



COMPARING SUBMAXIMAL EXERCISE TESTS FOR VO₂ MAX ESTIMATION: SIX-MINUTE WALK TEST VERSUS TECUMSEH STEP TEST IN OVERWEIGHT AND OBESE ADULTS

Physiotherapy

Dr Ayesha Mulla (PT)* Department of Physiotherapy, U N Mehta Institute of Cardiology and Research, Ahmedabad, India *Corresponding Author

Dr Rakeshkumar Singh (PT) Department of Physiotherapy, JRN Physiotherapy college, Udaipur, Rajasthan, India

Dr Shailendra Mehta (PT) Department of Physiotherapy, JRN Physiotherapy college, Udaipur, Rajasthan, India

ABSTRACT

Background: In young people, obesity presents serious health risks, especially with reference to cardiorespiratory fitness. Comparison of different submaximal exercise tests is essential for determining the accuracy and applicability of field-based measures of exercise capacity. Although both tests are simple, inexpensive, and feasible for large populations, they reflect different physiological constructs. Therefore, assessing and comparing VO₂ max estimates derived from the 6MWT and TST is important to determine whether these tests can be used interchangeably or whether they provide distinct insights into cardiorespiratory fitness, particularly in populations with altered exercise physiology such as overweight and obese adults. **Objective:** To evaluate the physiological reactions, prediction accuracy, and usefulness of the 6MWT and TST in young adults who are overweight or obese, paying particular emphasis to heart rate, subjective effort, and VO₂ max estimation. **Method:** Cross-sectional comparison investigation was conducted on 60 class I obese people (BMI 25–34.9 kg/m²; ages 18–30). Standard prediction models were used to estimate VO₂ max after the 6MWT and TST. Post-exercise heart rate, oxygen saturation, and perceived effort rating were noted. Non-parametric tests and paired t-tests were used to assess the data. **Result:** The VO₂ max in the TST was significantly greater than that in the 6MWT (33.66 ± 6.15 mL/kg/min, $p < 0.001$), at 27.12 ± 3.75 mL/kg/min. While SpO₂ stayed constant in both tests ($p = 0.67$), post-test HR and RPE were similarly significantly higher after TST ($p < 0.001$). The results show that TST imposes a higher physiological load because it causes more perceived and cardiovascular effort. **Conclusion:** In summary, the 6MWT and TST produce notably different estimations of VO₂ max and exertional responses, suggesting that they cannot be used interchangeably in groups that are overweight or obese. The assessment purpose, safety, and practicality should all be taken into consideration when choosing a test, and additional validation in various clinical contexts is necessary.

KEYWORDS

6 minute walk test, Tecumseh step test, VO₂ max

INTRODUCTION

The World Health Organization (WHO) defines obesity as having a body mass index (BMI) of 25–29.9 kg/m² as overweight and 30–34.9 kg/m² for grade one obesity. The world prevalence of obesity has increased exponentially over the past decade in both adults and children and is linked to a higher risk of cardiovascular disease, diabetes, and impaired quality of life. Obesity in young adults is of specific worry as it is related to decreased cardiorespiratory function, physical inactivity, and development of metabolic complications at an early age [1,2,3,4].

Recent research emphasizes that obesity levels are still on the rise globally, with a considerable percentage of young adults being obese [3]. Obesity at this age is associated with increased cardio-metabolic clustering of risk factors, such as hypertension, dyslipidaemia, and insulin resistance, which may result in long-term morbidity. Moreover, higher BMI is also associated with poor physical functioning and functional status, as indicated by walking ability and exercise tolerance [2,3,4].

Cardiorespiratory fitness, routinely measured by the determination of peak oxygen uptake (VO₂ max), is an important marker of the health of overweight and obese persons. The gold standard measurement for VO₂ max is the cardiopulmonary exercise test (CPX), but it is limited by cost, equipment, and the requirement for specialized staff [1,2,5]. Consequently, field-based tests like the Six-Minute Walk Test (6MWT) and step tests-the Tecumseh Step Test and the three -Minute Step Test (MST)-are popular substitutes [1,2,5,6].

