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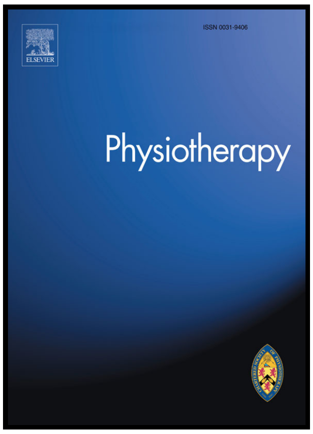

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R. Vilarinho, A Mesquita Montes, A Noites, F. Silva, C. Melo

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Reference values for the 1-minute sit-to-stand and 5 times sit-to-stand tests to assess functional capacity: a cross-sectional study

R. Vilarinho, PT, PhD[a,b,*], A Mesquita Montes, PT, PhD[a,c], A Noites, PT, PhD[a], F. Silva[b], C. Melo, PT, PhD[a,c]

[a] *Center for Rehabilitation Research (CIR), School of Health, Polytechnic Institute of Porto, 4200-072 Porto, Portugal*

[b] *FP-I3ID, Escola Superior de Saúde - Fernando Pessoa, 4200-256 Porto, Portugal*

[c] *Department of Physiotherapy, Santa Maria Health School, 4049-024 Porto, Portugal*

Email Addresses of Authors:

Rui Vilarinho: ruivilarinho1@gmail.com

António Mesquita Montes: antoniomesquitamontes@gmail.com

Andreia Noites: andreianoites@gmail.com

Fátima Silva: fsilva@ufp.edu.pt

Cristina Melo: mcdamelo@gmail.com

* **Corresponding author:** Rui Vilarinho, PT, PhD

Escola Superior de Saúde – Fernando Pessoa, Rua Delfim Maia 334, 4200-256 Porto, Portugal.

Phone: +351 22 507 1384

Email: ruivilarinho1@gmail.com

ABSTRACT

Objectives: To establish age-specific and sex-specific reference values and equations for the 1-minute sit-to-stand (1MSTS) and 5 times sit-to-stand (5TSTS) tests for Portuguese adults.

Design: Cross-sectional study. Descriptive statistics were explored to compute reference values and reference equations were established with a forward stepwise multiple regression.

Setting: Community.

Participants: In total, 546 adult volunteers without disabilities [age range 18 to 95 years; 58% female] were recruited.

Main outcome measures: Data on age, sex, height, weight, body mass index (BMI), smoking status and physical activity were collected using a structured questionnaire developed specifically for this study. Participants performed three repetitions of the 1MSTS and 5TSTS and the best repetition was used for analysis.

Results: Normative values were provided by sex for each age decade. Reference equations were: 1MSTS= 61.53 – (0.34 x age) – (3.57 x sex) – (0.33 x BMI), r^2=26%; and 5TSTS=3.89 + (0.10 x age) - (0.96 x physical activity), r^2=27%.

Conclusions: The proposed reference values and equations will help to interpret the results of functional capacity obtained from healthy or diseased adult populations.

Contribution of the paper:

- Sit-to-stand tests are accessible options to assess functional capacity.

- Reference equation for the Portuguese population was developed for the 1-minute sit-to-stand [61.53 – (0.34 x age) – (3.57 x sex) – (0.33 x body mass index)].
- Reference equation for the Portuguese population was developed for the 5-times sit-to-stand [3.89 + (0.10 x age) - (0.96 x physical activity)].

Keywords: Reference values, interpretability, 1-minute sit-to-stand test, 5-times sit-to-stand test, functional capacity

Introduction

Functional capacity is defined as the maximal potential of a person to perform a functional activity in a standardized environment [1]. According to the International Classification of Functioning, Disability, and Health (ICF), functional capacity specifically refers to the domain of activities, which is one of the important domains to comprehensively assess the health experience of patients [2]. In patients living with specific health conditions, decrements in this domain are usually called “limitations” [3].

