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The two-minute step test as a potential alternative to the six-minute step test for evaluating functional capacity: a cross-sectional study

O teste do degrau de dois minutos como alternativa ao teste do degrau de seis minutos para avaliação da capacidade funcional: um estudo transversal

Victor Regufe[1,2]; Larissa Costa Tavares[1]; Luana Soares de Oliveira[1]; Pedro Antonio Racca[1]; Thamyres Vitória Gomes[1]; Alessandra Choqueta de Toledo Arruda[1,3]; Michel Silva Reis[1,2,3]*

[1]Grupo de Pesquisa em Avaliação e Reabilitação Cardiorrespiratória (GECARE), Faculdade de Fisioterapia, Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, RJ, Brasil
[2]Programa de Pós-graduação em Educação Física, Escola de Educação Física e Desportos, Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, RJ, Brasil
[3]Programa de Pós-graduação em Ciências da Reabilitação, Faculdade de Fisioterapia e Faculdade de Medicina, Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, RJ, Brasil

Abstract

Background: Step tests are widely used to assess functional capacity in various clinical settings. However, the 6-minute step test (6MST) duration may limit its applicability in less conditioned individuals. **Aim**: To verify whether the 6-minute (6MST) and 2-minute (2MST) step tests are equivalent regarding peak heart rate (HR) and peak oxygen consumption (VO_2) in healthy individuals. **Methods:** This is an experimental, cross-sectional, and prospective study. Twenty-one healthy volunteers of both sexes, with a mean age of 24.00±5.50 years, mostly eutrophic and highly active (57.14%), attended three visits. In the first visit, questionnaires were applied, assessments performed, and demographic and anthropometric data collected, along with familiarization with the step test. On the second and third visits, the 6MST and 2MST were performed in a randomized order. HR and VO_2 were monitored throughout the tests. **Results:** Significant differences were found between 6MST and 2MST in performance, cadence, and power. However, strong correlations were observed for performance (r=0.81) and cadence (r=0.81), and a very strong correlation for power (r=0.90). Performance agreement was 76.19%. Weak (r=0.47) and very weak (r=0.37) correlations were found between VO_2 peak and HR peak in the 6MST and 2MST, respectively. No significant differences were found for peak VO_2 or subjective perception of effort. Regarding peak HR, both tests achieved values above 84% of the age-predicted maximum, comparable to those typically observed in maximal exercise tests. **Conclusion:** Participants showed similar physiological responses in some parameters, including performance, cadence, power, VO_2 peak and HR peak, suggesting some similarity between the 6MST and 2MST in healthy individuals, although the physiological results were somewhat inconsistent.

Keywords: Exercise test; Exercise tolerance; Oxygen consumption.

Resumo

Introdução: O teste de degrau é amplamente utilizado para a avaliação da capacidade funcional em diferentes contextos clínicos. Contudo, o tempo de execução de 6 minutos pode ser um fator limitante para a execução em indivíduos menos condicionados. **Objetivo:** Verificar se há equivalência entre os testes de degrau de 6 e 2 minutos (6MST e 2MST) em relação à frequência cardíaca (HR) pico e ao consumo de oxigênio (VO_2) pico em indivíduos saudáveis. **Métodos:** Trata-se de um estudo experimental, transversal e prospectivo. Vinte e um voluntários saudáveis, de ambos os sexos, com idade média de 24,00±5,50 anos, majoritariamente eutróficos e muito ativos (57,14%), foram submetidos a três visitas. Na primeira visita, foram aplicados questionários, realizadas avaliações, coletados dados demográficos e antropométricos, além da familiarização com o teste de degrau. Na segunda e terceira visitas, os testes 6MST e 2MST foram realizados de forma randomizada. A HR e o VO_2 foram monitorados ao longo dos testes. **Resultados:** Houve diferenças significativas entre o -6MST e o 2MST no desempenho, cadência e potência. No entanto, observou-se forte correlação no desempenho (r=0,81) e na cadência (r=0,81), além de correlação muito forte na potência (r=0,90). A concordância no desempenho foi de 76,19%. Foram encontradas correlações fraca (r=0,47) e muito fraca (r=0,37) entre o VO_2 pico e a HR pico no 6MST e 2MST, respectivamente. Não houve diferenças significativas no VO_2 pico ou na percepção subjetiva de esforço. Quanto à HR pico, apesar de diferença estatística, em ambos os testes ela foi acima de 84% do previsto para idade, se assemelhando à encontrada em testes de caráter máximo. **Conclusão:** Os participantes apresentaram respostas fisiológicas semelhantes em alguns parâmetros, considerando desempenho, cadência, potência, VO_2 pico e HR pico, sugerindo alguma similaridade entre o 6MST e o 2MST em indivíduos saudáveis, embora os resultados fisiológicos apresentem achados controversos.