The 6MWT is a quick, submaximal exercise test to assess the walking distance for six minutes on a level surface. It is economical, simple to administer, and well tolerated, and is appropriate for use in obese populations and in the assessment of changes in functional capacity over time. The Tecumseh Step Test and its derivative, the 6MST, consist of stepping up and down from a platform for a predetermined period of time, offering an alternative way to estimate VO₂ max and cardiorespiratory fitness, particularly when there is a lack of space or resources. Stepping tests can be more physiologically stressing and poorly tolerated by those with greater BMI. [1,2,5,6]

Although both tests are commonly utilized, very little research compares directly the efficacy of the tests among obese grade I young adults. Recent findings indicate that the 6MST measures greater VO₂ peak and heart rate values than the 6MWT, yet the two tests are not equivalent for evaluating aerobic capacity in this population. Due to the distinct physiological load and safety issues for obese persons, it is important to identify which measure is the most precise, convenient, and safest estimator of cardiorespiratory fitness [1, 5, 6]. The purpose of the present investigation was to assess the physiological responses, validity, and practicality of the Tecumseh Step Test (TST) with the Six-Minute Walk Test (6MWT) in individuals who are overweight and obese. The goals were to evaluate and compare the functional exercise capacity as determined by the two tests. The study also sought to examine the physiological reactions after the two tests, such as heart rate, oxygen saturation, and subjective exertion. Collectively, these objectives were intended to determine whether the Tecumseh Step Test could serve as a practical alternative to the 6MWT in overweight and obese populations, particularly in clinical or community settings with limited space.

MATERIALS & METHODS

A cross-sectional comparative study design was used, and the research was carried out in overweight and obese class I adults who were recruited from community health canters, obesity clinics, and university wellness programs. Participants were between 18 and 30 years of age and with a body mass index (BMI) of 25 to 34.9 kg/m² or higher, according to the World Health Organization (WHO) classification. Participants who were medically stable and fit for submaximal exercise testing were considered eligible. Participants with uncontrolled cardiovascular, pulmonary, or musculoskeletal disorders, those who had recently had major surgery, or those incapable of walking or step activity were excluded. A priori sample size calculation, using an assumed correlation coefficient of 0.6 between 6MWT and TST results, alpha of 0.05, and power of 0.80, hence 60 participants were considered for the study.

The 6-Minute Walk Test (6MWT) was performed in accordance with American Thoracic Society guidelines and standard protocols for use in young adults. The participants, between the ages of 18 to 30 years, were

requested to dress casually and wear suitable shoes. The participants were also asked to abstain from heavy exercise for at least two hours before the test. Baseline heart rate, blood pressure, and oxygen saturation were measured before the commencement of the test. Each participant was told about the test, with the stress that they should walk as far as they could in six minutes along a straight, level, 30-meter corridor, reversing direction at marked points. Participants began on the marked line, and the timer was started when they began walking. Encouragement was standardized at equal intervals, for example, every minute, to keep them motivated. During the test, the subjects were observed for symptoms such as chest pain, severe breathlessness, or dizziness, and the test was interrupted if any negative symptoms arose. Participants were asked to stop at six minutes, and the distance walked was recorded to the nearest meter. Heart rate, RPE, blood pressure, and oxygen saturation were assessed again immediately following the test. The main outcome was the six-minute walk distance, with secondary outcomes being heart rate response and any symptoms reported [7,8]. $6MWT\ VO_2\ max\ (mL/kg/min) = 12.701 + (0.06 \times 6MWD\ [m]) - (0.732 \times BMI\ [kg/m^2])$ [9].

Following a minimum two-hour rest period, the Tecumseh Step Test was conducted. The subjects were asked not to consume caffeine, smoke, or have a heavy meal at least two hours prior to the test. A 20.3 cm (8 inch) standardized step was employed. Baseline heart rate and blood pressure were recorded before the test. The participants were then requested to step up and down on the platform at 24 steps per minute for three minutes, as guided by a metronome or an audio cue. A step cycle involved stepping up with each foot alternately, followed by stepping down with each foot alternately [10, 11]. Participants were monitored for any distress reactions and the test was stopped if needed. At the end of three minutes, subjects sat down at once, and heart rate was recorded for one minute, beginning within five seconds of test termination. Symptoms and adverse events were noted. The main outcome was $VO_2\ max$ and post-exercise heart rate, with secondary outcomes being saturation and subjective exertion [12].

