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Featured Article

Validity of the two-minute step test for healthy older adults

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ABSTRACT

Background: In healthy older adults, the two-minute step test (2MST) does not have its concurrent validity tested against the six-minute walk test (6MWT), which is a valid cardiorespiratory fitness test frequently applied in geriatric samples.
Objective: To derive an equation to predict 6MWT from 2MST and to observe the agreement between observed and estimated 6MWT distances.
Methods: 6MWT and 2MST were measured in 51 older adults (72.9±4.6 years) from community multicomponent exercise programs. Multiple linear regression derives the predictive equation of 6MWT walked distance (dependent outcome) from steps obtained in 2MST, age, sex, and body mass index (independent outcomes).
Results: Correlation between 6MWT and 2MST was strong ($r=0.696$, $p<0.001$). The regression equation showed good agreement with measured values, when 6MWT was below 600 m.
Conclusion: The equation stands as a novel approach to obtaining a valid 6MWT estimation from the 2MST. 2MST is easier and faster, representing an alternative approach when time and space are limited.

Introduction

Physical fitness declines along the senescence process,[1] and the lower the fitness profile, the higher the risk of chronic health conditions, [2] and all-cause mortality.[3] Thus, physical fitness measurement is crucial for different reasons: First, an accurate exercise prescription must be based on precise physical fitness measurements[4]; Second, the exercise training impact on health outcomes and physical fitness relies on obtaining valid and reliable repeated measurements over time[5]; and third, because physical fitness predicts overall mortality,[3] and populational surveillance of this parameter has a public health importance in terms of early detection of a lower physical fitness profile.[3]

Amongst the health-related physical fitness components,[6] cardiorespiratory fitness has robust evidence supporting its association with health. For instance, higher cardiorespiratory fitness in older adults is related to a reduced length of hospital stay and lower in-hospital mortality,[7] better cognitive function,[8] longevity,[9] prevention of cardiovascular disease,[10] disability, and some types of cancers, among others.[9] Furthermore, regular physical activity enhances cardiorespiratory fitness in older adults, and some studies suggest that cardiorespiratory fitness can be improved by more than 20% with systematic training within this population.[11]

Despite providing the most valid and reliable results, the objective determination of cardiorespiratory fitness with maximal or peak oxygen consumption tests is expensive, time-consuming, and requires rigorous training of evaluators.[12] Furthermore, assessed participants, especially older adults, sometimes report discomfort when submitted to gas analyses procedures. Thus, cardiorespiratory fitness assessments using validated submaximal field exercise tests are a proper approach to overcome laboratory procedure constraints, like the six-minute walk test (6MWT).[12,13] The 6MWT is mainly applied in research and clinical settings, being a symptom-limited test with clinical significance.[9] For instance, PubMed retrieved 18,082 results with the search "six-minute walk test," on the 28th of March 2023.

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Although the 6MWT presents good psychometric properties,[14] several investigators characterize the 6MWT as time-consuming for clinicians.[15] Moreover, the 6MWT requires a large space to be performed (e.g., a 30-meter corridor,[16] or a 50-yard square[13]), often unavailable for healthcare providers.

Some researchers have proposed the two-minute step test (2MST) as an alternative to overcome the restraints of the 6MWT.[17] Although the 2MST has aroused scientific interest, it has not yet been studied in as much depth as the 6MWT (170 results on PubMed, with the search "two-minute step test," on 28th March 2023). In addition to the possibility of being applied in very small places, the 2MST is appropriate for older adults with lower physical capacity and incapacity to ambulate for longer distances.[18] Nonetheless, some researchers do not agree that the 2MST might replace the 6MWT for the cardiorespiratory fitness assessment,[19] but as a complementary assessment.[17] In addition, there are national-adjusted reference values to classify walked distance in the 6MWT,[17,20-23] but they are missing for the 2MST. Finally, the concurrent validity of the 2MST in estimating cardiorespiratory fitness is confirmed for specific populations (such as obese [24] and older adults post-coronary revascularization [25]), but not for healthy older adults. Thus, the development of an equation aiming to estimate the 6MWT distance covered from the 2MST steps would contribute to surveilling populations regarding cardiorespiratory fitness. To the best of our knowledge, these equations are still inexistent.

