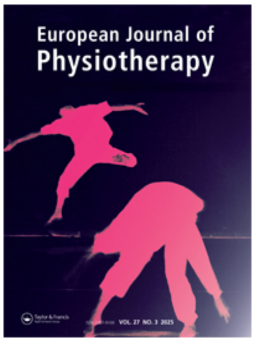

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RESEARCH ARTICLE

Normative values and reference equations of the 4-meter gait speed test for Portuguese adults: a cross-sectional study

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ABSTRACT

Purpose: To determine the normative values and reference equations of the 4-Meter Gait Speed Test (4MGS) at usual and maximal speed for Portuguese adults. We also assessed the participant experience during the performance of the 4MGS.

Materials and methods: A cross-sectional study was conducted with individuals without disabilities. Sociodemographic, anthropometric, smoking habits and physical activity (Brief Physical Activity Assessment Tool [BPAAT]) data were collected. Individuals performed 3 repetitions of 4MGS at usual and maximal speeds, and the best performances were recorded. Speed values were calculated by age and sex. Stepwise multiple regressions were used for the reference equations. Participants rated their comfort from 0 ('not comfortable at all') to 5 ('very comfortable') for each modality and indicated their preferences.

Results: A total of 287 individuals (62.4% female; 47.8 ± 19.5 years) were recruited. Speed was significantly reduced after the sixth decade of life compared with the other decades ($p < 0.001$). Reference equations were: Usual speed = 1.598 – (0.006 x age) + (0.060 x BPAAT classification), R^2= 27% and Maximal speed = 2.272 – (0.010 x age) + (0.157 x sex) + (0.73 x BPAAT classification), R^2= 38%. Most participants felt 'very comfortable' performing the 4MGS at usual speed (94.8%), maximal speed (75.6%) and no preference in 4MGS modalities (69%).

Conclusions: Speed is significantly affected by age. For the reference equations, age and physical activity explain the results of usual speed, and both associated with sex explain the results of maximal speed. Most participants were highly comfortable and expressed no preference in 4MGS modalities.

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Gait speed; field tests; interpretability; normative values; reference equations

Introduction

Gait has been identified as a potential 'vital sign' [1], as it can provide objective measures of whole-body functioning, highlight important abnormalities in systemic functions and, consequently, identify need for intervention [2]. Gait is also an important element to perform activities of daily life, and, therefore, it is one of the most used activities to assess functional capacity [3,4]. The assessment of functional capacity is crucial to guide rehabilitation and physiotherapy interventions, as it provides important data on a person's limitations, severity, and prognosis of the clinical condition [5].

To quantify functional capacity, evidence recommends the use of field tests, including gait speed tests, given their undeniable clinical relevance [3,4,6]. Gait speed tests have characteristics that make them attractive for application in clinical settings: they are easy to perform, use inexpensive equipment, have a short application time, and do not require a specific setting to be performed. Additionally, gait speed serves as an outcome measure in rehabilitation programs due to its strong correlation with overall functional status and quality of life [7,8].

The 4-meter gait speed test (4MGS) combines these advantages and presents two modes of application, the usual and the maximal walking speed [9,10]. This test has been shown to be a reliable, valid and responsive measure of functional capacity both in people without disabilities [10] and in people with chronic diseases [11–13]. In particular, 4MGS has been recognised as a prognostic indicator for adverse outcomes in people with different respiratory diseases [14,15]. Regarding its interpretability, which can be determined from normative values and reference equations derived from data collected from people without disabilities [16], evidence is still lacking. Yet, this is essential to describe the natural history of clinical conditions, assess and compare individual performance within a population and make comparisons across different clinical conditions [17]. Since characteristics of a specific population vary among countries and can affect the performance of field tests, it is expected that normative values and reference equations of a particular test may not be

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generalisable, but population-specific [18]. In the literature, we found that normative values for both modalities of the 4MGS have been solely established for the populations of the United States of America [19] and Brazil [10]. In addition, normative values for 4MGS at usual speed were established for the populations of Spain [20], Norway [21], and Vietnam [22]. To the best of our knowledge, there are no normative data and reference equations available for 4MGS at usual and maximal speed for the Portuguese population.

