

Body Composition and Anthropometric Indicators as Predictors of Health-Related Fitness

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ABSTRACT

Background: Cardiorespiratory fitness is a key health indicator in young adults and can be influenced by anthropometric characteristics and body composition. Body Mass Index (BMI), body fat percentage, and Waist-to-Hip Ratio (WHR) are indicators that can be used to describe these characteristics. However, findings regarding the contribution of each indicator to cardiorespiratory fitness remain inconsistent. This study aims to analyze the relationship of BMI, body fat percentage, and WHR with the cardiorespiratory fitness index among university students.

Research Methods: This study employed a cross-sectional design involving second-year students from the Department of Nutrition at Poltekkes Kemenkes Surabaya. A total of 98 respondents participated in the study. Data collected included body weight, height, body fat percentage, waist circumference, and hip circumference. Cardiorespiratory fitness was measured using the Harvard Step Test. Bivariate analysis was conducted using Spearman correlation, while multivariate analysis utilized multiple linear regression with heteroskedasticity-consistent standard errors (HC3).

Research Result: The mean age of the respondents was 18.68 ± 0.62 years; BMI was 22.65 ± 4.86 kg/m²; body fat percentage was $27.67 \pm 6.70\%$; WHR was 0.80 ± 0.06 ; and the Harvard Step Test score was 71.31 ± 16.51 . Bivariate analysis revealed a very strong negative correlation between BMI and the Harvard Step Test ($r = -0.816$; $p < 0.001$) and a moderate negative correlation between body fat percentage and the Harvard Step Test ($r = -0.508$; $p < 0.001$). WHR did not show a significant relationship with the Harvard Step Test ($r = -0.191$; $p = 0.059$). Regression analysis indicated that BMI was the only significant predictor when controlled for body fat percentage and WHR ($B = -2.863$; 95% CI: -3.945 to -1.780 ; $p < 0.001$). Body fat percentage ($B = 0.285$; $p = 0.377$) and WHR ($B = -26.037$; $p = 0.246$) did not show significant associations. The model simultaneously explained 57.9% of the variation in the Harvard Step Test, with an Adjusted R² of 56.6%.

Conclusion: BMI is the anthropometric indicator most consistently associated with the cardiorespiratory fitness index among university students. The higher the BMI, the lower the Harvard Step Test score. Although body fat percentage showed an association in the bivariate analysis, this relationship was no longer significant after controlling for BMI and the waist-to-hip ratio.

BACKGROUND

The advancement of digital technology is driving changes in the activity patterns of Generation Z, with an increasing number of activities being sedentary and involving the use of gadgets. This situation has the potential to reduce physical activity and increase the risk of being overweight or obese (Bai, Herforth and Masters, 2022). According to the 2023 Indonesian Health Survey (SKI), 23.4% of Indonesia's population engages in insufficient physical activity. (Kemenkes, 2023).

Body Mass Index (BMI) is a simple and widely used anthropometric indicator for assessing nutritional status based on weight and height. However, BMI cannot distinguish between fat mass and fat-free mass; consequently, individuals with the same BMI may have different body fat compositions and distributions (WHO, 1999).

The limitations of BMI need to be addressed by measuring body fat percentage and the Waist-to-Hip Ratio (WHR) to characterize the amount and distribution of body fat. Fat accumulation—particularly visceral fat—is associated with metabolic disorders and an increased risk of type 2 diabetes mellitus and cardiovascular disease (Fatimah et al., 2017).

Cardiorespiratory fitness is an important indicator of health in young people and reflects the body's ability to utilize oxygen during physical activity. One such indicator is maximal oxygen uptake ($\text{VO}_{2\text{max}}$), with higher values indicating better aerobic capacity and cardiorespiratory fitness.

The relationship between anthropometric status, body composition, and cardiorespiratory fitness has been reported in several studies. Research by Gantarialdha (2021) indicates a negative relationship between BMI and $\text{VO}_{2\text{max}}$; specifically, the higher the BMI, the lower the $\text{VO}_{2\text{max}}$ value (Gantarialdha, 2021). The findings indicate that an increase in weight relative to height may be associated with a decline in cardiorespiratory capacity. Furthermore, research by Amin (2024) demonstrates a significant relationship between body composition—specifically body fat—and cardiovascular endurance among students at Makassar State University. These results suggest that body composition characteristics are a factor that should be considered when assessing the cardiorespiratory fitness index in student populations. The objective of this study is to analyze the relationship between anthropometric status, body composition, and the cardiorespiratory fitness index (Amin, 2024).