Thus, the study aims to derive an equation to predict the 6MWT from the 2MST and to observe the agreement between observed and estimated 6MWT distances. We hypothesize that the 2MST has concurrent validity in healthy older adults when compared to the 6MWT.

Methods

Study design

This is a cross-sectional study based on a convenience sample, carried out between March and April 2022. Study procedures and protocols were accepted by the institutional scientific review panel (code number CEFADE 02.2018), and all participants signed an informed consent before any collection of any measurement, following the Declaration of Helsinki. The manuscript followed the STROBE guidelines for cross-sectional studies.

Inclusion criteria were age $\geq$ 65 years old and the presence of formal exercise sessions at least two times per week in the previous 6 months. Exclusion criteria were the presence of any cognitive impairment, orthopedic or musculoskeletal restrictions that disqualified participants from executing the study tests, and the presence of any cardiovascular condition that represented an absolute vigorous physical exercise contraindication (stated by the participant's physician during any earlier therapeutic consultation).

Participants and procedures

Participants were recruited from community multicomponent exercise programs from Penafiel, Paredes, Sobreira, and Ovar city councils, in the North of Portugal. The number of invited participants from each exercise program is shown in Fig. 1.

After approval by the ethics committee, the researchers sent an e-mail to the persons responsible for the exercise programs, requesting authorization to carry out the study with the programs' users. Posteriorly to the authorization, the responsible persons provided the contact details of the physical exercise instructors who oversaw the exercise classes. The instructors invited all older adults to participate voluntarily in the study, and those older adults who showed interest had their appointment scheduled. On data collection days, researchers met the older adults and explained the study's purpose and procedures. Those who agreed to participate, signed the informed consent and were screened for inclusion and exclusion criteria. Then the collection of the eligible older adults' data was begun.

Participants had only one day of assessment, and measurements were carried out in the following sequence: informed consent signature; inclusion and exclusion criteria screening; socio-demographic data; the 6MWT; a rest period of 20 minutes; and the 2MST evaluation.

Measurements

Sociodemographic: Age, educational level, and marital status were obtained by personal structured interview.

Anthropometrics: Participants had their body mass (kg) (Tanita inner Scan BC-522, Japan) and height (m) (wall-mounted stadiometer) assessed barefooted. Body mass index (BMI) was computed as kg/m ^{2}.

Cardiorespiratory fitness: The 6MWT was performed individually in a linear walkway (25 m long). There were markers (i.e., cones) positioned every 5 m apart. Total walked distance was measured by multiplying the total laps by 50 m (1 lap = 25 m + 25 m), plus the walked distance at the end of the 6 min time. The 6MWT is a validated and reliable submaximal field test for older adults when estimating cardiorespiratory fitness.[12,13]

The 2MST was performed individually with the participant positioned with the right side facing a wall and the left side facing the evaluator. The evaluator was positioned approximately 50 cm away, with a transversal view of the left side of the participant to give indications on the height of the knee elevation. A second assessor was set up behind the subject but close to him/her to ensure safety. The purpose of this test is to raise the knees until the midpoint between the patella and the anterosuperior iliac crest, and a 50 cm long line was marked on the wall with the purpose of helping the participants and the evaluator to visualize the height of knee elevation during the test. Two attempts (10 s each) with a 1-min rest interval between them were executed for familiarization purposes. After a 2 min rest, the test was finally executed. All 2MST were recorded using an iPhone SE cell phone (CA, USA), which was positioned on a universal tripod arranged at the height of the marking made on the wall. A third evaluator, who did not participate in the in-person evaluation, counted the number of right-knee raises using the video records, which was used as a 2MST result. The 2MST is valid and reliable for estimating cardiorespiratory fitness in specific populations (such as obese [24] and older adults post-coronary revascularization [25]).

Rate of perceived exertion: Immediately after both the 6MWT and the 2MST, participants were asked for their rate of perceived exertion (RPE) using a visual scale from 0 (no effort) to 10 (maximal effort).