$VO_2\ max$ was calculated with, $VO_2max = 84.687 - 0.722 \times HR_{post}(bpm) - 0.383 \times age(y)$ [13]



Fig1.1: Tecumseh Step Test



Fig 1.2: 6 Mwt

Statistical Analysis [as applicable]

Spss version 20 used for the analysis of the data. The demographic data were analysed by descriptive statistics, pre vitals and $VO_2\ max$ were assessed for the normality. All the normally distributed parameters were assessed with parametric and other were assessed with the non-parametric test.

RESULT

The mean age of the participants was 27.91 ± 5.45 and BMI was 29.37 ± 1.83 . In the present study 31 were female and 29 male were participated.

Table 1: Mean and Standard Deviation of Age, BMI and Gender Distribution

	Mean & sd
Age (year)	27.91±5.45
BMI (kg/m ²)	29.37±1.83
Gender distribution (%)	51% (Females) 49% (male)

The VO₂max from the six-minute walk test and step test showed the baseline normality, hence the paired t test used for the analysis, whereas post HR, RPE and SPO₂ were analysed with non-parametric test.

Table 2: VO₂max from Six-minute Walk Test and Tecumseh Step Test

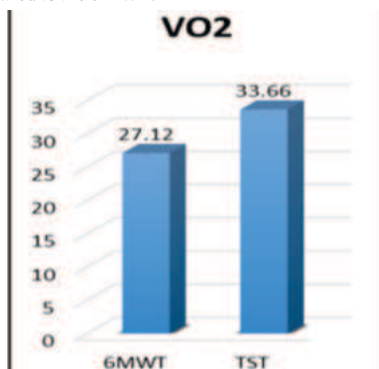
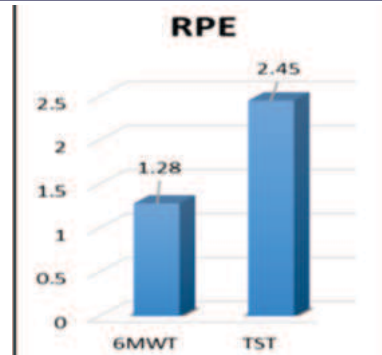
	6 MWT	Tecumseh step test	p value
VO ₂ max (ml/kg/min)	27.12 ± 3.75	33.66 ± 6.15	0.00

The VO₂max values estimated from the 6-minute walk test (6MWT) and the Tecumseh step test are shown in Table 2. The average VO₂max obtained from the 6MWT was 27.12 ± 3.75 ml/kg⁻¹.min⁻¹, while the Tecumseh step test produced a notably higher average VO₂ max of 33.66 ± 6.15 ml.kg⁻¹.min⁻¹. Statistical evaluation indicated a highly significant difference between the two tests (p = 0.00), suggesting that the Tecumseh step test consistently overestimates VO₂ max relative to the 6MWT. This variation implies that the two field tests cannot be used interchangeably for evaluating aerobic capacity in the studied population.

Table 3: Analysis of Post Vitals of 6MWT & TST by Non-parametric Test

	6 MWT	TST	p value
Post HR	92.87 ± 11.18	121.35 ± 18	0.00
Post RPE	1.28 ± 0.7	2.45 ± 1.24	0.00
Post SpO ₂	99.78 ± 0.5	99.81 ± 0.5	0.67

A statistically significant variation was noted in post-exercise heart rate (HR), with elevated values observed after the TST (121.35 ± 18 bpm) in comparison to the 6MWT (92.87 ± 11.18 bpm, p < 0.001). Similarly, ratings of perceived exertion (RPE) were markedly higher after the TST (2.45 ± 1.24) when compared to the 6MWT (1.28 ± 0.7, p < 0.00), reflecting greater subjective exertion during the step test. In contrast, oxygen saturation (SpO₂) remained consistent throughout both assessments, showing no significant difference between post-test results (6MWT: 99.78 ± 0.5%; TST: 99.81 ± 0.5%, p = 0.67). These results indicate that while both tests ensured sufficient oxygenation, the Tecumseh step test produced greater cardiovascular and perceptual strain compared to the 6MWT.