MATERIAL AND METHODS

This study employed a cross-sectional design and was conducted at the Department of Nutrition, Health Polytechnic of the Ministry of Health (Poltekkes Kemenkes) Surabaya, between May and August 2026. The inclusion criteria comprised all second-year students from the 2026/2027 academic year who were willing to participate as subjects. Exclusion criteria included students with inactive status and those with medical conditions preventing them from performing the Harvard Step Test ($\text{VO}_{2\text{max}}$). Primary data were collected through measurements of body weight, height, waist circumference, hip circumference, and body fat percentage. Specific equipment was used for these measurements: a 45 cm high bench, a metronome (to ensure accurate stepping tempo), a stopwatch, a stethoscope (for pulse rate monitoring), and a Harvard Step Test calculation form. BMI assessment involved measuring body weight using a digital scale (0.01 kg precision) and height using a stadiometer (0.01 cm precision). Body fat percentage was measured using Bioelectrical Impedance Analysis (BIA), while waist and hip circumferences were measured using a tape measure (0.01 cm precision). Data normality regarding $\text{VO}_{2\text{max}}$, BMI, body fat percentage, and waist-to-hip ratio (WHR) was assessed using the Kolmogorov-Smirnov test. Relationships between BMI, body fat percentage, WHR, and $\text{VO}_{2\text{max}}$ values were analyzed using Spearman's Rank correlation (bivariate) and multiple linear regression (multivariate); the latter involved prior testing for linearity, multicollinearity, heteroscedasticity (Glejser test), and residual autocorrelation (Durbin-Watson test). This study received ethical approval from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Sebelas Maret (Approval No.: 68/UN27.06.11/KEP/EC/2026).

RESULTS

The study was conducted over a two-week period involving students from the Department of Nutrition at Poltekkes Kemenkes Surabaya. The following is a general description of the data collected regarding age, $\text{VO}_{2\text{max}}$, body weight, height, body mass index, body fat percentage, waist circumference, hip circumference, and the waist-to-hip ratio.

Table 1. Distribution Data of Nutrition Student

Variable	Average $\pm$ SD	Minimum - Maksimum
Age (year)	18,68 $\pm$ 0,619	18 - 20
VO2Max (ml/kg/menit)	71,31 $\pm$ 16,51	45 - 99
Weight (kg)	54,77 $\pm$ 12,57	34 - 98
Height (cm)	155,54 $\pm$ 5,018	144 - 168
Body Mass Indeks (kg/m ²)	22,65 $\pm$ 4,86	15,2 - 40,7
Body Fat (%)	27,67 $\pm$ 6,7	11,2 - 42,9
Waist Size (cm)	74,28 $\pm$ 9,08	56 - 101
Hip Circumference (cm)	92,42 $\pm$ 10,67	74 - 125
Waist to Hip ratio	0,80 $\pm$ 0,059	0,68 - 0,96

Source : Primary Data (2026)

Based on a descriptive analysis of 98 respondents, the mean age was 18.68 $\pm$ 0.619 years (range: 18–20 years). Mean values were as follows: VO₂max 71.31 $\pm$ 16.51 ml/kg/min (45–99 ml/kg/min), body weight 54.77 $\pm$ 12.57 kg (34–98 kg), and height 155.54 $\pm$ 5.018 cm (144–168 cm). The mean BMI was 22.65 $\pm$ 4.86 kg/m² (15.2–40.7 kg/m²), indicating an average nutritional status within the normal category, despite variations ranging from underweight to obese. The mean body fat percentage was 27.67 $\pm$ 6.70% (11.2–42.9%). Meanwhile, the mean waist circumference, hip circumference, and waist-to-hip ratio (WHR) were 74.28 $\pm$ 9.08 cm, 92.42 $\pm$ 10.67 cm, and 0.80 $\pm$ 0.059, respectively. Overall, the respondents' ages were relatively homogeneous, whereas nutritional status, body composition, fat distribution, and cardiorespiratory fitness showed considerable variation.

Table 2. Data Normality Test

Variable	Kolmogorof Smirnov		
	Statistic	df	Sig
Body Mass Indeks	.115	98	.003
Body Fat	.067	98	.200*
Waist to Hip Ratio	.116	98	.002
VO2Max	.190	98	.000

Source : Primary Data (2026)

Normality testing was conducted using the Kolmogorov–Smirnov test, with criteria of $p > 0.05$ indicating a normal distribution and $p < 0.05$ indicating a non-normal distribution. The results showed that body fat percentage was normally distributed ($p = 0.200$), whereas BMI ($p = 0.003$), WHR ($p = 0.002$), and VO₂Max ($p < 0.001$) were not normally distributed. Therefore, the analysis of relationships between variables utilized the Spearman correlation test, a non-parametric test.