Palavras-chave: Teste de exercício; Tolerância ao exercício; Consumo de oxigênio.

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***Corresponding author:** Michel Silva Reis.
E-mail: msreis@hucff.ufrj.br

INTRODUCTION

The step test (ST) is a validated and practical tool for estimating functional capacity in various populations, offering advantages over other tests[1–3]. The 6-minute step test (6MST) is commonly used due to its comparison with the 6-minute walk test (6MWT)[4], but shorter protocols like the 2-minute step test (2MST) also exist[5–7].

Although the ST is generally considered a submaximal test , it can become maximal in certain populations, such as individuals with obesity and patients with chronic diseases[8,9]. Previous studies have shown that individuals with more compromised functional capacity often struggle to complete the 6MST[6,10], highlighting the need for shorter and more feasible protocols[3,5,7]. In this context, evidence showing no major differences in functional capacity estimation between the 12MWT and the 6MWT[11,12], suggests that a similar rationale could be applied to the step test, supporting the potential for comparison between the 6MST and the shorter 2MST. Furthermore, research has emphasized the role of subjective perception of exertion (SPE) in ST, which serves as a useful parameter for monitoring training effects and stratifying different populations[1,13].

Beyond functional performance, physiological responses such as peak oxygen uptake (VO_2 peak) and peak heart rate (HR peak) provide valuable markers of exercise intensity and cardiovascular stress during ST protocols[3,4]. Analyzing these variables allows for a more comprehensive assessment of test equivalence, since a shorter test should ideally elicit similar physiological responses to the longer one.

This study aims to evaluate the equivalence between 6MST and 2MST in terms of VO_2 peak and HR peak in healthy individuals, assessing whether the shorter test can replace the longer one in this population.

METHODS

Study design

This is an experimental, cross-sectional, and prospective study following STROBE guidelines.

Study participants

Participant recruitment and data collection were carried out between September 2019 and February 2020; however, the process had to be interrupted due to the COVID-19 pandemic.

Participants of both genders aged 18-40 years, without chronic conditions affecting test performance, were included[14]. Exclusion criteria included balance deficits (Romberg test)[15] failure to complete tests, non-attendance to all sessions, or inability to follow instructions.

The study was approved by the Research Ethics Committee in accordance with Resolution 466/2012 of the Brazilian National Health Council (CAAE: 26421619.1.0000.5257), and all participants provided written informed consent.

Experimental procedure

Participants attended three sessions, each 48 hours apart, with instructions to avoid smoking, alcohol, stimulants, and intense exercise before assessments.

All safety precautions were in place to ensure volunteer well-being. The assessments were conducted in a controlled laboratory setting by trained evaluators, prepared to handle any intercurrences and provide medical referral if needed.

First visit: Participants underwent demographic data collection, lifestyle questionnaires (Physical Activity Readiness Questionnaire – PAR-Q[16], International Physical Activity Questionnaire – IPAQ[17]), and a physical assessment that included measuring vital signs [heart rate (HR), blood pressure (BP), respiratory rate (RR)], spirometry[18], and static balance evaluation using the Romberg test, performed with feet together and eyes closed[15]. Anthropometric measurements such as height, weight, and body mass index (BMI) were recorded. Additionally, a familiarization session with ST was conducted, in which participants performed a 30-second step simulation[1].