Field walking tests, including the 6-minute walk test (6MWT) and the incremental shuttle walk test (ISWT), are generally selected in interventions or rehabilitation programmes to detect those limitations by their performance outcome (distance) [4]. These tests can be used in people with chronic diseases, but also in healthy people, due to the high level of evidence on their measurement properties and interpretability (reference values and equations) [5]. However, the application of the field walking tests in clinical practice can be limited especially outside the hospital (e.g. home-based rehabilitation programmes), because there is rarely enough space for the required tracks to perform the tests [4, 6]. Additionally, authors have reported that the assessment of functional capacity only based on the use of walking tests may not fully reflect the patients’ perspectives (based on patient-reported outcomes) on their limitations [7]. This provides considerable support for using different field tests to quantify the functional capacity. Thus, simple tests that require considerably less space, less time, and are easier to perform are important.

One of the alternatives most suggested in literature [8, 9] to assess the functional capacity is the sit-to-stand test, based on a mechanically demanding movement of daily life involving large muscle groups from the legs and trunk [10]. Two of the most used types of sit-to-stand tests are the 1-minute sit-to-stand (1MSTS) [8] and the 5 times sit-to-stand (5TSTS) [11]. Traditionally, these tests have been used in the assessment of lower limb strength in healthy people (e.g. the elderly) [12, 13], and now they have extended to other clinical populations, such as people with chronic respiratory diseases [11, 14] and cardiac diseases [15, 16]. As a result, the determination of the measurement properties of the 1MSTS and 5TSTS is currently explored in research [14, 17-19].

In addition to the study of measurement properties, the application of the 1MSTS and 5TSTS in clinical practice requires the determination of their interpretability, relying on the establishment of reference values and reference equations generated from data from healthy populations [20]. The development of reference values and reference equations based on large samples of people provide a comparative basis for the interpretation of the results obtained from a given patient, and thus allow the limitations to be quantified [21].

Since it is known that reference values and reference equations are population specific, to the best of our knowledge, no study has investigated reference values and reference equations for 1MSTS and 5TSTS in the Portuguese adult population. Thus, this study aimed to establish age-specific and sex-specific reference values and equations for the 1MSTS and 5TSTS for Portuguese adults.

Materials and Methods

Study design and setting

A cross-sectional study was conducted between March 2021 and April 2022 in people without disabilities. The Ethical Committee of the School of Health - XXX, Portugal approved the study (code number: XXX), and all participants signed an informed consent form. The study was designed according to STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines for observational studies

[22], and data collection was carried out at the XXX of School of Health - XXX and Senior Universities of XXX.

Participants

The study advertised for people without disabilities aged >18 years at the university campus and surrounding areas. Advertising was done through emails and phone contacts. According to another study that determined reference equations for field tests for Portuguese adults [23], in order to achieve maximum representativeness from community-dwelling people, people with the most prevalent age-related conditions (e.g. hypercholesterolemia, hypertension and diabetes) were included in the study. Exclusion criteria were the presence of one or more of the following conditions: acute (during the past 4 weeks) or chronic respiratory disease, cardiac disease, signs of cognitive or neuromuscular impairment, and significant musculoskeletal disorder (e.g. ankylosing spondylitis) that could interfere with the ability to perform the sit-to-stand tests.

Data collection

Sociodemographic (age, sex), anthropometric (weight, height and body mass index [BMI]), and clinical (comorbidities, smoking status – current smoker, past smoker, or never smoker and physical activity) data were collected through a structured questionnaire developed specifically for this study. Physical activity was assessed by asking participants whether or not they performed at least 150 minutes of moderate-intensity aerobic physical activity throughout the week, according to World Health Organization recommendations [24]. The severity of comorbid diseases was scored according to the Charlson Comorbidity Index (CCI), and subjects were divided into four groups: CCI score of 0, 1 to 2, 3 to 4, and ≥5 [25].

Age, sex, weight, height, BMI, smoking status and physical activity were selected as independent variables in the equations developed. The choice of these variables is due to the fact that they are simple to collect in clinical practice and have been included in other reference equations for the 1MSTS and 5TSTS for other countries [26, 27].

