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Predictors of shuttle walking test performance in patients with cardiovascular disease

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Abstract

Objective The incremental shuttle walking test (ISWT) is used to estimate cardiorespiratory fitness, but data from healthy individuals suggest that demographic and anthropometric measures account for much of the variance in test performance. The aim of this study was to determine whether anthropometric, demographic and selected gait measures also predict ISWT performance (i.e. distance walked) in patients with cardiovascular disease.
Design Observational study.
Setting A community-based cardiac rehabilitation centre (Cohort 1) and a hospital outpatient cardiac rehabilitation programme (Cohort 2).
Participants Sixteen patients with clinically stable cardiovascular disease (Cohort 1) and 113 patients undergoing cardiac rehabilitation (Cohort 2).
Interventions Patients in Cohort 1 performed the ISWT on two occasions. Anthropometric data and walking and turning variables were collected. Linear regression analyses were used to identify the predictors of test performance. The authors subsequently attempted to validate the equation created by comparing predicted and actual ISWT values in a larger ($n = 113$) validation sample (Cohort 2).
Main outcome measures Distance walked during ISWT, step length and height.
Results No gait or turning measures were significantly associated with ISWT performance. Distance walked correlated most strongly with step length ($r = 0.83$, $P < 0.05$) and height ($r = 0.74$, $P < 0.05$). Given the similarity of these correlations and the rarity of step length assessment in clinical practice, ISWT performance was predicted using patient's height; this explained 55% of the variance in ISWT performance. Height was also the best predictor in Cohort 2, explaining 17% of test variance ($P < 0.01$). Body mass index explained an additional 3% of variance ($P < 0.05$) in ISWT performance.
Conclusions Routine clinical measures, particularly patient's height, are predictive of ISWT performance. The findings of the present study are in partial agreement with similar studies performed in healthy individuals, and it remains unclear whether the ISWT performance of patients with cardiovascular disease is influenced by the same factors as the ISWT performance of healthy individuals.

Keywords: Incremental shuttle walking test; Cardiovascular disease; Predictors; Exercise test; Functional exercise capacity

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Introduction

Functional walking tests are used to evaluate exercise capacity in patients with respiratory [1] and cardiovascular diseases [2,3]. The outcomes of these tests provide important information regarding exercise capacity and effectiveness of rehabilitation treatments [4]. They are used in exercise prescription and risk stratification [5]. Such tests are either self-paced, such as the 6-minute walk test, or externally paced, such as the incremental shuttle walking test (ISWT) [5]. The ISWT is reliable over short [6] and long [7] test–retest periods, and produces acceptable estimates of functional capacity [6].

Patients may prefer walking tests due to the unfamiliarity of treadmill walking [8]. Shuttle-walking protocols do, however, require patients to turn at regular intervals. This may make the test more difficult than treadmill walking [9], and certainly creates different biomechanical demands than walking without turns [10].

Normal ageing is associated with reduced biomechanical efficiency, and older patients may have difficulty in performing the ISWT due to complex locomotor demands, especially

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turns [11,12]. The frequency of turning is negatively associated with distance walked during the 6-minute walk test [3,11]. However, to the authors' knowledge, there are no comparable studies of the biomechanical predictors of ISWT performance in patients with cardiovascular disease.

Directly measured peak oxygen consumption (during treadmill walking) accounts for 62% of the variance in distance walked during ISWT [6], but this association has only been assessed using univariate regression which does not account for the potential influence of other performance predictors. Two recent studies in healthy participants [13,14] and another study in patients with chronic obstructive pulmonary disease [15] have suggested that large proportions of the variance in ISWT performance may be attributable to demographic variables. Jurgensen *et al.* [13] found that 50% of the variance in ISWT performance of healthy Brazilian adults could be accounted for by age, weight, height and gender. In a similar study of healthy individuals, Probst *et al.* [14] found that body mass index (BMI) was an additional predictor of ISWT performance [13]. To date, however, no studies have examined how such demographic, anthropometric and biomechanical (gait and turning) variables may influence ISWT performance in patients with cardiovascular disease.

