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UJI VALIDITAS INSTRUMEN TES DAYA TAHAN KARDIOVASKULAR BERBASIS SENAM AEROBIK *STEP TEST*

VALIDITY TEST OF CARDIOVASCULAR ENDURANCE TEST INSTRUMENTS BASED ON AEROBIC STEP TEST

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Abstrak

Daya tahan kardiovaskular merupakan salah satu aspek penting kebugaran jasmani yang berpengaruh terhadap kesehatan dan performa fisik. Dalam pendidikan jasmani, pengukuran daya tahan kardiovaskular diperlukan untuk memantau tingkat kebugaran mahasiswa. Namun, uji laboratorium seperti graded exercise test (GXT) sering kali kurang praktis karena membutuhkan peralatan khusus dan biaya yang cukup besar. Oleh karena itu, diperlukan instrumen alternatif yang sederhana, efisien, dan tetap memiliki validitas tinggi, salah satunya adalah step test aerobik. Metode Penelitian ini menggunakan pendekatan kuantitatif dengan desain validitas kriteria. Subjek penelitian berjumlah 30 mahasiswa Prodi Pendidikan Jasmani yang dipilih secara purposive. Instrumen utama penelitian adalah step test aerobik dengan pengukuran denyut jantung pemulihan (HR1rec), sedangkan instrumen pembanding adalah graded exercise test (GXT) untuk pengukuran VO_2max. Analisis data dilakukan menggunakan uji korelasi Pearson, regresi linear sederhana, dan uji kesesuaian Bland Altman dengan bantuan SPSS. Hasil analisis menunjukkan adanya korelasi yang kuat antara VO_2max hasil step test aerobik dengan GXT ($r = 0.812$; $p < 0.001$). Nilai determinasi menunjukkan bahwa step test mampu menjelaskan 65,9% variasi hasil VO_2max ($R^2 = 0.659$). Analisis Bland Altman memperlihatkan bias 0.77 $ml \cdot kg^{-1} \cdot min^{-1}$ dengan limits of agreement ±4.85, yang masih dapat diterima secara praktis untuk penggunaan di lapangan. Step test aerobik terbukti valid sebagai instrumen sederhana, praktis, dan efisien dalam mengukur daya tahan kardiovaskular mahasiswa. Instrumen ini dapat digunakan sebagai alternatif uji kebugaran di bidang pendidikan jasmani ketika fasilitas laboratorium tidak tersedia.
Kata kunci: validitas, instrumen, daya tahan kardiovaskular, senam aerobik *step test*

Abstract

Cardiovascular endurance is a fundamental component of physical fitness that significantly influences both health and physical performance. In physical education, assessing cardiovascular endurance is essential to monitor students' fitness levels. However, laboratory-based tests such as the graded exercise test (GXT) are often impractical due to the need for specialized equipment and high costs. Therefore, there is a need for a simpler, more efficient, yet valid alternative instrument one of which is the aerobic step test. This study employed a quantitative approach with a criterion validity design. The research subjects consisted of 30 Physical Education students selected through purposive sampling. The primary instrument was the aerobic step test, in which recovery heart rate (HR1rec) was measured, while the comparative instrument was the graded exercise test (GXT) for VO_2max assessment. Data were analyzed using Pearson's correlation test, simple linear regression, and Bland Altman agreement analysis with the assistance of SPSS software. The findings revealed a strong correlation between VO_2max derived from the aerobic step test and that obtained from GXT ($r = 0.812$; $p < 0.001$). The coefficient of determination indicated that the step test could

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explain 65.9% of the variance in VO_2max (R^2 = 0.659). Bland Altman analysis demonstrated a bias of −0.77 ml·kg^{-1}·min^{-1} with limits of agreement of ±4.85, which is considered practically acceptable for field application. The aerobic step test is validated as a simple, practical, and efficient tool for assessing cardiovascular endurance among students. This instrument can serve as a reliable alternative to laboratory-based fitness testing in physical education settings where laboratory facilities are unavailable.
***Keywords**: validity, instrument, cardiovascular endurance, aerobic step test*

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INTRODUCTION

Physical fitness, particularly cardiovascular endurance, is a key component in supporting health, academic performance, and individual quality of life (Bagas Dewantara & Siti Nurrochmah, 2024; Jati et al., 2025; Permadi et al., 2024). Good cardiorespiratory capacity is also closely associated with a reduced risk of degenerative diseases such as hypertension, obesity, and coronary heart disease (Al-Mallah et al., 2018; Haidar & Horwich, 2023; Lang et al., 2024; Parto et al., 2015). Several cross-national studies have reported a declining trend in cardiovascular fitness in children and adolescents over the past three decades (Leone et al., 2023; Li et al., 2024; Tomkinson et al., 2019; Vanhelst et al., 2024). This situation emphasizes the need for valid and reliable test instruments to assess cardiovascular endurance, both in physical education and sports development.

