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Original Article

One Minute Stair Step Test in Predicting VO_2 max among Healthy Young Adults

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Abstract

Background: Cardiovascular risk factors such as hypercholesterolemia and hypertension, are increasing among Indonesian young adults despite their apparently healthy status. Valid field methods for assessing VO_2max, a key indicator of cardiorespiratory fitness, are needed for large-scale screening. This study validated the one-minute stair step test (OMSST) against the Bruce treadmill protocol as the reference standard.

Methods: This cross-sectional study included 51 healthy males (20.41±0.57 years, BMI 22.52±3.28 kg/m^2) in Bandung, Indonesia. VO_2max was measured using the Bruce protocol and estimated using the OMSST (40-cm step, 30 steps/min). Anthropometrics variables, heart rate recovery at 60 seconds (HRR60), and multiple regression variables (age, height, weight, and HRR60) were analyzed using paired t-tests, correlations, and Bland-Altman plots.

Results: The mean VO_2max estimated using the OMSST (50.91±3.29 mL/kg/min) closely matched that measured Bruce protocol (49.75±3.61 mL/kg/min; p=0.091), with a small positive bias (1.16 mL/kg/min) and 95% limits of agreement within acceptable bounds. A strong correlation (r=0.85, p<0.001) confirmed validity. HRR60 (91.12±15.10 bpm) significantly predicted VO_2max.

Conclusion: OMSST is a valid, simple, low-cost field surrogate for laboratory VO_2max testing in young males, ideal for middle-income settings. Future studies should assess diverse populations and longitudinal reliability.

Keywords: Bland-Altman analysis, cardiorespiratory fitness, heart rate recovery, step test, VO_2max

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Introduction

Low cardiorespiratory fitness (CRF), measured as VO_2max, is a major public health concern worldwide, particularly among adolescents and young adults, for whom sedentary lifestyles contribute substantially to cardiovascular disease risk.[1] The American Heart Association recognizes CRF as an independent predictor of cardiovascular morbidity and all-cause mortality, even among apparently healthy youth. World Health Organization data indicate that approximately 27% of adults globally do not meet minimum physical activity recommendations, with even lower adherence among young adults in urban settings.[2,3]

In low-and middle-income countries

such as Indonesia, rapid urbanization has accelerated the decline in physical activity levels among young adults aged 20–39 years.[4] National health surveys have documented increasing cardiovascular risk factors, including hypertension (10.7% prevalence by measurement in those aged 18–24 years and 17.4% in those aged 25–34 years) and high total cholesterol (2.8% in those aged 15–24 years and 7.8% in 25–34 years), among young adults who often perceive themselves as healthy.[5]

VO_2max or maximum oxygen consumption, is important for assessing cardiorespiratory fitness and overall health status.[6] This indicator reflects aerobic capacity and measures how efficiently the cardiovascular and respiratory systems meet the body's needs during physical activity. One study reported that the average VO_2max value in healthy young adult men was 45.30±7.35 mL/kg/min.[7] VO_2max measurements can help identify the risk of chronic diseases, including cardiovascular disease. A study in Central India determined normative VO_2max for young adults aged 17–28 years and highlighted that this measurement can be used for health risks stratification.[8,9]

Fixed-rate step tests estimate VO_2max based on the theoretical framework that submaximal heart rate (HR) response during standardized stepping reflects aerobic capacity through the linear relationship between HR and oxygen uptake (Fick equation: VO_2=cardiac output × arteriovenous O_2 difference).[4] However, Hansen et al. observed a mean exercise intensity of 85±24% of CPET VO_2peak, with 41% participants exceeding 95% of VO_2peak. These findings raise concerns regarding physiological validity and medical safety across diverse populations.[4] These findings raise concerns about physiological validity and medical safety, particularly because interindividual variability in age, BMI, sex, and fitness level may produce inconsistent relative intensities across populations.[10]

Although the Rockport 1-mile walk test provides field-based fitness screening, its fitness classification norms remain unvalidated for Indonesian populations. One study reported only a moderate correlation between Rockport and treadmill protocol (SEE=4.2 mL/kg/min) in healthy adults.[11] The Bruce treadmill protocol, considered the reference standard for direct VO_2max measurement because of its progressive maximal intensity reaching >85% of maximum HR and its validation against open-circuit spirometry, requires specialized laboratory equipment and trained personnel.[12] In contrast, the One-Minute Stair Step Test (OMSST) offers a submaximal alternative suitable for field settings. This study aimed to validate the OMSST against the Bruce protocol in healthy male university students aged 20–22 years to establish its utility for field-based screening.