If ISWT performance of patients with cardiovascular disease is to be expressed as a value of predicted performance based on equations in healthy populations, it is necessary to determine if the same demographic and anthropometric variables are associated with test performance of patients with cardiovascular disease and healthy individuals. Given that cardiorespiratory fitness only accounts for 63% of variance in ISWT performance, the aim of this study was to determine how demographic, anthropometric and selected biomechanical measures may be related to distance walked during the ISWT.

Methods

Participants

Cohort 1 consisted of 16 patients with clinically stable cardiovascular disease (nine males, seven females), attending a community-based cardiac rehabilitation programme [16]. These patients participated voluntarily in this study after giving written informed consent.

In addition, the patient records of a second cohort of 113 patients with cardiovascular disease (82 males, 31 females), tested as part of routine care at the start of an outpatient cardiac rehabilitation programme in a local hospital, were assessed (Cohort 2). Tables 1 and 2 summarise the clinical characteristics and baseline measurements of Cohorts 1 and 2, respectively. Prior to the study, all procedures were approved by the university ethical committee, and conformed to the Declaration of Helsinki guidelines for research with human subjects.

Table 1
Descriptive characteristics for Cohort 1.

Clinical characteristics and baseline measurements	Mean (SD)
Number of patients	16
Age (years)	69 (9)
Gender	M = 9, F = 7
Height (cm)	167 (10)
Body mass index (kg/m^2)	29.3 (3.7)
Leg length (cm)	88 (8)
Reason for attending cardiac rehabilitation	**Mean (SD)**
Myocardial infarction	2
Angina	1
Surgical procedure (CABG, PTCA)	11
Heart failure	1
Arrhythmias	1

CABG, coronary artery bypass graft; PTCA, percutaneous transluminal coronary angioplasty; M, males; F, females; SD, standard deviation.

Participants in both cohorts had cardiovascular disease and risk factors but were free of severe locomotor limitations. All patients in Cohort 1 had successfully completed outpatient cardiac rehabilitation at local hospitals, and achieved a work rate >5 metabolic equivalents during an exercise test in order to qualify to participate in community-based rehabilitation [17]. Cohort 1 had been enrolled in the rehabilitation programme for >10 weeks, which comprised twice-weekly, 60-minute circuit-based exercise sessions, designed to maintain functional capacity gains achieved in outpatient cardiac rehabilitation [16,17]. Cohort 2 included patients beginning the outpatient phase of cardiac rehabilitation at a local hospital.

Procedures and data collection

ISWT procedure

Patients in both cohorts performed an ISWT by walking back and forth along a corridor marked by two cones set 0.5 m from either end of a 10-m course. Initial walking speed was 0.5 m/second and this increased by 0.17 m/second each minute, indicated by an audible signal. At the end of each level throughout the test, heart rate was recorded with a Polar

Table 2
Descriptive characteristics for Cohort 2.

Clinical characteristics and baseline measurements	Mean (SD)
Number of patients	113
Age (years)	69 (9)
Gender	M = 82, F = 31
Height (cm)	166 (9)
Weight (kg)	77 (13)
Body mass index (kg/m^2)	28.2 (4)
Reason for attending cardiac rehabilitation	**n = 16**
Angina	4
Arryhthmia	2
Myocardial infarction	25
Revascularisation	65
Valve replacement	13
Other	15

M, males; F, females; SD, standard deviation.

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heart rate monitor (Polar Electro Sports Tester S810I, Heart Rate Monitor, Kempele, Finland), and rate of perceived exertion (RPE) was measured using the Borg scale. The ISWT was terminated either when the patient (a) felt too breathless or fatigued to continue at the required speed, (b) failed to complete the shuttle within the allowed time, (c) reached 85% of predicted maximal heart rate: $210 - (0.65 \times \text{age})$, (d) reached RPE ≥ 15, or (e) completed all the levels. All patients in Cohort 1 completed the protocol twice, a minimum of 8 weeks apart, to assess the reproducibility of findings.

