INDONESIAN JOURNAL OF RESEARCH IN PHYSICAL EDUCATION, SPORT, AND HEALTH
e-ISSN: 2986-8831
Vol. 4 No 1, April 2026

Research Article

Cardiorespiratory fitness in Indonesian adolescents: Limited role of BMI and dominant influence of age and sex in a large cross-sectional study

Anies Setiowati[1*], Sri Sumartiningsih[2], Nur Ilhaini Sucipto[3], Fatih Hazar[4], Philip X. Fuchs[5]
[1,2] Department of Sports Science, Faculty of Sports Science, Universitas Negeri Semarang, Indonesia
[3] Departement of Medicine, College of Medicine, Taipei Medical University, Taipei, Taiwan
[4] Department of Sports Science, Faculty of Sport Sciences, Bitlis Eren University, Türkiye
[5] Department of Physical Education and Sport Sciences, National Taiwan Normal University, Taipei,Taiwan

*Corresponding author, email: setiowatianies@mail.unnes.ac.id

ABSTRACT
Background: Cardiorespiratory fitness (CRF) is a crucial indicator of long-term cardiovascular and metabolic health. Whether body mass index (BMI) independently predicts CRF beyond demographic factors in large, real-world adolescent cohorts remains inconsistently defined. Objective: To determine the independent contributions of body mass index (BMI), age, and sex to cardiorespiratory fitness among Indonesian adolescents using a large community-based dataset.. Methods: A cross-sectional study was conducted using community-based fitness screening data from Central Java, Indonesia. A total of 2,730 adolescents aged 10-18 years (mean 13.3 +/- 2.2 years; 49.6% male) were included. The primary outcome was CRF measured by the 1,600-meter run time (seconds). BMI was analyzed as both a continuous and a categorical variable. Multivariable linear regression models, including non-linear Restricted Cubic Spline (RCS) modeling, were applied. Result: The median run time was 453.0 seconds (IQR 360.6-660.0). Males ran significantly faster than females (491.4 vs. 658.6 seconds; t = -3.02, p = 0.003). BMI category was not significantly associated with run time (ANOVA F = 0.34, p = 0.799) or in adjusted models (beta = 3.8, p = 0.621). Age (beta = 56.7 s/year, p < 0.001) and sex (beta = 156.5 s, p = 0.005) were the sole significant predictors. Neither linear nor non-linear BMI modeling improved model fit (adjusted R2 ~1.0%). Conclusion: BMI did not independently predict CRF in this large Indonesian adolescent cohort. Age and sex were the dominant predictors. These findings challenge the use of BMI as a CRF surrogate in school-based health screening and call for direct fitness assessments with age- and sex-standardized benchmarks.

ARTICLE HISTORY
Received January 21, 2026
Accepted March 31, 2026
Published April 01, 2026
KEYWORDS
Adolescents; body mass index; cardiorespiratory fitness; school-based health screening.

Introduction

Cardiorespiratory fitness (CRF) represents the capacity of the cardiovascular and respiratory systems to deliver oxygen to working skeletal muscles during sustained physical activity. It is widely recognized as one of the most powerful predictors of all-cause and cardiovascular mortality (Ross et al., 2016). Low CRF in childhood and adolescence is independently associated with heightened risk of non-communicable diseases (NCDs), including hypertension, type 2 diabetes mellitus, metabolic syndrome, and dyslipidemia in early adulthood (Mintjens et al., 2018; Schmidt et al., 2016).

Over the past four decades, the global prevalence of overweight and obesity among adolescents has increased substantially, representing a major public health concern (Abarca-Gómez et al., 2017). This trend is also evident in Southeast Asia, including Indonesia, where rapid urbanization and lifestyle transitions have contributed to declining physical activity levels. The 2022 Indonesia Report Card on Physical Activity for Children and Adolescents assigned an 'F' grade for physical fitness, with mean VO_2max values of approximately 30.33 mL/kg/min in boys and 25.56 mL/kg/min in girls—levels below international normative standards (Active Healthy Kids Indonesia, 2022). National data from the 2023 Indonesian Health Survey indicate that more than half of adolescents are physically inactive, with prevalence rates of 58% among those aged 10–14 years and 50% among those aged 15–19 years (Kementerian Kesehatan Republik Indonesia, 2014).