Table 3. Result of Bivariate Analysis of Independent and Dependent Variables

Variable	VO2Max
Body Mass Indeks	$r = -.816^{**}$ $p = .000$ $n = 98$
Body Fat	$r = -.565^{**}$ $p = .000$ $n = 98$
Waist to Hip Ratio	$r = -.191$ $p = .059$ $n = 98$

Source : Primary Data (2026)

Spearman correlation test results indicate a very strong negative relationship between BMI and Harvard Step Test scores ($r = -0.816$; $p < 0.001$; $n = 98$). This means that the higher the BMI, the lower the Harvard Step Test score or cardiorespiratory fitness level. This relationship is statistically significant, indicating that BMI is closely associated with the respondents' fitness levels.

Spearman correlation test results indicate a moderate negative relationship between body fat percentage and Harvard Step Test scores ($r = -0.508$; $p < 0.001$; $n = 98$). This means that the higher the body fat percentage,

the lower the Harvard Step Test score. The relationship is statistically significant, demonstrating that an increase in body fat percentage is associated with a decline in cardiorespiratory fitness.

Spearman correlation test results indicate a very weak negative relationship between waist-to-hip ratio (WHR) and Harvard Step Test scores ($r = -0.191$; $p = 0.059$; $n = 98$). Since $p > 0.05$, the relationship is not statistically significant. This means there is no significant association between WHR and cardiorespiratory fitness levels in the subjects.

Multivariate Analysis (Regression Assumption Testing)

Table 4. Linearity Test

Variable	Deviation of Linirity	Asumsi Linieritas
Body Mass Indeks	0,062	Terpenuhi
Body Fat	0,818	Terpenuhi
Waist to Hip Ratio	0,039	Tidak Terpenuhi

Source : Primary Data (2026)

Body Mass Indeks

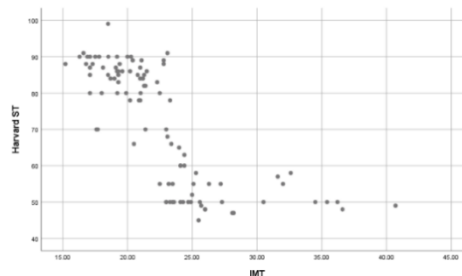


Chart C.1. Scatter Plot The Relationship between BMI and Harvard Step Test

The scatter plot reveals a visually apparent, relatively strong negative relationship between BMI and the Harvard Step Test score. As BMI increases, the Harvard Step Test score tends to decrease. The plot indicates a trend of a negative relationship between BMI and Harvard Step Test scores; an increase in BMI is generally accompanied by a decline in the Harvard Step Test score. Visually, the relationship shows a fairly strong negative trend, despite the observed dispersion and clustering of data points across certain BMI ranges.

Body Fat

Analysis of the relationship between body fat percentage and Harvard Step Test (HST) scores using the Pearson correlation test revealed a statistically significant association between the two variables. A correlation coefficient of $r = -0.508$ was obtained, with a p -value of 0.000 ($p < 0.001$), based on data from 98 study subjects. The correlation coefficient of -0.508 indicates a negative relationship of moderate strength between body fat percentage and Harvard Step Test scores. This negative relationship implies that higher body fat percentages in respondents correspond to lower Harvard Step Test scores. Conversely, respondents with lower body fat percentages tend to achieve higher Harvard Step Test scores, reflecting a superior level of cardiorespiratory fitness.

The significance level of $p < 0.001$ confirms that the relationship is statistically significant. Thus, it can be concluded that there is a significant association between body fat percentage and cardiorespiratory fitness levels—as measured by the Harvard Step Test—among the study participants.

Based on standard correlation strength classifications, the value of $r = -0.508$ falls within the moderate correlation category (0.40–0.59). These results demonstrate that an increase in body fat percentage is associated with a decline in cardiorespiratory fitness. Physiologically, higher body fat percentages can increase the workload during physical activity, reduce oxygen utilization efficiency, and lower the cardiovascular system's work capacity, thereby tending to result in lower Harvard Step Test scores.