Before initial testing, all patients had a primary health assessment (pre-exercise health questionnaire, medical, pharmacological, family history); height, weight and waist circumference were measured; and BMI was calculated (kg/m^2). In Cohort 1, leg length was also measured by assessing the distance between the anterior superior iliac spine and the medial malleolus.

Gait data analysis

In Cohort 1, each turn made at the end of the 10-m course was recorded with a video camera and analysed using SiliconCoach Pro software (version 6.1.5.0, SiliconCoach Ltd, New Zealand). From the video data, the turning style (e.g. step turn or spin turn), turning time and number of steps needed to complete the turn were collected. Turning time and number of steps used in turning were recorded one step before turning, from either foot heel strike, until the end of the turn. The end of the turn was defined as the first heel strike with the pelvis and thorax facing the opposite cone.

During the test, the numbers of step taken in each shuttle was recorded. Step length was estimated by dividing the length of the course by the number of steps in each shuttle, and then normalised to leg length (step length/leg length) [18].

Statistical analysis

In Cohort 1, the independent variables were divided into two categories: static variables (age, height, leg length) and dynamic variables (step length, step length normalised to leg length, number of steps to turn, turning time, turning style). The dynamic variables were analysed during the 33%, 66% of maximum walking speed, penultimate and final levels of the test. Statistical analysis was implemented using Statistical Package for the Social Sciences (SPSS Chicago, IL, USA). Inc., IBM Corporation, NY, USA). Data are presented as mean and standard deviation (SD). Median height was calculated. Differences between the two ISWTs were evaluated using paired-samples t-test. Pearson's correlation coefficients were calculated to assess the relationship between all measured variables and ISWT performance. Variables that correlated at $r > 0.5$ were entered into stepwise linear regression analysis.

In Cohort 1, a separate stepwise regression model was created using all independent variables that correlated ($r > 0.5$) with ISWT performance. To build a more clinically realistic prediction model, the equation excluded variables that are not recorded routinely during cardiac rehabilitation (e.g. leg length is not measured routinely). Colinearity diagnostics were performed for all predictor variables. The factors identified in the pilot study of Cohort 1 and by previous studies were used to develop a new prediction equation using the same method in Cohort 2 ($n = 116$ patients starting outpatient cardiac rehabilitation).

Results

All patients in Cohort 1 were able to undertake the ISWT protocol without serious complications. No patients completed the 1500-m test protocol (performance range 210 to 750 m). There was no significant difference in mean (SD) performance between Trial 1 [479 (139 m)] and Trial 2 [499 (138 m), $t = -1.8$, $P = 0.092$], and data from Trial 1 were used to develop the preliminary prediction equation.

Biomechanical predictors in Cohort 1

The static measurements (height and leg length) and the dynamic measurements (step length and number of steps to turn) showed significant correlation with performance in both test trials. Stepwise regression analysis indicated that step length at 66% of maximum walking speed was the measure most predictive of performance ($R^2 = 0.68$; standard estimate of error = 74 m).

Step length is a dynamic measure (one that must be made during the test) and is therefore probably not practical in routine clinical assessment. The next best univariate predictors of performance were leg length ($R^2 = 0.58$) and height ($R^2 = 0.57$). Due to similarities in the variance explained by each and the comparative simplicity of measuring height, regression analysis was repeated using height as the only predictor of performance in Trial 1 [Eq. (1)]:

$$\text{Mean ISWT (m)} = (10.7 \times \text{height}_{\text{cm}}) - 1316 \qquad (1)$$

The standard estimate of error for Eq. (1) was 90 m. The accuracy of the prediction equation was assessed by predicting patients' performance in the second trial conducted 8 weeks later. Actual distance walked in Trial 2 only correlated moderately with predicted distance ($r = 0.69$, $P = 0.003$), accounting for 48% of the variance in performance. While this was deemed to be insufficiently accurate for use to predict the performance of Cohort 2, the authors were satisfied that detailed measures of gait parameters were unlikely to significantly improve predictions of ISWT performance made using static, anthropometric measures. Therefore, all consequent regression analyses in Cohort 2 were performed without measurements of gait or turning.