Despite the previously mentioned characteristics that make 4MGS attractive for application in clinical settings, to the best of our knowledge, there is currently no documented assessment of participant experience regarding the performance of the 4MGS. By actively listening to people and considering their feedback on the field tests, healthcare professionals can better understand their preferences, leading to more personalised and effective care and improved outcomes and people satisfaction.

Thus, the main aim of this study was to establish normative values and reference equations of the 4MGS at usual and maximal speed for Portuguese adults. As a secondary aim, we assessed the participant experience during the performance of the 4MGS.

Material and methods

Study design

A cross-sectional study was conducted from November 2022 to April 2023. The study included adults without disabilities from the northern region of Portugal, including individuals from both the community and university settings. Data collection took place at various locations, including the School of Health - Polytechnic of Porto, School of Health Fernando Pessoa, and two Senior Universities in Porto.

The study received ethical approval from the Ethics Committees of the School of Health - Polytechnic Institute of Porto (reference CE 0089C) and School of Health Fernando Pessoa (reference ESS/PI – 321/22). Informed consent was obtained from all participants, after the study procedures and objectives were explained. This study was written following the recommendations of the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guideline [23].

Participants

The study included healthy Portuguese adults aged ≥18 years. Participants with some of the most prevalent conditions in the population, such as controlled arterial hypertension, diabetes, and hypercholesterolaemia, were considered healthy and therefore eligible [24]. This decision was grounded on the World Health Organization's definition of 'healthy' as a state of complete physical, mental, and social well-being, and not merely the absence of disease [25], which ensured a greater representativeness of the Portuguese population. Exclusion criteria were defined as follows: self-reported acute (within the past month) or chronic respiratory and cardiac diseases, presence of cognitive dysfunction, neuromuscular diseases, neurological disorders, severe musculoskeletal pathology (e.g. kyphoscoliosis) and use of walking aids.

Data collection

Sociodemographic information (age, sex), anthropometrics (body weight, height, body mass index [BMI]), clinical data (smoking habits, comorbidities using the Charlson Comorbidity Index [CCI]), and physical activity levels (Brief Physical Activity Assessment Tool [BPAAT]) were first collected. Body weight and height were assessed with a digital scale and stadiometer, respectively. In smoking habits, the pack-year number was calculated. Individuals with former and current smoking habits were classified as light smokers (0.1–20.0 pack-years), moderate smokers (20.1–40.0 pack-years), and heavy smokers (> 40 pack-years) [26]. The Charlson Comorbidity Index (CCI) assesses the number of comorbidities in the person and is validated for the Portuguese population [27]. The final score corresponds to the sum of the value assigned to each item, quantifying the degree of comorbidity, and is classified as: 'mild' (1–2 points), 'moderate' (3–4 points), and 'severe' (≥5 points) [28]. The BPAAT consists of two questions regarding the frequency and duration of moderate and vigorous physical activity during a typical week. The total score ranges from 0 to 8 points and allows the individual to be classified as 'insufficiently active' (0–3) or 'sufficiently active' (≥4) [29]. This questionnaire demonstrates good construct validity (0.39 ≤ Spearman correlation coefficient (ρ) ≤ 0.44) in individuals with various health conditions [29–32].

Then the participants performed three 4MGS at their usual speed and three 4MGS at their maximal speed [33], following this order. Both tests were conducted indoor on flat ground. Two cones and a measuring tape were used to mark the required length for the tests (4 metres), followed by 2 additional metres used as a deceleration zone. The execution of each modality was explained in detail to the participants according to Furlanetto et al. (2022) instructions [10]. Two researchers from the team (physiotherapists), who underwent prior training to ensure consistency in the testing procedures, collected the data. Participants were asked to stand with both feet touching the starting line and start walking upon hearing the command 'go', aiming to reach the other cone at their usual speed ('day-by-day') and to maximal speed ('walk as fast as possible, but without running'). Timing started when the participant initiated the movement and stopped when their leading foot fully cleared the cone. The time taken in seconds was recorded with a digital stopwatch and later converted into speed (metres/second) by dividing the distance by the time taken. The highest speed achieved on each modality was used in the analysis.