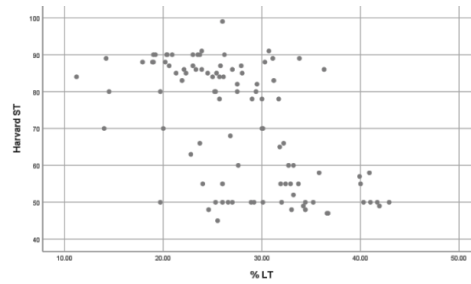


Chart C.2. Scatter Plot The Relationship between Body fat and Harvard Step Test

Based on the scatterplot, a tendency toward a negative relationship between body fat percentage (%BF) and the Harvard Step Test is evident. As body fat percentage increases, the Harvard Step Test score tends to decrease. The pattern of data points indicates a downward trend, signifying an inverse relationship between the two variables.

Waist to Hip Ratio

The analysis of the relationship between the Waist-to-Hip Ratio (WHR) and Harvard Step Test scores using the Spearman correlation test yielded a correlation coefficient of $r = -0.191$, with a significance value of $p = 0.059$, based on data from 98 respondents.

The correlation coefficient of -0.191 indicates a negative relationship between WHR and Harvard Step Test scores, with a very weak strength of association. The negative direction of the relationship suggests a tendency for Harvard Step Test scores to decrease as WHR values increase; however, this relationship is relatively weak.

Statistical test results showed a p-value of 0.059, which exceeds the significance threshold of 0.05. Consequently, the relationship between WHR and Harvard Step Test scores is not statistically significant. This means there is insufficient evidence in this study to establish a meaningful association between the waist-to-hip ratio and cardiorespiratory fitness levels as measured by the Harvard Step Test.

Based on correlation strength classifications, the value of $r = -0.191$ falls into the "very weak" correlation category (0.00–0.19). Although the direction of the relationship suggests a tendency for increased WHR to coincide with lower Harvard Step Test scores, the relationship lacks statistical significance. This indicates that body fat distribution, as measured by WHR, is not a factor significantly associated with cardiorespiratory fitness levels in the study population. Other factors—such as Body Mass Index (BMI), body fat percentage, physical activity level, age, or muscle mass—likely exert a greater influence on cardiorespiratory fitness.

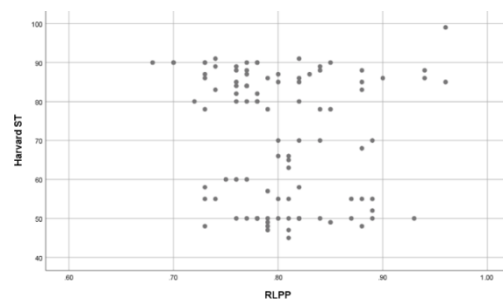


Chart C.3. Scatter Plot Hubungan RLPP dan Harvard Step Test

Based on the scatterplot, the relationship between RLPP and the Harvard Step Test appears weak and does not exhibit a clear linear pattern. The data points are quite dispersed across various RLPP values, although a very weak negative trend is observed. This aligns with the results of the previous correlation analysis ($r = -0.191$; $p = 0.059$), which indicated no significant relationship between RLPP and Harvard Step Test scores.

Table 5. Residual Normality

	<i>Kolmogorov-Smirnov^a</i>			<i>Shapiro-Wilk</i>		
	<i>Statistic</i>	<i>df</i>	<i>Sig.</i>	<i>Statistic</i>	<i>df</i>	<i>Sig.</i>
<i>Unstandardized Residual</i>	0.093	98	0.035	0.968	98	0.018

Lilliefors Significance Correction

Based on the residual normality test using the Kolmogorov-Smirnov method, the statistical value was 0.93 with a significance value of 0.035 ($p < 0.05$). Thus, the regression model residuals are not statistically normally distributed.

Table 6. Multicollinearity Test

Variable	Tolerance	VIF	Interpretasi
Body Mass Index	0,341	2,932	Multicollinearity does not occur.
Body Fat	0,340	2,937	Multicollinearity does not occur.
Waist to Hip Ratio	0,997	1,003	Multicollinearity does not occur.

Source : Primary Data (2026)

Based on the multicollinearity test results, the tolerance values obtained were 0.341 for BMI, 0.340 for body fat percentage, and 0.997 for WHR. The corresponding VIF values were 2.932, 2.937, and 1.003. All variables exhibited tolerance values greater than 0.10 and VIF values less than 10; therefore, it can be concluded that there is no multicollinearity issue in the multiple linear regression model.

