aerobic capacity, although this interpretation is tentative because none of them was measured here. Physical activity, training history, biological maturation, sex, body composition, hemoglobin status, sleep, nutrition, and motivation during field testing may contribute to CRF variability (Raghuveer et al., 2020). School-based interventions show that structured physical activity can improve CRF (Minatto et al., 2016; Wang et al., 2026), and exercise interventions in youth with overweight or obesity also improve CRF (Cao et al., 2026); these studies address change after training rather than the cross-sectional associations examined here.

The restricted range of the outcome should also be considered. Estimated VO_2max values spanned only 49.25–60.58 $mL \cdot kg^{-1} \cdot min^{-1}$ (SD = 3.45), which limits between-participant variability and may attenuate correlations. In addition, field-based estimates of aerobic capacity contain measurement and prediction error. A systematic review indicates that the reliability and criterion validity of the Cooper test in pre-adolescents and adolescents vary across protocols and populations (Martínez-Lemos et al., 2024), and the validity of other field tests also depends on age and population (Mayorga-Vega et al., 2015), underscoring the importance of population-appropriate equations and careful interpretation of estimated VO_2max.

The present findings are too imprecise to support specific recommendations for physical education (PJOK) teachers on their own. Read together with the broader literature, they are consistent with the caution that aerobic capacity should not be inferred from BMI or muscular-endurance tests alone. Where resources allow, a school fitness assessment that includes anthropometry, a dedicated CRF test, and muscular-fitness measures captures different aspects of health-related fitness (Rosa et al., 2024), in line with evidence that physical fitness is an important health marker in youth and that CRF surveillance is recommended in pediatric populations (Ortega et al., 2008; Raghuveer et al., 2020). Fitness may also have educational relevance, as systematic reviews report positive associations between CRF or overall fitness and academic performance (Santana et al., 2017), although this was not examined here.

Strengths of this study include standardized field procedures, assessment of multiple muscular-endurance components, and joint analysis of BMI and muscular fitness with confidence-interval reporting. Its limitations are: (1) the very small sample (N = 20), which limits power, makes regression estimates unstable, and restricts generalizability, with only large effects ($R^2 \approx .37$) reliably detectable; (2) the cross-sectional design, which precludes causal inference; (3) BMI does not quantify body composition, and sex, physical activity, and biological maturation were not measured or adjusted for; (4) the Cooper test gives an indirect estimate of VO_2max whose validity in adolescents is uncertain; and (5) the muscular-fitness composite has no established norms, which limits comparison with other studies. Future studies should recruit larger and more heterogeneous samples, analyze boys and girls separately or adjust for sex, include direct or validated age-specific measures of body composition and aerobic capacity, and consider physical activity, maturation, and lifestyle covariates.

5. Conclusion

In this small exploratory sample of junior high school students aged 14–16 years, no significant association of BMI or muscular fitness with estimated aerobic capacity was detected, and their combined contribution was minimal (0.9% of VO_2max variance). Because the confidence intervals were wide and the study could reliably detect only large effects, these results do not show that the variables are unrelated. Aerobic capacity in adolescents should be evaluated as a multidimensional characteristic rather than inferred from BMI or muscular-endurance performance alone. Future research should use larger, sex-balanced samples and include body composition, habitual physical activity, maturation, and lifestyle factors.

6. Author Contributions

Andi Ihsan: conceptualization, methodology, investigation, data curation, formal analysis, and writing – original draft. Muhammad Rizky Al Mufarid: methodology, investigation, and writing – review and editing.

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