At the end of the visit, the participants completed a brief questionnaire developed by the researchers to assess the level of comfort experienced during each modality and to determine if they had a preference (supplementary material 2). The level of comfort was assessed on a Likert scale ranging from 0 to 5, where 0 meant 'not comfortable at all' and 5 meant 'very comfortable'. The use of simple comfort and preference questionnaires allows the analysis of participant experience in assessments [34] and interventions [35,36] in order to provide excellent patient-centered care delivery.

Data analysis

Data analysis was performed using IBM SPSS Software (version 28.0, International Business Machines, United States of America). Graphs were created using Microsoft Excel (Microsoft Corporation, 2021). The significance level was set at 0.05.

Descriptive statistics were used to characterise the total sample, describe the 4MGS performance (total sample and by sex/age group) and the level of comfort/preference. Continuous variables were presented as mean and standard deviation or median [percentile 25–75], depending on the normality of the data distribution, assessed using the Kolmogorov-Smirnov test. Absolute and relative frequencies (%) were used for categorical variables.

To compare the characteristics of the sample between sexes, the independent samples t-test was used for quantitative data that followed a normal distribution. For non-normally distributed data, Mann-Whitney U test was used. The chi-square or Fisher's exact tests were used to assess the association between categorical variables.

Normative values were presented by age groups (18–29, 30–39, 40–49, 50–59, 60–69, 70–79 and ≥80) and by sex within each age group. To obtain the normative values, mean, standard deviation, with 95% confidence interval and the 10th percentile for the lower limit of normality of the highest speed achieved on each test were presented. One-way analysis of variance (ANOVA) with Bonferroni correction was used to compare mean values across age groups, and independent samples t-test to compare sexes within age groups. Multiple linear regression was used to establish the reference equations for usual and maximal speed. The sample size was determined based on the recommendations of Green:

$$N > 50 + 8m,$$

where N is the total sample size and m is the number of independent variables [37]. Since 8 independent variables were considered (age, sex, body weight, height, BMI, smoking habits, BPAAT classification, and BPAAT score), a minimum of 114 participants was the target during the recruitment phase.

Pearson correlation coefficient was used to examine the correlations between the dependent variables (highest usual and maximal speed achieved) and the independent variables (age, body weight, height, BMI, and BPAAT score). In turn, point-biserial correlation coefficient was used to examine correlations between the dependent variables with sex, BPAAT classification and smoking habits. Since the smoking habits variable has three categories (never, former, or current smoker), point-biserial correlations were performed between all possible pairs of categories with the dependent variable. The dependent variables that showed significant correlations with the independent variables were suitable in a further selection stepwise multiple regression. Two stepwise multiple regressions were performed, one for usual speed and one for maximal speed. Assumptions for each multiple regression model were confirmed (i.e. linear relationship between dependent and independent variables; absence of multicollinearity among independent variables; homoscedasticity; absence of outliers; normality of residuals), and the coefficient of determination (R^2) was used to assess the performance of each regression model.

Table 1. Characteristics of participants (*n* = 287).