Body mass index (BMI) has traditionally been used as a proxy indicator of adiposity and is frequently examined as a determinant of CRF, with evidence from high-income countries consistently demonstrating an inverse association between BMI and aerobic fitness, particularly among overweight and obese youth (Dykstra et al., 2024; Herraiz-Adillo et al., 2026; Rosa et al., 2024). However, the strength and nature of this relationship remain debated, as BMI does not distinguish between fat mass and lean body mass, potentially limiting its ability to reflect physiological fitness accurately (Chiang et al., 2022; Jarvis et al., 2024). Additionally, many studies rely on categorical BMI classifications, which may obscure non-linear or threshold effects across the BMI spectrum (Flegal et al., 2014). Although converting continuous BMI into categories may reduce statistical power, categorical BMI remains widely used in epidemiological and school health surveillance studies. Therefore, comparing continuous and categorical approaches to BMI may help clarify whether inconsistencies in the literature are partly attributable to information loss from categorization. Emerging research suggests that BMI may function as a mediating or confounding factor rather than a primary determinant of CRF (Zeiher et al., 2019).

In contrast, age and sex are well-established biological determinants of CRF. Aerobic fitness typically increases during adolescence due to growth and maturation, including improvements in cardiovascular efficiency and muscle mass (Armstrong & Welsman, 2019; Mačinskas et al., 2023). Sex differences are also consistently observed, with boys generally demonstrating higher CRF levels than girls, likely due to differences in body composition, hemoglobin concentration, and physical activity patterns (Tomkinson et al., 2019). Despite this, the relative contribution of BMI compared with these fundamental biological factors remains insufficiently explored, particularly in countries where standardized physical fitness surveillance systems and direct fitness testing remain limited. Differences in access to organized sport participation, physical activity opportunities, school-based fitness monitoring, and nutritional transitions may influence the relationship between anthropometric status and cardiorespiratory fitness across populations.

Evidence from Southeast Asia is notably limited, and findings from high-income countries may not be directly generalizable due to differences in environmental, cultural, and socioeconomic contexts. Importantly, it remains unclear whether BMI provides meaningful predictive value for CRF beyond its co-linearity with age and sex—an issue with significant implications for screening strategies and public health interventions.

Therefore, the present study utilized a large community-based dataset from Central Java, Indonesia, comprising 2,730 adolescents aged 10–18 years, to examine the association between body mass index (BMI) and cardiorespiratory fitness. Cardiorespiratory fitness was assessed using standardized field-based running tests: the 1,000-meter run for adolescents aged 10–12 years and the 1,600-meter run for those aged 13–18 years. These tests are widely used as practical indicators of aerobic capacity in school and public health settings (Lang et al., 2018). This study aimed to determine the independent contributions of BMI, age, and sex to the variation in cardiorespiratory fitness among Indonesian adolescents. It was hypothesized that age and sex would be significant predictors of cardiorespiratory fitness, whereas BMI would show only a weak independent association after adjustment for demographic factors.

Method

Research Design

This cross-sectional study utilized data from the 2024 Cardiorespiratory Fitness Screening Program conducted by the Semarang City Health Office, Central Java, Indonesia. The study population consisted of school-based adolescents recruited from multiple schools across subdistricts and community health center catchment areas in Semarang. The program aimed to assess physical fitness levels among school-aged youth as part of routine public health surveillance.

Participants

The original surveillance dataset, obtained from a 2024 Cardiorespiratory Fitness Screening Program conducted by a regional governmental health authority in Indonesia (anonymized for peer review), included 3,184 adolescents aged 10–18 years, in accordance with the Indonesian Ministry of Health's definition of adolescence (Kementerian Kesehatan Republik Indonesia, 2014). Participants were school-based adolescents recruited from multiple schools across subdistricts and community health center catchment areas. After excluding participants with incomplete data on running performance (1,000-meter or 1,600-meter run time) or body mass index (BMI) variables (n = 454), the final analytical sample comprised 2,730 adolescents, including 1,355 males and 1,375 females.

Ethical Approval Statement

This study received ethical approval from the Health Research Ethics Committee, Faculty of Medicine, Universitas Negeri Semarang, Indonesia (Approval No. 295/KEPK/FK/KLE/2026). All procedures were conducted in accordance with the principles of the Declaration of Helsinki. Participant data were anonymized prior to analysis to ensure confidentiality and privacy.

Research Instruments

Cardiorespiratory fitness was assessed using standardized running tests: a 1,000-meter test for participants aged 10–12 years and a 1,600-meter test for those aged 13–18 years, administered by trained health workers at community health centers. Participants were instructed to complete the assigned distance as quickly as possible under standardized conditions. Completion times recorded in MM: SS format were converted into total seconds for analysis. The running performance data were subsequently interpreted according to age-specific national reference standards established by the Indonesian Ministry of Health to obtain cardiorespiratory fitness classifications. For descriptive purposes, cardiorespiratory fitness levels were categorized as very poor, poor, fair, good, or excellent according to these standardized criteria (Kementerian Kesehatan Republik Indonesia, 2019).

