

Assessing agreement between six-minute walk test and the incremental shuttle walk test in healthy sedentary adults

Anindira Rustandi¹, Nury Nudswiningtyas¹, Nurul Paramita², Retno Asti Werdhani³



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Authors' affiliations:

¹Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia, ²Department of Physiology, Faculty of Medicine, Universitas Indonesia, Cipto Mangunkusumo Hospital, Jakarta, Indonesia, ³Faculty of Medicine, Universitas Indonesia, Cipto Mangunkusumo Hospital, Jakarta, Indonesia

Corresponding author:

Anindira Rustandi
 Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Universitas Indonesia, Jalan Diponegoro No. 71, Kenari, Senen, Central Jakarta 10430, DK Jakarta, Indonesia
 Tel/Fax: +62-21-3907561
 E-mail: anindira.rustandi@gmail.com

ABSTRACT

BACKGROUND The incremental shuttle walk test (ISWT) and six-minute walk test (6MWT) assess cardiorespiratory endurance in sedentary populations, with the ISWT being externally paced and the 6MWT self-paced. This study aimed to evaluate whether both tests produce comparable cardiorespiratory responses.

METHODS 100 healthy sedentary adults (18–59 years) from Cipto Mangunkusumo Hospital completed both tests. Outcomes measured included distance traveled, maximal heart rate (HR_{max}), and Borg scale scores (rating of perceived exertion [RPE], dyspnea, and leg fatigue).

RESULTS Of 100 sedentary adults (25 men, 75 women), the ISWT resulted in significantly longer walking distances ($p < 0.001$), higher post-test Borg dyspnea scores (median [interquartile range]: 2 [1–3]) versus 1 [0–2]; $p = 0.024$), and the higher HR_{max} (70.9 [9.2%] bpm versus 67.9 [10.9%] bpm; $p = 0.004$) compared to the 6MWT. No significant differences were observed in other parameters, and Bland–Altman analysis revealed no proportional bias for Borg leg fatigue scores ($p = 0.561$).

CONCLUSIONS In healthy sedentary adults, the 6MWT and ISWT showed no agreement in distance traveled, Borg dyspnea scale scores, or HR_{max} , but they agreed on Borg leg fatigue scores.

KEYWORDS exercise test, exercise tolerance, incremental shuttle walk test, physical fitness, six-minute walk test

Health is not merely the absence of disease but also encompasses physical fitness, with cardiorespiratory fitness representing a key component.¹ It reflects the integrated function of the cardiovascular, respiratory, and muscular systems to perform dynamic physical activity at moderate-to-high intensities over sustained periods. This capacity, commonly quantified by oxygen uptake (VO_2), reflects an individual's ability to carry

out daily activities that rely on prolonged aerobic metabolism.²

Cardiorespiratory fitness can be assessed using laboratory- or field-based exercise tests.¹ Among field tests, the six-minute walk test (6MWT) and the incremental shuttle walk test (ISWT) are widely used. The 6MWT is a simple, low-cost, valid, and reliable submaximal exercise test. However, as a self-

paced test, it may underestimate an individual's true functional capacity because walking speed is not externally regulated.³

The ISWT is a symptom-limited, externally paced test with gradually increasing intensity. It provides a more standardized protocol than the 6MWT and has emerged as an alternative method for evaluating cardiorespiratory fitness. Some studies have classified the ISWT as a maximal test; for example, Gonçalves et al⁴ allowed participants to exceed 12 levels and to jog or run to minimize ceiling effects. In contrast, another study has categorized the ISWT as a submaximal test in specific populations, such as individuals with obesity.⁵ Agreement between the ISWT and 6MWT has been investigated in populations with chronic lung disease,⁶ stroke,⁷ and cystic fibrosis.⁸ However, to our knowledge, no studies have examined their agreement in healthy sedentary adults, particularly within an Indonesian population. Building on prior research exploring factors influencing ISWT performance,⁵ this study aimed to investigate the ISWT as an alternative exercise test and to assess its agreement with the 6MWT in healthy sedentary Indonesian adults. We hypothesized that walking distance, Borg scale ratings, and heart rate (HR) responses would demonstrate agreement between the 6MWT and ISWT in healthy sedentary adults.