	Total sample (*n* = 287)	Men (*n* = 108)	Women (*n* = 179)	p value
Age (years)	47.8 ± 19.5	48.0 ± 19.4	47.6 ± 19.6	0.831
Body weight (kg)	69.4 ± 12.5	75.4 ± 11.3	65.7 ± 11.7	0.382
Height (m)	1.70 ± 0.1	1.73 ± 0.1	1.61 ± 0.7	0.020
BMI (kg/m²)	25.2 ± 4.1	25.2 ± 3.5	25.3 ± 4.4	0.020
BMI classification, n (%)				
Underweight	10 (3.5%)	0 (0%)	10 (5.6%)	0.070
Normal weight	147 (51.2%)	62 (57.4%)	85 (47.5%)	
Pre-obesity	92 (32.1%)	33 (30.6%)	59 (33%)	
Obesity class I	32 (11.1%)	11 (10.2%)	21 (11.7%)	
Obesity class II	6 (2.1%)	2 (1.9%)	4 (2.2%)	
Smoking status, *n* (%)				
Never	207 (72.1%)	60 (55.6%)	147 (82.1%)	<0.001
Former	43 (15%)	25 (23.1%)	18 (10.1%)	
Current	37 (12.9%)	23 (21.3%)	14 (7.8%)	
Pack-years, M [p25-p75]	5 [1.88 – 15]	9.2 [4 – 18.8]	2.5 [0.95 – 7.63]	0.001
Light smokers	69 (86.3%)	40 (83.3%)	29 (90.6%)	0.168
Moderate smokers	11 (13.7%)	8 (16.7%)	3 (9.4%)	
CCI (score), M [p25-p75]	0 [0 – 2]	0 [0 – 2]	0 [0 – 2]	0.730
BPAAT (score), M [p25-p75]	3 [0 – 5]	3 [0 – 6]	2 [0 – 4]	0.141
Classification BPAAT, *n* (%)				
Insufficiently active	187 (65.2%)	65 (60.2%)	122 (68.2%)	0.174
Sufficiently active	100 (34.8%)	43 (39.8%)	57 (31.8%)	
4MGS				
Usual (m/s)	1.32 ± 0.25	1.34 ± 0.24	1.31 ± 0.25	0.582
Maximal (m/s)	1.88 ± 0.36	1.98 ± 0.38	1.82 ± 0.33	0.154

The values are expressed as mean ± standard deviation unless otherwise indicated. P-value corresponds to the comparison of values between sexes. Abbreviations: BMI - Body Mass Index; CCI - Charlson Comorbidity Index; BPAAT - Brief Physical Activity Assessment Tool; M – median; m/s - metres per second; p25-p75 - 25th and 75th percentiles.

Results

Participants

A total of 303 participants were recruited, but 16 were excluded due to respiratory ($n=11$), cardiac ($n=2$), neurological ($n=2$), and oncological ($n=1$) diseases. Therefore 287 participants were included in the study (62.4% female), with a mean age of 47.8 ± 19.5 years (18–88 years). Participants had a mean BMI of 25.23 ± 4.08 kg/m^2, and most were non-smokers (72.1%). According to the CCI score, participants had a mild degree of comorbidity (0 [0 - 2]), and based on the BPAAT score, most participants were insufficiently active (65.2%). Comparing the sexes, men were significantly taller, had lower BMI values, and had higher smoking habits (Table 1).

4MGS normative values

Table 2 shows that for the total sample, no significant differences were observed in speed for both tests among the younger age groups (18–29, 30–39, 40–49, and 50–59 years). However, a significant decrease in speed was observed in the age group 60–69. Between the 6th and 7th decades of life, there were no significant differences. The age group above 80 years had the slowest speeds in both tests, and these speeds were significantly different from all other age groups (Tables 2 and S1).

In men, comparing age groups, significant differences in speeds appeared in the 7th decade of life, with lower values in both modalities. The speeds in this decade were similar to the 60–69 and ≥80 age groups (Tables 2 and S2).

In women, comparing the usual speed among age groups, no significant differences were observed until the 50–59 age group. The 60–69 age group had a usual speed similar to 50–59 and 70–79 age groups. In the >80 age group, women had significantly lower usual speeds compared to all other age groups (Table 2 and S3). In maximal speed, significant differences were observed between the younger age groups and the 60–69 age group, except for the 40–49 age group. The 70–79 age group only present similar maximal speed with the 60–69 age group. The oldest age group (>80 years) had the slowest maximal speed, and it was significantly different from all other age groups (Tables 2 and S3).