Table 7. Glejser Test

Variable	Sig.	Conclusion
Body Mass Index	0,008	Indications of heteroscedasticity were found
Body Fat	0,722	No indication of heteroscedasticity was found
Waist to Hip Ratio	0,014	Indications of heteroscedasticity were found

Source : Primary Data (2026)

Based on the heteroscedasticity test results using the Glejser method, the significance values obtained were 0.008 for BMI, 0.722 for body fat percentage, and 0.014 for the waist-to-hip ratio (WHR). The significance values for BMI and WHR were below 0.05, whereas the value for body fat percentage exceeded 0.05. Thus, there is an indication of heteroscedasticity regarding the BMI and WHR variables within the regression model.

The Glejser test results indicate the presence of heteroscedasticity for the BMI ($p=0.008$) and WHR ($p=0.014$) variables, while no such indication was found for body fat percentage ($p=0.722$). Consequently, to address the impact of heteroscedasticity on standard error estimation and the significance testing of regression coefficients, multiple linear regression analysis was conducted using heteroscedasticity-consistent standard errors (HC3). This approach allows for the estimation of regression coefficients within a linear model framework while utilizing standard errors that are more robust to the presence of heteroscedasticity.

Multiple Linear Regression Analysis with Heteroskedasticity-Consistent Standard Errors (HC3)

Table 8. Parameter Estimates with Robust Standard Errors

Parameter	B	Robust Error ^a	Std. t	Sig.	95% Interval Lower Bound	Confidence Upper Bound	Conclusion
Intercept	149.2	17.308	8.620	.000	114.832	183.562	Significant
BMI	-2.863	.545	-5.252	.000	-3.945	-1.780	Significant
Body Fat	.285	.321	.887	.377	-.353	.922	Not Significant
WHR	-26.037	22.286	-1.168	.246	-70.286	18.211	Not Significant

HC3 method

The multiple linear regression analysis revealed that the model comprising BMI, body fat percentage, and waist-to-hip ratio (WHR) simultaneously explained 57.9% of the variation in Harvard Step Test scores. The model was significant overall.

The B-value for BMI was -2.863 ($p < 0.001$); this indicates that, after controlling for body fat percentage and WHR, every 1 kg/m^2 increase in BMI was associated with a decrease of approximately 2.863 points in the Harvard Step Test score. This relationship was statistically significant. The B-value for body fat percentage was 0.285 ($p = 0.377$), indicating that, after controlling for BMI and WHR, body fat percentage was not significantly associated with the Harvard Step Test. The B-value for WHR was -26.037 ($p = 0.246$), indicating that, after controlling for BMI and body fat percentage, WHR was not significantly associated with the Harvard Step Test.

Thus, among the three predictors, BMI was the only variable significantly associated with the Harvard Step Test after simultaneous control for the other variables. The multiple linear regression analysis showed that the model comprising BMI, body fat percentage, and WHR was significantly associated with Harvard Step Test scores ($F = 43.118$; $p < 0.001$), with an R^2 of 0.579 and an Adjusted R^2 of 0.566. At the individual level, BMI showed a significant association with the Harvard Step Test ($p < 0.001$), whereas body fat percentage ($p = 0.315$) and WHR ($p = 0.168$) did not show significant associations.

DISCUSSION

The respondents were aged 18–20 years, with a mean BMI of 22.65 kg/m^2 , body fat percentage of 27.67%, waist-to-hip ratio (WHR) of 0.80, and a fitness score of 71.31. Despite the relatively homogeneous age, there was variation in anthropometric and fitness characteristics.

BMI showed a very strong negative correlation with the Harvard Step Test ($r = -0.816$; $p < 0.001$), indicating that higher BMI is associated with lower fitness. This may be attributed to the increased body load during physical activity. These findings align with research on university students showing a negative correlation between BMI and VO_2max (Komunitas, Novitasari and Setiarini, 2020; Antara and Dan, 2024). More recent findings also reinforce the importance of BMI in the context of fitness. A 2025 study on the relationship between BMI and cardiorespiratory fitness in young adults indicates that BMI may play a role in the association between cardiorespiratory fitness and vascular characteristics in this age group. (Semmler et al., 2024).

