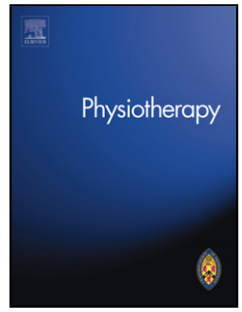

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Authors: A. Marques, P. Rebelo, C. Paixão, S. Almeida, C. Jácome, J. Cruz, A. Oliveira

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Enhancing the assessment of cardiorespiratory fitness using field tests

A. Marques[a,b,*], P. Rebelo[a,b], C. Paixão[a,b], S. Almeida[a,b], C. Jácome[a,c], J. Cruz[a,d], A. Oliveira[a,b]

[a]*Lab 3R – Respiratory Research and Rehabilitation Laboratory, School of Health Sciences, University of Aveiro, Aveiro, Portugal*

[b]*Institute for Biomedicine, University of Aveiro, Aveiro, Portugal*

[c]*Centre for Health Technology and Services Research, Faculty of Medicine, University of Porto, Porto, Portugal*

[d]*Centre for Innovative Care and Health Technology, Polytechnic Institute of Leiria, Leiria, Portugal*

[*]Corresponding author. Address: Lab 3R – Respiratory Research and Rehabilitation Laboratory, School of Health Sciences, University of Aveiro, Agras do Crasto - Campus Universitário de Santiago, Edifício 30, 3810-193 Aveiro, Portugal.

E-mail address: amarques@ua.pt (A. Marques).

Abstract

Objective To establish normative values and reference equations of the 6-minute walk test (6MWT), incremental shuttle walk test (ISWT) and unsupported upper limb exercise test (UULEX) for Portuguese adults.

Design Cross-sectional study. Descriptive statistics and differences between age decades and genders were explored using univariate general linear models to compute reference values. Reference equations were established with a forward stepwise multiple regression.

Setting General community.

Participants In total, 645 adult volunteers without disabilities [43% male, mean age 55.1 (standard deviation 23.6) years] were recruited from the university campus and surrounding community.

Intervention Not applicable.

Main outcome measures Data on age, gender, height, weight, body mass index and smoking status were collected using a structured questionnaire. Physical activity was evaluated using the Brief Physical Activity Assessment Tool. Participants performed two repetitions of the 6MWT, ISWT and UULEX, and the best repetition was used for analysis.

Results Overall, performance was better in males than in females, and decreased with age. Participants' performance was significantly reduced after the sixth decade of life compared with the other decades (P<0.001). Reference equations were: 6MWT=226.93-(5.00×age)+(360.41×height), R^2=71%; ISWT=393.81-(17.98×age)+(185.64×gender)+(775.88×height), R^2=83%; and UULEX=16.71-(0.14×age)+(2.66×gender), R^2=57%.

Conclusion Leg or arm exercise field tests are affected significantly by age and gender. These results will aid health professionals to interpret the results of field tests obtained from healthy or diseased adult populations.

Keywords: Reference values; 6-minute walk test; Incremental shuttle walk test; Upper limb

<A>Introduction

Cardiorespiratory fitness (CRF), also known as aerobic fitness or maximal aerobic power, is defined as the maximum amount of oxygen that can be taken in, transported to and utilised by working tissue during dynamically strenuous exercise involving large muscle mass [1].

A growing body of epidemiological and clinical evidence from the past two decades [2,3] demonstrates that CRF is a more powerful predictor of risk for adverse outcomes (e.g. cardiovascular diseases, cancer and all-cause mortality) than established risk factors, including hypertension, lipid abnormalities, smoking, physical inactivity, obesity and diabetes mellitus [4,5]. For these reasons, since 2016, CRF has been acknowledged by the American Heart Association as the fifth vital sign, and it should be included in patients' clinical routine assessments [6].

Maximum oxygen consumption is widely recognised as one of the best indices to measure CRF capacity [3], and it can be measured objectively and reliably during cardiopulmonary maximal exercise testing. However, this maximal test is expensive, time consuming, and requires the use of sophisticated equipment and trained evaluators [3,7]. Thus, its use in primary care centres (community-based and private practices), where most routine clinical appointments take place, is limited.

Field tests, including the 6-minute walk test (6MWT), the incremental shuttle walk test (ISWT) and the unsupported upper limb exercise test (UULEX), have emerged as suitable alternatives to assess CRF [8,9]. The 6MWT and ISWT are frequently used in clinical practice to assess exercise capacity in patients with chronic diseases [10]. Although less commonly reported, the UULEX has already shown significant correlation with arm ergometry ($r \geq 0.64$, $P<0.05$) [11], and thus has been used to determine arm exercise capacity in patients where this function is compromised (e.g. patients with chronic obstructive pulmonary disease) [11,12]. All three of these field tests have been shown to be reliable, valid and responsive measures of exercise capacity in healthy people [9,13,14] and in people with chronic diseases [8,12,15].