BMI was calculated as weight (kg)/height2 (m2). For regression, continuous BMI was used. For descriptive analyses, participants were classified as underweight (BMI < 18.5), normal (18.5-22.9), overweight (23.0-24.9), or obese (>=25.0 kg/m2) using Asian-Pacific cut-offs. (Masih et al., 2023). The exact fractional age was calculated from the date of birth to the assessment date. Sex was coded as Male (0) or Female (1).

Data Analysis

Descriptive statistics reported as mean +/SD or median (IQR) for continuous, and frequency (%) for categorical variables. Normality and homogeneity assumptions were assessed using Shapiro–Wilk test, and Levene's test Group comparisons used Welch's t-test (sex) and one-way ANOVA (BMI categories). Three multivariable linear regression models were built: Model 1 (linear BMI), Model 2 (sex × BMI interaction), and Model 3 (natural cubic spline of BMI, 3 df) using the splines package. Model comparisons used likelihood ratio tests. All analyses performed in R version 4.5.2. Statistical significance: alpha = 0.05 (two-tailed).

Methodological triangulation was conducted by comparing findings from classroom observations, interview responses, video analysis, and reflection documents. Data integration at the interpretation stage enabled a comprehensive understanding of how LS contributed to improvements in ALT-PE effectiveness and instructional quality.

Results and Discussion

Results

Participant Characteristics

A total of 2,730 adolescents were included: 1,355 males (49.6%) and 1,375 females (50.4%), with a mean age of 13.3 +/- 2.2 years (range 10.0-18.0). Mean BMI was 18.9 +/- 3.8 kg/m2. Most participants had normal BMI (72.7%), with 15.6% overweight, 10.6% underweight, and 1.1% obese. Participant characteristics are detailed in Table 1 (by sex) and Table 2 (by BMI category) below.

Table 1. Baseline Characteristics of Study Participants by Sex

Variable	Overall N = 2,730[1]	Male N = 1,355[1]	Female N = 1,375[1]	p-value[2]
Age (years)	13.3 (2.2)	13.3 (2.1)	13.4 (2.3)	0.077
BMI (kg/m²)	18.9 (3.8)	18.9 (3.9)	18.9 (3.6)	0.5
BMI Category				<0.001
Underweight	290 (11%)	173 (13%)	117 (8.5%)	
Normal	1,984 (73%)	915 (68%)	1,069 (78%)	
Overweight	427 (16%)	246 (18%)	181 (13%)	
Obese	29 (1.1%)	21 (1.5%)	8 (0.6%)	
Run Time (seconds)	575.6 (1,460.0)	491.4 (230.8)	658.6 (2,041.4)	<0.001
Fitness Category				<0.001
Unfit	20 (0.7%)	13 (1.0%)	7 (0.5%)	
Very Poor	750 (27%)	423 (31%)	327 (24%)	
Poor	367 (13%)	202 (15%)	165 (12%)	
Fair	724 (27%)	355 (26%)	369 (27%)	
Good	461 (17%)	194 (14%)	267 (19%)	
Exellent	408 (15%)	168 (12%)	240 (17%)	

[1]Mean (SD); n (%)

[2]Wilcoxon rank sum test; Pearson's Chi-squared test

Table 2. Baseline Characteristics Stratified by BMI Category

Variable	Overall N = 2,730[1]	Underweight N = 290[1]	Normal N = 1,984[1]	Overweight N = 427[1]	Obese N = 29[1]	p-value[2]
Age (years)	13.3 (2.2)	13.3 (2.2)	13.4 (2.2)	13.1 (2.2)	11.8 (1.9)	<0.001
Sex						<0.001
Male	1,355 (50%)	173 (60%)	915 (46%)	246 (58%)	21 (72%)	
Female	1,375 (50%)	117 (40%)	1,069 (54%)	181 (42%)	8 (28%)	
Run Time (seconds)	575.6 (1,460.0)	522.0 (279.4)	592.2 (1,704.0)	533.4 (277.9)	594.8 (241.0)	0.2
Fitness Category						
Unfit	20 (0.7%)	1 (0.3%)	13 (0.7%)	6 (1.4%)	0 (0%)	
Very Poor	750 (27%)	86 (30%)	507 (26%)	144 (34%)	13 (45%)	
Poor	367 (13%)	37 (13%)	275 (14%)	50 (12%)	5 (17%)	
Fair	724 (27%)	63 (22%)	549 (28%)	102 (24%)	10 (34%)	
Good	461 (17%)	51 (18%)	344 (17%)	65 (15%)	1 (3.4%)	
Exellent	408 (15%)	52 (18%)	296 (15%)	60 (14%)	0 (0%)	