Statistical analysis

A Kolmogorov–Smirnov test verified data normality. Measures of central tendency and dispersion were used to present continuous variables, while proportions describe categorical data. Differences by sex were tested with a t-test (continuous variables) and chi-square (categorical variables). Paired t-test ascertains RPE differences according to the 6MWT and the 2MST. Correlation coefficients observe the correlation between the 6MWT and the 2MST and between the 6MWT/2MST and anthropometric variables. Multiple linear regression (dependent variable: 6 MWT) with "enter method" of independent variables (2MST, age, sex, and body mass index) derive the 6MWT predictive equation. The Bland Altman plot was used to verify the agreement between the estimated and measured 6MWT. Statistical analysis was performed with SPSS (version 24, Chicago IL, USA), with a significance level of 0.05.

A priori sample size calculation was performed by the G*Power software (3.1.9.2; Heinrich Heine University Düsseldorf, Düsseldorf,

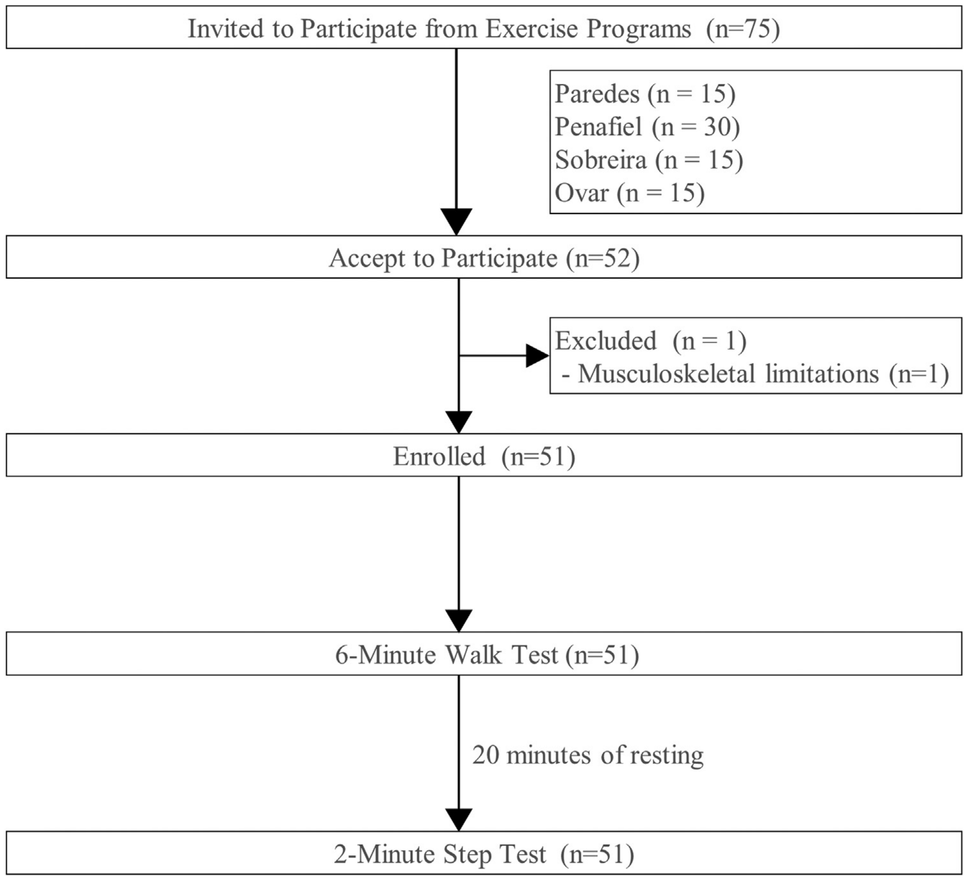


Fig. 1. Study flow diagram.

Germany) using F family tests (linear multiple regression: fixed model, R^2 increase). In addition, an effect size of 0.15, an α error probability of 0.05, and a power (1-β error probability) of 0.70 were selected. Thus, a total sample size of 44 participants was necessary to achieve the aim of the study. Finally, considering a possible loss of 15% of participants during the study, a sample size of 51 volunteers was recruited.

Results

Seventy-five older adults were invited to participate in the study, and 23 refused. In total, 52 older people were voluntarily screened in this study, and 1 participant was excluded due to a musculoskeletal limitation. The final sample size thus comprised 51 community-dwelling older adults who had both 6MWT and 2MST measures and were integrated into the study (Fig. 1).