Cardiorespiratory field tests are easier to implement than cardiopulmonary maximal exercise tests, but their interpretation relies on comparisons with normative data or reference equations generated from data of healthy populations [16,17]. Normative and reference data aim to characterise a defined population at a specific point or period of time, and have been considered essential to describe the natural history of clinical conditions [18], evaluate and compare an individual's performance within a population, establish comparisons between different clinical conditions, and evaluate the effectiveness of interventions [19]. It is known that normative data and reference equations are population specific, as population characteristics (e.g., height, weight, lifestyles) vary across countries, and may affect performance in cardiorespiratory field tests [6,20]. Specifically, according to the World Health Organization, body mass index (BMI), physical activity (PA) and smoking status differ considerably between continents and between countries within the same continent [18,21–23]. Since anthropometric and lifestyle health-related data are commonly part of the existing reference equations [10], it is expected that equations developed in a given population are not generalisable worldwide. Thus, the European Respiratory Society and the American Thoracic Society have emphasised the need to produce reference values for different countries [8]. To the authors' knowledge, no study to date has investigated normative values and/or reference equations for CRF during lower and upper limb exercise field tests in the Portuguese adult population. Therefore, the absence of these data hampers the interpretation of these tests, which will, ultimately, prevent health professionals from identifying people with lower CRF and prescribing adequate cardiorespiratory exercise training.

This study aimed to establish the Portuguese adult normative values and reference equations for the three field tests used most commonly to assess CRF: 6MWT, ISWT and UULEX.

<A>Materials and methods

<B>Study design

A cross-sectional study was conducted between September 2012 and September 2017 in people without disabilities. Before data collection, the Ethical Committee of the Health Sciences Research Unit, [name of city - omitted for blinding purposes], Portugal approved the study, and all participants signed an informed consent form.

<B>Participants

The study was advertised for people without disabilities aged >18 years at the university campus and surrounding areas (e.g. fitness centres, community centres, senior universities). Posters, flyers and the university and research websites were used for advertisement, so interested participants could contact the research team directly. In order to achieve maximum representativeness from community-dwelling people, people with the most prevalent age-related conditions, such as controlled hypertension, hypercholesterolaemia and diabetes, were included in the study [24]. This is in accordance with the World Health Organization's definition of 'health' as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity [25]. Exclusion criteria were the presence of one or more of the following conditions: acute (within the past month) or chronic respiratory disease, cardiac disease, signs of cognitive or neuromuscular impairment, and significant musculoskeletal disorder (e.g. kyphoscoliosis) that could interfere with the ability to perform the lower and upper limb exercise field tests. For walking tests, subjects using walking aids were also excluded.

<B>Data collection

Sociodemographic (age and gender), anthropometric (weight and height measurements to compute BMI) and clinical (smoking status, comorbidities and PA) data were collected. Smoking status was evaluated through a survey on current or previous smoking habits. The severity of comorbid diseases was recorded and 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 [26]. PA was assessed using the Brief PA Assessment Tool [27], which consists of two questions assessing the frequency and duration of moderate and vigorous PA undertaken in a usual week. A total score was calculated (range 0 to 8) in which higher scores correspond to high PA levels (i.e. scores <4 indicate that the person is insufficiently active and scores ≥4 indicate that the person is sufficiently active) [27]. The Brief PA Assessment Tool has been shown to be valid against accelerometers (r=0.53, P<0.001) [28], reliable (k=0.53, P<0.001) [27] and feasible for implementation during a single assessment appointment in clinical practice [27].

Age, gender, weight, height, BMI, smoking status and PA were selected as independent variables in the equations developed because they are simple to collect in clinical practice and have been associated with general exercise capacity [29], or specifically with the 6MWT, ISWT or UULEX (e.g. age, gender, weight, height, BMI and PA) [9,10].

Finally, participants performed two repetitions of one lower limb exercise field test (i.e. 6MWT or ISWT) and the UULEX, with a 30-minute rest period between them. There was no standard order for performing the field tests. Data were collected by trained physiotherapists with experience in applying these tests.

All tests were terminated at the participant's request, if abnormal physiological responses occurred (i.e. participants reached 90% of their maximum age-predicted heart rate [30] or peripheral oxygen saturation was <85%), or if the participant was unable to continue performing the test according to the recommendations [11,31,32]. Chest pain, intolerable dyspnoea, dizziness, leg cramps, diaphoresis and pallor were additional criteria for stopping the test. Immediately after finishing each test, distance walked (6MWT and ISWT) or total exercise time (UULEX) was recorded. The best performance (i.e. longer distance walked for the 6MWT/ISWT and longer exercise time for the UULEX) was used in the analysis.