Participants performed three repetitions of 1MSTS and 5TSTS, with a 5-minute rest period between the attempts of the same test and a 10-minute rest period between the tests. There was no standard order for performing the sit-to-stand tests. Data were collected by physiotherapy final year undergraduate students under the coordination of trained physiotherapists with experience in applying these tests. For this study, we have followed the most recent recommendations of Furlanetto et al. to perform the sit-to-stand tests [26]. For both sit-to-stand tests, the participants start seated on a chair (with a standardized seat of 46cm high), with the feet flat on the floor and arms crossed over the chest. They were encouraged to fully stand up and sit-down landing firmly as fast as possible. In order to reach full stand-up position, the knees had to reach full extension, whereas to reach full sit-down position the buttocks had to fully touch the chair (the participants' back did not have to touch the chair back). The assisted use of the arms was not allowed during the tests.

Immediately after finishing each test, number of repetitions (1MSTS) and time (5TSTS) was recorded. The best performance (i.e. highest number of repetitions for the 1MSTS and shortest time for the 5TSTS) was used in the analysis.

1-minute sit-to-stand test

In 1MSTS, the participant was instructed to stand up and sit down as many times as possible for 1 minute. The stopwatch was started on the command “go” and stopped when the time was completed, and only full stand ups were counted. The participant was allowed to rest during the test; however, if this was the case, the time in the stopwatch was kept running [26].

5 times sit-to-stand test

In 5TSTS, the participant was instructed to stand up and sit down 5 times as fast as possible. The stopwatch was started on the command “go” and stopped at the end of the full fifth stand [26].

Sample size and statistical analysis

For this study, the sample size for multiple linear regression to establish the reference equation of the 1MSTS and 5TSTS was determined according to Green’s (1991) recommendations [28].

$N > 50 + 8m$ (1)

where N is the total sample size and m is the number of independent variables. Since seven independent variables (age, sex, height, weight, BMI, smoking status, and physical activity) were considered, a minimum of 106 participants per reference equation were recruited.

The statistical analysis was performed using SPSS version 27.0 (IBM Corporation, Armonk, NY, USA). The level of statistical significance was set at p<0.050. The normality of data distribution was checked using the Kolmogorov-Smirnov test.

Descriptive statistics were used to characterize the sample, and reference values were established per sex and age decade using medians and percentiles 25 and 75.

The development of the reference equations was performed using a random selection of 80% of the included participants. This sample size was established in accordance with another study that determined reference equations for field tests for Portuguese adults [23]. Since normality of data distribution was not observed, Spearman's correlation coefficients (ρ) were calculated to explore the association between the dependent variable (1MSTS number of repetitions and 5TSTS time) and the independent variables (age, sex, height, weight, BMI, smoking status, and physical activity). The strength of correlations was classified according to British Medical Journal guidelines: significant correlation coefficients of 0–0.19 as very weak, 0.2–0.39 as weak, 0.4–0.59 as moderate, 0.6–0.79 as strong, and 0.8–1 as very strong [29]. The dependent variables that were significantly correlated with the independent variable were appropriate to be used in a further selection stepwise multiple regression. The assumptions of the multiple regression were confirmed, namely linear relationship between dependent and independent variables, absence of multicollinearity within the independent variables, homoscedasticity, outliers, and normality of residuals and R^2 was used to assess the performance of each model. The performance of each developed equation was further assessed with the remaining 20% of the sample. This analysis consisted of comparing the results from the equations with the actual values achieved by 20% of the sample with Wilcoxon signed-rank test.

Results

In total, 546 adults (range 18 to 95 years) participated in the study. All participants performed both sit-to-stand tests. Most had never smoked, did not perform at least 150 minutes of moderate-intensity aerobic physical activity throughout the week and, according to the CCI, presented none, one to two comorbidities. The most common comorbidities were hypercholesterolemia and hypertension. Participants' characteristics are shown in Table 1.

Table 1. Participants' characteristics (n=546).