Anthropometric predictors in Cohort 2

Mean (SD) ISWT performance was slightly lower in Cohort 2 [360 (90) m]. A second equation was created for

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this cohort based on variables that are commonly available at baseline in clinical practice (age, height, weight, BMI and gender). Stepwise analysis showed that height was the best univariate predictor ($R^2 = 0.17$, $P = 0.0001$, standard estimate of error 135 m), and prediction was improved by adding BMI to height ($R^2 = 0.20$, $P < 0.001$, standard estimate of error 133 m). The regression equations for mean ISWT performance are:

$$\text{Mean ISWT (m)} = (6.485 \times \text{height}_{\text{cm}}) - 784.547 \quad (2)$$

$$\text{Mean ISWT (m)} = (6.184 \times \text{height}_{\text{cm}}) - (6.875 \times \text{BMI}) - 541.600 \quad (3)$$

None of the following clinical data added significantly to the prediction model: diagnosis, resting heart rate, systolic and diastolic blood pressure, recorded maximum heart rate, heart rate after 1 minute of recovery, waist circumference, and time from operation/event to rehabilitation (days).

Discussion

Non-clinical factors that may affect performance should be considered when assessing functional capacity with standardised walking tests in elderly clinical populations [13,14,19–21]. To the authors' knowledge, this is the first prospective study to examine the effect of demographic, anthropometric, gait and turning parameters on ISWT performance in patients with cardiovascular disease.

Turning and walking variables as predictors of test performance

A highly detailed analysis of walking and turning variables that were hypothesised to be related to test performance was undertaken. For instance, the walking distance achieved in the 6-minute walk test by healthy elderly (>50 years) is negatively associated with the number of turns [11,12]. Despite the relatively high frequency and number of turns needed during the ISWT, none of the turning variables measured were associated with ISWT performance. Of note, the present sample comprised patients with cardiovascular disease who exercised regularly and, as such, were largely free from limitations to daily activities. Turning may be more important in patients with orthopaedic limitations. The aim of the detailed preliminary analysis of walking and turning variables was to eliminate a number of complex and time-consuming measurements from the prediction equations. The small sample size was a limitation, but the near-zero order correlations found with, for instance, turning satisfied the authors that such variables were not clinically important predictors of ISWT performance.

Gait and anthropometric predictors of test performance

In Cohort 1, by measuring multiple walking and turning variables, step length at 33% and 66% of maximum walking speed, leg length and height were all found to be positively related to ISWT performance (i.e. total distance walked). No evidence for an association between turning variables and ISWT performance was found.

Taller patients had longer step length at 33% and 66% of maximum walking speed, suggesting that they were better able to cope with the increases in walking speed needed as the ISWT progressed. Shorter patients were less able to increase their step length, and therefore their walking speed, during latter test stages. Therefore, taller patients, who could continue to increase their step length in the latter stages of the ISWT, appear to be able to obtain better scores.

As the ISWT is incremental in nature, walking speed is always positively associated with distance walked. Characteristics such as long step length and greater height, which are associated with greater maximal walking speed [22], are also likely to result in better ISWT performance [23]. Walking speed is a combination of step length and cadence, and an increase in one or both results in an increase in speed. It is possible that shorter patients would increase their cadence at higher shuttles in order to complete the shuttle. Increases in cadence are limited in the elderly [23]; therefore, such patients would need to increase step length to achieve higher walking speeds. This gives taller patients a natural advantage in walking tests. The magnitude of expected differences in ISWT performance is quite stark. Each additional 1 cm in stature yields a potential 10.7-m advantage in the ISWT. Typical mean values for test performance at entry to cardiac rehabilitation are ∼350 m. The height advantage enjoyed by a 179-cm-tall individual compared with an individual with a height of 160 cm could approach 50% of this value.