One widely used method is the aerobic step test, as it is relatively easy, inexpensive, and applicable in schools and sports communities. Recent research in children aged 8–16 years shows that the step test has a high correlation with VO_2max capacity, a key indicator of cardiorespiratory fitness (Bruggeman et al., 2020; Maggio et al., 2017; Mall et al., 2024). However, systematic reviews have shown variations in step test protocols (duration, stride frequency, step height), which can lead to differences in validity between populations (Bennett et al., 2016). This underscores the importance of validating aerobic step test instruments in Indonesia, particularly in the context of physical education and fitness gymnastics, to ensure that measurement results accurately and contextually reflect students' fitness levels. Although several international studies have demonstrated a high correlation between the aerobic step test and VO_2max capacity, an indicator of cardiovascular endurance, most of these studies were conducted in foreign populations with physiological conditions, environments, and physical activity habits that differ from those in Indonesia. Furthermore, variations in test protocols, such as bench height, music tempo, and stride duration, often result in differing validity results between studies. Research in Indonesia is still limited to the use of general fitness tests, while the validity of aerobic step test instruments in local contexts, particularly in fitness gymnastics and physical education, has been limited. This situation creates a research gap: the lack of a validated standard instrument for assessing aerobic gymnastics-based cardiovascular endurance that is appropriate for the characteristics of Indonesian students.

This research is highly urgent because cardiovascular endurance is a fundamental indicator of physical fitness that is directly related to long-term health. In the context of physical education in Indonesia, simple, inexpensive, yet highly valid instruments for measuring student fitness are still limited. The availability of a validated aerobic step test instrument can assist physical education teachers and coaches in conducting fitness assessments more objectively, efficiently, and appropriately within the often-limited school facilities and infrastructure. Practically, this research also supports the national physical literacy movement, which

emphasizes the importance of systematically measuring physical fitness to increase students' active participation in sports activities.

This study aims to test the validity of the aerobic step test instrument as a measure of cardiovascular endurance in Indonesian students. Specifically, this study aims to determine whether the instrument can be used accurately, practically, and appropriately in the context of physical education and fitness gymnastics, so that the measurement results truly reflect students' cardiovascular fitness levels.

METHOD

This study employed a quantitative design with a correlational approach. The primary objective was to test the validity of the aerobic step test instrument as a measure of cardiovascular endurance by comparing its results to a recognized standard measure, namely estimated VO_2max. This design was chosen because validity analysis essentially requires testing the relationship (correlation) between the scores of the tested instrument and the criterion benchmark (Creswell, 2017). The correlational approach is considered most appropriate for the context of validity research, as it provides empirical evidence through correlation coefficient calculations, Bland-Altman analysis, and inter-measure reliability tests.
The study population consisted of all students in the Physical Education, Health, and Recreation (PJKR) Study Program at the Bina Guna College of Sports and Health. This population was chosen because PJKR students are directly involved academically and practically in physical fitness, particularly in cardiovascular endurance, thus ensuring more relevant and applicable research results. The study sample consisted of 40 students aged 18–22, selected using a purposive sampling technique.

The primary instrument in this study was the aerobic step test, a simple fitness test using a 30 cm high bench/step, a metronome to control stride rate, and a stopwatch to measure time. The step test was chosen because it is practical, inexpensive, and has a high correlation with VO_2max capacity (Castro-Piñero et al., 2021; Weisstaub et al., 2025). The protocol involved subjects performing up-and-down movements to the rhythm of a metronome for three minutes, then measuring their first-minute recovery heart rate (HR1rec) to estimate VO_2max. The interpretation principle used is that the lower the HR1rec, the better the subject's cardiovascular endurance capacity.

As a comparison instrument (gold standard), this study used direct measurement of VO_2max through a graded exercise test (GXT) in an exercise physiology laboratory using a metabolic cart. The GXT is considered the gold standard for measuring VO_2max due to its high accuracy (Midgley et al., 2007; Noonan & Dean, 2000). If laboratory facilities are unavailable, an alternative comparison instrument is the beep test (multi-stage shuttle run test), which has been proven to be a validated VO_2max estimate in young populations (Léger et al., 1988).

