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Six minute walk distance in healthy subjects aged 55–75 years

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Summary
Background: The six minute walk test (6MWT) is the most commonly used exercise test in pulmonary rehabilitation; however, the paucity of six minute walk distance (6MWD) reference values from population-based samples limits data interpretation in patients. This study was undertaken to determine 6MWD in a population-based sample of healthy subjects and to identify predictors of 6MWD in this group.
Methods: Seventy Caucasian subjects (33 males) aged 55–75 years performed three tests using a standardised protocol. 6MWD was defined as the greatest distance achieved from the three tests. Other measurements included height, leg length, weight, forced expiratory volume in 1 s (FEV_1), exhaled carbon monoxide and self-reported physical activity including habitual walking.
Results: The average 6MWD was 659 ± 62 m (range 484–820 m). Males walked 59 ± 13 m further than females ($P < 0.001$). Height ($r = 0.54$, $P < 0.01$), weight ($r = 0.25$, $P < 0.05$) and FEV_1 ($r = 0.48$, $P < 0.001$) were significantly correlated with 6MWD. Forwards stepwise multiple regression showed height ($R^2 = 0.294$) and FEV_1 (R^2 change $= 0.045$) to be independent predictors of 6MWD ($P < 0.05$), explaining 33.9% of the variance.
Conclusions: 6MWD in this healthy population-based sample of males and females exceeds values previously reported. Height and FEV_1 were identified as significant independent predictors of 6MWD in this group.

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Introduction

The six minute walk test (6MWT) is the most frequently used exercise test in pulmonary rehabilitation and is considered to provide a reliable and valid measure of functional exercise capacity.[1–3] Despite the popularity of the 6MWT there is limited data relating six minute walk distance (6MWD) in patients with lung disease to that of healthy subjects. The paucity of 6MWD reference values from population-based healthy subjects limits the interpretation of 6MWD in patients and poses problems for clinicians wishing to provide patients with a measure of their expected 6MWD in the absence of disease.

To date, four studies have determined regression equations to predict 6MWD in healthy populations.[4–7] However, the universal application of these reference values is limited due to differences in the population studied and 6MWT protocol. In two studies[5,6] subjects were drawn from a convenience sample which can introduce bias. Performing a single 6MWT, as was done in two of the studies,[4,7] will underestimate 6MWD, as repeated testing is required to account for the effect of familiarisation on the distance walked by both healthy subjects and patients with chronic obstructive pulmonary disease (COPD).[5,6,8–12] Course length, pre-test instructions and the frequency of encouragement also differed between the studies. Taken together, these differences highlight the need to determine 6MWD in a healthy population-based sample following a standardised protocol.

This study sought to determine 6MWD in a healthy population-based sample of males and females. As the majority of patients with COPD undergoing pulmonary rehabilitation are aged 55–75 years, only individuals falling within this age range were studied. The study also aimed to identify factors which could predict 6MWD. Most previous studies have shown that age, gender, height and weight account for between 19% and 42% of the variability in 6MWD.[4,6,7,12] In addition to these variables, we included measures of leg length, exhaled carbon monoxide,[13] forced expiratory volume in 1 s (FEV_1), and habitual walking activity as potential predictors of 6MWD.

Methods

Subjects

A population-based sample of healthy males and females were recruited from a database of research volunteers established by the Centre for Asthma, Allergy and Respiratory Research (Perth, Western Australia) for genetic studies. Volunteers were included in the database following postal requests mailed to randomly selected individuals (using the program Marketing Pro, DtMS, Blackburn, Victoria, Australia) listed in the telephone directory of a state capital city (Perth, Western Australia, population 1.3 million). All volunteers underwent an interview to confirm their healthy status and spirometry testing at the time of recruitment to the database.