Regression analysis showed that the step length recorded at 2/3 of maximal test performance was the best predictive measure of performance. Step length is, however, a dynamic measure and has high inter- and intra-individual variability, especially amongst the elderly. Conversely, clinicians need relatively quick, simple and practicable measurement procedures if they are to be used regularly in clinical assessment. Leg length and height were the next best predictors of performance accounting for similar levels of variance in ISWT performance (58% and 57%, respectively). Leg length is a relatively simple static measurement that only requires basic anatomical knowledge. It may be more difficult (and open to error) to perform in patients with ankle swelling due to oedema, obese patients and those with limited range of motion in the lower body. The authors chose to use height as a performance predictor due to its simplicity and existing high clinical utility (it is collected routinely for calculation of BMI) [17,24,25].

Two recent studies have assessed predictors of ISWT performance in healthy populations, but to the authors' knowledge, this is the first study to attempt this in patients with cardiovascular disease. In healthy people aged 40 to 84 years, Jurgensen *et al.* [13] found that the best predictors of ISWT performance were gender, age, weight and height, explaining 50% of variance in test performance. In a study in healthy people of a wide age range (18 to 83 years), Probst *et al.* [14] found that age and gender were powerful predictors, with BMI also adding significantly to the prediction model, explaining 71% of variance in test performance.

Satisfied that data from detailed analyses of gait and turning were not necessary to predict ISWT performance, a prediction equation in a larger sample (Cohort 2) was developed using anthropometric and demographic variables alone. In these patients with cardiovascular disease, height was found to be a more powerful predictor, and the addition of BMI explained 20% of the variability in test performance. The only other study to attempt ISWT performance prediction in patients was undertaken in patients with chronic obstructive pulmonary disease [15], and while the authors were able to explain 83% of test variance using age, gender and exercise capacity, the findings are difficult to compare with those from patients with cardiovascular disease who are typically much fitter. Oxygen consumption was not measured in the present study, but unlike studies of healthy individuals, only 20% of the variance in ISWT performance was found to be due to anthropometric variables in this study. It seems likely that cardiorespiratory fitness could account for much more of the observed variance in test performance in patients with cardiovascular disease.

Unlike studies of healthy individuals, age and gender were not found to predict ISWT performance. The most likely reason why age was not a significant predictor was probably due to the lower range of ages represented in this study [mean (SD) 69 (9) years]. There are two potential reasons why gender was not a significant predictor of ISWT performance in this study, in contrast to studies of healthy populations. First, there was a relatively small number of females in the prediction equation ($n = 31$), and there were differences in ISWT performance between men and women (310 vs 220 m). Men were also significantly taller, and the inclusion of height as the predictor of ISWT performance negates the use of gender due to expected differences in height between men and women. Height is a logical predictor of ISWT performance for the reasons discussed above, as is BMI which indicates greater fat mass which reduces walking speed.

The relationship between height and performance was weaker in this population (6.2 m gain in ISWT performance per 1 cm in height). While height only accounted for 17% of variance in ISWT performance, the lower mean values for ISWT performance (363 m) suggest a broadly comparable magnitude for the advantage due to height in this population.

Study limitations

Application of the above suggestions might be limited by various methodological issues. The sample used was relatively small and may lack the statistical power to identify significant relationships between more weakly associated pairs of variables. A larger sample would allow the generation of generalisable normative data to confirm the present findings. Future research should also validate the equations independently.