[1]Mean (SD); n (%)

[2]Kruskal-Wallis rank sum test; Pearson's Chi-squared test; NA

Sex Differences in Cardiorespiratory Fitness

The overall median run time was 453.0 seconds (IQR 360.6-660.0). Males completed the 1,600 m run significantly faster than females (mean 491.4 +/- 231.0 vs. 658.6 +/- 2,041.0 seconds; Welch's t = -3.02, df = 1,409.6, p = 0.003). The markedly high standard deviation in females likely reflects measurement heterogeneity across multi-site field conditions, discussed further in Section 4.

CRF Across BMI Categories

Mean run times by BMI category were underweight 522 +/- 279 s; normal 592 +/- 1,704 s; overweight 533 +/- 278 s; and obese 595 +/- 241 s. No statistically significant difference in run time was observed across BMI categories (ANOVA: F3,2726 = 0.34, p = 0.799). Results are summarised in Table 2 and illustrated in Figure 1.

Multivariable Regression Analysis

Model 1, age was the only significant predictor of run time (beta = 56.7 s/year, 95% CI 31.2-82.3, p < 0.001). Female sex was also significant (beta = 156.5 s, 95% CI 47.3-265.7, p = 0.005). Continuous BMI was not significant (beta = 3.8, p = 0.621). Adjusted R2 = 0.010. In Model 2, neither BMI (p = 0.811) nor the sex x BMI interaction (p = 0.841) was significant; no improvement over Model 1 (F1,2722 = 0.04, p = 0.841). In Model 3 (RCS), all spline components were non-significant (all p > 0.44), confirming the absence of non-linear BMI effects. Findings from all models are presented in Table 3. The spline curves are illustrated in Figure 2.

Table 3. Multivariable Linear Regression Models for Run Time (seconds)

	Model 1 (Linear)			Model 2 (Interaction)			Model 3 (Splines)		
Characteristic	Beta	95% CI	p-value	Beta	95% CI	p-value	Beta	95% CI	p-value
Age	57	31, 82	<0.001	57	31, 82	<0.001	55	29, 81	<0.001
Sex			0.005			0.7			0.006
Male	—	—		—	—		—	—	
Female	156	47, 266		100	-463, 663		154	45, 264	
BMI	3.8	-11, 19	0.6	2.5	-18, 23	0.8			
Sex * BMI						0.8			
Female * BMI				3.0	-26, 32				
ns(BMI, df = 3)									0.9
ns(BMI, df = 3)1							140	-218, 498	
ns(BMI, df = 3)2							442	-902, 1,785	
ns(BMI, df = 3)3							114	-676, 903	