<B>Six-minute walk test

The 6MWT was carried out using a 30-m straight walk course, according to the guidelines of the American Thoracic Society [32]. The course was marked out on a flat surface, with chairs placed at both ends of the course and along the course against the corridor wall. Participants were instructed to stand at the zero mark of the walk course, and then walk as fast as possible for 6 minutes. Standardised verbal encouragement was given in every minute of the test. Participants could stop and rest during the test if necessary, but were instructed to restart walking as soon as they were able to do so. The total distance (in m) was recorded.

<B>Incremental shuttle walk test

The ISWT was performed using a 10-m course identified by two cones placed 0.5 m from each end point, according to the test instructions [31]. Participants were instructed to walk (or run) around the course according to the speed dictated by an audio signal. The initial walking speed was 0.5 m/second and this increased by 0.17 m/second each minute. An adaptation of the modified protocol was used as described by Probst *et al.* [17] to avoid a ceiling effect as participants were healthy subjects, hence ensuring their maximal effort. The initial explanation was standardised [31], and no verbal encouragement was given to participants during the test. The total distance (in m) was recorded.

<B>Unsupported upper limb exercise test

Participants were instructed to sit on a chair, hold a plastic bar (0.2 kg) and lift it through eight levels at a constant cadence of 30 beats per minute, dictated by a metronome [11]. When the maximum height was reached, participants received a heavier bar (0.5 kg). Thereafter, the weight of the bar was increased by 0.5 kg, to a maximum weight of 2 kg, every minute [11]. An adaptation of the protocol [11] (i.e. continuing the cadence until participants stopped, but not increasing the weight) was used to avoid a ceiling effect as participants were healthy subjects, hence ensuring their maximal effort. The total time (in minutes) was recorded.

<B>Sample size and statistical analysis

The sample size for multiple linear regression to establish the reference equations was determined according to the 'rule of thumb' proposed by Green in 1991 [33]:

$N > 50 + 8m$ (1)

where *N* is the sample size and *m* is the number of independent variables. As eight independent variables (gender, age, smoking status, PA, height, weight and BMI) were considered in this study, a minimum of 114 participants per reference equation formulated were recruited.

All statistical analyses were performed using SPSS Version 24.0 (IBM Corp., Armonk, NY, USA), and plots were created using GraphPad Prism Version 5.01 (GraphPad Software, San Diego, CA, USA). The level of statistical significance was set at $P<0.05$.

The normality of data distribution was checked using histograms and Q–Q plots. Descriptive statistics were used to characterise the sample, and normative values were established per gender and age decade using means and 95% confidence intervals. Comparisons between age decades and gender (within each age decade) were explored using univariate general linear models with Bonferroni's correction.

Using a random selection of 70% of the included participants, reference equations were developed for each field test. As normality of data distribution was observed, Pearson's univariate correlation coefficients (*r*) were computed to examine the association between each of the dependent variables (i.e. 6MWT distance, ISWT distance and UULEX time) and the independent variables (age, gender, weight, height, BMI, smoking status and PA). The dependent variables that were significantly correlated with each of the independent variables were fitted in a forward selection stepwise multiple regression. The assumptions of the multiple regression were confirmed (i.e. 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 and reliability of each developed equation were further assessed with the remaining 30% of the sample. This sample size was established in accordance with recent literature, in which tests of the reference equations are conducted in samples of 8% to 40% [14,17,34,35]. This analysis consisted of comparing (one-way analysis of variance), and testing for absolute reliability (Bland and Altman plots) [36–38], the results obtained with each new equation with previous existing reference equations. Similar analysis was then conducted comparing the results from the new equations with the actual values achieved by 30% of the sample. The criteria for selecting equations for comparison were based on geographical proximity, ease of implementation in clinical practice, variance explained and general acceptability by the scientific community (i.e. citations in scientific papers). Thus, the reference equations proposed by Enright *et al.* [39] for the 6MWT and by Probst *et al.* [39] for the ISWT were used for comparison purposes.

No comparison equation was used for the UULEX as this was the first study to develop a reference equation for this test.

<A>**Results**

In total, 563 adults participated in the study {44% male, mean age 53 [standard deviation (SD) 25] (range 18 to 97) years, mean BMI 26 (SD 5) kg/m^2}. Most were non-smokers (*n*=446, 79%), insufficiently active (*n*=372, 66%) and, according to the CCI, presented no (*n*=244, 43%) or one to two (*n*=105, 19%) comorbidities. All participants performed the UULEX plus one lower limb exercise field test. However, 26 participants only performed the UULEX due to use of walking aids, and 18 participants only agreed to performed one field test (11 performed the UULEX, five performed the 6MWT and two performed the ISWT). The reasons for test selection were participants' time constrains and personal preferences. Thus, 298 subjects completed the 6MWT [39% male, mean age 52 (SD 24) years, mean BMI 26 (5) kg/m^2], 228 subjects completed the ISWT [51% male, mean age 51 (SD 24) years, mean BMI 26 (SD 5) kg/m^2], and 556 subjects completed the UULEX [43% male, mean age 54 (SD 25) years, mean BMI 26 (SD 5) kg/m^2]. Participants' characteristics are shown in Table 1.