Second and third visits: On these days, participants randomly performed either the 6MST or the 2MST, with the order determined by a sealed-envelope draw. The test was conducted on a 20-cm-high, 80-cm-wide, 40-cm-deep step without hand support[10]. Before the test, volunteers were familiarized with the SPE scale [Modified Borg Scale (CR-10)] for exertion, assessing dyspnea and lower limb (LL) fatigue. During the test, participants were instructed to ascend and descend as many steps as possible within the stipulated time, receiving standardized verbal encouragement[10]. Performance was recorded as the total number of steps climbed, cadence (steps/min), and power (work/time), in which the total displacement was the product of three factors: stride (considered as the same as the height of the step), height of step and number of steps climbed, and the force was equal to the individual's body mass, that is, Power (watt) = body mass (kg) x total displacement (m) / time (s)[19]. Steps were counted manually when both feet reached the ground.

Physiological data were collected using an ergospirometry system (VO_{2000} – Portable Medical Graphics Corporation®), which provided real-time values for oxygen consumption (VO_2), carbon dioxide production (VCO_2), minute ventilation (VE), and gas exchange ratios (RER). The test commenced when RER stabilized at ~0.8[20]. HR was monitored with a Polar® V800 HR monitor, and evaluators ensured participants did not exceed the predicted HR max limit based on the Karvonen formula[21].

Before each test, participants sat for 10 minutes in a comfortable position for baseline measurements. After completing the test, they sat for an additional 10 minutes for recovery. HR and SPE were recorded at baseline, during, and after the test (at the fifth and tenth minutes), while BP was measured at rest, at the end of the test and during the recovery period. The third visit followed the same procedures but with the alternate ST.

Statistical analysis

Data were analyzed using the SigmaPlot 11.0 statistical software, and the level of significance was set at $p < 0.05$.

First, the Shapiro-Wilk normality test and Levene's homogeneity of variances test were applied to determine the sample distribution. Then, the performance in the 6MST and the 2MST were compared, and measured in the number of steps climbed using three tests: the Wilcoxon test was applied to verify if the variables were similar. Effect sizes were calculated based on the available sample, and interpreted according to the following thresholds: values < 0.41 were considered small, between 0.41 and 0.70 moderate, and > 0.70 large[22]. The degree of association was verified by Spearman's correlation and the degree of agreement was verified using the Bland-Altman test. The mean cadence and mean power of the 6MST and the 2MST were also compared using the Wilcoxon test and Spearman's correlation. The performance obtained in the 6MST, measured in the number of steps climbed, was compared with the value predicted by two formulas[2,23]. The Wilcoxon test and Spearman correlation were performed to verify the similarity and degree of association between these measures.

There were also comparisons of peak VO_2 and peak HR in the 6MST and 2MST through Spearman's correlation the and Wilcoxon test.

Parametric data were presented as mean and standard deviation, and non-parametric data were presented as median and interquartile intervals. The established significance level was 95% ($p < 0.05$). The reference values used in the Spearman correlation were: 0-0.19 – very weak correlation; 0.20-0.39 – weak correlation; 0.40-0.69 – moderate correlation; 0.70-0.89 – strong correlation; and 0.90-1 very strong correlation[24]. The Bland-Altman analysis with a 95% confidence interval was adopted to evaluate the agreement between the protocols[25].

RESULTS

There were 32 volunteers recruited, none were excluded for presenting a positive Romberg test and there were no complications during the tests. Ten individuals were excluded for missing any of the sessions within a period of 30 calendar days and one was excluded for an outlier performance, totaling 21 individuals in the protocol.

Table 1 reveals the characteristics of the volunteers who were analyzed (except for those excluded, n = 21). Most volunteers were young (mean age 24.00 ± 5.50), eutrophic (mean BMI of 24.91 ± 3.08 kg/m²) and highly active (57.14%), 57.14% female. None of them presented results compatible with pulmonary disease in spirometry.

Table 1. Characterization of the sample.

Demographic characteristics (n = 21)	
Age (years)	24.00 ± 5.50
Gender (female / %)	12 / 57.14
Anthropometric characteristics	
Height (m)	1.67 ± 0.06
Body Mass (kg)	69.93 ± 17.00
BMI (kg/m²)	24.91 ± 3.08
Body Classification	
Eutrophic (n / %)	12 / 57.14
Overweight (n / %)	7 / 33.33
Obesity (n / %)	2 / 9.52
IPAQ rating	
Highly active (n / %)	12 / 57.14
Physically active (n / %)	3 / 14.29
Sedentary (n / %)	6 / 28.57
Spirometry	
FEV_1 (% of predicted)	99.05 ± 15.04
FVC (% of predicted)	97.90 ± 11.03
FEV_1 /FVC (% of predicted)	97.10 ± 8.23

Abbreviations: %: percentage; m: meters; kg: kilogram; kg/m²: kilogram per meter squared; IPAQ: International Physical Activity Questionnaire; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; FEV_1 /FVC: ratio between forced expiratory volume in one second and forced vital capacity.