Abbreviation: CI = Confidence Interval

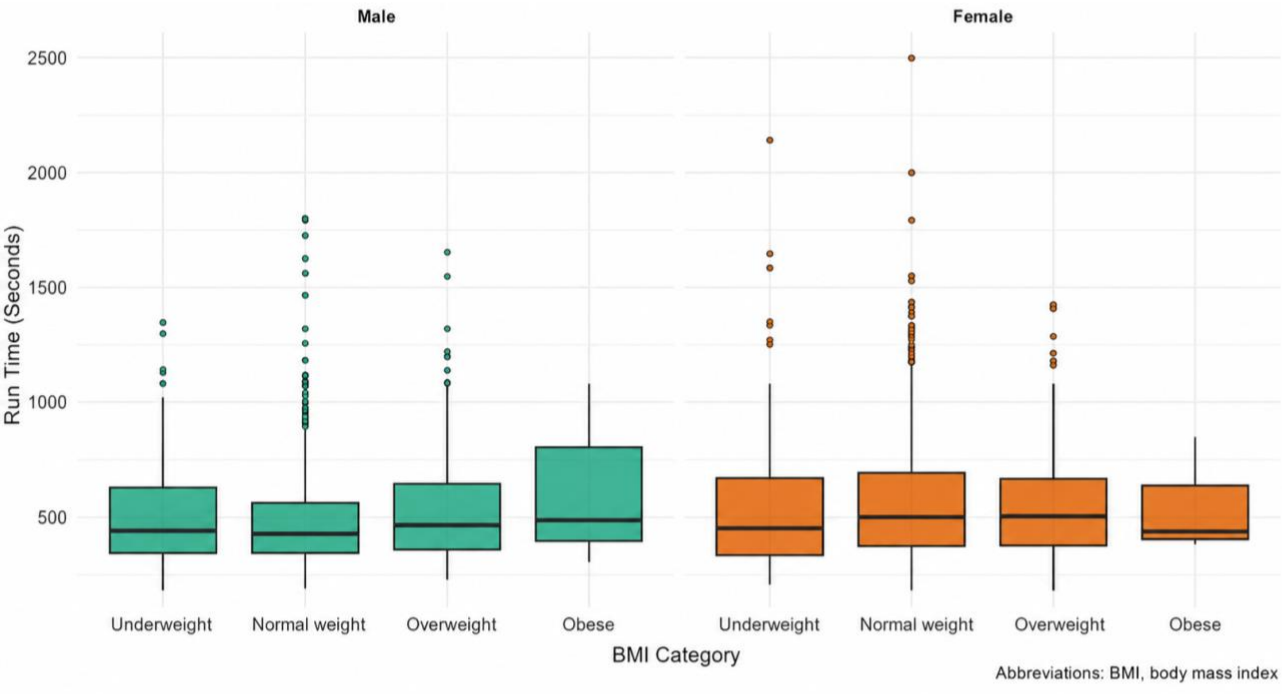

Figure 1. Distribution of Run Time by BMI Category and Sex

Figure 1 shows the distribution of run time by BMI category and sex. Overall, males consistently run faster than females across all BMI categories, indicating better cardiorespiratory fitness. There is no clear pattern or meaningful difference in running time across BMI categories, as the distributions largely overlap. Additionally, greater variability and more extreme values are observed among females. These findings suggest that sex plays a more important role than BMI in determining CRF.

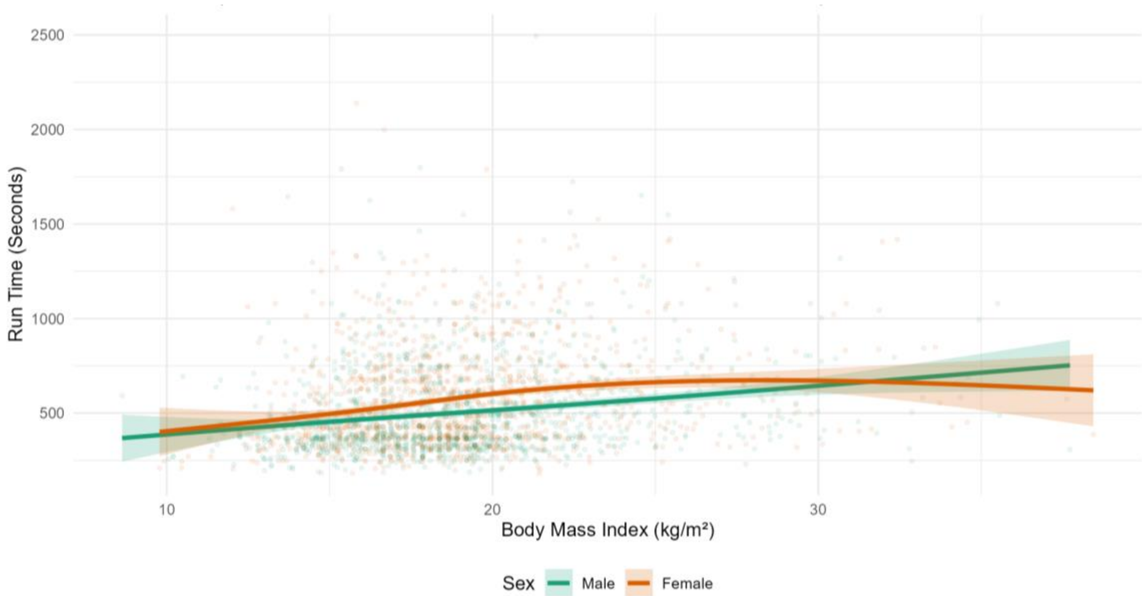

Figure 2. Non-Linear Restricted Cubic Spline Curve of BMI vs Run Time by Sex

Figure 2 shows a weak, nearly flat, nonlinear relationship between BMI and running time for both sexes. The wide, overlapping confidence intervals indicate high variability and no meaningful association, suggesting that BMI is not a strong predictor of CRF. Shaded bands represent 95% confidence intervals, and the spline was modeled with 3 degrees of freedom (natural cubic splines).