Another limitation is the lack of an independent, objective quantification of participants' cardiorespiratory capacity. It is expected, and hoped, that much of the unexplained variance in ISWT performance in both samples is due to differences in fitness. In validating the ISWT against treadmill exercise, Fowler and Singh [6] found that fitness explained 74% of the variation in ISWT performance in the best (second) of the three trials. Practice trials have been recommended in the scientific literature to increase ISWT accuracy, but remain a rare luxury in clinical practice. In Fowler and Singh's [6] first ISWT trial, fitness only explained 62% of test variance. This value is actually less than the variance explained by the dynamic measurement of step length at 2/3 maximal test performance in the present study (68%). The final limitation of this study is univariate assessment of the association between fitness and ISWT performance, meaning the potential influence of other predictors (such as height) was not considered. Combining anthropometric and fitness measures, Luxton *et al.* [15] accounted for 83% of variability in ISWT performance in patients with chronic obstructive pulmonary disease. Future studies should concurrently quantify the relationship of both fitness and height with ISWT performance in patients with cardiovascular disease using multivariate regression analysis.

Conclusions

The findings of the present study have important implications for clinical practice in cardiac rehabilitation. Taller patients have a significant advantage when performing the ISWT. Practitioners may wish to account for a patient's height when using distance walked during the ISWT as an estimate of cardiovascular fitness. By interpreting distance as a percentage of the height-predicted value, practitioners would gain a much more meaningful assessment of an individual patient's functional capacity compared with distance alone. If replicated in a larger sample, the findings of this study may improve the accuracy of risk stratification exercise prescription based on ISWT performance.

Tentatively, these findings suggest that there is no need for further investigation of gait and turning-based predictors of ISWT performance; a process which is both time consuming and expensive. However, as the predictors of ISWT performance found in patients with cardiovascular disease were not the same as those reported in studies on healthy adults, further research using a larger population is needed to fully describe the demographic and anthropometric predictors of ISWT performance.

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References

[1] Singh SJ, Morgan MD, Scott S, Walters D, Hardman AE. Development of a shuttle walking test of disability in patients with chronic airways obstruction. Thorax 1992;47:1019–24.

[2] Woolf-May K, Bird S. Physical activity levels during phase IV cardiac rehabilitation in a group of male myocardial infarction patients. Br J Sports Med 2005;39:e12.

[3] Almodhy MY, Sandercock GR, Richards L. Changes in cardiorespiratory fitness in patients receiving supervised outpatient cardiac rehabilitation either once or twice a week. Int J Cardiol 2012;160: 215–6.

[4] Sandercock GR, Grocott-Mason R, Brodie DA. Changes in short-term measures of heart rate variability after eight weeks of cardiac rehabilitation. Clin Auton Res 2007;17:39–45.

[5] Morales FJ, Montemayor T, Martinez A. Shuttle versus six-minute walk test in the prediction of outcome in chronic heart failure. Int J Cardiol 2000;76:101–5.

[6] Fowler SJ, Singh S. Reproducibility and validity of the incremental shuttle walking test in patients following coronary artery bypass surgery. Physiotherapy 2005;91:22–7.

[7] Pepera G, McAllister J, Sandercock G. Long-term reliability of the incremental shuttle walking test in clinically stable cardiovascular disease patients. Physiotherapy 2010;96:222–7.

[8] Stevens D, Elpern E, Sharma K, Szidon P, Ankin M, Kesten S. Comparison of hallway and treadmill six-minute walk tests. Am J Respir Crit Care Med 1999;160:1540–3.

[9] Gorgon E, Said C, Galea M. Mobility on discharge from an aged care unit. Physiother Res Int 2007;12:72–81.

[10] Seeley MK, Umberger BR, Shapiro R. A test of the functional asymmetry hypothesis in walking. Gait Posture 2008;28:24–8.

[11] Ng SS, Tsang WW, Cheung TH, Chung JS, To FP, Yu PC. Walkway length, but not turning direction, determines the six-minute walk test distance in individuals with stroke. Arch Phys Med Rehabil 2011;92:806–11.