Methods

This cross-sectional validation study used a tripartite methodological framework to evaluate OMSST predictive validity (correlation and standard error of estimate [SEE]), method agreement (Bland-Altman analysis), and influencing factors (regression) against Bruce treadmill gold standard.

Participants were recruited from male undergraduate students in Bandung, Indonesia. The target sample size of 51 was determined using a priori power analysis for detecting moderate correlation (r=0.5) between OMSST and Bruce protocol, with 80% power and α=0.05, using G*Power 3.1.[13] This sample size exceeds the minimum requirement of 29 participants for paired t-tests and provided adequate precision for Bland-Altman analysis.

The inclusion criteria were as follows: healthy male participants aged 20–22 years at screening, On the Physical Activity Readiness Questionnaire (PAR-Q), the subjects do not answer any Yes, and willingness to participate in the study. The exclusion criteria were cardiovascular and pulmonary disease, hypertension, orthopedic disabilities, caffeine or alcohol consumption within 24 hours before testing, food consumption within 2 hours before testing, and strenuous exercise within 10 hours before the testing.

Sixty male undergraduate students underwent initial screening, including PAR-Q and inclusion criteria assessment, yielding 51 eligible healthy participants aged 20–22 years. Participants were randomized to test order and completed the primary paired tests in Week 1: the OMSST followed immediately by a 30-minute rest period and then Bruce treadmill protocol (COSMED metabolic cart) in a single session. The Optional YMCA Step Test was conducted in Week 2 as a methodological comparator. All 51 participants provided complete OMSST-Bruce pairs for the primary analysis (predictive validity and Bland-Altman agreement), achieving 85% retention from screening with no missing data (figure 1).

All participants underwent screening

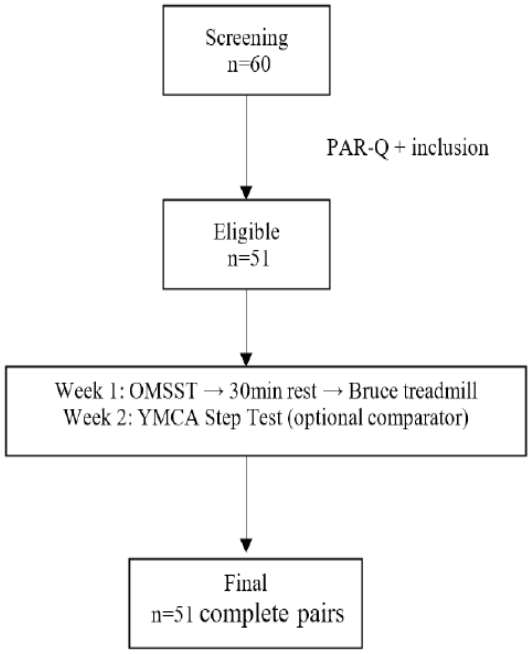

Figure 1 Study Protocol Flow Chart Showing Participant Recruitment

to confirm health status and eligibility for exercise testing. This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of Universitas Padjadjaran (protocol code: No. 586/UN6.KEP/EC/2024). Participants attended a briefing session explaining the study objectives and procedures. All participants completed the PAR-Q. Before physical testing, anthropometric measurements, including body weight, height, and body mass index (BMI) were obtained.

Direct measured VO_2max was obtained using the Bruce treadmill protocol, a progressive maximal test that increases speed and incline every 3 minutes (Stage 1: 1.7 mph/10%; Stage 2: 2.5 mph/12%; up to volitional exhaustion). Peak oxygen consumption was estimated using the standard Bruce equation: VO_2max (mL/kg/min)=14.8–1.379×T+0.451×T^2–0.012×T^3+1.235×S, where T is the total treadmill time (minutes) and S is body slope (%). Testing was supervised by certified exercise physiologists with ECG monitoring until participants reached ≥85% of age-predicted HRmax (220-age) or RER>1.10.