The mean age was 72.87 ± 4.58 years old, with a maximum age of 85 years old, and 53.8% had 0–6 years of education. Men were significantly heavier and taller than females ($p<0.05$). The mean 6MWT distance was 534.15 ± 66.46 m, and men walked 40.06 ± 17.58 m more than women (t (50.000): 2.279; p= 0.027). The mean number of steps reached during the 2MST was 86.29 ± 19.77, and men obtained 10.85 ± 5.27 more steps than women (t (46.447): 2.058; p = 0.045). More details on the characteristics of the sample are available in Table 1. The RPE at the end of the tests was superior for the 2MST (5.82 ± 1.87) in comparison to the 6MWT (4.11 ± 2.03; $p < 0.001$).

Fig. 2 shows the strong correlation between the distance covered during the 6MWT and the number of steps obtained in the 2MST (r = 0.696, $p < 0.001$).

The correlation between age, weight, height, and body mass index with covered distance (6MWT) and the number of steps (2MST) is presented in Table 2. For the 6MWT, age (r = −0.352), height (r = 0.325), and BMI (r = −0.331) were significantly correlated with walked meters. Regarding the 2MSR, the number of steps correlated with age (r = −0.288).

The regression equation to estimate the 6MWT walked distance from the independent variables 2MST, sex, age, and body mass index is: Estimated 6MWT [m] = 739.382 + 1.823 (2MST [number of steps]) − 3.128 (age [years]) − 5.036 (BMI [kg/m ^{2}]) + 18.363 (sex [0 for women; 1 for men])

Fig. 3 shows the agreement between distances observed (obtained from the 6MWT) and estimated from the equation.

It is possible to observe that almost all the dots are in between the 95% confidence interval (-81.88 to 81.82). Nonetheless, it is possible to observe a heteroskedasticity (r = -0.382; p = 0.006) as long as the covered distance increases (>600 m). Sensitivity analysis, removing participants who covered 600 m or more, corrected the heteroskedasticity (r = -0.090; p = 0.559).

Discussion

The present study aimed to obtain a predictive equation for the 6MWT distance covered from the 2MST steps, as well as to observe the agreement between observed and estimated 6MWT walked distances. Results showed a strong correlation between the distance covered in the 6MWT and the number of steps obtained in the 2MST. In addition, the distance from the 6MWT was correlated with age, height, and BMI; thus, these variables plus sex were introduced in the equation as independent variables. In addition, results obtained

Table 1
Sample characteristics (values are mean ± SD or frequencies) and between-groups comparison (t-test and chi-square)

Characteristics	Overall (n = 51)	Men (n = 24)	Women (n = 27)
Age (years, mean ± SD)	72.87 ± 4.58	73.38 ± 3.48	72.43 ± 5.36
Educational Level (%)			
0–6 years	53.8	37.5	67.9
6–9 years	26.9	37.5	17.9
9–12 years	19.2	25.0	14.3
Marital Status (%)			
Unmarried, Widowed or Divorced	23.3	10.0	34.8
Married or Common-law	76.7	90.0	65.2
Physical Measures (mean ± SD)			
Weight (kg)	73.5 ± 11.98	78.00 ± 11.46*	69.64 ± 11.20*
Height (m)	161.63 ± 8.54	167.06 ± 7.22*	156.98 ± 6.68*
Body mass index (kg/m^2)	28.05 ± 3.51	27.85 ± 2.88	28.22 ± 4.02
Cardiorespiratory fitness (mean ± SD)			
6MWT (m)	535.15 ± 66.46	555.72 ± 58.50	515.45 ± 68.26
2MST (no. of steps)	86.29 ±19.77	81.18 ± 22.05	92.04 ± 15.33

Note: *p<0.05 between sex comparisons. 6MWT = six-minute walk test; 2MST = two-minute step test.

from the equation were in agreement with the observed results from the 6MWT.

Based on the strong correlation between the 6MWT and the 2MWT (r = 0.696), we assumed that both the 6MWT and the 2MST measure cardiorespiratory fitness and, thus, we propose a model to predict the distance of the 6MWT from the 2MST. Nonetheless, the assumption that the 6MWT and 2MST measure cardiorespiratory fitness equally must be ascertained.