Discussion

This large cross-sectional study of 2,730 Indonesian adolescents demonstrates that BMI—whether modeled as a continuous, categorical, or flexible non-linear spline—does not independently predict cardiorespiratory fitness (CRF) after adjustment for age and sex. Instead, age (~57 s/year) and sex (~157 s difference) emerged as the only consistent determinants of CRF performance. These findings reinforce growing evidence that BMI may be an insufficient proxy for aerobic fitness in youth populations. As a crude anthropometric indicator, BMI fails to capture key physiological components, including fat distribution, skeletal muscle mass, and cardiorespiratory reserve capacity (Musálek et al., 2020; Wu et al., 2024). Consequently, adolescents with normal BMI may still exhibit poor fitness due to sedentary behavior. At the same time, some overweight individuals with higher lean mass may maintain adequate CRF, consistent with the "metabolically healthy obese" phenotype (Murlasits et al., 2022). The very low prevalence of obesity in this cohort (1.1%) may have further attenuated the ability to detect any meaningful BMI–CRF association.

The strong influence of age and sex observed in this study aligns with well-established biological mechanisms underpinning CRF development. Aerobic capacity typically evolves during adolescence through growth- and maturation-related improvements in cardiovascular efficiency, oxygen transport, and muscle mass (Ledergerber et al., 2026). The observed sex differences—where males demonstrated superior CRF performance—are consistent with global findings and are largely attributable to higher hemoglobin concentration, greater lean mass accrual, and enhanced cardiac output following puberty (Domaradzki et al., 2025). Interestingly, the finding that older age was associated with slower run times may reflect contextual factors, such as reduced motivation, declining physical activity, or selection bias among older adolescents, highlighting the need for future studies that incorporate behavioral and longitudinal data (Domaradzki et al., 2022; Rosa et al., 2024).

Importantly, these findings have direct public health implications. The absence of a significant BMI–CRF association suggests that reliance on BMI alone in school-based health screening may lead to substantial misclassification of fitness status. Notably, 41.6% of participants in this study were classified as having poor or very poor CRF regardless of BMI category, indicating that low fitness is a population-wide issue rather than one confined to overweight or obese individuals. This supports global recommendations emphasizing direct assessment of CRF using field-based fitness tests, such as the 20-m shuttle run or Cooper test, alongside the development of age- and sex-specific normative benchmarks (Lang et al., 2018; Tomkinson et al., 2019). In Indonesia, strengthening the Physical Fitness Program by incorporating standardized CRF assessment tools and national reference values may substantially improve adolescent health surveillance and risk stratification.

Limitations of Study

Several limitations should be acknowledged. The cross-sectional design precludes causal inference, and the use of multi-site field testing may have introduced measurement variability in run-time outcomes. Additionally, the absence of key covariates—such as physical activity levels, dietary intake, pubertal status, and socioeconomic factors—limits the ability to disentangle the determinants of CRF fully. Blood pressure data were available only for a subset of participants, restricting cardiometabolic subgroup analyses, and BMI measurements obtained in field settings may be subject to measurement error.

Despite these limitations, this study has several notable strengths. It utilizes a large, population-based sample of Indonesian adolescents, a population underrepresented in global CRF literature. The use of a continuous CRF outcome, combined with both linear and flexible non-linear modeling approaches (Restricted Cubic Splines), provides a robust and comprehensive evaluation of the BMI–CRF relationship. Collectively, these findings contribute important context-specific evidence and challenge the prevailing reliance on BMI as a primary indicator of adolescent fitness.

Conclusions

In this large community-based cross-sectional study of 2,730 Indonesian adolescents aged 10-18 years, BMI did not significantly predict cardiorespiratory fitness in unadjusted or multivariable-adjusted analyses, including non-linear spline modeling. Age and sex were the dominant predictors. These findings challenge the use of BMI as a primary fitness marker in school-based health screening. Indonesian health authorities should prioritize the use of direct CRF measurement tools and develop age- and sex-specific fitness norms to improve the accuracy of adolescent health risk stratification.

Acknowledgments

The authors would like to express their sincere appreciation to the Semarang City Health Office and all participating schools for their support in implementing the Cardiorespiratory Fitness Screening Program. The authors also thank the health personnel and field staff for their assistance in data collection, as well as all students who participated in this study.