Screening

Subjects were considered for the study if they were aged 55–75 years and had no documented cardiopulmonary disease. Exclusion criteria were abnormal lung function ($FEV_1 < 80\%$ predicted [pred] or FEV_1/forced vital capacity [FVC] $< 70\%$); medications affecting exercise capacity; hypertension (blood pressure $> 150/100$ mmHg); diabetes mellitus; recent illness including upper respiratory tract infection or the presence of any factor that may limit ability to participate in the 6MWT (e.g. impaired cognitive function, neuromuscular disease, claudication, severe musculoskeletal problems affecting the lower extremity or spine or use of a walking aid).

An information sheet was mailed to 168 consecutive non-asthmatic individuals listed on the database. Twenty-five individuals were unable to be contacted and 37 declined to participate. The remaining 106 individuals agreed to participate in the study and were contacted by telephone to determine suitability for inclusion. Thirty-three were subsequently excluded due to the presence of cardiovascular disease ($n = 15$), osteoarthritis ($n = 9$), respiratory disease ($n = 4$) and other illness ($n = 5$). Seventy-three subjects attended for assessment, of whom a further two were excluded due to abnormal lung function and one subject failed to comply with the 6MWT protocol. Thus, the study population comprised 70 healthy subjects, all were of Caucasian origin and 33 were males. Approval for the study was granted by the Human Research Ethics Committees at Sir Charles Gairdner Hospital and Curtin University of Technology. Written, informed consent was obtained from each subject prior to testing.

Procedure

Data collection took place over a 4-month period with each subject attending on a single occasion. Subjects were asked to avoid caffeine, alcohol and consumption of a heavy meal for at least 2 h prior to testing and strenuous physical exercise in the previous 24 h.

Smoking history and blood pressure were recorded. Weight and height were measured and used to calculate body mass index (BMI). Leg length for the right and left leg was measured[14] and mean leg length was used in subsequent analyses. Lung function was measured in accordance with the recommendations of the American Thoracic Society[15] using a Vitalograph wedge bellows spirometer (Model S, Vitalograph Ltd., Buckingham, UK). Exhaled carbon monoxide was measured in duplicate using an EC50 Micro Carbon Monoxide Monitor (Micro Medical Ltd., Southampton, UK). This monitor provides a conversion to percentage of carboxyhaemoglobin (COHb) and the higher of the two measurements was recorded.

Subjects completed a Physical Activity Questionnaire[16] to determine the amount of physical activity performed in the previous week, or another recent week if the last week was atypical. Questionnaire responses were used to classify subjects as undertaking sufficient physical activity, insufficient physical activity for health benefits, or inactive using the definitions from the Survey of Physical Activity Levels of Western Australian Adults 1999.[16]

Six minute walk test

The 6MWT was performed over a 45 m long straight course within an enclosed level corridor. To allow familiarisation with the protocol, subjects performed the test three times separated by 20 min rest intervals. The same investigator (BC) supervised all tests. The temperature of the corridor was $25.8 \pm 1.5\,^{\circ}C$ and humidity was below 55% during all tests.

Taped standardised instructions (modified from Sciurba and Slivka[9]) were played to subjects prior to each 6MWT. Subjects were told to "walk as quickly as you can for six minutes so that you cover as much ground as possible." They were informed that they could slow down or rest if necessary. At the end of each minute subjects were given feedback on the elapsed time and standardised encouragement in the form of statements such as "you're doing well, keep it up" and "do your best.[17]"

Measures

Heart rate (HR) was recorded at rest and at the end of each minute during the 6MWT using a lightweight telemetric HR monitor (Polar Electro Oy, Kempele, Finland). Oxygen saturation (SpO_2) was recorded prior to and upon completion of the 6MWT using an oximeter and finger sensor (Ohmeda Biox 3700e, Ohmeda, Colorado, USA). At the end of the test, the distance was measured and, where applicable, leg fatigue was rated using a modified Borg 0–10 scale.[18]

During the 20 min rest between consecutive tests subjects were provided with a glass of water and asked to remain seated. HR was re-measured at the end of the rest period to ensure that it was within 10 beats per minute (bpm) of the previous resting value and where necessary the rest period was extended.