<insert Table 1 near here>

<B>Normative values

Table 2 shows the normative values for the 6MWT, ISWT and UULEX for each age decade and gender. Participants walked a mean distance of 524 (SD 208) m in the 6MWT and 843 (SD 568) m in the ISWT, and took 10.4 (SD 4.9) minutes to perform the UULEX. Generally, performance in cardiorespiratory field tests was found to decrease with age. Significantly poorer performances in the ISWT emerged after the fifth decade of life, whilst for the 6MWT and the UULEX, poorer performances were presented after the sixth decade of life (*P*<0.001).

Gender differences within each age decade were observed mainly for the ISWT and UULEX. In the 6MWT, males performed significantly better than females until the fourth decade of life (P<0.05). In the ISWT, males walked significantly further than females (P<0.05) in almost every age decade, except for the fifth, seventh and eighth decades of life. Finally, for the UULEX, males performed significantly better than females, especially from the fourth decade of life onwards (P<0.05), but also in the second decade of life (P<0.001). Exact P-values for multiple comparisons can be found in the online supplementary material.

<insert Table 2 near here>

<B>Reference equations

<C>Six-minute walk test

The best performance in the 6MWT of 208 (70% of 298) participants [42% male, mean age 53 (SD 24) years, mean BMI 26 (SD 5) kg/m^2] was used to compute the reference equation. There were significant correlations between distance walked in the 6MWT and gender (r=0.23, P=0.003), age (r=-0.82, P<0.001), smoking status (r=0.14, P=0.04), PA (r=0.27, P<0.001), height (r=0.59, P<0.001) and BMI (r=-0.44, P<0.001), but not with weight (r=-0.001, P=0.98). A model of stepwise multiple regression showed that age and height explained 71% (P<0.001) of variability in the 6MWT. Age had the strongest (β=-0.70 vs β=0.24 for height) relationship with the 6MWT (Table 3). The reference equation for distance walked in the 6MWT was:

$$6MWT_{pred} = 226.93 - \left(5.00 \times age_{years}\right) + (360.41 \times height_m) \ (2)$$

Reliability of Equation (2) was tested in 90 (30% of 298) participants. Analysis of the Bland and Altman plots dictated the removal of four outliers, so 86 participants were analysed [33% male, mean age 53 (SD 24) years, mean BMI 26 (SD 5) kg/m^2]. No significant differences were observed between the actual values achieved by participants and the values predicted by

Equation (2) or by the equation of Enright *et al.* [39] (P=0.67). No systematic bias was observed between values achieved by participants and those predicted by any of the equations (Fig. 1).

<insert Fig 1 near here>

<C>Incremental shuttle walk test

The best performance in the ISWT of 159 (70% of 228) participants [49% male, mean age 51 (SD 25) years, mean BMI 26 (SD 5) kg/m^2] was used to compute the reference equation. There were significant correlations between distance walked in the ISWT and gender (r=0.30, P<0.001), age (r=-0.87, P<0.001), PA (r=0.38, P<0.001), height (r=0.66, P<0.001) and BMI (r=-0.50, P<0.001), but not with smoking status (r=0.01, P=0.94) and weight (r=-0.02, P=0.79). A model of stepwise multiple regression showed that age, gender and height explained 83% (P<0.001) of variability in the ISWT. Age had the strongest (β=-0.79 vs β=0.17 for gender vs β=0.15 for height) relationship with the ISWT (Table 3). The reference equation for distance walked in the ISWT was:

$$ISWT_{pred} = 393.81 - (17.98 \times age_{years}) + (185.64 \times gender) + (775.88 \times height_m) \quad (3)$$

where female=0 and male=1.

Reliability of Equation (3) was tested in 69 (30% of 228) participants. Analysis of the Bland and Altman plots dictated the removal of four outliers, so 65 participants were analysed [52% male, mean age 52 (SD 24) years, mean BMI 27 (SD 5) kg/m^2]. No significant differences were observed between the actual values achieved by participants and the values predicted by Equation (3) or by the equation of Probst *et al.* [17] (P=0.97). No systematic bias was observed between values achieved by participants and those predicted by Equation (3) (Fig. 2A). However, systematic bias was observed using the equation proposed by Probst *et al.* [17], i.e. a significant overestimation of lower scores and underestimation of higher scores was observed (Fig. 2B).

<insert Fig 2 near here>

<C>Unsupported upper limb exercise test

The best performance in the UULEX of 389 (70% of 556) participants [43% male, mean age 54 (SD 25) years, mean BMI 27 (SD 5) kg/m^2] was used to compute the reference equation. There were significant correlations between the duration of performance in the UULEX and gender (r=0.34, P<0.001), age (r=-0.71, P<0.001), smoking status (r=0.14, P=0.004), PA (r=0.35, P<0.001), height (r=0.59, P<0.001) and BMI (r=-0.35, P<0.001), but not with weight (r=-0.09, P=0.08). A model of stepwise multiple regression showed that age and gender explained 57% (P<0.001) of variability in the UULEX. Age had the strongest (β=-0.68 vs β=0.26 for gender) relationship with the UULEX (Table 3). The reference equation for distance walked in the UULEX was:

$$UULEX_{pred} = 16.71 - (0.14 \times age_{years}) + (2.66 \times gender) \quad (4)$$

where female=0 and male=1.