Characteristics	Total sample (n=546)
Age, years, median (p25-75) range	42 (26-56) 18 to 95
Sex (female), n (%)	317 (58)
Height, m, median (p25-75)	1.65 (1.60-1.72)
Weight, kg, median (p25-75)	68 (60-76)
BMI, kg/m^2, median (p25-75)	25 (22-27)
Smoking status, n (%)	
Current smokers	30 (6)
Past smokers	54 (10)
Never smokers	462 (85)
CCI (categories), n (%)	
0	350 (64)
1-2	90 (17)
3-4	70 (13)
≥5	36 (7)
Performed ≥150 minutes of moderate-intensity aerobic physical activity throughout the week, n (%)	133 (24)

BMI, body mass index; CCI, Charlson Comorbidity Index; SD, standard deviation

Reference values

Figures 1 and 2 show the median values for the number of repetitions in the 1MSTS and the time in the 5TSTS, respectively, by sex for each age group. Normative values (median [IQR])by sex for each age group can be found in the online supplementary material.

Reference equations and performance

1-minute sit-to-stand test

The best performance in the 1MSTS of 436 (80% of 546) participants was used to compute the reference equation. There were significant correlations between the number of repetitions and age (r=-0.47, moderate, p<0.001), sex (r=-0.11, very weak, p=0.018), height (r=0.17, very weak, p<0.001), BMI (r=-0.22, weak, p<0.001) and physical activity (r=0.20, weak, P<0.001), but not with weight (r=-0.07, p=0.15) and smoking status (r=0.1, p=0.95). A model of stepwise multiple regression showed that age, sex and BMI explained 26% (p<0.001) of variability in the 1MSTS. Age had the strongest (β=-0.46) relationship with the 1MSTS, followed by sex (β=-0.13) and IMC (β=-0.10) (Table 2). The reference equation for the number of repetitions in the 1MSTS was:

$1MSTS_{pred} = 61.53 - (0.34\ x\ age) - (3.57\ x\ sex) - (0.33\ x\ BMI)$, where male = 0 and female = 1.

Table 2. Multiple linear regression analysis with 1-minute sit-to-stand test (number of repetitions) as dependent variable.

	R^2	Unstandardized Coefficients B	Unstandardized Coefficients Standard Error	Standardized Coefficients β	95% CI	p-value	Estimated standard error
1MSTS	0.26						
Constant		61.53	3.60		54.44 to 68.62		11.35
Age		-0.34	0.03	-0.46	-0.40 to -0.28	<0.001	
Sex		-3.57	1.11	-0.13	-5.75 to -1.39	0.001	
BMI		-0.33	0.14	-0.10	-0.61 to -0.5	0.02	

R^2, coefficient of determination; B, unstandardized coefficients; β, standardized coefficients; CI, confidence interval; BMI, body mass index.

Performance of the equation was tested in 110 (20% of 546) participants. No significant differences (p=0.71) were observed between the actual values achieved by participants and the values predicted by the equation [33 (25-45) vs 35 (29-41) repetitions, respectively].

5 times sit-to-stand test

The best performance in the 5TSTS of 436 (80% of 546) participants was used to compute the reference equation. There were significant correlations between the number of repetitions and age (r=0.48, moderate, p<0.001), weight (r=0.11, very weak, p=0.019), height (r=-0.18, very weak, p<0.001), BMI (r=0.26, weak, p<0.001) and physical activity (r=-0.22, weak, p<0.001), but not with sex (r=0.07, p=0.18) and smoking status (r=0.1, p=0.68). A model of stepwise multiple regression showed that age and physical activity explained 27% (p<0.001) of variability in the 5TSTS. Age had the strongest (β=0.49 vs β=-0.11 for physical activity) relationship with the 5TSTS (Table 3). The reference equation for the number of repetitions in the 5TSTS was:

$5TSTS_{pred} = 3.89 + (0.10\ x\ age) - (0.96\ x\ physical\ activity)$, where less than 150 minutes of moderate-intensity aerobic physical activity throughout the week = 0 and more than 150 minutes of moderate-intensity aerobic physical activity throughout the week = 1.