METHODS

Study design and participants

This cross-sectional study included healthy individuals with sedentary lifestyles, recruited through consecutive sampling at Cipto Mangunkusumo Hospital, Jakarta, between 2022 and 2023. A sedentary lifestyle was defined as engaging in no vigorous physical activity for ≥ 20 min/day on ≥ 3 days per week, or no moderate-intensity activity or walking for ≥ 30 min/day on ≥ 5 days per week. Participants included students, workers, and the family members of patients. Inclusion criteria were: age of 18–59 years; cardiorespiratory health confirmed by physical examination; clearance for physical activity using physical activity readiness questionnaire (PAR-Q+); normal electrocardiography and spirometry (forced expiratory volume in 1 second [FEV₁] $>80\%$ predicted and FEV₁/forced vital capacity $>70\%$); sedentary lifestyle; normal body mass index (BMI) (18.5–24.99 kg/m²); intact hearing and visual acuity; normal

balance (negative Romberg test) and sensation; absence of neurological or neuromuscular disorders; and willingness to participate. Exclusion criteria included the inability to follow instructions, history of lower-extremity surgery or deformity, unstable hemodynamic status, use of ambulatory aids, and smoking. Sample size ($n = 100$) was estimated using multiple approaches, including rules of thumb for method-comparison studies, calculations based on expected mean differences,⁹ and requirements for Bland–Altman agreement analysis.¹⁰

Measurements

For the 6MWT, participants were instructed to walk as far as possible within 6 min along a 30-m enclosed corridor. Standardized verbal encouragement was provided at 1-min intervals. The total distance walked was recorded.¹¹ For the ISWT, participants walked back and forth along a 10-m course marked by two cones placed 9 m apart, following audio pacing signals. Walking speed increased at 1-min intervals, starting at 0.5 m/sec and increasing by 0.17 m/sec per level, up to a maximum of 12 levels. Jogging or running was not permitted.⁴

After receiving a detailed explanation of the study protocol, eligible participants underwent baseline assessments, including physical examination, electrocardiography, spirometry, and anthropometric measurements. Participants were instructed to: (1) obtain adequate sleep the night before testing; (2) avoid exercise for 24 hours prior; and (3) be in a postprandial state for at least 2 hours. Standardized testing conditions included comfortable footwear, medical-grade face masks, and sterilized equipment for each session. The testing protocol consisted of two 6MWT trials on Day 1 and the ISWT on Day 2, with a 30-min rest period between trials.

Outcome measures and statistical analysis

Following each test, the vital signs (blood pressure, HR, and oxygen saturation) of participants were recorded, and perceived exertion was assessed using the Borg scale, including rating of perceived exertion ([RPE] 6–20), dyspnea, and leg fatigue (1–10). The target RPE range was 12–13 (“somewhat hard”), while maximal scores (RPE = 20, dyspnea = 10, or fatigue = 10) were considered criteria for test termination.

Statistical analyses were performed using SPSS software version 20.0 (IBM Corp., USA). Data normality

was assessed using the Kolmogorov–Smirnov test. Continuous variables are presented as mean (standard deviation [SD]) for normally distributed data and median (interquartile range [IQR]) for non-normally distributed data. Between-test comparisons were conducted using paired *t*-tests (parametric) for normally distributed variables and Wilcoxon (non-parametric) signed-rank tests for non-normally distributed variables. Agreement between the 6MWT and ISWT was evaluated using Bland–Altman analysis. Linear regression of the difference against the mean was performed to assess proportional bias ($p < 0.05$); statistically significant proportional bias was interpreted as evidence of systematic disagreement between the tests. Bland–Altman plots were constructed for parameters that did not demonstrate significant between-test differences ($p \geq 0.05$).

Ethical statement

This study was approved by the Ethics Committee of the Faculty of Medicine, Universitas Indonesia – Cipto Mangunkusumo Hospital (No: KET-198/UN2.F1/ETIK/PPM.00.02/2022), and the Board Research Ethics Committee of Cipto Mangunkusumo Hospital (No: LB.02.03/2.6.1/0370/2022). Verbal and written informed consent were obtained from all participants. This study was conducted following the principles of the Declaration of Helsinki.

RESULTS

Of 100 eligible participants enrolled in this study, 75% were female, with a median age of 23.50 (18–51) years. All participants had completed at least an associate degree (diploma 3). The characteristics of the participants are presented in Table 1.

Walking distance comparison

Distances achieved during the 6MWT were normally distributed, with a mean (SD) distance of 538.3 (57.8) m (Table 2). In contrast, ISWT distances were non-normally distributed, with a median (IQR) distance of 460 (220–700) m.