Predicted VO_2max was estimated using the OMSST, a submaximal field test performed at 30 steps/min for 60 seconds on a 40-cm stair. Post-exercise heart rate (HRpost) at 60 seconds recovery (HRR60) was measured. VO_2max was initially calculated using an equation derived from multiple regression based on the collected data, as follows: VO_2max=52.78+0.04 (Age)+0.07 (Height)-0.22 (Weight)-0.10 (HR60).

Statistical analyses were performed using SPSS software version 24.0. Data were expressed as mean±standard deviation (SD). A paired t-test was used to compare measured VO_2max (COSMED) and predicted VO_2max from the step test equation. Pearson or Spearman correlation tests were applied based on data distribution to assess validity. Agreement between measured and predicted VO_2max was evaluated using Bland–Altman analysis.

Results

In total, 51 male students participated in this study. The mean age was 20.41±0.57 years, indicating a homogeneous young adults group. Body weight (64.21±11.26 kg) and height (168.57±6.24 cm) resulted in a BMI of 22.52±3.28 kg/m^2, which falls within the normal range. The HRR60 value of 91.12±15.10 bpm indicates a fairly good heart rate recovery after exercise. Physiologically, higher HRR

Table 1 Anthropometrics and Cardiorespiratory Fitness of Male Students From Bandung (n=51)

Parameter	Mean±SD
Age (year)	20.41±0.57
Weight (kg)	64.21±11.26
Height (cm)	168.57±6.24
BMI	22.52±3.28
Underweight	3 (5.9%)
Normal	38 (74.5%)
Obese	10 (19.6%)
HRR_{60}	91.12±15.10

HRR60=heart rate recovery 60 seconds after the 1-minute step test

reflects faster parasympathetic reactivation, which is an indicator of better cardiac fitness (Table 1).

Figure 2 illustrates the VO_2max estimated across four methods among 51 healthy young men. The OMSST (50.91±3.29 mL/kg/min) most closely matched the Bruce protocol (49.75±3.16mL/kg/min; mean difference 1.1 mL/kg/min), demonstrating excellent predictive validity. The regression-adjusted OMSST (50.91 ±3.29mL/kg/min) showed comparable accuracy. The YMCA step test significantly underestimated VO_2max (41.25±6.57mL/kg/min; p<0.001), supporting the superiority of the OMSST for field screening.

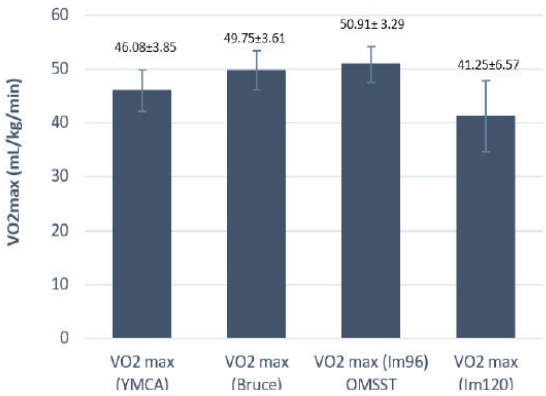

Figure 2 Comparison of VO_2max Measured by the YMCA 3-Minute Step Test, Predicted 1-Minute Step Test, and Treadmill Test Using the Bruce Protocol. The Prediction Model Included Age, Weight, Height, and HR60

Figure 2 The difference in VO_{2max} between the YMCA 3-min step test, step test 1-min predicted, calculated from multiple regression analysis for age, weight, height, and HR_{60}, and treadmill test using Bruce protocol

Figure 3 demonstrates a strong positive linear correlation between OMSST-predicted VO_2max (x-axis) and Bruce protocol-measured VO_2max (y-axis) among 51 healthy young adults. Data points clustered closely around the line of identity (y=x), with minimal scatter and no systematic deviation, indicating excellent agreement between the two