No significant differences were found between sexes within each age group for both tests (Tables 2 and S4).

4MGS predictive equations

Age (r=-0.507 and r=-0.567), height ($r=0.243$ and $r=0.328$), BPAAT classification ($r_{pb}=0.162$ and $r_{pb}=0.155$) and BPAAT score ($r=0.140$ and $r=0.156$) were significantly associated with both usual and maximal speed, respectively. Sex ($r_{pb}=0.222$) and BMI (r=-0.198) were also significantly associated with maximal speed. The multiple regression models showed that age and BPAAT classification explained 27% of variability in the usual speed and that age, sex, and BPAAT classification explained 38% of variability in the maximal speed (Table 3). The reference equations were:

Table 2. Normative values of the 4MGS test by age groups and sex ($n=287$).

		Age groups (years)						
		18–29	30–39	40–49	50–59	60–69	70–79	≥80
4MGS Usual speed, m/s	Total (n = 287)	**n = 66** 1.41 ± 0.19 (1.37–1.46) **LN: ≥1.14**	**n = 45** 1.39 ± 0.18 (1.33–1.44) **LN: ≥1.18**	**n = 52** 1.40 ± 0.18 (1.35–1.45) **LN: ≥1.19**	**n = 37** 1.43 ± 0.25 (1.35–1.51) **LN: ≥1.08**	**n = 34** 1.23 ± 0.16[c] (1.17–1.29) **LN: ≥1.00**	**n = 36** 1.14 ± 0.17[b] (1.08–1.20) **LN: ≥0.94**	**n = 17** 0.85 ± 0.20[a] (0.75–0.95) **LN: ≥0.58**
	Men (n = 108)	**n = 22** 1.39 ± 0.19 (1.30–1.47) **LN: ≥1.12**	**n = 19** 1.37 ± 0.21 (1.27–1.47) **LN: ≥1.17**	**n = 18** 1.39 ± 0.14[f] (1.32–1.45) **LN: ≥1.21**	**n = 15** 1.54 ± 0.27 (1.39–1.69) **LN: ≥1.11**	**n = 15** 1.25 ± 0.18[e] (1.15–1.36) **LN: ≥1.01**	**n = 14** 1.14 ± 0.14[d] (1.06–1.23) **LN: ≥0.98**	**n = 5** 0.89 ± 0.21[c] (0.63–1.15) **LN: ≥0.65**
	Women (n = 179)	**n = 44** 1.43 ± 0.19 (1.37–1.49) **LN: ≥1.16**	**n = 26** 1.40 ± 0.16 (1.34–1.47) **LN: ≥1.13**	**n = 34** 1.41 ± 0.21 (1.34–1.48) **LN: ≥1.12**	**n = 22** 1.36 ± 0.21[h] (1.26–1.45) **LN: ≥1.08**	**n = 19** 1.21 ± 0.15[g] (1.14–1.29) **LN: ≥1.00**	**n = 22** 1.14 ± 0.19[b] (1.06–1.23) **LN: ≥0.85**	**n = 12** 0.83 ± 0.21[a] (0.70–0.96) **LN: ≥0.57**
4MGS Maximal speed, m/s	Total (n = 287)	**n = 66** 1.99 ± 0.25 (1.93–2.05) **LN: ≥1.68**	**n = 45** 2.04 ± 0.19 (1.99–2.10) **LN: ≥1.81**	**n = 52** 2.01 ± 0.25 (1.94–2.08) **LN: ≥1.77**	**n = 37** 2.02 ± 0.34 (1.91–2.13) **LN: ≥1.60**	**n = 34** 1.74 ± 0.27[c] (1.64–1.84) **LN: ≥1.37**	**n = 36** 1.56 ± 0.22[b] (1.49–1.63) **LN: ≥1.20**	**n = 17** 1.15 ± 0.31[a] (0.99–1.31) **LN: ≥0.78**
	Men (n = 108)	**n = 22** 2.06 ± 0.31 (1.93–2.20) **LN: ≥1.70**	**n = 19** 2.07 ± 0.22 (1.97–2.18) **LN: ≥1.80**	**n = 18** 2.15 ± 0.30[f] (2.00–2.30) **LN: ≥1.69**	**n = 15** 2.21 ± 0.32 (2.03–2.39) **LN: ≥1.71**	**n = 15** 1.83 ± 0.31[e] (1.65–2.02) **LN: ≥1.36**	**n = 14** 1.62 ± 0.20[d] (1.50–1.73) **LN: ≥1.36**	**n = 5** 1.24 ± 0.42[c] (0.72–1.76) **LN: ≥0.85**
	Women (n = 179)	**n = 44** 1.96 ± 0.21 (1.90–2.02) **LN: ≥1.67**	**n = 26** 2.02 ± 0.15 (1.94–2.08) **LN: ≥1.77**	**n = 34** 1.94 ± 0.19 (1.88–2.01) **LN: ≥1.77**	**n = 22** 1.89 ± 0.28 (1.76–2.02) **LN: ≥1.55**	**n = 19** 1.67 ± 0.22[c] (1.56–1.77) **LN: ≥1.38**	**n = 22** 1.52 ± 0.22[b] (1.42–1.62) **LN: ≥1.17**	**n = 12** 1.11 ± 0.27[a] (0.94–1.28) **LN: ≥0.73**