Statistical analyses

Data were checked for distribution and means and standard deviations calculated. All data were normally distributed with the exception of FEV_1/FVC, COHb and minutes walked in the previous week. Acceptable normalisation of these variables was achieved with a square root transformation.

A one-way repeated measures ANOVA with contrasts was used to compare the three 6MWD's. Reproducibility of the 6MWD was examined using intraclass correlation coefficient (ICC) and coefficient of variation (CV).

Maximum 6MWD from the three tests was identified for each subject and used in the following analyses. Unpaired *t*-tests were performed to determine differences in subject characteristics and 6MWD between males and females. Pearson's univariate correlation coefficients (r) were computed to examine the association between subject characteristics and 6MWD. Forward stepwise multiple regression was used on the variables height, age, weight, gender, leg length, FEV_1 (L) and minutes walked in the previous week to determine their contribution to 6MWD.

The 6MWD measured in our study was compared with predicted 6MWD derived from three published equations[4–6] using scatter plots and paired *t*-tests. Comparisons were made of maximum 6MWD obtained from an equivalent number of tests where possible. Specifically, when comparing our data to that of Enright and Sherrill[4] and Troosters et al.[5] we used the 6MWD from the first test and the best of the first and second tests, respectively. The maximum 6MWD from the three tests in each subject was compared to the data of Gibbons et al.[6] whose subjects performed four tests. No comparison was made with the most recently published reference equation[7] as subjects in the study were aged 77 ± 4 years.

Analyses were performed using the SPSS computer package (Version 11). An alpha value of 0.05

was used to determine significance and data are reported as mean ± standard deviation (SD).

Results

Subject characteristics

The characteristics of the 70 subjects (33 males) are summarised in Table 1. The majority of subjects (63%) were overweight or obese. Sixty-three subjects (90%) were classified as undertaking sufficient physical activity for health benefits.[16] The subjects had a high level of education, with 37 subjects (53%) having attended a vocational training college or university. In eight subjects COHb levels were above the normal range. Males were taller by 10.1 ± 1.5 cm ($P<0.001$); however, there was no significant difference in leg length between males and females (88.0 ± 6.5 cm vs 85.3 ± 7.0 cm, $P=0.11$). There were also no significant differences between the males and females in BMI, minutes walked in the last week, physical activity levels and smoking history.

Six minute walk distance

No test was terminated prematurely by the investigator and no subject required a rest during the 6MWT. The resting HR prior to commencing successive tests was not different, being 75.3 ± 10.8, 76.6 ± 11.0 and 77.7 ± 10.8 bpm.

6MWD during tests 1, 2 and 3 was 626 ± 63, 645 ± 58 and 655 ± 61 m, respectively. There was a significant increase in 6MWD between consecutive tests with subjects walking 18 ± 30 m (a 3.0 ± 5.0% increase, maximum 20.7%) further on the second test ($P<0.001$) and 10 ± 17 m (a 1.6 ± 2.7% increase,

Table 1 Characteristics of the 70 healthy subjects.