**Graph 1: VO₂ max from 6MWT & TST****Graph 2: HR from 6MWT & TST****Graph 3: RPE from 6MWT & TST**

DISCUSSION

An increasing amount of research has concentrated on evaluating cardiorespiratory fitness in individuals who are overweight and obese, with the Six-Minute Walk Test (6MWT) and the Three-Minute Step Test (TST), which includes the Tecumseh Step Test variation) being two commonly used field assessments. This discussion integrates current findings that compare these assessments, especially among individuals classified as overweight and obese class 1, and assesses their interchangeability and physiological responses.

In this study involving individuals with overweight and class I obesity, the VO₂ max values estimated through the Six-Minute Walk Test and the Tecumseh Step Test were notably different, and there were also significant variations in post-test heart rate (HR) and perceived exertion (RPE). This clearly demonstrates that while both tests are classified as submaximal, they measure different aspects of cardiorespiratory fitness. Due to their distinct physiological requirements and estimation methodologies, these tests should not be considered interchangeable for evaluating VO₂max in this demographic.

The 6MWT focuses on self-paced walking, prioritizing the distance travelled. VO₂ max estimation is based on regression models that take into account distance along with factors such as BMI or body composition (e.g., fat-free mass) [14]. The Tecumseh Step Test involves a consistent stepping rate on an elevated platform, with VO₂max estimated by measuring heart rate recovery (HRR) within 30–60 seconds after the exercise [10]. These various modalities naturally engage different metabolic and autonomic pathways.

A recent observational study directly compared the 6MWT and 6MST in class I obese adults (BMI 30–34.9 kg/m², aged 18–25). The results demonstrated a statistically significant difference in VO₂ peak values calculated from the two tests, with the 6MST yielding higher VO₂ peak estimates than the 6MWT (p < 0.05) [14]. This finding indicates that the physiological demands and energy expenditure differ between the tests, likely due to the greater involvement of lower limb muscle strength and the vertical component of the step test. Obese individuals expend more energy per kg during walking (~10% higher metabolic cost) and adopt altered gait patterns (shorter, wider steps), limiting walking performance on 6MWT [15,16]. These biomechanical constraints can dampen distance walked, biasing 6MWT-based VO₂max estimates downward. The Tecumseh test's reliance on HRR makes its VO₂max estimates especially sensitive to these obesity-related changes. The self-paced 6MWT allows for comfort and pacing modifications, which may result in reduced RPE and HR. The fixed-cadence Tecumseh step test, on the other hand, requires a continuous vertical workload, which frequently results in increased exertional HR and RPE, particularly in people who are overweight. Together, these modality-specific and obesity-modulated factors explain why VO₂ max and post-test HR/RPE differ markedly, confirming non-interchangeability.

The fact that 6MWT and 6MST performance only moderately correlated (r = 0.501; p = 0.01) in another investigation of overweight and obese young adults further supports the hypothesis that these tests are not directly interchangeable for VO₂ max estimate [2]. Lower limb muscle strength also predicted the 6MST performance, demonstrating the impact of musculoskeletal parameters in addition to cardiorespiratory fitness [17].

Both studies reported significant differences in post-test heart rate (HR) and ratings of perceived exertion (RPE) between the two tests. The 6MST consistently elicited higher HR and RPE values compared to the 6MWT [18]. This suggests that the step test imposes a greater cardiovascular and subjective workload, which may affect test tolerability and safety, especially in individuals with low fitness or comorbidities.