Reliability of Equation (4) was tested in 167 (30% of 556) participants. Analysis of the Bland and Altman plots dictated the removal of four outliers, so 163 participants were analysed [43% male, mean age 54 (SD 25) years, mean BMI 26 (SD 5) kg/m^2]. No significant differences were observed between the actual values achieved by participants and those predicted by

Equation (4) (P=0.46). No systematic bias was observed between values achieved by participants and those predicted by Equation (4) (Fig. 3).

<insert Fig 3 and Table 3 near here>

<A>Discussion

This study showed that gender and age significantly affect performance in cardiorespiratory field tests, especially after the sixth decade of life, with males and young people generally presenting better performances. Variability in reference equations developed for the 6MWT, ISWT and UULEX was mainly explained by age.

Few studies exist that include intervals of age wide enough to compute normative values of field tests for age decades [20,40]. Nevertheless, age has been indicated as a powerful predictor of performance in exercise field tests [41], and previous authors have shown a marked decline in the 6MWT after the fifth or sixth decade of life [20,40]. This study supports these findings and adds to the body of knowledge that a similar pattern is also present in other cardiorespiratory field tests, such as the ISWT and UULEX.

Similar to age, gender has been considered as a powerful predictor of CRF [42]. In this study, differences between genders, according to age decade, were mainly present in the ISWT and UULEX, rather than in the 6MWT. Additionally, gender was not included as a predictor in the 6MWT reference equation [Equation (2)]. The absence of gender as a predictor of distance walked in the 6MWT has been reported previously [34,43], as it has been found that after correcting for height, males do not walk further than females [39]. The normative values in this study did not take height into account; therefore, mean differences of approximately 40 m between genders were observed in all age decades, which exceeds the established minimal clinical differences in most studied populations [44]. Thus, despite the lack of statistical differences between genders among age decades, the clinically relevant differences found demand that normative values per gender are confirmed when interpreting patients' performance in CRF tests.

The equations developed for the 6MWT and ISWT [Equations (2) and (3)] were compared with those from Enright *et al.* [39] and Probst *et al.* [17], and no significant differences were observed between the predicted values. Nevertheless, in contrast to the previous equations, systematic bias was not observed, limits of agreement were narrower and larger variability was explained by Equation (2) for the 6MWT (73% vs 32% for male and 48% for female [39]) and Equation (3) for the ISWT (84% vs 71% [17]). Similar to previous studies [17,35,45], these discrepancies between equations may be attributed to population differences between samples, as the subjects in the present study were slightly taller than those in the study by Probst *et al.* [17], and significantly shorter than those enrolled by Enright *et al.* [39]. These results illustrate the errors that could arise from using equations that were not developed specifically for the population being assessed, and highlight the importance of developing population-specific reference equations, supporting the recommendations of the European Respiratory Society and the American Thoracic Society [8].

Regarding the UULEX, similar to walking tests and previous research [9], participants over 50 years of age performed significantly worse than younger people. Evidence suggests that the aging process can decrease muscular functional performance, leading to worse performance of daily living activities involving the upper limbs [46]. Nevertheless, the amount of variability explained for the UULEX (59%) was much lower than the amount of variability explained for the walking tests (73% and 84%), meaning that the variables assessed may not be adequate to explain variability in the UULEX. It is known that upper limb exercise intolerance and dysfunction are associated with reduced maximal strength [47,48]. Thus, upper limb muscle strength might be a good indicator of performance in the UULEX. Future studies should be performed to verify this hypothesis.

To the authors' knowledge, this is the first study to develop reference equations for three CRF field tests for the Portuguese adult population. Given the population specificity of reference equations and normative data [10], and the discrepancies found between this study and previous equations, it is suggested that the equations developed should be preferred to those reported previously. Additionally, all three equations were developed using a wide age range (18 to 97 years) and gender representative samples, and only include easy-to-acquire anthropometric and/or demographic data, facilitating their direct translation to everyday clinical practice of health professionals. These equations and normative values will allow for more appropriate evaluation and interpretation of the exercise capacity of patients with chronic diseases, guiding personalised and tailored interventions involving exercise prescription.