Characteristic	Mean ± SD (range) or number/percentages
Males/females	33/37
Age (years)	64.5 ± 5.2 (55.1–74.5)
55.0–64.9	36
65.0–75.0	34
Height (cm)	167.8 ± 7.9 (151.0–190.0)
Leg length (cm)	86.6 ± 6.8 (69.0–98.0)
Weight (kg)	74.3 ± 13.0 (48.0–109.8)
BMI (kg/m^2)	26.2 ± 3.5 (20.2–37.9)
Normal (20–24.9)	26 (37.1%)
Overweight (25–29.9)	33 (47.1%)
Obese (⩾30)	11 (15.7%)
FEV_1 (L)	3.00 ± 0.69 (1.77–4.69)
% pred FEV_1	116.7 ± 18.0 (81.0–160.0)
FVC (L)	3.86 ± 0.85 (2.44–5.67)
% pred FVC	108.5 ± 16.2 (73.0–145.0)
FEV_1/FVC (%)	77.8 ± 4.3 (70.0–94.0)
COHb (%)	0.8 ± 0.5 (0.3–3.6)
Resting HR (bpm)	73.0 ± 10.5 (53.0–100.0)
Minutes walked prev wk	177.8 ± 146.3 (0.0–840.0)
Physical activity level[16]	
Sufficient	63 (90.0%)
Insufficient	6 (8.5%)
Inactive	1 (1.5%)
Smoking history	
Smoker	2 (2.8%)
Ex-smoker	29 (41.5%)
Non-smoker	39 (55.7%)
Pack years	22.5 ± 26.2

BMI: body mass index; FEV_1: forced expiratory volume in 1 s; FVC: forced vital capacity; COHb: carboxyhaemoglobin; HR: heart rate; SpO_2: oxygen saturation; Prev wk: previous week.
Pack years are calculated for smokers and ex-smokers. COHb categories: 0–0.8 non-smoker; 1–1.6 light smoker; 1.8–12 heavy smoker.

maximum 13.0%) further on the third test ($P<0.001$). Distances walked on tests 1, 2 and 3 were 652 ± 58, 669 ± 49 and 685 ± 49 m in the males, and 603 ± 60, 623 ± 57 and 628 ± 59 m in females. Analysis by gender showed the increase between the second and third test was significant for males only (males 16 ± 20 m, $P=0.03$; females 5 ± 12 m, $P=0.07$). The number of subjects achieving their maximum distance on the first, second and third test was 4, 15 and 51, respectively. The ICC for the three tests was 0.84 and the CV was 2.9% (range 0.23–11.0%).

The overall maximum 6MWD (best of the three tests) was 659 ± 62 m (range, 484–820 m) and was greater in males than females by 59 ± 13 m ($P<0.001$), being 690 ± 53 and 631 ± 57 m in males and females, respectively.

Heart rate, oxygen saturation and leg symptoms

Peak HR was 135 ± 20 bpm (87 ± 13% predicted maximum HR [220-age]) on the best of the three tests with 39 subjects exceeding 85% of predicted maximum HR (HRmax). There were no significant differences in pre- and post-test SpO_2 (96.7 ± 1.1% vs. 96.6 ± 1.34%, $P=0.09$). Fifteen subjects reported leg fatigue (score >0) at the end of the 6MWT.

Associations with six minute walk distance

Univariate correlation coefficients between 6MWD and subject variables are presented in Table 2. Significant correlations were observed with height, weight and FEV_1 but not with age, leg length, BMI, COHb or minutes walked in the previous week.

Predictors of six minute walk distance

Forward stepwise multiple regression analysis revealed that height and FEV_1 were significant independent predictors ($P<0.05$) and together explained 33.9% of the variability in 6MWD. The regression equation for this relationship is: 6MWD(m) = 64.69+3.12 (height, cm)+23.29 (FEV_1, L). Height alone accounted for 29.4% of the variance and FEV_1 explained an additional 4.5% of the variance in 6MWD. Gender was not a significant predictor and explained only 2.7% of the variance in 6MWD.

Multiple regression analysis on height, age, weight and gender, shown to be predictors of 6MWD in other studies,[4,5] explained 36% of the variance in 6MWD. The regression equation for this relationship is: 6MWD(m) = 216.90+4.12 (height, cm)−1.75 (age, years)−1.15 (weight, kg)−34.04 (gender, where males = 0 and females = 1).