The values are expressed as mean ± standard deviation, with a 95% confidence interval; LN: Limit of normality calculated for each test based on 10th percentile. Legend: m/s - metres per second.
[a]Different from all other age groups.
[b]Different from the other age groups, except for the 60–69 age group.
[c]Different from the other age groups, except for the 70–79 age group.
[d]Different from the other age groups, except for the ≥80 and 60–69 age groups.
[e]Different from the other age groups, except for the 70–79, 40–49, 30–39, and 18–29 age groups.
[f]Different from the other age groups, except for the 60–69, 50–59, 30–39, and 18–29 age groups.
[g]Different from the other age groups, except for the 70–79 and 50–59 age groups.
[h]Different from the other age groups, except for the 60–69, 40–49, 30–39, and 18–29 age groups.

Table 3. Multiple linear regression analysis with 4-meter gait speed test at usual and maximal speeds as dependent variables.

		Unstandardised coefficients		Standardised coefficients			
	R^2	B	Standard Error	β	95%CI	p-value	Estimated standard error
4MGS Usual speed	0.27						
Constant		1.598	0.035		1.53–1.67		0.21
Age		−0.006	0.001	−0.499	−0.008– −0.005	<0.001	
BPAAT Classification		0.060	0.026	0.117	0.008 – 0.112	0.044	
4MGS Maximal speed	0.38						
Constant		2.272	0.048		2.18–2.37		0.28
Age		−0.010	0.001	−0.560	−0.012– −0.008	<0.001	
Sex		0.157	0.035	0.215	0.089 – 0.225	<0.001	
BPAAT Classification		0.073	0.035	0.098	0.003 – 0.142	0.040	

Abbreviations: R^2 - coefficient of determination; B – unstandardised coefficients; β – standardised coefficients; CI - confidence interval; BPAAT - Brief Physical Activity Assessment Tool.