The research data were analyzed quantitatively using SPSS version 29.0.2.0. The Shapiro–Wilk normality test was used to ensure the data distribution met the requirements for parametric analysis. Criterion validity was tested by calculating the Pearson correlation between the VO_2max estimate from the aerobic step test and the VO_2max value from the comparison instrument (beep test or GXT). This analysis was used to determine the strength of the relationship between the instruments. Next, a simple linear regression analysis was used to construct a VO_2max prediction equation based on HR1rec, with the coefficient of determination (R^2) as an indicator of how much variation in VO_2max can be explained by the model.

A Bland-Altman analysis was also applied to test the agreement between the step test results and direct VO_2max measurements, which is recommended in physiological research. In addition, reliability was tested using the Intraclass Correlation Coefficient (ICC) and Standard Error of Measurement (SEM).

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RESULTS

Data Description

This study involved 40 Physical Education students aged 18–22. The primary data collected were estimated VO_2max values from the aerobic step test and VO_2max values from the graded exercise test. A summary of descriptive statistics is presented in Table 1.

Table 1. Descriptive Statistics of Measurement Results

Variable	n	Mean	SD	Min	Max
VO_2max Step Test ($ml \cdot kg^{-1} \cdot min^{-1}$)	40	42.35	4.82	34.2	51.1
VO_2max GXT ($ml \cdot kg^{-1} \cdot min^{-1}$)	40	43.12	5.1	35.5	52.4

Descriptive results indicate that the average VO_2max from the aerobic step test was slightly lower than the GXT. However, the range of values for both instruments was relatively comparable, making them suitable for validity analysis.

Criterion Validity Test

Pearson correlation analysis was used to determine the relationship between the estimated VO_2max from the aerobic step test and the VO_2max from the GXT.

Table 2. Pearson Correlation between VO_2max from the Step Test and VO_2max from the GXT

Variable	r	p-value
Step Test vs. GXT	0.812	0

The analysis results showed a very strong correlation ($r = 0.812$; $p < 0.001$) between the results of the aerobic step test VO_2max and GXT. This indicates that the aerobic step test is valid for use as an instrument to measure cardiovascular endurance.

Linear Regression Analysis

A simple linear regression analysis was performed to obtain a prediction equation for VO_2max based on HR1rec from the aerobic step test.

Table 3. Summary of Regression Analysis Results

Model	R	R^2	F	p-value
Step → VO_2max	0.812	0.659	72.34	0

The regression equation obtained is: $VO_2max = 68.12 - 0.25 \times HR1rec$

Interpretation: Each decrease of 1 heart rate in the first minute of recovery (HR1rec) will increase the estimated VO_2max by 0.25 ml kg^{-1} min^{-1}. The R^2 value of 0.659 indicates that 65.9% of the variation in VO_2max can be explained by HR1rec from the aerobic step test.

Bland-Altman Analysis

A goodness-of-fit analysis was performed using the Bland-Altman method. The results showed a mean difference of –0.77 ml kg^{-1} min^{-1} with limits of agreement (LoA) of ±4.85. This means that the aerobic step test tends to slightly underestimate VO_2max compared to the GXT, but is still within practically acceptable limits of agreement.

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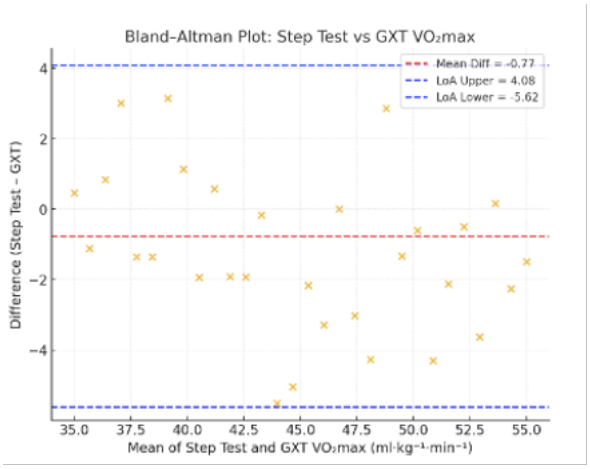

Figure 1. Bland Altman plot graph

Reliability Test (Test-Retest)

A subsample of 10 students took the aerobic step test again after 7 days. The results of the reliability analysis are shown in Table 4.

Table 4. Results of the Aerobic Step Test Reliability Test

Reliability Statisticss	Value
ICC (95% CI)	0.893
SEM	1.25

The ICC value of 0.893 indicates excellent reliability. The relatively small SEM value strengthens the evidence that the aerobic step test provides consistent measurement results.