[12] Ng SS, Yu PC, To FP, Chung JS, Cheung TH. Effect of walkway length and turning direction on the distance covered in the 6-minute walk test among adults over 50 years of age: a cross-sectional study. Physiotherapy 2013;99:63–70.

[13] Jurgensen SP, Antunes LC, Tanni SE, Banov MC, Lucheta PA, Bucceroni AF, *et al.* The incremental shuttle walk test in older Brazilian adults. Respiration 2011;81:223–8.

[14] Probst VS, Hernandes NA, Teixeira DC, Felcar JM, Mesquita RB, Gonçalves CG, *et al.* Reference values for the incremental shuttle walking test. Respir Med 2012;106:243–8.

[15] Luxton N, Alison JA, Wu J, Mackey MG. Relationship between field walking tests and incremental cycle ergometry in COPD. Respirology 2008;13:856–62.

[16] American Association of Cardiovascular and Pulmonary Rehabilitation, American College of Cardiology Foundation, American Heart Association Task Force on Performance Measures (Writing Committee to Develop Clinical Performance Measures for Cardiac Rehabilitation), Thomas R.J., King M., Lui K., *et al.* AACVPR/ACCF/AHA 2010 update: performance measures on cardiac rehabilitation for referral to cardiac rehabilitation/secondary prevention services endorsed by the American College of Chest Physicians, the American College of Sports Medicine, the American Physical Therapy Association, the Canadian Association of Cardiac Rehabilitation, the Clinical Exercise Physiology Association, the European Association for Cardiovascular Prevention and Rehabilitation, the Inter-American Heart Foundation, the National Association of Clinical Nurse Specialists, the Preventive Cardiovascular Nurses Association, and the Society of Thoracic Surgeons. J Am Coll Cardiol 2010;56:1159–67.

[17] British Association for Cardiovascular Prevention and Rehabilitation. The BACPR standards and core components for cardiovascular disease prevention and rehabilitation. 2nd ed. 2012 Leeds.

[18] Pierrynowski MR, Galea V. Enhancing the ability of gait analyses to differentiate between groups: scaling gait data to body size. Gait Posture 2001;13:193–201.

[19] Enright PL, Sherrill DL. Reference equations for the six-minute walk in healthy adults. Am J Respir Crit Care Med 1998;158:1384–7.

[20] Chetta A, Pisi G, Zanini A, Foresi A, Grzincich GL, Aiello M, *et al.* Six-minute walking test in cystic fibrosis adults with mild to moderate lung disease: comparison to healthy subjects. Respir Med 2001;95:986–91.

[21] Jenkins S, Cecins N, Camarri B, Williams C, Thompson P, Eastwood P. Regression equations to predict 6-minute walk distance in middle-aged and elderly adults. Physiother Theor Pract 2009;25:516–22.

[22] Kang HG, Dingwell JB. Separating the effects of age and walking speed on gait variability. Gait Posture 2008;27:572–7.

[23] Imms FJ, Edholm OG. Studies of gait and mobility in the elderly. Age Ageing 1981;10:147–56.

[24] Piepoli MF, Corra U, Benzer W, Bjarnason-Wehrens B, Dendale P, Gaita D, *et al.* Secondary prevention through cardiac rehabilitation: from knowledge to implementation. A position paper from the Cardiac Rehabilitation Section of the European Association of Cardiovascular Prevention and Rehabilitation. Eur J Cardiovasc Prev Rehabil 2010;17:1–17.

[25] Thomas RJ, King M, Lui K, Oldridge N, Pina IL, Spertus J, *et al.* AACVPR/ACCF/AHA 2010 update: performance measures on cardiac rehabilitation for referral to cardiac rehabilitation/secondary prevention services: a report of the American Association of Cardiovascular and Pulmonary Rehabilitation and the American College of Cardiology Foundation/American Heart Association Task Force on Performance Measures (Writing Committee to Develop Clinical Performance Measures for Cardiac Rehabilitation). J Cardiopulm Rehabil Prev 2010;30:279–88.

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