Comparisons with published regression equations[4–6]

Figure 1 shows the individual data points for these comparisons and demonstrates that, regardless of which equation was used, the predicted 6MWD tended to underestimate our measured 6MWD. Group mean 6MWD±SD (95% CI) was underestimated by 119 ± 65 m (103–134 m)[4] (Fig. 1a) ($P<0.01$), 19 ± 55 m (6–32 m)[5] (Fig. 1b) ($P<0.01$) and 22 ± 55 m (9–35 m)[6] (Fig. 1c) ($P<0.01$).

Discussion

This study demonstrated that the average 6MWD in healthy subjects aged 55–75 years recruited from our database in Western Australia was 659 m. Height and FEV_1 were significant independent predictors of 6MWD and together explained 33.9% of the variance in 6MWD.

Small but statistically significant improvements in 6MWD were observed between consecutive tests and may be explained by test familiarisation which has been shown to influence intra-subject variability in 6MWD in both healthy subjects and COPD patients.[3,5,6,8–12] Data comparing the magnitude of any learning effects in males and females is absent in COPD patients and scarce in healthy subjects. In

Table 2 Univariate correlation coefficients (r) for 6MWD and subject variables ($n=70$).

	Age (years)	Height (cm)	Leg length (cm)	Weight (kg)	BMI (kg/m^2)	COHb (%)	FEV_1 (L)	Mins walked
6MWD (m)	−0.03	0.54	0.05	0.25	−0.07	−0.09	0.48	0.13
P value	NS	<0.01	NS	<0.05	NS	NS	<0.001	NS

NS: not significant at $P<0.05$; Mins walked: minutes walked in previous week.