Males outperformed females in both tests. The significant difference between test outcomes, together with the different distribution patterns, suggests that the two tests reflect distinct performance characteristics. Therefore, Bland–Altman agreement analysis was not performed for walking distance.

Table 1. Characteristics of participants

Variables	N = 100
Age (years), median (min–max)	23.50 (18–51)
Male	22 (19–51)
Female	26 (18–41)
Sex, n (%)	
Male	25 (25)
Female	75 (75)
BW (kg), mean (SD)	56.0 (8.9)
Male	65.0 (8.3)
Female	53.0 (6.0)
Body height (cm), mean (SD)	161.2 (8.0)
Male	171.7 (5.248)
Female	157.71 (5.125)
BMI (kg/m ²), mean (SD)	21.53 (2.07)

BMI=body mass index; BW=body weight; SD=standard deviation

Table 2. Walking distance between 6MWT and ISWT

Variables	Mean (SD)/median (IQR) (N = 100)	<i>p</i>
Walking distance in 6MWT (m)	538.3 (57.8)	0.03[†]
Male	568.0 (64.6)	
Female	528.4 (57.7)	
Walking distance in ISWT (m)	460 (220–700)*	0.049[†]
Male	520.0 (109.8)	
Female	445.6 (113.3)	
<i>p</i> for walking distance between two tests		<0.001

6MWT=six-minute walk test; IQR=interquartile range;

ISWT=incremental shuttle walk test; SD=standard deviation

*Non-normal distribution (median); [†]paired *t*-test

Borg scale comparison

Pre- and post-test Borg scale measurements are presented in Table 3.

Borg scale for effort (RPE)

Borg RPE data (pre- and post-test) for the 6MWT and ISWT were non-normally distributed. Both tests demonstrated significant within-test increases in RPE scores from pre- to post-test (all $p < 0.001$). However, no significant difference was observed between the post-test RPE scores of the two tests. Given the absence of a significant between-test difference in post-test RPE ($p > 0.05$), Bland–Altman agreement analysis was performed (Figure 1). Linear regression revealed

Table 3. Borg scale (RPE, dyspnea, and leg fatigue) and HR between 6MWT and ISWT

Variables	6MWT	ISWT	<i>p</i>
RPE, median (min–max)			
Pre-test	7 (6–13)	6 (6–13)	0.214*
Post-test	12 (6–16)	13 (7–15)	0.214*
<i>p</i>	<0.001*	<0.001*	
Dyspnea, median (min–max)			
Pre-test	0 (0–2)	0 (0–2)	0.453*
Post-test	1 (0–6)	2 (0–5)	0.024*
<i>p</i>	<0.001*	<0.001*	
Leg fatigue, median (min–max)			
Pre-test	0 (0–2)	0 (0–3)	0.871*
Post-test	2 (0–7)	2 (0–7)	0.828*
<i>p</i>	<0.001*	<0.001*	
HR, mean (SD)			
Pre-test	93.72 (13.902)	93.06 (14.16)	0.646†
Post-test	132.04 (22.39)	137.62 (18.42)	0.004†
<i>p</i>	<0.001†	<0.001†	

6MWT=6-minute walk test; HR=heart rate; ISWT=incremental shuttle walk test; RPE=rating of perceived exertion; SD=standard deviation
 *Wilcoxon test; †paired t-test