Source: The authors.

Table 2, in turn, reveals the average results obtained in the tests performed. The median performance was 197 (185 – 221) steps climbed on the 6MST, which is equivalent to 124 (118 –134) % of the predicted; and 74 (66 – 81) steps climbed on the 2MST. Regarding the physiological variables, the median HR values found were 176 (162 – 185) bpm in the 6MST, which is equivalent to 90 (85 – 98) % of the predicted value; and 163 (151 – 170) bpm in the 2MST, which is equivalent to 84 (80 – 91) % of the predicted value, while the median VO_2 peak values were 20 (17 – 28) (mL/kg.min^{-1}) in the 6MST and 20 (16 – 26) (mL/kg.min^{-1}) in the 2MST. Peak SPE values were also recorded using the Borg scale (0 – 10) for dyspnea and LL fatigue. The median values obtained were respectively 4 (2 – 6) and 4 (3 – 6) in the 6MST and 3 (2 – 5) and 2 (1 – 5) in the 2MST. The median cadence and power were also calculated, respectively obtaining 33 (31 – 37) steps per minute and 11 (9 – 14) watts in the 6MST, while in the 2MST 37 (33 – 41) steps were obtained per minute and 12 (10 – 15) watts.

There were significant differences between the 6MST and the 2MST, for the performance variable, measured by the number of steps climbed (Table 2), as expected. However, a strong correlation was found between them ($r = 0.81$; $p < 0.05$) (Figure 1A). The Bland–Altman test, in turn, showed that most data points (76%) were within the limits of agreement between the two tests (Figure 2).

The comparison between cadence values in the 6MST and the 2MST showed a significant difference between them (Table 2). Despite this, it resulted in a strong correlation ($r = 0.81$; $p < 0.05$) (Figure 1B). The comparison between the power values in the 6MST and the 2MST also resulted in a significant difference between them (Table 2), although there was a very strong association ($r = 0.90$; $p < 0.05$) (Figure 1C).

The performance obtained in the 6MST was also compared with the value predicted by the formula based on gender and age[2,23]. Twenty of the twenty-one volunteers (95% of the sample) exceeded 100% of the predicted value. Furthermore, significant differences were found when comparing the obtained and predicted performance, in addition to a strong association between the values ($r = 78$; $p < 0.05$).

On the other hand, the comparison between SPE values for both dyspnea and LL fatigue in the 6MST and the 2MST showed that there was no significant difference between them (Table 2).

Physiological behavior markers during the tests were also analyzed. Considering the VO_2 peak and HR peak, were found: a very weak correlation between the VO_2 peak obtained in the 6MST and the VO_2 peak obtained in the 2MST ($r = 0.37$; $p > 0.05$) (Figure 3A), and a weak correlation between the HR peak obtained in the 6MST and the HR peak obtained in the 2MST ($r = 0.47$; $p < 0.05$) (Figure 3B). On the other hand, no significant differences were found between the VO_2 peak in the 6MST and the 2MST (Figure 3C), with weak effect size (0.11), while differences were found in the HR peak obtained in both tests (Figure 3D), with moderate effect size (0.64).

Table 2. Values obtained in the tests

Variable	6MST	2MST	p value
Performance (steps)	197 (185 – 221)	74 (66 – 81) *	< 0.001
Peak HR (bpm)	176 (162 – 185)	163 (151 – 170) *	< 0.001
Peak HR (% of predicted)	90 (85 – 98)	84 (80 – 91) *	< 0.001
VO_2 peak (mL/kg.min^{-1})	20 (17 – 28)	20 (16 – 26)	0.602
Borg dyspnea peak (0-10)	4 (2 – 6)	3 (2 – 5)	0.136
Borg LL peak (0-10)	4 (3 – 6)	2 (1 – 5)	0.057
Cadence (steps/minute)	33 (31 – 37)	37 (33 – 41) *	< 0.001
Power (watts)	11 (9 – 14)	12 (10 – 15) *	< 0.001

Abbreviations: %: percentage; m: meters; kg: kilogram; kg/m ^{2}: kilogram per meter squared; HR: heart rate; bpm: beats per minute; VO_2: oxygen consumption; mL/kg.min^{-1}: milliliters per kilogram per minute; LL: lower limb; steps/minute: steps per minute; watt: Joule per second; 6MST: Six-minute step test; 2MST: Two-minute step test. *****: Significant difference

Source: The authors.