Previous studies are in agreement with us. For instance, some studies judge the 2MST as complementary to the 6MWT for subjects with coronary artery disease,[18] or could even serve as an alternative for older adults with hypertension,[26] for patients with symptomatic peripheral artery disease,[27] and for patients with systolic heart failure.[19] Similarly to us, others have also observed an association between both tests [28] in healthy older people,[17] and in those with pathologies.[19,26] Węgrzynowska-Teodorczyk et al.[19] found a correlation between 6MWT and 2MST measurements with all cardiopulmonary exercise test parameters (i.e., exercise total time and ventilatory response, and peak oxygen consumption) in patients with systolic heart failure. Therefore, these authors suggest assessing the integrated global response to exercise of all human body systems (respiratory, cardiovascular, and neuromuscular systems, and muscle metabolism) with 2MST.

In contrast to our finding, Braghieri et al.[27] observed no correlation between the 2MST number of steps with the 6MWT walked distance (convergent validity, r = 0.26, p = 0.23); however, they verified that the 2MST number of steps was significantly correlated with the 6MWT number of steps (concurrent validity, r = 0.55, p < 0.01). The authors explain that this discrepancy could be due to the significant correlation between the participant's height and the 6MWT covered distance (r = 0.70, p < 0.01), but not with the 6MWT number of steps (r = -0.035, p = 0.87) and the 2MST (r = -0.31, p = 0.14). Consequently, taller patients would be more likely to obtain longer distances in the 6MWT.[27] However, this concern cannot be applied to our study, since

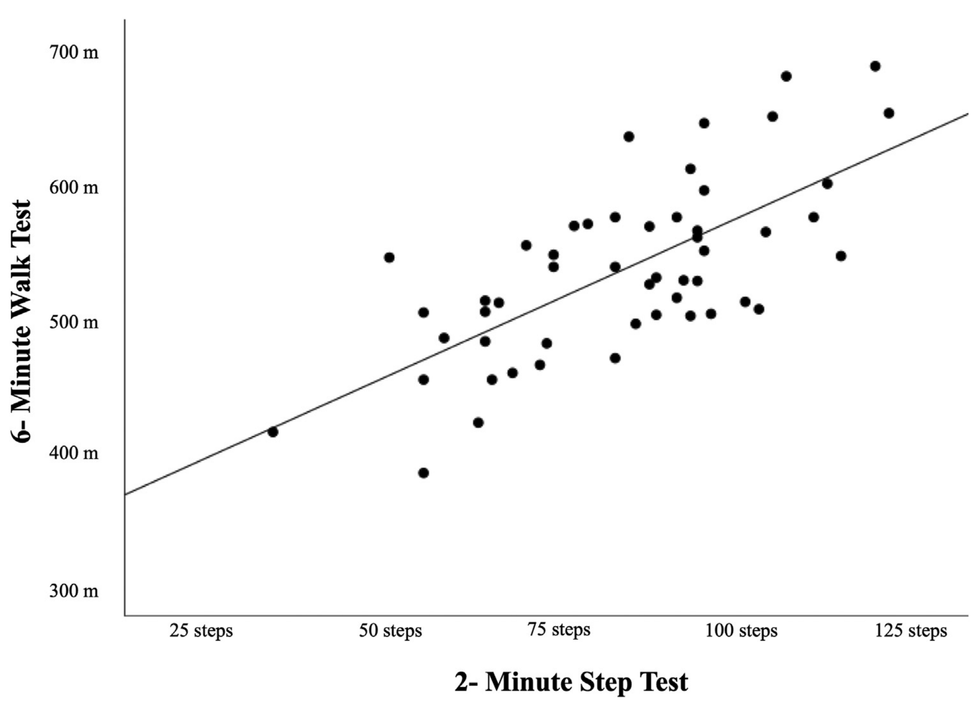


Fig. 2. Correlation between the two-minute step test (number of steps) and the six-minute walk test (distance covered in meters).