The 6MWT is more likely to be completed than the step test, according to evidence from a wider age range (14–85 years), with the latter being less practical for older, less fit, or higher BMI people [4]. The 6MWT is a safer choice for field testing in clinical and community settings since it is usually thought to be less physically demanding and better tolerated [5]. The 6MST has shown good construct validity and intrarater reliability in groups that are overweight or obese, with performance repeatability (ICC > 0.8) for both cardiovascular variables and test results [17]. However, the influence of muscle strength on step test outcomes and the moderate connection with 6MWT performance highlight the necessity of interpreting these tests in light of their unique physiological demands.

The 6MWT distance decreases as BMI increases, and obese individuals consistently perform worse than their normal-weight counterparts, with men outperforming women in all BMI categories [1]. Improvements in 6MWT performance after exercise interventions correlate with favourable changes in metabolic parameters (insulin, cholesterol, HOMA-IR) in children with obesity, supporting its utility as a monitoring tool [18]. The 6MWT is widely accepted, cost-effective, and well-tolerated, making it suitable for repeated assessments in both paediatric and adult obese populations [5].

Clinical and Research Implications

- Avoid Interchangeability:** Significant discrepancies between VO_2max estimated via 6MWT and Tecumseh step test, along with different HR/RPE responses, confirm that these tests should not be used interchangeably, especially across serial measurements.
- Test Selection Based on Assessment Goals:** Use 6MWT when assessing functional ambulatory capacity, mobility, and endurance relevant to daily living. Choose step tests, like Tecumseh or 6MST, when evaluating cardiovascular recovery, autonomic function, or risk stratification, as HRR is a validated marker of cardiometabolic risk [19].
- Standardization and Equation Choice:** Stick with one test and one prediction equation for repeated measures to ensure consistency and avoid misattributing modality differences to physiological change.

Limitations: Current findings are based on indirect VO_2max estimations, without direct metabolic measurement, which remains the gold standard (CPET).

CONCLUSION

In conclusion, the 6MWT and Tecumseh Step Test (TST) provide valuable but distinct information about functional capacity in overweight and obese individuals. Statistically significant differences in VO_2max /peak, heart rate, and perceived exertion preclude their interchangeable use. Test selection should be guided by the specific assessment goals, participant characteristics, and safety considerations. Ongoing research is warranted to refine test protocols and expand their applicability across the obesity spectrum.