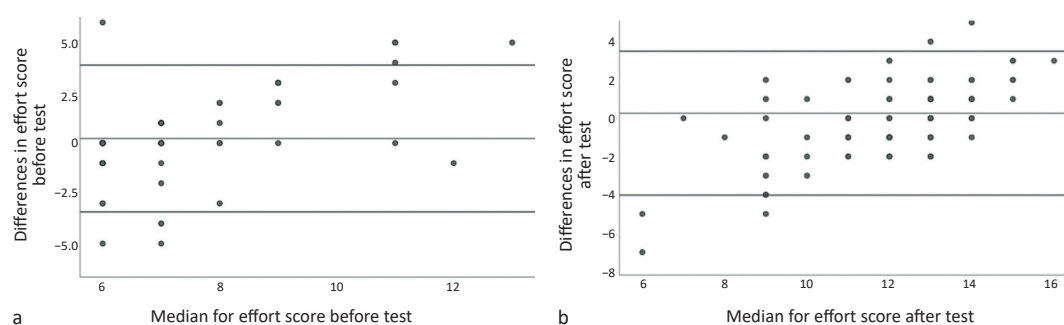
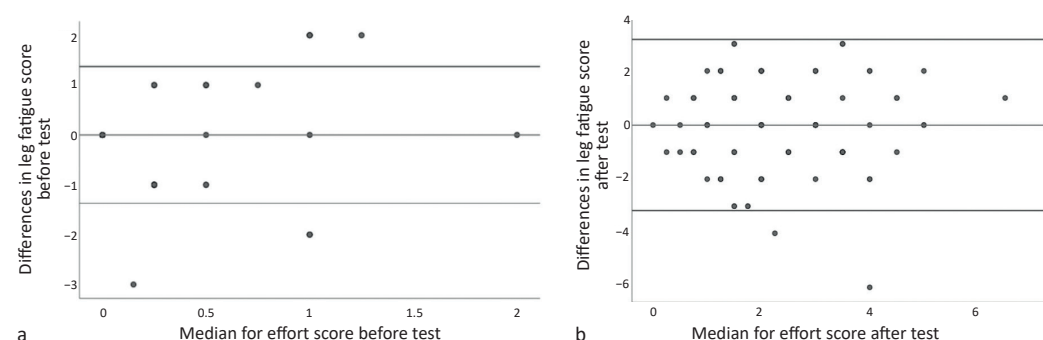
significant proportional bias ($p < 0.05$), indicating systematic divergence in post-test RPE responses between the ISWT and 6MWT.

Borg scale for dyspnea

Borg dyspnea scores (pre- and post-test) for the 6MWT and ISWT were non-normally distributed (Table 3). Median dyspnea scores increased significantly from pre- to post-test in both tests. Between-test comparison showed no significant difference in pre-test dyspnea scores ($p = 0.453$); however, post-test dyspnea scores were significantly higher following the ISWT than the 6MWT ($p = 0.024$).

Borg scale for leg fatigue

Borg leg fatigue scores (pre- and post-test) for both tests were non-normally distributed (Table 3). In the 6MWT, the median (min–max) leg fatigue score increased significantly from 0 (0–2) to 2 (0–7) ($p < 0.001$). A similar increase (0 [0–3] to 2 [0–7]) ($p < 0.001$) was observed in the ISWT. No significant differences were found between tests in either pre- or post-test leg fatigue scores. Because post-test scores did not differ significantly, Bland–Altman agreement analysis was performed (Figure 2). Linear regression showed no significant proportional bias ($p = 0.561$), indicating agreement between the tests for leg fatigue responses. Both tests elicited significant ($p > 0.05$) increases in perceived leg fatigue of comparable magnitude.

**Figure 1.** Bland–Altman plot for Borg rating of perceived exertion (RPE) scale. (a) Before intervention; (b) after intervention**Figure 2.** Bland–Altman plot for leg fatigue in Borg scale. (a) Before intervention; (b) after intervention

Comparison of HR

Pre-test HRs for the 6MWT and ISWT were normally distributed, with no significant difference ($p = 0.646$) between tests at baseline. The mean (SD) pre-test HR was 93.72 (13.90) beats per minute (bpm) for the 6MWT and 93.06 (14.16) bpm for the ISWT. Post-test HR also followed a normal distribution, and both tests produced significant increases from baseline (both $p < 0.001$). However, peak HR (HR_{peak}) values were significantly higher during the ISWT 137.62 (18.42) bpm than during the 6MWT (132.04 [22.39] bpm, $p = 0.004$). Similarly, the percentage of predicted maximal heart rate (HR_{max}) achieved was significantly greater during the ISWT (70.9 [9.2%]) than during the 6MWT (67.9 [10.9%]), ($p < 0.01$). Because post-test HR responses differed significantly between the two tests, Bland-Altman agreement analysis was not conducted, as the results indicate distinct cardiovascular demands.