Table 3. Multiple linear regression analysis with 5 times sit-to-stand test (seconds) as dependent variable.

	R^2	Unstandardized Coefficients		Standardized Coefficients	95% CI	p-value	Estimated standard error
		B	Standard Error	β			
5TSTS	0.27						
Constant		3.88	0.42		3.06 to 4.71		3.21
Age		0.10	0.09	0.49	0.08 to 0.12	<0.001	
Physical activity		-0.96	0.36	-0.11	-1.67 to -0.25	0.008	

R^2, coefficient of determination; B, unstandardized coefficients; β, standardized coefficients; CI, confidence interval.

Performance of the equation was tested in 110 (20% of 546) participants. No significant differences (p=0.27) were observed between the actual values achieved by participants and the values predicted by the equation [7.88 (5.33-10.00) vs 8.59 (6.09-9.98) seconds, respectively].

Discussion

This study established age-specific and sex-specific reference values and equations for the 1MSTS and 5TSTS for Portuguese adults. For the reference equations, the variables that explained the variability in the number of repetitions for the 1MSTS (age, sex and BMI) and time for the 5TSTS (age and physical activity) are commonly found in reference equations for other simple and accessible tests to assess functional capacity in clinical practice [21, 26, 30]. Additionally, their variability was mainly explained by age, which presented the strongest relationship. In fact, according to our results, the number of repetitions in the 1MSTS decreases and time in the 5TSTS increases with age. These findings were expected due to the changes associated with the aging process, such as the loss of contractile function in skeletal muscles, a decrease in oxygen consumption and a decrease in the quality and efficacy of sensory inputs (including proprioceptive inputs), leading to a decline in functional capacity [31-33]. These results are consistent with other studies that examined normative values, which also observed this effect of age on sit-to-stand test performances, in other populations/countries [26, 27] and also in other field tests [34-36].

To the best of our knowledge, only two other studies, Furlanetto et al. 2021 [26] and Strassmann et al. 2013 [27], developed normative values specifically for these sit-to-stand tests for adults. The proposed reference values in our study for the 1MSTS and 5TSTS are similar to Furlanetto et al. 2021 [28], but quite different from the reference values for the 1MSTS presented by Strassmann et al. 2013. These findings may have been due to methodological differences, such as the instruction to “sit down landing firmly”, as described in our study and the study by Furlanetto et al., when compared to “touch the chair with the buttocks”, as described in the study by Strassmann et al. In fact, different instructions for sit-to-stand tests are available in the literature, which can provide different performances. The instructions provided in our study are also in accordance with the ones applied by authors that determined the level of evidence of the measurement properties for the 1MSTS and 5TSTS in various clinical conditions

[17, 19, 37, 38] . This homogeneity facilitates the application of our reference values and equations in people with several conditions, improving the clinical usefulness of these tests.

On the other hand, methodological similarities were used between our study and Berglang et al. for the reference values of the 5TSTS. However, direct comparisons between the values are not possible given the differences in the age range (40–80+ years) and age groups (intervals of only 5 years) used by Berglang et al [36].

Another interesting finding is that the R^2 values of the equations (0.26 for 1MSTS and 0.27 for 5TSTS) found in our study are in accordance with the values shown by Furlanetto et al. (0.30 for 1MSTS and 0.28 for 5TSTS) [26] and by Strassmann et al. (0.24 and 0.28 for 1MSTS) [27]. Despite these similarities, the combination of variables included in our equations (age, sex and BMI for 1MSTS; age and physical activity for 5TSTS) are different from Furlanetto et al. (age, sex, height and BMI for 1MSTS; age and BMI for 5TSTS) and Strassmann et al. (age, sex, smoking status, BMI and physical activity for 1MSTS). These results illustrate the heterogeneity that could arise from developing equations from different populations and highlight the importance of developing population-specific reference equations. However, it is important to acknowledge that these amounts of variability for our sit-to-stand tests are low, meaning that the variables assessed may not be adequate to explain variability in the sit-to-stand tests. Physical variables related to lower limb functional capacity may be important in the performances of sit-to-stand tests. As an example, it is known that lower limb limitations are associated with reduced maximal strength [39, 40]. Therefore, lower limb muscle strength should be considered in future studies to verify if the amount of variability in sit-to-stand performances can be explained by this variable.