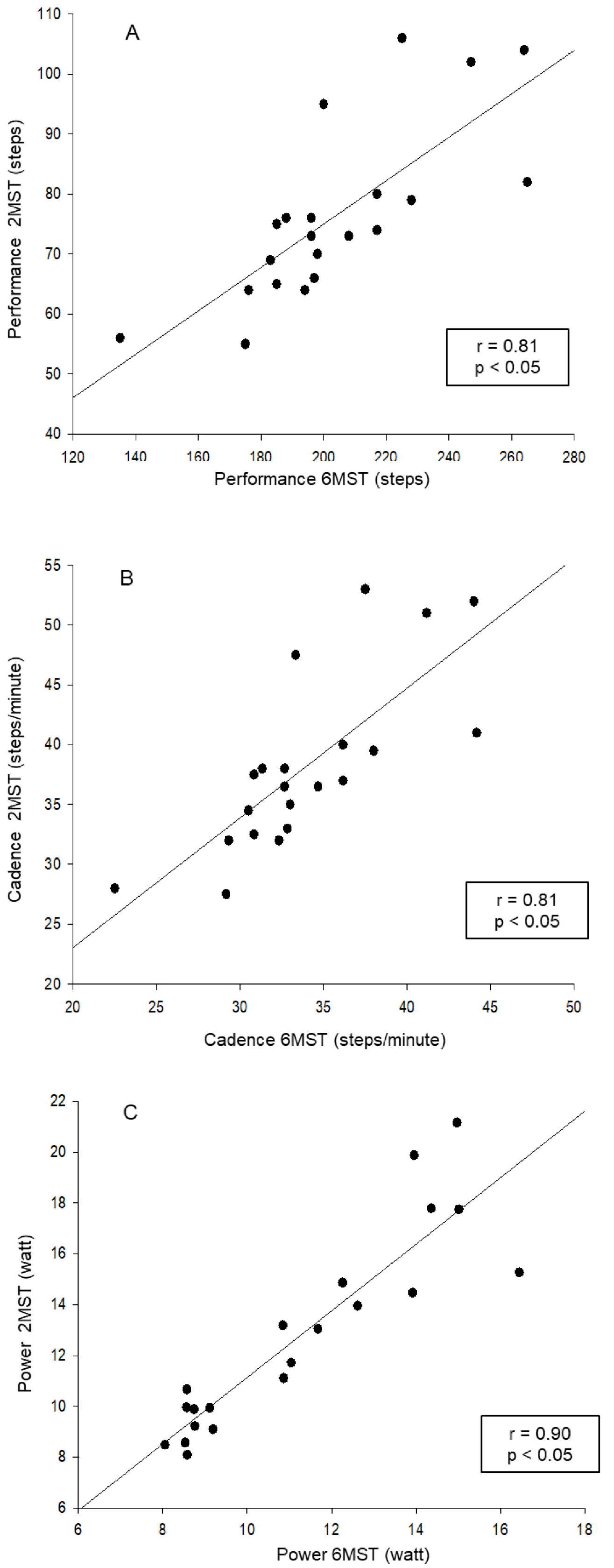

Figure 1. Correlation between the 6MST and the 2MST. A: Pearson's correlation, showing strong association between performance in the 6MST and the 2MST (r = 0.81); B: strong association between cadence in the 6MST and the 2MST (r = 0.81); C: very strong association between power in the 6MST and the 2MST (r = 0.90); 6MST: six-minute step test; 2MST: two-minute step test; steps/minute: steps per minute; watt: Joule per second.
Source: The authors.