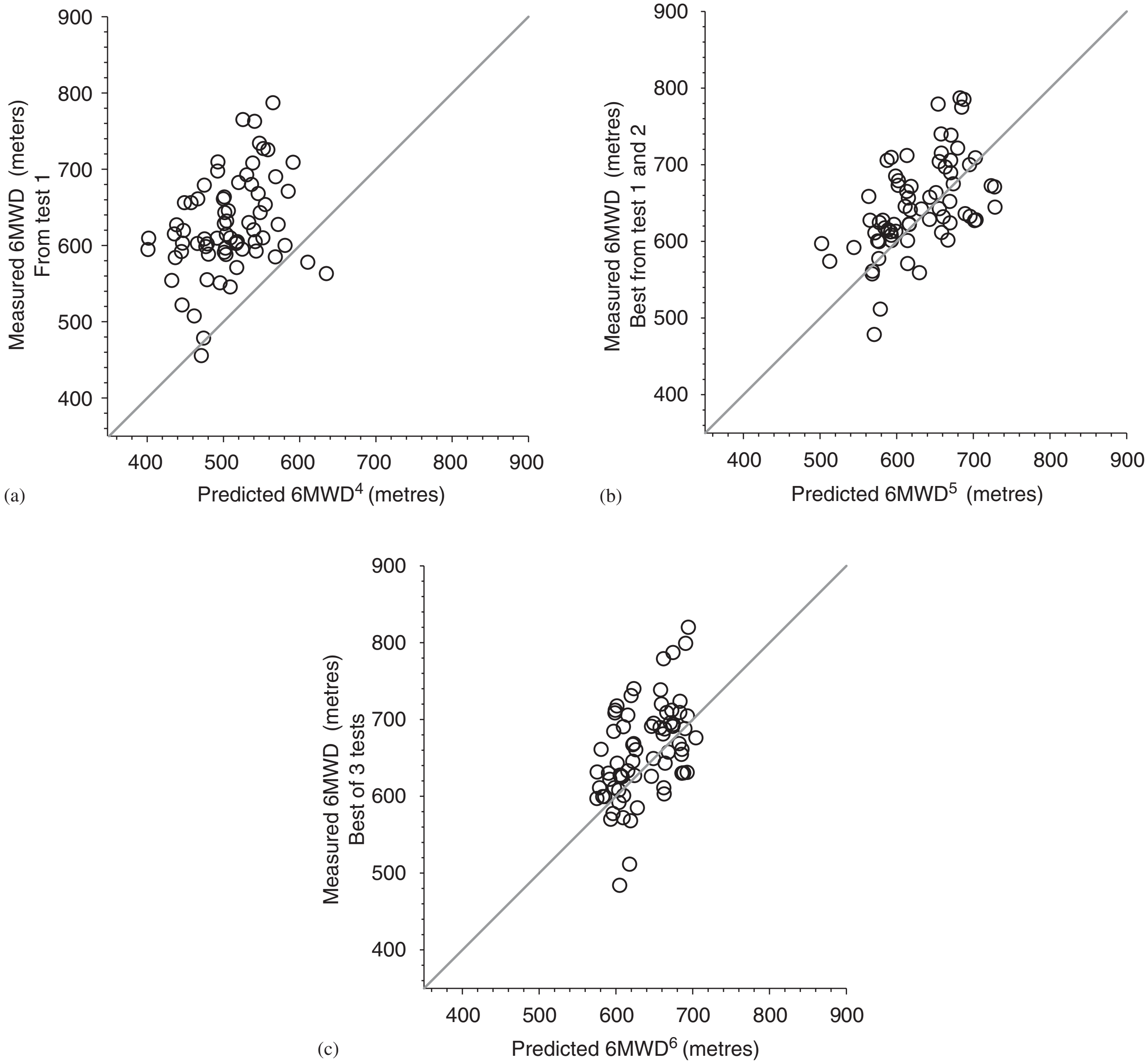

Figure 1 (a) Comparison of measured and predicted 6MWD determined from Enright and Sherrill[4] Line of identity is shown. (b) Comparison of measured and predicted 6MWD determined from Troosters et al.[5] Line of identity is shown. (c) Comparison of measured and predicted determined from Gibbons et al.[6] Line of identity is shown.

our healthy females, the distance plateaued by the second test but in males 6MWD significantly increased from test 2 to test 3. The latter finding is consistent with Wu et al.[12] who showed healthy males required more practice tests than females to reach a maximal 6MWD. Further improvements in 6MWD may have been achieved in male subjects with a fourth test; however, the magnitude of any such increase is likely to be small.[6,12] While a statistically significant gender difference was noted for 6MWD in our study, the mean increase between the first and third test for males and females was small (6.0% and 4.8%, respectively), suggesting that in studies with large numbers of healthy subjects a single test may provide a useful representative measure of 6MWD. It was notable, however, that the magnitude of increase was large in some individuals being 23% in both one male and one female subject. There were no obvious identifying characteristics in these individuals.

Comparison of 6MWD with other studies

Compared to estimated 6MWD using regression equations from other studies,[4–6] the healthy subjects in our study walked significantly further. The increase was modest when compared to studies by Troosters et al.[5] and Gibbons et al.[6] (19 and 22 m, respectively), but substantial when compared to the study of Enright and Sherrill[4] (119 m). It is difficult to explain the large difference between Enright's[4] results and ours, as both studies used standardised instructions and encouragement, which are important during a self-paced test such as the 6MWT,[17] and the subjects' age and anthropometric characteristics were similar in the two studies. It is possible that the effort levels of the subjects studied by Enright and Sherrill[4] were submaximal, as HR during their 6MWT (only one test performed) reached $<65\%$ age-predicted HRmax. This contrasts to a HR of 81% of predicted maximum attained in our subjects on their first 6MWT, 80% of predicted HRmax achieved on the first 6MWT in the study by Kervio et al.[10] and 77% of predicted HRmax attained on the best of two 6MWTs (HR for first test not reported) in the study by Troosters et al.[5]

Predictors of six minute walk distance

Significant positive correlations were found between 6MWD with height, weight and FEV_1 but not with age, leg length, BMI, COHb or minutes walked in the previous week. The observed association between height and weight with 6MWD is consistent with previous findings.[4,5,7] While this is the first study to report a significant correlation between 6MWD and FEV_1 in healthy subjects, Webb et al.[19] recently found an association between FEV_1 and the distance walked on the incremental shuttle walking test in healthy males.