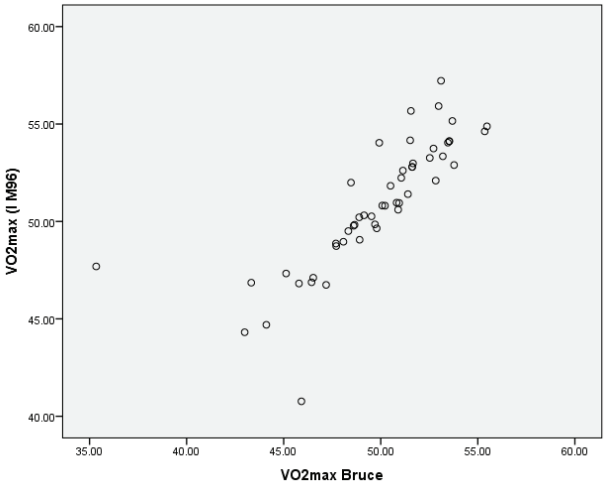

Figure 3 Correlation Between Predicted Vo_2max of Step Test 1-Mi The Bruce Protocol

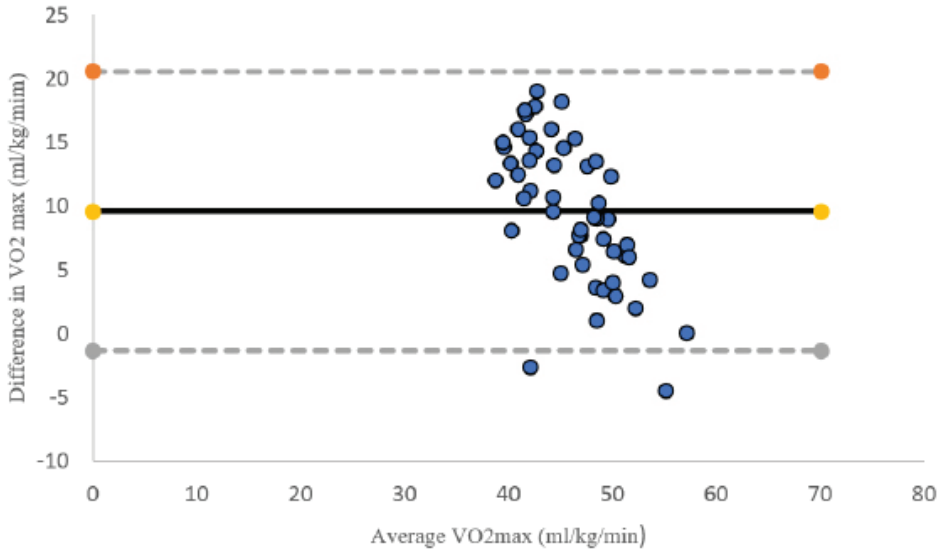

Figure 4 Agreement between Predicted OMSST VO_2max and Treadmill VO_2max Using the Bruce protocol. The Prediction Model Included Age, Height, Weight, and Heart Rate at 60 Seconds After OMSST

methods. The narrow distribution and lack of outliers confirmed the predictive validity of OMSST, supporting its use as a reliable field-based surrogate for laboratory gold-standard assessment.

Figure 4 showed acceptable agreement between OMSST-predicted and Bruce-measured VO_2max values, with a small positive mean bias (approximately 1.2 mL/kg/min; solid line), indicating slight overestimation by OMSST. most data points fell within the limits of agreement (±1.96 SD; dashed lines), demonstrating no proportional bias across the range of mean VO_2max values (40–60 mL/kg/min). Minimal scatter and few outliers confirmed the clinical interchangeability of OMSST for field-based cardiorespiratory fitness assessment in healthy young adults.

Discussion

The average VO_2max estimated using the OMSST among healthy young adult males was very close to the VO_2max measured using the Bruce treadmill protocol, with a statistically non-significant difference and a small positive bias in the Bland–Altman analysis, indicating acceptable accuracy and agreement between the two methods.