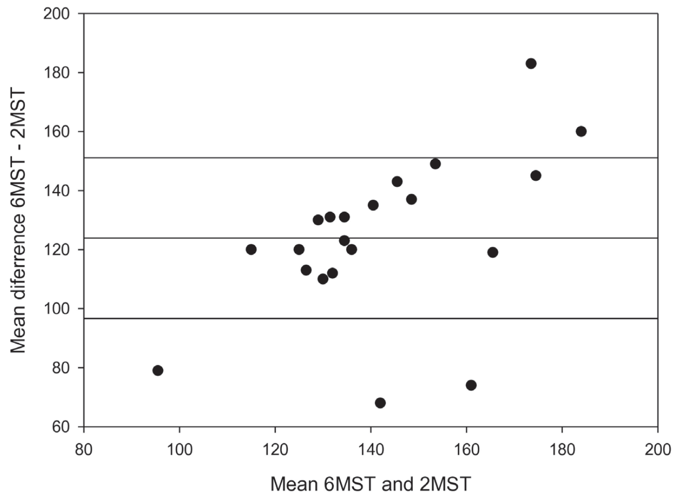

Figure 2. Bland–Altman plot showing the agreement between the 6MST and 2MST. The solid line represents the mean difference (bias), and the upper and lower lines represent the limits of agreement (±1.00 SD). Most data points lie within these limits (76%), indicating good agreement between the two protocols; 6MST: six-minute step test; 2MST: two-minute step test.
Source: The authors.

DISCUSSION

The objective of the study was to evaluate the equivalence between 6MST and 2MST in terms of VO_2 peak and HR peak in healthy individuals. The results indicated that the effort exerted by the participants during the 6MST and the 2MST was somehow comparable. Furthermore, no significant disparities were observed in terms of VO_2 peak and performance between the two tests, and there were no statistical distinctions in the peak values of the SPE scale, whether related to lower limb muscle fatigue or dyspnea. Such results may indicate that the tests are similar in terms of aerobic and metabolic demand. In addition, there was a strong association between the number of steps climbed in each test (r = 0,81) and agreement analysis showed that most data points (76%) lay within the limits of agreement, reinforcing the similarity between the two protocols . However, there was a difference between the HR peak value obtained in the 6MST and the 2MST, with the HR achieved in the 6MST being higher.

Despite that, based on HR peak, 95% of the volunteers reached a value greater than or equal to 75% of the age-predicted maximum[21] in both tests, suggesting similar cardiovascular stress between the two protocols. This response is consistent with that reported in studies using the Chester step test protocol[1,26-28], where reaching 80% of the predicted HR was considered indicative of a maximal effort. Fagundes et al.[29]. also found heart rate values above 80% of the predicted in obese individuals during a six-minute self-paced protocol, similar to the one performed in the present study. Nevertheless, HR alone is not sufficient to determine whether a test is maximal; SPE and ventilatory variables must also be considered.

Although it is not possible to classify the tests as truly maximal based solely on HR, their cardiovascular stress profiles were comparable between the two protocols.

Regarding VO_2, our data showed no significant difference between the values obtained in the 6MST and the 2MST, supporting the idea of a similar metabolic stress in both protocols. Ritt et al.[30] evaluated individuals with heart failure (HF) and coronary artery disease (CAD), comparing the 6MST with a cardiopulmonary exercise test (CPET) on a treadmill, and observed a moderate association ($r = 0.69$) between VO_2 values and no significant difference in heart rate (HR) between the tests. Similarly, Marinho et al.[31] compared the 6MST with CPET on a cycle ergometer in patients with HF and found a strong association between VO_2 values ($r = 0.71$) and no differences in HR between the two tests. Travensolo et al.[32], in turn, found higher peak HR values in the 6MST compared to the 6MWT in patients with CAD, suggesting a greater metabolic stress in the 6MST compared to the submaximal walking test. These findings confirm that, in these populations, the metabolic stress elicited by the 6MST may be comparable to that of near-maximal tests. In the present study, we found that this phenomenon may also occur in the 2-minute protocol, especially in less conditioned individuals.

Although the variables indicated a similar metabolic stress, in the present study, was found weak ($r = 0.47$) and very weak ($r = 0.37$) correlation between peak VO_2 and peak HR in the two protocols. This correlation may have been affected by the sample size and should be retested in studies with larger samples.