Table 2
Bivariate correlation between both tests with age and anthropometric variables (values are r and p-value)

	6MWT (m)	2MST (n° of steps)
Age (years)	-0.352 (0.010)	-0.288 (0.040)
Weight (kg)	-0.048 (0.234)	-0.024 (0.866)
Height (m)	0.324 (0.019.)	0.150 (0.292)
Body mass index (kg/m^2)	-0.331 (0.017)	-0.155 (0.277)

Note: 6MWT = six-minute walk test; 2MST = two-minute step test.

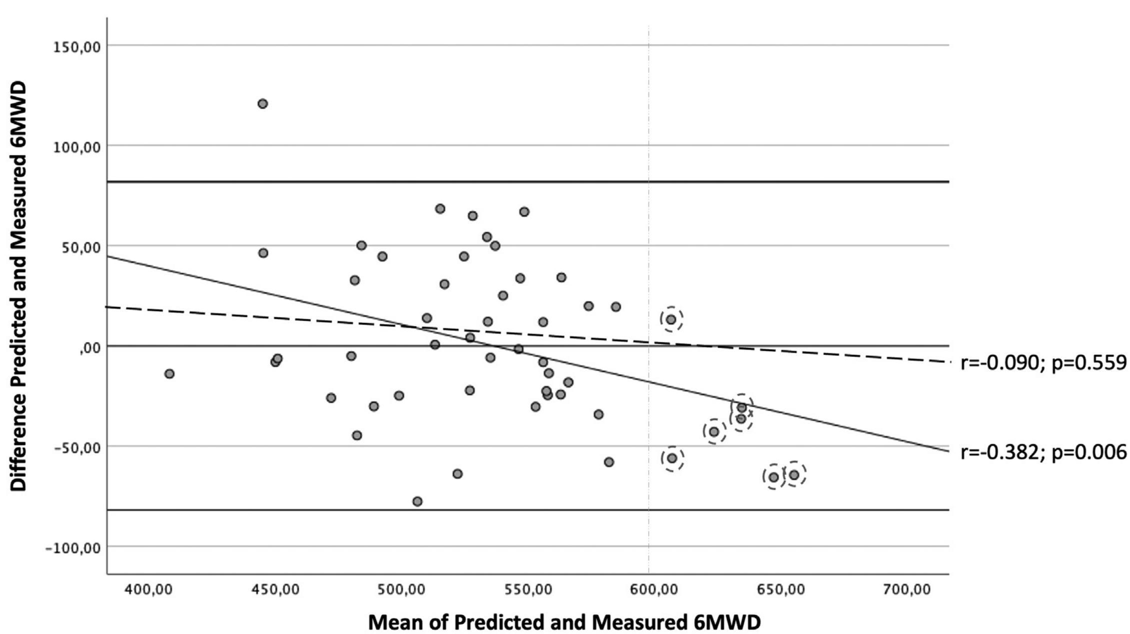
correlations were also found between height and the 6MWT covered distance, without a relationship between height and the 2MST number of steps. Furthermore, we observed a correlation between the 2MST number of steps and the 6MWT walked distance. In addition to height, BMI and age also correlated with the 6MWT walked distance in our participants, as well as in other studies with healthy older adults [29] or those with pathology.[19]

Moreover, Węgrzynowska-Teodorczyk et al.[19] claim that the 2MST, independently from assessing cardiorespiratory fitness, could be considered for the evaluation of lower-limb strength. They obtained a correlation of 2MST and 6MWT results with quadriceps strength in men with heart failure. Due to the movement biomechanics involved in the 2MST, presumably, the lower-body-strength intensity in the 6MWT would be higher. In the 2MST execution, participants raise their knees to a height equal to the mid-level between the patella and the iliac crest, requiring greater physical skills, intensity, and duration of single leg support compared to the standard step when walking.[30] In this regard, the possibility of higher physiological demand with the similar movement of climbing stairs with the 2MST, even when this test is shorter than the 6MWT, could explain why the RPE was significatively higher in the 2MST (5.82 $\pm$ 1.87) compared to that of the 6MWT (4.11 $\pm$ 2.03; $p < 0.001$).