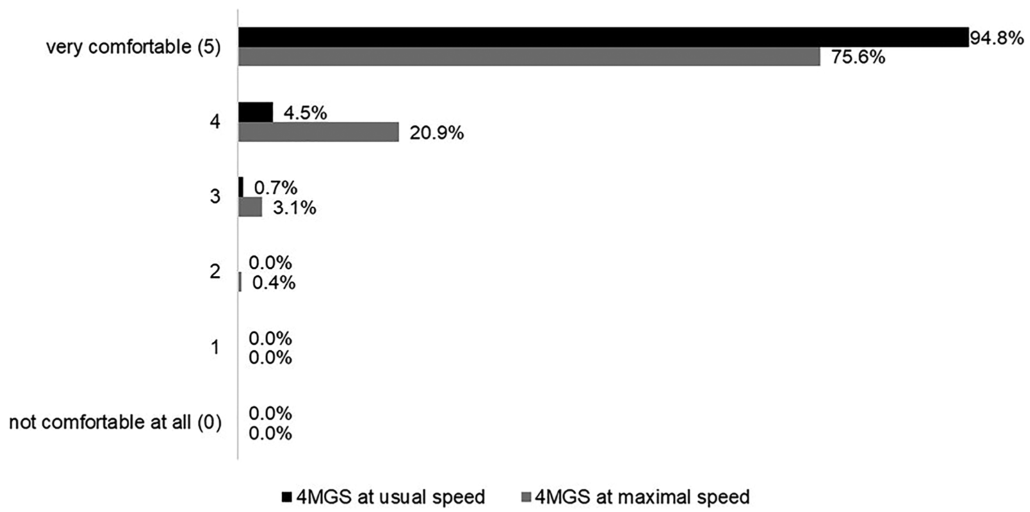

Figure 1. Degree of comfort experienced during the execution of 4MGS at usual ad maximal speed ($n = 287$).

$$\text{Usual speed}(m/s) = 1.598 - (0.006 \times \text{age}) + (0.060 \times \text{BPAAT classification})$$

$$\text{Maximal speed}(m/s) = 2.272 - (0.010 \times \text{age}) + (0.157 \times \text{sex}) + (0.073 \times \text{BPAAT classification})$$

where in sex: 0 = female, 1 = male and in BPAAT classification: 0 = insufficiently active, 1 = sufficiently active.

Participant experience

Most participants (94.8%) felt 'very comfortable' performing the 4MGS at their usual speed, as well at their maximal speed (75.6%) (Figure 1). For 69% of participants, it was indifferent to perform the 4MGS modalities, while 19.9% preferred the 4MGS at usual speed and 11.1% preferred the 4MGS at maximal speed.

Discussion

Our study provides normative values and reference equations for the 4MGS at usual and maximal speed for Portuguese adults without disabilities in line with common practice in similar studies [10,19–22].

We found that gait speed in both modalities (usual and maximal speed) decreases with age, specifically starting from the sixth decade of life. This result is consistent with other studies that examined normative values in other populations [19,21]. Additionally, the meta-analysis by Bohannon & Williams Andrews (2011) highlighted an age effect on gait speed, indicating a substantial reduction in gait speed above 60 years of age [38]. This finding was expected due to the changes associated with the ageing 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 vestibular and proprioceptive inputs), leading to a decline in functional capacity [39,40].

Another result we obtained was that individuals aged ≥80 years had significantly slower gait speeds compared to the younger age groups, which is also consistent with findings from other studies [40]. The biomechanical changes in gait characteristics associated with advancing age may contribute to the underlying mechanisms of declining gait speed. Additionally, older adults tend to have shorter steps [41,42], lower cadence, increased stance, and double support phases [43].

Another noteworthy aspect is that the decline in gait speed occurs for women in the 60–69 age group, while for men, it occurs a decade later. These results are consistent with studies conducted in Norway [21]. The greater decline in lower limb muscle function, muscle atrophy due to loss of muscle fibres in women during ageing [44] and, on the other hand, the attribution of longer step length observed in men may explain these results [45].

On the establishment of the reference equations, we observed that age and BPAAT classification explained the variability in both gait speeds. We found that the increase in age leads to a decrease in gait speed, while being classified as 'sufficiently active' increases gait speed. Indeed, the increase in age, reflecting the natural ageing of biological functions, has a curvilinear relationship with the loss of functional capacity [46], and it is considered the strongest predictor of functional capacity in field tests, including gait tests [16,47,48]. Similarly, it was expected that the level of physical activity would impact gait speed, as there are several studies that link ageing, physical activity level and changes in gait [49]. For example, the combination of increasing age and decreasing physical activity leads to a decline in gait speed [50], explaining why sedentary older adults, compared to more active adults, adopt a cautious gait with shorter and slower steps [51]. Another factor that emerged in the multiple linear regression model and explains the variability in maximal gait speed was sex. This finding is likely due in part to the presence of sex-related changes in neuromuscular control through life [52], where women present lower muscle activation and movement patterns during exercises [53,54]. Therefore, from the obtained equation for maximal speed, we can infer that men will present higher maximal gait speed compared to women.