<B>Study limitations

This study has some limitations that need to be acknowledged. Firstly, the use of a convenience sample might have affected the results. Although this methodology has been adopted by most studies in this area [16,17,39,49], efforts were made to recruit participants from different settings, geographical locations, educational levels and economic activities across the country to obtain a representative sample. It is believed that this limitation was minimised by also assessing the reliability of the equations proposed through prospective assessment in a randomly selected, similar sample of participants. Secondly, the order of tests was not randomised, but was performed according to the participants' preference. Although local fatigue was avoided by assuring that participants only performed an upper and/or one of the two lower exercise field tests, with a 30-minute rest period between tests, generalised fatigue was not controlled and may have affected performance on the second test. Thirdly, the limits of agreement between the equations developed for the 6MWT and ISWT [Equations (2) and (3)] and the actual values achieved by participants can be interpreted as being wide (i.e. above or below more than 100 m), which could somewhat affect the validity of equations. Nevertheless, the equations developed in this study still present narrower limits of agreement and lower bias than the equations tested, and thus the equations developed in this study should be preferred when assessing Portuguese patients. Fourthly, comorbidities were self-reported, as assessed with the CCI, and could not be confirmed by medical records. To minimise this limitation, a detailed assessment of all study participants was performed to ensure that those presenting with comorbidities that could affect the outcomes of the study were not included. Finally, regarding the UULEX, other variables which could also have a role in explaining the variance in this test were not assessed, such as upper limb peripheral muscle strength.

<A>Conclusion

Gender and age significantly affect performance in the 6MWT, ISWT and UULEX, especially after the sixth decade of life, with males and young people generally achieving better results than females and older people. Age was a determinant variable for the reference equations of all exercise field tests. These results will help health professionals to detect people with lower CRF and develop adequate exercise prescription in diseased populations, according to the best recommendations from international societies. Nevertheless, the findings from this study should only be considered when using the same testing protocol in order to avoid misinterpretation of the reference values and/or equations.

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Ethical approval: Ethical Committee of the Health Sciences Research Unit [omitted for blinded purposes].

Conflict of interest: None declared.

Contribution of the paper

Key messages of the article

- Lower and upper limb exercise field tests are affected significantly by age and gender.
- Participants' performance on exercise tests is significantly reduced after the sixth decade of life.

New knowledge added by this study

- Reference equations for the Portuguese population were developed for the 6-minute walk test [226.93-(5.00×age)+(360.41×height)] and the incremental shuttle walk test [393.81-(17.98×age)+(185.64×gender)+(775.88×height)],
- A reference equation for the unsupported upper limb exercise test was developed [16.71-(0.14×age)+(2.66×gender)]

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Part of this work was presented at the 28th European Respiratory Society International Congress as a thematic poster.

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Fig. 1. Bland and Altman plots of the difference between (A) the predicted (with the developed equation) and actual values of the 6-minute walk test (6MWT) plotted against the mean of the predicted (with the developed equation) and actual values of the 6MWT; and (B) the predicted (with Enright *et al.* equation) and actual values of the 6MWT plotted against the mean of the predicted (with Enright *et al.* equation) and actual values of the 6MWT. ULA, upper limit of agreement; LLA, lower limit of agreement.

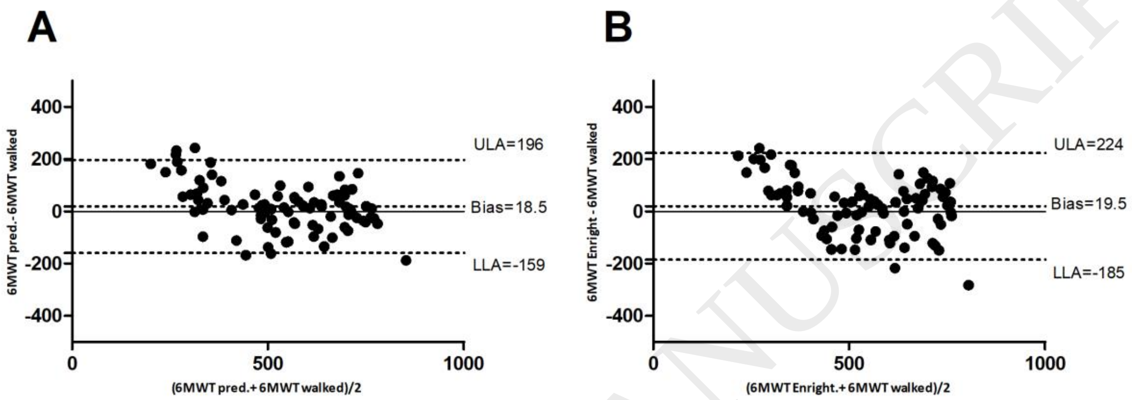

Fig. 2. Bland and Altman plots of the difference between (A) the predicted (with the developed equation) and actual values of the incremental shuttle walk test (ISWT) plotted against the mean of the predicted (with the developed equation) and actual values of the ISWT; and (B) the predicted (with Probst *et al.* equation) and actual values of the ISWT plotted against the mean of the predicted (with Probst *et al.* equation) and actual values of the ISWT. ULA, upper limit of agreement; LLA, lower limit of agreement.