The use of the equations can be exemplified by the prediction of 1MSTS performance of a 62-year-old woman with a BMI of 25.6 kg/m^2: the predicted number of repetitions is $61.53 - (0.34 \times 62) - (3.57 \times 1) - (0.33 \times 25.6) = 28\, repetitions.$ If during the performance of the 1MSTS the woman had 21 repetitions, this would represent 75% of the predicted value.

The present study has strong methodological characteristics. To the authors' knowledge, this is the first population-based study to provide reference data for the sit-to-stand tests for the Portuguese adult population, with a large sample size. Additionally, the two equations were developed using a wide age range representative sample (18 to 95 years), and only include easy-to-apply variables, facilitating their application to clinical practice. These results are intended to provide advantages in clinical practice, facilitating the assessment and interpretation of patients' functional capacity and guiding personalized interventions. The proposed reference values and equations could facilitate the implementation of the 1MSTS and 5TSTS tests to assess functional capacity in Portuguese clinical practice. For this purpose, individuals without disabilities and with low performances on the sit-to-stand tests can be informed about the risks associated with decreased lower limb muscular strength and receive counselling on how to improve them through training programmes.

Study limitations

This study has some limitations that need to be acknowledged. The use of a convenience sample might have affected the results. In future studies, efforts to recruit participants from different settings, geographical locations and socio-demographic levels across the country is important to obtain a representative sample. In addition, the number of participants in the older age decades (60-69, 70-79 and ≥ 80 years) was relatively low [115 participants, 21% of total sample (n=546)] compared to the others;

thus, extrapolating these findings as a population reference should be done with prudence.

Conclusion

Reference values and reference equations were determined for the 1MSTS and 5TSTS to assess functional capacity for Portuguese adults. These findings will help health professionals to assess, quantify and interpret limitations on functional capacity through the use of these sit-to-stand tests.

Conflict of interest: None declared.

Ethical approval: The Ethical Committee of the School of Health xxx approved the study (code number: (xxx).

Ethical approval: The Ethical Committee of the School of Health - Polytechnic Institute of Porto, Portugal approved the study (code number: (CE0013B 24/02/2021).

Conflict of interest: None declared.

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Figures legends

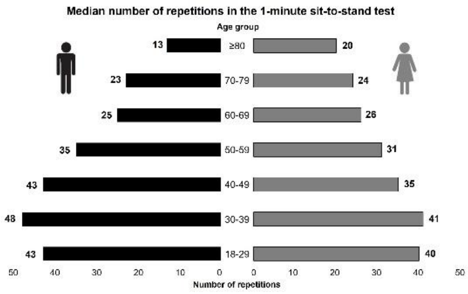

Figure 1. Reference values for the 1-minute sit-to-stand test by sex for each age decade.

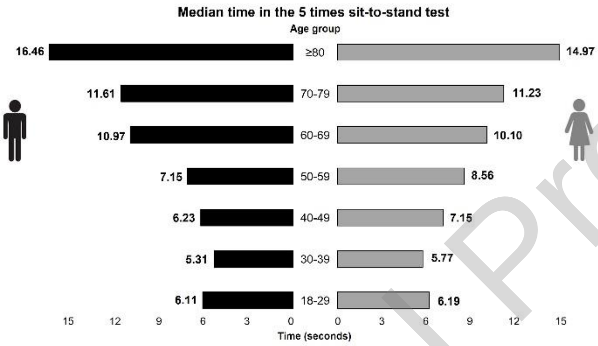

Figure 2. Reference values for the 5 times sit-to-stand test by sex for each age decade.