Other studies comparing fatigue between the 6MWT and the 2MST [19] or between the 6MWT and other step tests similar to the 2MST [31] confirm higher RPE in step tests compared to the 6MWT, which is performed walking. Even in other physiological outcomes in patients with severe chronic obstructive pulmonary disease, higher blood lactate concentrations, more dyspnea, and more pronounced hyperinflation of the lungs were detected in stair-climbing tests compared to the 6MWT.[32] In contrast, in the study by Braghieri et al.,[27] the 2MST promoted lower cardiovascular stress, as maximum heart rate scores were lower compared to the 6MWT ($p < 0.05$).

Due to the importance of cardiorespiratory fitness in older people for preventing cardiovascular diseases,[10] as well as for improving general health,[8-10] applying a submaximal test to assess this outcome is essential in both the general and clinical population. The 6MWT is a well-standardized submaximal field test for healthy individuals [29] and one of the most widely used in clinical and research settings to assess cardiorespiratory fitness.[9] Nevertheless, it requires a lot of time and space,[13,16] therefore it seems important to find other tests to assess cardiorespiratory fitness in less time and space.[31] Such is the case of the 2MST, which can be applied in less time and in very small places, which is an advantage for those with lower physical capacity and inability to complete longer walking distances.[18] In addition to measuring cardiorespiratory fitness, the 2MST is used for training assessment and monitoring,[28] and it correlates significantly with some important outcomes in specific populations, such as global cognitive function, attention, executive performance, depression, and language tests in older adults with heart failure [33,34], as well as with knee osteoarthritis,[35] and it could be useful to help identify people at risk of falling.[30] Furthermore, the 2MST has shown validity and reliability for populations with pathologies,[27,35] although more research is needed on the validity, reliability, and responsiveness of this test in both healthy adults and those with pathology.[28]

However, one of the problems we may face when using the 2MST instead of the 6MWT for the assessment of cardiorespiratory fitness is that for the 6MWT there are a great number of reference values available for several countries and populations,[17,20–23] but less 2MST data for healthy older adults.[17,36] Therefore, using the 2MST to estimate the result of the 6MWT could be important for contexts in which performing the 6MWT would be more difficult; therefore, the



Note: 6MWD = six minute walking distance; — — — = Trend line disconsidering mean values higher than 600 meters (n=7); ( ) = 6MWD higher than 600 meters (n=7).

Fig. 3. Agreement between distances observed (obtained from the 6MWT) and estimated from the equation.

development of a predictive equation could solve this inconvenience. The proposed equation did well against the direct measurement of the 6MWT, especially after removing older adults with superior walked distances (>600 meters). In other words, there is no correlation between the Bland Altman axes x and y, which implies that the mean error is small (≅0) and constant along the different possible performances (400 to 600 m). Correlating distance covered in the 6MWT with the number of steps achieved in the 2MST, we could state that our equation could be used when a patient's result is above 113 steps, which is usually below the level of those with clinical conditions, such as Parkinson's Disease,[37] cancer survivors,[38] or stroke survivors,[39] among others. This information is important because in clinical settings, such as hospitals and nursing homes, older adults are usually not able to walk long distances, so there is an alternative that fits better for those who have lower cardiorespiratory fitness.

Other studies have made a correlation between both tests,[18,26] but they do not generate a predictive equation, which highlights the novelty of our study. In addition, our equation is easy to use and only needs simple data, such as sex, age, weight, and height; but further research is needed to confirm our findings and future research should generate specific prediction equations for different populations and pathologies. The study limitations include the lack of physiological measurements that could provide objective information on the effort of each test, such as oxygen consumption or blood lactate concentrations. Although we have calculated a priori the needed sample, it would be important to replicate the experiment in different samples to confirm our results.

Conclusion

Our equation stands as a novel approach to obtain a valid result for the 6MWT from another cardiorespiratory field test, the 2MST, which is easier and faster to conduct due to time and space limitations. To be more specific, our proposal is to estimate the 6MWT distance of older adults who perform fewer than 113 steps in the 2MWT. However, the proposed equation must be applied in different and larger samples (healthy, in good condition [>113 steps in the 2MWT], and in clinical populations) to confirm its validity and reliability.

Authors' contributions

LAB, MMD conception, data collection, data treatment, writing, and final revision. PA writing and final revision. EA data collection, data treatment, final revision. JM writing and final revision. LB conception, data collection, data treatment, writing, and final revision.

Declaration of Competing Interest

The authors declare that have no conflict of interests to disclose.
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