In our reference equations, the factors that explained the variability in gait speeds had somewhat low R^2 values (27% for usual speed and 38% for maximal speed), but still were higher than those observed in the study that established reference equations for usual speed and maximal speed in the Brazilian population (13% and 24%, respectively) [10]. However, there are differences between the factors included in our equations (age, sex and BPAAT) and in the Brazilian equations (age, BMI, and height) that can be attributed to the differences in the choice of the independent variables included in the multiple regressions and population differences between samples. For the Brazilian equations, the authors only included 5 independent variables (age, weight, height, BMI, and sex), not considering the smoking and physical activity level (BPAAT score and classification), which were also independent variables included in our multiple regressions (total of 8 variables). On the other hand, there are differences in participant characteristics between the studies, especially in the anthropometric measures of height and weight: our participants had less weight and were slightly taller than those in the study by Furlanetto et al. (2022) [10]. These results illustrate the heterogeneity that could arise from developing equations from different populations and highlight the importance of developing population-specific reference equations.

Regarding participant experience, the execution of the 4MGS test was reported to be highly comfortable, where most participants showed no preference for either of the test options. This provides important information in the decision-making process of healthcare professionals to choose the two 4MGS modalities in clinical practice to assess functional capacity.

This study has some strengths and limitations that need to be mentioned. This is the first study to establish normative values and reference equations for 4MGS at usual and maximal speed for Portuguese adults which is considered a strength of the study. Also, these values were obtained from participants with a wide age range between 18 and 88 years. The fact that we included interpretability of the maximal speed along with the usual speed offers an advantage for earlier detection of functional decline in patients in clinical practice, since maximal walking speed is a valuable assessment because it has been shown to decline more rapidly than usual walking speed with advancing age [55,56].

One limitation relates to the sample selection (convenience sampling), which may have affected the results. Similarly, the fact that the participants were mostly from the northern regions of the country may not be representative of the entire Portuguese population. Another limitation concerns to the sample size, which was estimated to produce reference equations but not normative values. The total number of participants in the study should have been larger to obtain normative values, as seen in studies that established normative values for other countries [19,21]. Therefore, we suggest in further studies a priori sample size calculation for each age range and sex. Additionally, as data from all individuals recruited were used to produce the reference equations proposed, the performance of the equations was not assessed using an independent group of individuals. Future studies should assess the performance and reliability of each developed equation, by comparing the results from the equations with the actual values achieved. Another limitation is the heterogeneity in the number of participants among age groups, as the older age groups in our sample have a smaller number of participants. Lastly, comorbidities were self-reported, as assessed with the Charlson Comorbidity Index, and could not be confirmed by medical records or with diagnostic/monitor tests (e.g. spirometry). This would be important since individuals with smoking habits were recruited. However, these individuals included in our sample were mostly non-smokers and the individuals with former and current habits were more often classified as light smokers. Even so, to mitigate this limitation, detailed eligibility criteria and assessment of all study participants were conducted to exclude participants with comorbidities that could potentially influence the outcomes of the study.

Conclusion

Normative values of the 4MGS at usual and maximal speed for the Portuguese population were determined. For the total sample, gait speeds significantly decrease from the 6th decade of life. The reference equation for usual speed identified age and BPAAT classification as factors that explained the variability in usual gait speed, and those factors associated with sex explained the variability in maximal speed. Most participants presented a high level of comfort and expressed no preference in the performance of 4MGS modalities.

These results are intended to provide advantages in clinical practice, facilitating the assessment and interpretation of patients' functional capacity and guiding personalised interventions.

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Data availability statement

The data underlying this article will be shared on reasonable request to the corresponding author.

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