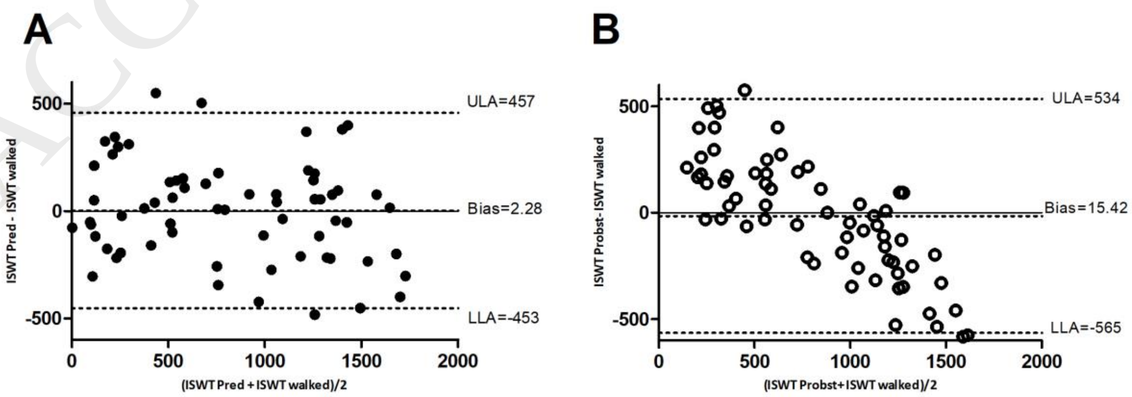

Fig. 3. Bland and Altman plots of the difference between the predicted and actual values of the unsupported upper limb exercise test (UULEX) plotted against the mean of the predicted and actual values of the UULEX. ULA, upper limit of agreement; LLA, lower limit of agreement.

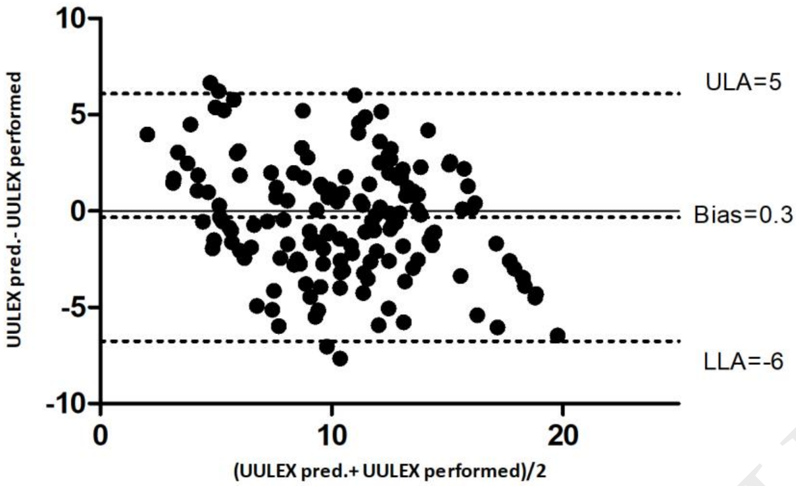

Table 1

Characteristics of participants (*n*=563)

Characteristics	Total sample (*n*=563)	6MWT (*n*=298)	ISWT (*n*=228)	UULEX (*n*=556)
Age, years, mean (SD)	53 (25)	52 (24)	51 (24)	54 (25)
Gender (male), *n* (%)	245 (44)	115 (39)	116 (51)	241 (43)
Height, m, mean (SD)	1.63 (0.11)	1.63 (0.11)	1.66 (0.11)	1.64 (0.11)
Weight, kg, mean (SD)	70 (14)	70 (15)	71 (13)	70 (14)
BMI, kg/m^2, mean (SD)	26 (5)	26 (5)	26 (5)	26 (5)
Smoking status, *n* (%)				
Current smokers	77 (14)	45 (15)	30 (13)	73 (13)
Past smokers	38 (7)	20 (7)	17 (8)	38 (7)
Never smokers	448 (80)	233 (78)	181 (79)	445 (80)
CCI, categories				
0	244 (43)	123 (44)	111 (49)	241 (43)
1–2	105 (19)	62 (21)	41 (18)	103 (19)
3–4	158 (28)	71 (24)	63 (28)	157 (28)
≥5	56 (10)	33 (11)	13 (6)	55 (10)
Physical activity (score 0–8), median (IQR)	3 (1–4)	3 (1–4)	3 (1–4)	3 (1–4)
Sufficiently active (≥4), *n* (%)	191 (34)	95 (32)	87 (38)	154 (35)

6MWT, 6-minute walk test; BMI, body mass index; ISWT, incremental shuttle walk test; UULEX, unsupported upper limb exercise test; CCI, Charlson Comorbidity Index; SD, standard deviation; IQR, interquartile range.