Based on the analysis, it can be concluded that the aerobic step test has strong criterion validity against VO_2max GXT results, as well as excellent reliability upon repeated measurements. Therefore, this test is suitable for use as a practical instrument to assess the cardiovascular endurance of Physical Education students.

DISCUSSION

The results showed that the aerobic step test had strong criterion validity against VO_2max values obtained through the graded exercise test (GXT), with a correlation coefficient of $r = 0.812$ ($p < 0.001$). This indicates that the simple bench-based test can accurately reflect the cardiovascular endurance capacity of students. Regression analysis further supported this finding with an R^2 value of 0.659, indicating that more than 65% of the variation in VO_2max can be explained by the recovery heart rate (HR1rec) from the aerobic step test.

Furthermore, the Bland-Altman analysis revealed a mean difference (bias) of –0.77 ml kg^{-1} min^{-1}, with a limit of agreement (LoA) of ±4.85. This means that the aerobic step test tends to slightly underestimate VO_2max values compared to the GXT, but this difference is still within practically acceptable limits. Thus, this test can be viewed as an efficient, inexpensive, and easily implemented alternative instrument for assessing the cardiovascular fitness of Physical Education students, especially in field settings with limited laboratory facilities.

The findings of this study are consistent with several previous studies that have confirmed the validity of step-based tests as predictors of cardiovascular endurance. The Chester Step Test has a high correlation with laboratory VO_2max in healthy adult populations, making it recommended for use in both fitness and clinical settings (Coll et al., 2020; Hansen et al., 2016; Izquierdo et al., 2019). Research has shown that the Harvard Step Test can be used to

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assess student fitness with a reasonable degree of accuracy, although there is interindividual variation in results (Bhagat et al., 2014; Iyakrus et al., 2020). Therefore, these results strengthen the evidence that simple step-based protocols can be effectively adapted for both physical education and sports research.

Field fitness tests such as the step test and beep test tend to provide slightly lower VO_2max estimates than direct measurements with a metabolic cart (Hong et al., 2019; Kravchychyn et al., 2015; Serhiyenko, 2015). This was also evident in this study, where a negative bias of –0.77 ml kg^{-1} min^{-1} emerged in the Bland-Altman analysis. However, this difference remains within acceptable limits of agreement.

Step-based fitness tests can be integrated with wearable heart rate monitors to improve the accuracy of VO_2max estimates, opening opportunities for the development of modern instruments based on traditional protocols (Hong et al., 2019; Matsuo et al., 2020; Spathis et al., 2022). Thus, the results of this study not only support the validity of the aerobic step test in the context of Physical Education students but also emphasize its relevance in the development of contemporary sports science.

The results of this study indicate a small bias in VO_2max estimates using the aerobic step test compared to the GXT. This difference may be influenced by several factors. Biologically, the recovery heart rate response (HR1rec) is strongly influenced by an individual's fitness level, age, gender, and cardiac autonomic variability (Bunn et al., 2018; Cornell et al., 2024; Neshitov et al., 2023). Students with better fitness levels tend to have lower recovery heart rates, resulting in more accurate VO_2max estimates, while in subjects with lower fitness, accuracy may be reduced.

Step height, metronome tempo, and consistency of the up-and-down movements significantly determine the outcome of the test. If the movements are performed out of rhythm or if local muscle fatigue occurs in the legs, the recovery heart rate may increase, decreasing the accuracy of VO_2max estimates. Furthermore, the use of digital heart rate monitors with varying sensitivity can lead to variations in data recording (McAvoy et al., 2021; Perry et al., 2019; Tiemens et al., 2018; Wallert & Madison, 2014).

A major limitation is the difference in intensity between the field and laboratory tests. The incremental protocol on the GXT treadmill is progressive to maximal fatigue, while the aerobic step test lasts only three minutes at submaximal intensity. This difference in paradigms may explain why the step test tends to produce slightly lower estimates than direct measurements. However, the variation in results, which is within the limits of agreement, indicates that the aerobic step test remains feasible for use in field conditions with limited facilities.

CONCLUSION

This study demonstrates that the aerobic step test has high validity as a cardiovascular endurance measurement instrument in Physical Education students. Correlation and regression analyses demonstrate a strong relationship between VO_2max estimates from the step test and VO_2max measurements using the GXT. Bland-Altman analysis also shows a small bias within the limits of practical agreement. Therefore, the aerobic step test can be used as a simple, efficient, and reliable fitness assessment tool in the context of physical education.

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