Authors' contributions

A.S. conceived and designed the study, performed the data analysis, interpreted the findings, and drafted the manuscript. S.S. supervised the study and critically revised the manuscript. N.I.S. and F.H. contributed to data interpretation and manuscript revision. P.X.F. provided methodological guidance and critically reviewed the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare no competing interests.

AI Disclosure Statement

During the preparation of this manuscript, the authors used DeepL Translate and Grammarly to support translation, grammar checking, and language refinement. All generated outputs were carefully reviewed and edited by the authors to ensure accuracy, clarity, and adherence to academic standards. The authors take full responsibility for the content of this manuscript.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to restrictions containing information that could compromise the privacy of research participants.

Funding

This research received no external funding.

Publisher's Note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors, and the reviewers. Any product that may be evaluated in this article, or a claim its manufacturer may make, is not guaranteed or endorsed by the publisher.

References

Abarca-Gómez, L., Abdeen, Z. A., Hamid, Z. A., Abu-Rmeileh, N. M., Acosta-Cazares, B., Acuin, C., Adams, R. J., Aekplakorn, W., Afsana, K., Aguilar-Salinas, C. A., Agyemang, C., Ahmadvand, A., Ahrens, W., Ajlouni, K., Akhtaeva, N., Al-Hazzaa, H. M., Al-Othman, A. R., Al-Raddadi, R., Al Buhairan, F. (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. *The Lancet, 390*(10113), 2627–2642. [Crossref]

Active Healthy Kids Indonesia. (2022). The 2022 Indonesia report card on physical activity for children and adolescents (Global Matrix 4.0). [Crossref]

Armstrong, N., & Welsman, J. (2019). Development of peak oxygen uptake from 11–16 years was determined using both treadmill and cycle ergometry. *European Journal of Applied Physiology, 119*(3), 801–812. [Crossref]

Chiang, H. H., Lee, P. F., Chen, Y. T., Lin, C. F., Xu, S., Lin, Y. T., Lin, Y. T., Su, Y. J., Shia, B. C., ChangChien, W. S., & Ho, C. C. (2022). Low Cardiorespiratory Fitness, Muscular Fitness, and Flexibility Are Associated with Body Fat Distribution and Obesity Risk Using Bioelectrical Impedance in Taiwanese Adults. *International Journal of Environmental Research and Public Health, 19*(14), 8858. [Crossref]

Domaradzki, J., Alvarez, C., Szafraniec, R., & Koźlenia, D. (2025). Biological maturation determines the beneficial effects of high-intensity functional training on cardiorespiratory fitness in male adolescents. *PeerJ, 13*, e19756. [Crossref]

Domaradzki, J., Koźlenia, D., & Popowczak, M. (2022). The Relative Importance of Age at Peak Height Velocity and Fat Mass Index in High-Intensity Interval Training Effect on Cardiorespiratory Fitness in Adolescents: A Randomized Controlled Trial. *Children, 9*(10), 1554. [Crossref]

Dykstra, B. J., Griffith, G. J., Renfrow, M. S., Mahon, A. D., & Harber, M. P. (2024). Cardiorespiratory and Muscular Fitness in Children and Adolescents with Obesity. *Current Cardiology Reports, 26*(5), 349–357. [Crossref]

Flegal, K. M., Kit, B. K., & Graubard, B. I. (2014). Body Mass Index Categories in Observational Studies of Weight and Risk of Death. *American Journal of Epidemiology, 180*(3), 288–296. [Crossref]

Herraiz-Adillo, Á., Ahlqvist, V. H., Hedman, K., Higueras-Fresnillo, S., Hagström, E., Fortuin-de Smidt, M., Daka, B., Lenander, C., Olsson, A., Berglind, D., Östgren, C. J., Rådholm, K., Ortega, F. B., & Henriksson, P. (2026). Associations of Adolescent BMI and Physical Fitness With Cardiovascular Health in Middle Age: A Population-Based Prospective Study of Swedish Men. *American Journal of Preventive Medicine, 70*(4), 108128. [Crossref]

Jarvis, S., Giles, H., & New, K. J. (2024). The Cardiorespiratory Fitness of Children and the Anthropometric Determinants During Late Childhood Within South East Wales: Potential Implications for Future Health. *Global Pediatric Health, 11*, 2333794X241259908. [Crossref]

Kementerian Kesehatan Republik Indonesia. (2014). Peraturan Menteri Kesehatan Republik Indonesia Nomor 25 Tahun 2014. In Berita Negara Republik Indonesia Tahun 2014. [Crossref]