Height and FEV_1 were the only significant independent predictors of 6MWD, explaining 33.9% of the between-subject variance in 6MWD. This is comparable to the variance explained by most other studies in healthy subjects (19–42%).[4,6,7] An exception is the study by Troosters et al.[5] who found that age, height, weight and gender explained 66% of the variance in 6MWD. Using the same four variables we were still only able to account for 36% of the variance in 6MWD. The reason for the difference is not clear but may relate to differences in subject characteristics and the greater range of 6MWD in Troosters et al.[5] study (383–820 m) compared to ours (484–820 m). Verification of our regression equation and 6MWD achieved by subjects in our study should be undertaken in a prospective cohort of healthy subjects recruited using identical inclusion criteria.

Age was not a significant predictor of 6MWD, a finding that contrasts with previous studies.[4–7] Stringent exclusion criteria prohibited the participation of subjects with age-related health problems that may have adversely affected walking speed. Some studies have shown that age is not a significant predictor of walking speed when plantar flexor strength and the presence of health problems are taken into consideration,[20] suggesting that pathology associated with ageing rather than chronological age may account for a greater proportion of the variation in walking speed during the 6MWT.[20] We anticipated that weight or BMI would be a significant predictor of 6MWD as excess weight can influence gait and increase workload.[4,7] However, our findings did not support this. This is most likely because only nine of our subjects had a $BMI > 30$, a value which has been identified as the upper threshold for a low 6MWD in healthy subjects.[7] Inclusion of subjects with a wider range of BMI may be necessary to more clearly define the relationship between BMI and 6MWD. Alternatively, it may be that other anthropometric variables such as waist size could account for a greater proportion of the variability in 6MWD.[7]

The absence of gender as a predictor of 6MWD is consistent with the observations of Enright et al.[7] who found that after correcting for height, males did not walk further than females. We chose not to measure quadriceps strength as it does not appear to be a predictor of 6MWD in healthy subjects after correcting for height, weight, age and gender.[5]

In an attempt to explain a greater proportion of the variability in 6MWD we assessed the contribution of leg length, minutes walked in the previous week and COHb. We hypothesised that leg length may be a better predictor of 6MWD than height as it is a primary determinant of stride length.[4] However, this was not supported by our data. We hypothesised that 6MWD would be greater in individuals who walked for prolonged periods on a regular basis. Of particular interest was the time spent walking for continuous periods of at least 10 min either for recreation, exercise or transport. However, minutes walked in the previous week was not a predictor of 6MWD. This finding is consistent with other studies that also failed to demonstrate an association between self-reported physical activity and 6MWD.[5,6] It is possible that the speed of habitual walking, which was not assessed in this study, may be a more relevant predictor of 6MWD than time spent walking. Since high levels of carbon monoxide in arterial blood reduce the oxygen carrying capacity of haemoglobin and may reduce exercise capacity[21], we hypothesised that elevated levels of COHb may contribute to a lower 6MWD.

However, we were unable to identify an association between raised COHb levels and decreased 6MWD. This is most likely because the selection criteria required subjects to have normal lung function and the majority of subjects (89%) had a level of COHb within the normal range. To more specifically examine the effect of COHb on 6MWD, a study with larger sample size, including greater numbers of current smokers would be required. A greater proportion of the variability in 6MWD may also be explained by inclusion of factors such as mood, attitude, motivation and race, which have also been shown to influence 6MWD.[7,22]

In conclusion, this study has shown that 6MWD in a healthy population-based sample of 55–75-year-old males and females from Western Australia exceeds values reported in previous studies. A prediction equation containing height and FEV_1 explained 33.9% of the variance in 6MWD.

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