DISCUSSION

This study examined the agreement between walking distance, Borg RPE, Borg dyspnea, Borg leg fatigue, and HR responses during the 6MWT and ISWT tests in healthy sedentary adults. Distances achieved in the 6MWT were normally distributed, with a mean (SD) distance of 538.3 (57.8) m, consistent with findings reported by Nurdwinuringtyas et al¹¹ in a similarly aged population (547.5 [54.2] m). Male (600 [91] m) participants achieved greater walking distances than females (417 [103] m), which aligns with established biomechanical differences, including shorter stride lengths in females that require higher step frequencies to maintain speed.^{9,12,13} In contrast, ISWT distances were non-normally distributed and showed more pronounced sex-related disparities, a pattern comparable to that reported by Dourado et al⁹. These differences may be influenced by anthropometric variation across populations. Agarwal et al¹⁴ and Itaki¹⁵ reported race-related performance differences, while Nurdwinuringtyas et al¹¹ demonstrated shorter stride lengths in Indonesian individuals (40–42.8 cm) than in Caucasian populations (72 cm).³ These findings underscore the importance of population-specific reference values.

When comparing the two tests, the 6MWT consistently produced longer walking distances than the ISWT. Similar patterns have been observed in Brazilian patients with congestive heart failure and

chronic obstructive pulmonary disease (COPD).¹⁶ This discrepancy is primarily attributed to differences in test design. The self-paced nature of the 6MWT allows participants to maintain a steady and physiologically tolerable rhythm, facilitating greater overall distance. In contrast, the ISWT imposes externally regulated incremental pacing, which increases cardiopulmonary demand more rapidly (evidenced by elevated HR and dyspnea) and may limit total distance achieved. These mechanistic differences underscore the distinct physiological demands and clinical roles of the two tests.

Walking distance was the primary output of both tests and served as an indirect indicator of cardiorespiratory fitness and maximal oxygen uptake (VO_{2max}), which can be estimated using predictive equations. Regression models incorporating height, age, and sex have been used to predict walking distance and subsequently estimate VO_{2max} . However, although height is an important determinant, predictive equations that adequately incorporate this variable remain limited. Existing models, including those summarized in the systematic review by Singh et al¹⁷ for patients with chronic lung disease, Nurdwinuringtyas et al¹¹ for healthy Indonesian adults (6MWT), and Azman et al¹⁸ for healthy Asian populations (ISWT), demonstrate that VO_2 prediction is strongly influenced by population-specific characteristics. For the ISWT, age and sex are key determinants of both VO_{2max} and highest amount of oxygen consumed at peak exercise (VO_{2peak}), and the absence of Indonesia-specific predictive equations further highlights the need to develop tailored models for this population.¹⁹

This study evaluated physiological responses using pre- and post-test measurements of HR, Borg RPE, dyspnea, and leg fatigue. Participants demonstrated a more comfortable walking pace during the 6MWT, reflected by significantly lower Borg RPE and dyspnea scores, as well as lower HR responses, compared with during the ISWT. These differences are likely attributable to the externally regulated, incremental pacing of the ISWT, which imposes progressively greater physiological demand.²⁰ Studies in patients with myocardial infarction (MI) and COPD have similarly suggested that the ISWT may better reflect maximal aerobic capacity because its standardized incremental protocol more closely resembles cardiopulmonary exercise testing (CPET).^{20,21}

In this study, HR_{max} achieved during the ISWT was significantly higher than during the 6MWT. Similar

findings have been reported in other populations, including patients with COPD in India and MI in Korea, where the ISWT elicited higher HR_{max} and greater metabolic demand than the 6MWT.^{20,22} Similar trends have also been observed in patients with cystic fibrosis in Turkey.⁸ Lim et al²⁰ further explained that the two tests produce distinct physiological response patterns. The 6MWT is characterized by a rapid initial increase in cardiorespiratory parameters, followed by a plateau, whereas the ISWT induced progressive increases throughout the test.²⁰ This distinction is supported by significantly higher VO_{2peak} , carbon dioxide production (VCO_{2peak}), minute ventilation (VE_{peak}), and HR_{peak} during the ISWT, indicating greater metabolic demand compared with that of the 6MWT. Despite these differences, both tests have been classified as submaximal assessments and may be used for cardiorespiratory training.²⁰

Both tests elicited submaximal exercise responses, as indicated by Borg RPE scores of 12–13 and HR of approximately 120 bpm (70–75% of HR_{max}), remaining below anaerobic threshold levels ($RPE \geq 15$ –16).^{3,23} The observed lack of agreement in post-test RPE (with ISWT requiring higher perceived exertion at comparable intensities) suggests that the ISWT imposes greater physiological stress on sedentary healthy individuals than the 6MWT. Higher RPE and dyspnea scores during the ISWT reflect its greater metabolic demand, driven by externally imposed incremental pacing. The increased ventilatory requirement during the ISWT may be related to progressively rising ventilatory load, which can increase inspiratory effort and breathing frequency. These adjustments contribute to heightened perceptions of breathlessness, reflected in elevated dyspnea scores, through increases in tidal volume and respiratory rate.⁶