Kementerian Kesehatan Republik Indonesia. (2019). Panduan Pembinaan Kebugaran Jasmani Bagi Peserta Didik Melalui Uks/M. Direktorat Kesehatan Kerja dan Olahraga Direktorat Jenderal Kesehatan Masyarakat Kementerian Kesehatan RI Tahun 2019. [Crossref]

Lang, J. J., Wolfe Phillips, E., Orpana, H. M., Tremblay, M. S., Ross, R., Ortega, F. B., Silva, D. A. S., & Tomkinson, G. R. (2018). Field-based measurement of cardiorespiratory fitness to evaluate physical activity interventions. *Bulletin of the World Health Organization, 96*(11), 794–796. [Crossref]

Ledergerber, R., Faude, O., & Donath, L. (2026). Development and Trainability of Cardiorespiratory Fitness Across Childhood and Adolescence. *Current Issues in Sport Science (CISS), 11*(2), 006. [Crossref]

Mačinskas, E., Stasiulė, L., Pužas, K., & Stasiulis, A. (2023). Physiological Variables that Contribute to Aerobic Fitness in Boys During Early Adolescence in the Context of Basketball Training and the Maturity Level. *Journal of Human Kinetics, 86*(1), 145–154. [Crossref]

Masih, D., Rakhra, G., Vats, A., Verma, S. K., Singh, V. K., Kirar, V., Tripathi, J. K., & Singh, S. N. (2023). Optimal Cut-Off Values for Body Mass Index and Fat Mass Index Based on Age in Physically Active Males Using Receiver Operating Characteristic Curve. *Diseases, 11*(4), 137. [Crossref]

Mintjens, S., Menting, M. D., Daams, J. G., van Poppel, M. N. M., Roseboom, T. J., & Gemke, R. J. B. J. (2018). Cardiorespiratory Fitness in Childhood and Adolescence Affects Future Cardiovascular Risk Factors: A Systematic Review of Longitudinal Studies. *Sports Medicine, 48*(11), 2577–2605. [Crossref]

Murlasits, Z., Kupai, K., & Kneffel, Z. (2022). Role of physical activity and cardiorespiratory fitness in metabolically healthy obesity: a narrative review. *BMJ Open Sport & Exercise Medicine, 8*(4), e001458. [Crossref]

Musálek, M., Clark, C. C. T., Kokštejn, J., Vokounova, Š., Hnízdil, J., & Mess, F. (2020). Impaired Cardiorespiratory Fitness and Muscle Strength in Children with Normal-Weight Obesity. *International Journal of Environmental Research and Public Health, 17*(24), 9198. [Crossref]

Rosa, G. B., Staiano, V., Ponikvar, K., Magalhães, J. P., Correia, I. R., Hetherington-Rauth, M., & Sardinha, L. B. (2024). Cardiorespiratory fitness and muscular fitness correlates in youth: A hierarchy of behavioral, contextual, and health-related outcomes. *Journal of Science and Medicine in Sport, 27*(7), 486–492. [Crossref]

Ross, R., Blair, S. N., Arena, R., Church, T. S., Després, J.-P., Franklin, B. A., Haskell, W. L., Kaminsky, L. A., Levine, B. D., Lavie, C. J., Myers, J., Niebauer, J., Sallis, R., Sawada, S. S., Sui, X., & Wisløff, U. (2016). Importance of Assessing Cardiorespiratory Fitness in Clinical Practice: A Case for Fitness as a Clinical Vital Sign: A Scientific Statement From the American Heart Association. *Circulation, 134*(24). [Crossref]

Schmidt, M. D., Magnussen, C. G., Rees, E., Dwyer, T., & Venn, A. J. (2016). Childhood fitness reduces the long-term cardiometabolic risks associated with childhood obesity. *International Journal of Obesity, 40*(7), 1134–1140. [Crossref]

Tomkinson, G. R., Lang, J. J., & Tremblay, M. S. (2019a). Temporal trends in the cardiorespiratory fitness of children and adolescents representing 19 high-income and upper middle-income countries between 1981 and 2014. *British Journal of Sports Medicine, 53*(8), 478–486. [Crossref]

Wu, Y., Li, D., & Vermund, S. H. (2024). Advantages and Limitations of the Body Mass Index (BMI) to Assess Adult Obesity. *International Journal of Environmental Research and Public Health, 21*(6), 757. [Crossref]

Zeiher, J., Ombrellaro, K. J., Perumal, N., Keil, T., Mensink, G. B., & Finger, J. D. (2019). Correlates and determinants of cardiorespiratory fitness in adults: a systematic review. *Sports medicine-open, 5*(1), 39. [Crossref]