These findings align with a systematic review reporting that various submaximal step tests show moderate to strong validity in estimating VO_2max among healthy adults, with standard errors of estimate typically below 5–6 mL/kg/min.[14] The validity of the OMSST approaches that of the Bruce protocol, yet its duration of only 1 minute places this protocol within the performance range of other validated step tests, such as StepTest4all and workplace step procedures incorporating heart rate responses during and after exercise.[15,16]

In this study, the YMCA 3-minute step test significantly underestimated VO_2max compared with the Bruce protocol, making it less suitable for field fitness screening in healthy young adult males. These results are consistent with criticisms of fixed-rate step tests, which highlight issues of physiological validity and medical safety due to inter-individual variability in age, BMI, sex, and fitness level that may cause differences in relative exercise intensity.[4,10]

The OMSST regression model in this study incorporated age, height, weight, and 60-second heart rate recovery (HRR60) as predictors, consistent with the theoretical framework that submaximal heart rate responses during step exercise reflect aerobic capacity through the linear relationship between HR and oxygen consumption (Fick equation).[4] The mean HRR60 value of 91.12±15.10 bpm indicates adequate recovery; physiologically, higher HRR reflects faster parasympathetic reactivation

and superior cardiac fitness.[17]

Recent studies also indicate that incorporating heart rate measurements during and after exercise into multiple regression models enhances VO_2max estimation accuracy compared to single-point measurement approaches.[15,18] The finding that HRR60 significantly influences VO_2max in this study reinforces the role of HRR as a key indicator of autonomic recovery dynamics and aerobic capacity.

The Bruce treadmill protocol remains the gold standard for VO_2max measurement because of its progressive intensity reaching >85% of HRmax and high validity against open-circuit spirometry, however, it requires specialized laboratory facilities, equipment, and trained personnel, making it impractical for large-scale screening.[12] In contrast, the OMSST, a 1-minute submaximal test using a 40-cm step at 30 steps/min offers a simple, cost-effective, and field-applicable alternative.

However, this study has several limitations. Limitations relate to sample characteristics and study design. All participants were healthy young males aged 20–22 years with normal-range mean BMI, limiting direct generalizability to females, other age groups, individuals with chronic diseases, and individuals with different nutritional status. The cross-sectional design permits validity assessment at a single timepoint only, precluding evaluation of test-retest reliability or OMSST sensitivity to changes in VO_2max over time. Additionally, all measurements were conducted at one center with a relatively small sample (n=51), potentially limiting estimation precision and the accuracy of Bland–Altman limits of agreement, thereby requiring confirmation in larger and more diverse samples. Finally, OMSST validation was specific to the Bruce protocol; its performance against other maximal VO_2max tests, such as alternative treadmill protocols or cycle ergometry, remains unknown and warrants future investigation.

In conclusion, the OMSST is a valid, simple, low-cost alternative to the Bruce protocol for estimating VO_2max in healthy young males and is suitable for large-scale field screening in middle-income settings such as Indonesia. Regression modeling based on age, height, weight, and HRR60-based regression modeling confirms its physiological validity, with important implications for fitness monitoring despite limitations requiring diverse-population and longitudinal settings is still required.

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Author Contribution.

LAF, IS, and ZJ contributed to the conceptualization of the study. LAF, UR, LAR, HRDR, RAG, and ZJ contributed to the study methodology and design. UR and FM were responsible for software support. FM, UR, and IS performed validation. UR and FM conducted the formal analysis. LAF, LAR, and HRDR conducted the investigation. LAF provided the study resources. LAR was responsible for data curation. LAF and IS interpreted the data. LAF, UR, IS, and ZJ drafted the original manuscript. LAF, UR, IS, LAR, HRDR, RAG, and FM reviewed and edited the manuscript. UR contributed to visualization. IS supervised the study. LAF, LAR, and HRDR were responsible for project administration. LAF acquired the funding. All authors have read and approved the final version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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Generative AI Disclosure Statement

During the preparation of this manuscript, the authors used Grammarly Premium solely to improve the English language, grammar, spelling, punctuation, and overall readability of the text. The authors reviewed and edited all suggestions generated by the software and take full responsibility for the final content of the manuscript. No generative AI tool was used for data collection, data analysis, interpretation of results, or generation of scientific conclusions.

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