In the bivariate analysis, body fat percentage was also significantly and negatively associated with fitness. However, after controlling for BMI and waist-to-hip ratio (WHR), this association was no longer significant ($B = 0.285$; $p = 0.377$), indicating that the relationship between body fat percentage and fitness may be influenced by BMI. Body fat percentage is associated with cardiorespiratory fitness, as increased adiposity can be linked to lower aerobic capacity. Recent evidence suggests that changes in body fat percentage and cardiorespiratory fitness are interrelated, with specific exercise interventions capable of reducing body fat while simultaneously increasing VO_2max (Xie et al., 2025). Interestingly, previous research on young adults found that body fat percentage can actually be a stronger predictor of VO_2max than BMI. (Article, Mondal and Mishra, 2017).

The WHR showed a very weak, non-significant negative correlation with the Harvard Step Test ($r = -0.191$; $p = 0.059$). These results indicate that fat distribution, as measured by WHR, does not demonstrate a significant relationship with fitness among the respondents. This study's findings align with research by Apriyanto et al. (2024) on non-sports major students, which showed that WHR was not significantly associated with VO_2max ($p = 0.377$) (Antara and Dan, 2024). Similar findings were reported by Komala et al. (2024) regarding high school students, showing no relationship between WHR and VO_2max ($r = 0.112$; $p = 0.284$), even though BMI and body fat percentage did show a relationship with VO_2max . (Index, Percentage and Circumference, 2024).

Multiple linear regression results indicate that every 1 kg/m^2 increase in BMI is associated with a 2.863-point decrease in Harvard Step Test scores after controlling for body fat percentage and waist-to-hip ratio ($B = -2.863$; $p < 0.001$). These findings align with recent research showing that BMI is an independent predictor of VO_2max and is negatively associated with cardiorespiratory fitness. Studies involving university students

also demonstrate a strong negative correlation between BMI and the fitness index derived from the modified Harvard Step Test.(Sri et al., 2026).

This relationship can be explained physiologically by the fact that the Harvard Step Test is a weight-bearing activity requiring the body to repeatedly lift its own mass against gravity. Consequently, an increase in body mass can raise the workload during the activity and potentially reduce cardiorespiratory performance efficiency. However, since BMI cannot distinguish between fat mass and fat-free mass, this relationship cannot be interpreted solely as an effect of increased body fat.(Sweatt, Garvey and Martins, 2024).

In this study, body fat percentage and the waist-to-hip ratio (WHR) no longer showed a significant association after controlling for BMI. This indicates that the independent contribution of these two indicators to the fitness index is reduced once relative body mass characteristics are taken into account. Although BMI and body fat percentage are conceptually linked, the multicollinearity test results indicated no problematic multicollinearity.(Alam, Kumar and Jha, 2024). Therefore, BMI can be considered a practical anthropometric indicator for identifying students potentially possessing lower cardiorespiratory fitness, while acknowledging its limitations in reflecting body composition. Collectively, BMI, body fat percentage, and waist-to-hip ratio explained 57.9% of the variation in Harvard Step Test performance (Adjusted $R^2 = 56.6\%$). However, only BMI remained a significant predictor, whereas body fat percentage and waist-to-hip ratio were not significant.(Sudersanadas et al., 2024). Thus, in this study, BMI is the indicator most consistently associated with the cardiorespiratory fitness of university students.

CONCLUSIONS

This study demonstrates that BMI is the factor most consistently associated with the cardiorespiratory fitness index, compared to body fat percentage and the waist-to-hip ratio (WHR). Bivariate analysis revealed that increases in BMI and body fat percentage were associated with a decline in the fitness index, whereas WHR showed no significant association. Upon simultaneous analysis of the three variables, only BMI remained significantly associated with the fitness index. These findings indicate that the influence of body characteristics on fitness among university students is more strongly represented by relative body mass than by fat distribution as measured by WHR.

RECOMMENDATION

This study demonstrates that BMI is the anthropometric indicator most consistently associated with the cardiorespiratory fitness index—as measured by the Harvard Step Test—among Nutrition students. Bivariate analysis revealed a significant negative association between the fitness index and both BMI and body fat percentage, whereas the waist-to-hip ratio (WHR) showed no significant association. Upon simultaneous analysis using multiple linear regression with HC3 robust standard errors, only BMI maintained a significant association with the fitness index. The model incorporating BMI, body fat percentage, and WHR explained 57.9% of the variation in the fitness index (Adjusted $R^2 = 56.6\%$). These findings suggest that BMI serves as a practical anthropometric indicator for identifying students potentially at risk of lower cardiorespiratory fitness levels. However, the use of BMI should be considered alongside other body composition indicators, given its inability to distinguish between fat mass and fat-free mass.

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