Table 2

Normative values [mean (range)] for cardiorespiratory field tests by age decade and gender

		Age groups (years)						
		18–29	30–39	40–49	50–59	60–69	70–79	≥80
6MWT, m (*n*=298)	Total	*n*=78[d] 710 (695–725)	*n*=28[c] 701 (635–767)	*n*=27[c] 637 (604–670)	*n*=30[d] 609 (570–649)	*n*=42[a] 541 (488–541)	*n*=41[a] 430 (389–471)	*n*=52[a] 270 (237–303)
	Male	*n*=49[e] 692 (663–721)	*n*=18[e] 712 (626–798)	*n*=11[e] 685 (634–736)	*n*=11 652 (558–746)	*n*=17 541 (497–585)	*n*=15 466 (390–542)	*n*=16 313 (259–366)
	Female	*n*=29 741 (703–779)	*n*=10 633 (588–677)	*n*=16 604 (565–643)	*n*=19 584 (549–620)	*n*=25 496 (462–530)	*n*=27 409 (359–459)	*n*=36 267 (227–307)
ISWT, m (*n*=228)	Total	*n*=59[a] 1436 (1358–1514)	*n*=28[d] 1180 (1058–1302)	*n*=25[d] 1162 (993–1331)	*n*=24[a] 799 (674–924)	*n*=25[b] 479 (347–610)	*n*=27[b] 379 (295–464)	*n*=40[a] 156 (122–190)
	Male	*n*=29[e] 1224 (1138–1309)	*n*=14[e] 1357 (1220–1494)	*n*=17[e] 1356 (1204–1509)	*n*=14 873 (683–1063)	*n*=11[e] 632 (419–847)	*n*=14 460 (320–600)	*n*=16 159 (96–223)
	Female	*n*=30 1641 (1557–1725)	*n*=14 1004 (840–1169)	*n*=8 750 (497–1003)	*n*=10 696 (542–850)	*n*=14 358 (201–515)	*n*=13 292 (208–376)	*n*=24 154 (112–195)
UULEX, minutes (*n*=556)	Total	*n*=136[a] 14.4 (13.9–15.0)	*n*=56[d] 13.1 (12.1–14.0)	*n*=51[d] 13.0 (11.9–14.1)	*n*=55[d] 11.7 (10.7–12.8)	*n*=66[a] 9.2 (8.5–10.0)	*n*=78[a] 7.5 (6.7–8.4)	*n*=114[a] 5.2 (4.6–5.7)
	Male	*n*=78[e] 12.9 (12.2–13.6)	*n*=31 13.8 (12.3–15.2)	*n*=28[e] 14.9 (13.6–16.3)	*n*=26[e] 13.2 (11.4–15.0)	*n*=28[e] 10.2 (9.1–11.3)	*n*=35[e] 8.4 (7.0–9.8)	*n*=35[e] 6.1 (5.0–7.3)

	Female	*n*=58 16.5 (15.6–17.3)	*n*=25 12.2 (11.1–13.4)	*n*=23 13.0 (1.9–14.1)	*n*=29 10.4 (9.3–11.4)	*n*=38 8.5 (7.5–9.5)	*n*=43 6.8 (5.8–7.8)	*n*=79 4.7 (4.1–5.3)

6MWT, 6-minute walk test; ISWT, incremental shuttle walk test; UULEX, unsupported upper limb exercise test.

Statistical differences ($P<0.05$) were identified using the following symbols:

aDifferent from all age groups.

bDifferent from all age groups, except 60–69 and 70–79 years.

cDifferent from all age groups, except 18–29, 30–39 and 40–49 years.

dDifferent from all age groups, except 30–39 and 40–49 years.

eDifferent from female

Table 3

Multiple linear regression analysis with 6-minute walk test (6MWT), incremental shuttle walk test (ISWT) and unsupported upper limb exercise test (UULEX) as dependent variables

		Unstandardised coefficients		Standardised coefficients			
	R^2	B	SE	β	95% CI	*P*-value	SE of estimate
6MWT	0.7						
Constant		226.9	120.5		-10.6 to 464.6		93.3
Age		-5.0	0.3	-0.7	-5.6 to -4.4	<0.001	
Height		360.4	67.8	0.2	226.6 to 494.2	<0.001	
ISWT	0.8						
Constant		393.8	480.3		-554.9 to 1342.5		233.0
Age		-18.0	1.0	-0.8	-19.9 to -16.1	<0.001	
Gender		185.6	54.5	0.2	78.0 to 293.2	0.001	
Height		775.9	281.2	0.2	220.3 to 1331.5	0.007	
UULEX	0.6						3.3

Constant		16.7	0.4		15.8 to 17.6		
Age		-0.1	0.0	-0.68	-0.2 to -0.1	<0.001	
Gender		2.7	0.3	0.26	2.0 to 3.3	<0.001	

BMI, body mass index; CI, confidence interval; PA, physical activity; B, unstandardised coefficients; β, beta (standardised coefficient); SE, standard error.