Both tests produced significant increases in perceived leg fatigue; however, the comparable magnitude of change and absence of between-test differences ($p > 0.05$) on Bland–Altman analysis suggest similar lower-extremity demand in sedentary healthy individuals. One study reported that the incremental pacing of the ISWT may recruit glycolytic muscle fibers as intensity approached the lactate threshold,⁹ respectively whereas participant-paced 6MWT typically remains below this threshold. However, Pulz et al²⁴ observed minimal lactate elevation during both tests, indicating that exercise metabolism remains predominantly aerobic. They also suggested that a

ceiling effect (precluding running) during the ISWT may limit anaerobic contribution and influence the ventilatory efficiency (VE/VCO_2) response. Despite comparable baseline dyspnea scores, post-exercise Borg dyspnea ratings were consistently higher following the ISWT (2 versus 1 in the 6MWT), indicating greater perceived respiratory effort in sedentary healthy individuals.

Both tests reflected submaximal exercise intensity. The observed responses suggest that neither protocol reached the anaerobic threshold (typically requiring $>85\% HR_{max}$ or $RPE \geq 15$ –16). Instead, exercise intensity appeared to remain within approximately 70–75% of maximal capacity, together with post-test Borg RPE scores of 12–13, consistent with established criteria for submaximal exercise in sedentary populations.^{1,3,23} Additional methods for confirming exercise intensity, such as blood lactate measurement, have been used in previous studies of the 6MWT.³ Further physiological assessment would help verify intensity classification in future research.

This study included participants aged 18–59 years, with a predominance of female participants and a median age of 26 years. Male participants demonstrated a younger median age (22 years) and greater age variability. These demographic characteristics differ from those reported by Dourado et al,⁹ likely due to differences in age inclusion criteria. The higher proportion of female participants may reflect workforce demographics in Central Jakarta (52.37%)²⁵ and the use of consecutive sampling at Cipto Mangunkusumo Hospital.

Anthropometric data indicated that most participants had a normal BMI. This is clinically relevant, since an elevated BMI has been associated with reduced walking speed.¹² Previous studies have shown that obesity is linked to lower lean body mass, shorter walking distances, and increased basal metabolic demand compared with individuals of normal weight,^{9,26} leading to greater cardiovascular and ventilatory strain.²⁶ Moreover, the lower average height observed in female participants contributes to shorter stride length and higher stride frequency during walking.⁹

The study was conducted during the coronavirus disease 2019 pandemic, which introduced some limitations. The cohort consisted predominantly of young adults and female participants, potentially limiting the generalizability of the findings to

Indonesia's broader and more diverse population. Physical distancing protocols restricted evaluator proximity during walking tests, which may have influenced participant performance. Additionally, the use of the English-language PAR-Q+ questionnaire may have posed challenges for participants with lower educational backgrounds. Despite these limitations, the study has several strengths. To our knowledge, this is the first study to provide a comparative analysis of 6MWT and ISWT performance and physiological responses in sedentary, healthy Indonesian adults. The study offers clinically relevant data using field-based tests without the need for CPET equipment. The focus on an understudied population enhances the study's novelty and practical relevance. Furthermore, ethical standards were rigorously maintained, and the methodological rigor, including a sample size with >95% statistical power (Z beta) and strict BMI and activity-level criteria, supports the reliability and applicability of the findings.

In conclusion, this study demonstrated significant differences between the 6MWT and ISWT in sedentary healthy adults, particularly in walking distance, Borg dyspnea scores, and HR responses, while Borg leg fatigue responses were comparable between the two tests. These findings highlight the distinct physiological demands of the two field-based exercise tests. The results provide a basis for future research to evaluate test performance across broader and age-stratified populations, conduct multicenter studies, and develop population-specific prediction equations for walking distance and VO_2 during the ISWT in Indonesian adults. Additionally, incorporating blood lactate measurements in future studies may further clarify the physiological intensity of these tests.

Conflict of Interest

The authors affirm no conflict of interest in this study.

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