Considering cadence and power, the comparison between the 6MST and the 2MST showed a difference in both, although there was strong ($r = 0.81$; $p < 0.05$) and very strong ($r = 0.90$; $p < 0.05$) associations, respectively. The good association reinforces the similarity between the tests. The difference between the tests can be justified by the duration of each test. The fact that the 6MST is three times longer than the 2MST implies an expected difference in step-climbing pace. In fact, the volunteers reached a faster rhythm in the shorter test [33 (31 – 37) steps per minute in the 6MST and 37 (33 – 41) steps per minute in the 2MST], confirming this hypothesis. Power, in turn, is calculated using the time variable as a denominator, which also suggests that a longer test gives a lower power value. The values found [11 (9 – 14) watts in the 6MST and 12 (10 – 15) watts in the 2MST] confirm this hypothesis. Thus, cadence and power comparisons obtained between the 6MST and the 2MST reaffirm the similarity between the tests.

Finally, the percentage predicted by the Arcuri et al.[2] formula was 129%, whereas the percentage predicted by the Albuquerque et al.[23] formula was 111%, supporting the increased intensity of the test. However, in the first case, 95% of the volunteers exceeded the predicted value, while in the second case, only 73% did so. These findings reinforce that, for the population evaluated in the present study, the 6MST may have represented a maximal effort. Additionally, they suggest that Arcuri's formula may underestimate individual conditioning, even in sedentary and obese participants, whereas Albuquerque's formula demonstrated a higher accuracy rate. This may be because Albuquerque's formula is based on a self-paced protocol, similar to the one used in this study, making it more applicable to this population. In contrast, Arcuri et al.[2] employed an incremental limited-cadence test protocol, which may explain the discrepancy between the estimated and obtained values. More importantly, these differences between predicted and observed values reveal potential limitations in the applicability of both formulas to young and highly active populations.

Some limitations must be pointed out. The need to attend the laboratory three times caused many losses, as expected. Furthermore, the fixed step height which was not adapted to the height of the volunteers. However, this height is widely used for step tests[1,2,10,27]. Another limitation is the fact that most volunteers used the same front leg to climb the step, which might have contributed to early fatigue on this leg compared to the other one. And they performed the test wearing an ergospirometry mask, which may have increased the discomfort and impacted the result. Finally, the gold standard for VO_2 maximum analysis – cardiopulmonary exercise test (CPET) – was not used. Although this was not the main objective of the study, which focused on comparing the 6MST and 2MST rather than predicting VO_2 maximum, the absence of a direct comparison with CPET limits the external validity of the proposed equivalence between the two step test protocols.

CONCLUSION

The 6MST and 2MST may impose similar levels of cardiovascular stress in healthy individuals when considering peak VO_2 and HR responses. However, the present results are not conclusive regarding the physiological equivalence between the two protocols. Further studies with larger and less conditioned populations, and using gold-standard methods for comparison, are needed to clarify these findings. From a practical perspective, shorter protocols may be preferable for less conditioned individuals.

IMPLICATIONS FOR PHYSIOTHERAPY PRACTICE

The ST is a cheap, non-invasive, and easy-to-apply method for estimating functional capacity, and can be used for diagnostic and prognostic purposes or as a pre- and post-intervention assessment. Depending on the protocol, it can be a maximum test. The study's findings indicate that due to the similarity of the 6MST and the 2MST, one can choose to use the tool with the shorter time, further facilitating the applicability of the test, especially in less conditioned or more compromised populations.

FUNDING

None to declare.

CONFLICT OF INTEREST

None to declare.

RESEARCH DATA AVAILABILITY

Research data is only available upon request.

AUTHOR CONTRIBUTIONS

Victor Regufe: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. Larissa Costa Tavares: Investigation, Project administration, Visualization. Luana Soares de Oliveira: Conceptualization, Investigation, Methodology. Pedro Antonio Racca: Investigation. Thamyres Vitória Gomes: Investigation. Alessandra Choqueta de Toledo Arruda: Funding acquisition, Resources, Supervision. Michel Silva Reis: Conceptualization, Formal analysis, Funding acquisition, Resources, Supervision, Writing – original draft, Writing – review & editing.

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