Declaration by Authors

Ethical Approval: Approved

Acknowledgement: None

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

- Santos-Martínez, L., Osegueda-Palomera, N., Montoya-Landa, C., Reséndiz-Herrera, R., Ordoñez-Reyna, A., Arroyo-González, J., Quevedo-Paredes, J., & Moreno-Ruiz, L. [Six minute walk test: From normal to morbid obesity subject]. *Archivos de cardiología de México*. 2023 <https://doi.org/10.24875/ACM.22000079>.
- Valerio, G., Licenziati, M., Tortorelli, P., Calandriello, L., Alicante, P., & Scalfi, L. Lower Performance in the Six-Minute Walk Test in Obese Youth With Cardiometabolic Risk Clustering. *Frontiers in Endocrinology*. 2018; 9. <https://doi.org/10.3389/fendo.2018.00701>.
- Lin, X., & Li, H. Obesity: Epidemiology, Pathophysiology, and Therapeutics. *Frontiers in Endocrinology*. 2021; 12. <https://doi.org/10.3389/fendo.2021.706978>.
- Beaumont, M. et al. (2019) 'Comparison of 3-minute Step Test (3MStepT) and 6-minute Walk Test (6MWT) in Patients with COPD', *COPD: Journal of Chronic Obstructive Pulmonary Disease*, 16(3–4), pp. 266–271. doi: 10.1080/15412555.2019.1656713.
- Larsson, U., & Rejnisdottir, S. The six-minute walk test in outpatients with obesity: reproducibility and known group validity. *Physiotherapy research international : the journal for researchers and clinicians in physical therapy*. 2008; 13 2. <https://doi.org/10.1002/pri.398>. Bohannon, Richard W et al. "Six-Minute Walk Test Vs. Three-Minute Step Test for Measuring Functional Endurance." *Journal of strength and conditioning research* vol. 29,11 (2015): 3240-4. doi:10.1519/JSC.
- ATS statement: guidelines for the six-minute walk test. *American journal of respiratory and critical care medicine*. 2002; 166 1.
- Halliday, S., Wang, L., Yu, C., Vickers, B., Newman, J., Fremont, R., Huerta, L., Brittain, E., & Hemmes, A. Six-minute walk distance in healthy young adults. *Respiratory medicine*. 2020; 165. <https://doi.org/10.1016/j.rmed.2020.105933>.
- Enright PL, Sherrill DL. The six-minute walk test as a predictor of maximal aerobic power ($\text{VO}_{2\text{max}}$) in healthy working-aged adults. *Scand J Med Sci Sports*. 2018;28(7):1529–1538.
- Hughes, A., & Chaturvedi, N. Estimation of maximal oxygen consumption and heart rate recovery using the Tecumseh sub-maximal step test and their relationship to cardiovascular risk factors. *Artery Research*. 2017; 18. <https://doi.org/10.1016/j.artres.2017.02.005>.
- Sunghyun Hong, Junga Lee, Jihye Park, Mikyung Lee, J. Kim, Kyong-chol Kim, Sun Hyun Kim, J. Im, S. Chu, S. Suh, Sang Hwan Kim and J. Jeon. "Association between cardiorespiratory fitness and the prevalence of metabolic syndrome among Korean adults: a cross sectional study." *BMC Public Health*, 14 (2014): 481 - 481. <https://doi.org/10.1186/1471-2458-14-481>.
- Kim, Ji Young, Min Ji hee and J. Jeon. "Criterion-related Validity of Tecumseh Step-test for Estimating Cardiopulmonary Fitness.", 29 (2015): 99-110. <https://doi.org/10.16915/jkapesgw.2015.09.29.3.99>.
- Hughes AD, Chaturvedi N. Estimation of maximal oxygen consumption and heart rate recovery using the Tecumseh sub-maximal step test and their relationship to cardiovascular risk factors. *Prev Med Rep*. 2017;6:154-159.
- Metz L, Thivel D, Peirera B, Richard R, Julian V, Duclos M. A new equation based on the 6 min walking test to predict VO_2peak in women with obesity. *Disability and Rehabilitation*. 2017 March 27;40(14):1702-1707. doi: 10.1080/09638288.2017.1304582.
- Dharini P. Vengurlekar, Jahnvi Panwar. Six Minute step test vs. six minute walk test to measure VO_2peak in obese class 1 adults: an observational study. *Int J Health Sci Res*. 2024; 14(5):70-76. DOI: <https://doi.org/10.52403/ijhsr.20240508>
- Browning RC, Kram R. Effects of obesity on the biomechanics of walking at different speeds. *Medicine & Science in Sports & Exercise*. 2007 JI:39(10):1632-1641. doi:10.1249/mss.0b13e31804f43fa.
- Pereira, T, De Lima, A., Monte, J, Da Silva Araujo, L, De Vasconcelos, C, & Soares, A. Six-minute step test for overweight and obese subjects: concurrent validity, intrarater reliability and prediction equation.2020;19. <https://doi.org/10.33233/rbfex.v19i5.4296>.
- Ghosh T, Shinde M., Kawale S., Kumar S., & D'souza, A. Six-Minute Walk Test among obese and nonobese subjects: A comparative analysis among apparently healthy volunteers. *Annals of Medical Science & Research*. 2024 <https://doi.org/10.4103/amr.amr.48.23>.
- Giovanelli, L, Bernardelli, G, Facchetti, S, Malacarne, M, Vandoni, M, Pellino, V, Zuccotti, G, Calcaterra, V, & Lucini, D. Metabolic improvement after exercise training in children with obesity: Possible role of the six-minute walking test. *PLOS One*. 2025; 20.
- Di Thommazo Luporini L, Carvalho LP, Luporini RL, Trimer R, Pantoni CB, Catai AM, Arena R, Borghi Silva A. The Six Minute Step Test as a predictor of cardiorespiratory fitness in obese women. *Eur J Phys Rehabil Med*. 2015;51(6)