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Breaking barriers: novel reference equations for the six-minute walk distance and work in obese Chinese adults

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Abstract

Background The six-minute walk test (6MWT) is a key tool for assessing fitness in obese individuals, but existing reference equations for the six-minute walk distance (6MWD) are limited and overlook the six-minute walk work (6MWW), in turn limiting the clinical applicability of the test. This study aims to establish new 6MWD and 6MWW equations to improve our understanding of functional capacity in obese Chinese adults.

Methods A cross-sectional study was conducted at Wenzhou People's Hospital from July 2021 to June 2023. Obese Chinese adults (BMI > 30 kg/m^2), aged 18–69 years, completed the 6MWT following the ATS/ERS guidelines. Stepwise multiple regression was used to create sex-specific reference equations for the 6MWD and 6MWW.

Results A total of 309 obese Chinese adults participated in this study, achieving a mean 6MWD of 550.7 ± 45.85 m and a mean 6MWW of 46149.9 ± 6403.58 kg·m. Sex-specific equations for the 6MWD and 6MWW explained a significant portion of the variance in the values (34-61%).

Conclusion The proposed reference equations for the 6MWD and 6MWW increase the accuracy and applicability of functional capacity assessment tests, outperforming existing reference equations. The inclusion of the 6MWW provides a relatively novel metric that integrates metabolic workload and mechanical efficiency, offering unique insights into the functional performance of obese individuals and allowing tailored health interventions.

Keywords Six-minute walking test, Obesity, Functional capacity, Reference equations

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Introduction

Obesity is a global public health issue that significantly impacts individual health and healthcare systems, and its prevalence is increasing rapidly worldwide [1]. In China, the growth of the obese population presents unique challenges; due to their changes in specific lifestyles and dietary habits, obese individuals have difficulty maintaining their walking ability and cardiorespiratory fitness [2, 3]. Accurate assessment tools are therefore crucial for evaluating functional capacity in this population and informing tailored health interventions.

The six-minute walk test (6MWT) is a widely used tool for assessing the functional status of obese individuals, including those in China; the test reflects the cardiopulmonary fitness, muscle function, and metabolic efficiency of the participant, making it a valuable metric for population-specific health assessments [4–6]. However, most existing reference equations for the six-minute walk distance (6MWD) are based on general populations or non-obese cohorts and often neglect key factors such as body mass, a significant determinant of functional capacity in obese individuals [7–11]. Consequently, existing models have limited applicability in clinical settings, particularly for obese populations. In addition, these models typically fail to account for the metabolic load associated with obesity, and they do not consider the integrated measure of mechanical load and metabolic efficiency provided by the six-minute walk work (6MWW).

The incorporation of body weight into the calculation of the 6MWW allows a more comprehensive assessment of functional capacity by capturing both the mechanical burden of excess weight and its metabolic impact, offering deeper physiological insights than the 6MWD alone. The 6MWW has been shown to have important clinical value in the assessment of obese patients with limited exercise capacity and may also be a useful predictive tool for lung disease, thus supporting clinical decision-making [12–14]. Unlike the 6MWD, which measures only the distance covered in six minutes, the 6MWW integrates both the mechanical burden of excess weight and the metabolic efficiency required for walking. This dual assessment makes the 6MWW a more comprehensive measure of functional capacity, particularly in obese individuals, where body mass significantly affects both mechanical load and energy expenditure. Delbressine et al. established reference equations for the 6MWD and 6MWW in Caucasian adults, highlighting the need for similar equations tailored to the Chinese population to increase the accuracy and clinical utility of functional capacity assessments in these individuals [15]. However, only approximately 20% of the study population was obese, and the reference equations employed for the 6MWD and 6MWW were not suitable for the Chinese population, underscoring the urgency of developing population-specific equations to address the unique health challenges faced by obese Chinese adults [15].

Current reference equations for the 6MWD also fail to fully capture the unique challenges posed by obesity, such as the increased mechanical load and energy expenditure. These models are not suitable for accurately evaluating the functional capacity of obese populations, especially in China, where unique cultural and environmental factors influence walking capacity. Furthermore, existing models overlook the 6MWW, a more comprehensive measure that accounts for both mechanical load and metabolic efficiency, making it a superior tool for evaluating functional capacity in obese individuals.

This study aimed to develop new reference equations for the 6MWD and 6MWW for Chinese adults with obesity, in line with the American Thoracic Society (ATS)/European Respiratory Society (ERS) 6MWT guidelines, addressing a critical gap in the literature and providing a valuable resource for clinicians and public health professionals in China [15–19]. By developing these equations, we hope to improve our understanding of functional capacity in obese Chinese adults and support the development of more effective health interventions for these individuals.

Methods

Study design

Between July 2021 and June 2023, we conducted a cross-sectional study at Wenzhou People's Hospital with the objective of developing reference equations for the 6MWD and 6MWW specific to the Chinese obese population. Ethical approval for the study was granted by the Ethics Committee of Wenzhou People's Hospital, and written informed consent was obtained from each participant prior to their inclusion.

Subjects

Chinese subjects with obesity (BMI greater than 30 kg/m^2) aged 18–69 years were recruited for this study, as this age range encompasses the majority of adults who are obese in China. Participants were recruited from multiple regions within Wenzhou, a city with diverse demographic characteristics, to ensure that the sample reflects the broader obese population in China. Before undergoing the 6MWT, the participants completed health questionnaires consisting of sections on basic demographic information, medical history, lifestyle habits, and current health conditions. The exclusion criteria included a self-reported history of cerebrovascular, cardiovascular, pulmonary, or other diseases; the need for a walker or walking difficulties; a baseline heart rate ≥ 100 bpm or < 50 bpm; and unstable blood pressure with a baseline systolic blood pressure ≥ 160 mmHg or diastolic blood pressure ≥ 100 mmHg.

Physical examination

The participants presented their identity cards to verify their age. Anthropometric measurements were taken according to standard protocols. Height and weight were measured with a calibrated stadiometer and weight scale, respectively (Su Hong, China). For the height measurements, the participants were asked to stand barefoot and look straight ahead, while for the weight measurements, they were instructed to wear light clothing and no shoes. All the measurements were obtained by trained professionals to ensure consistency and accuracy.

Six-minute walk test

For each participant, the 6MWT was meticulously conducted in a straight, flat 30-metre corridor to ensure a consistent and reliable test environment. Orange cones marked turning points, and distance markers were set every three metres. Coloured tape indicated the start and end points of the 30 m. To reduce the influence of biological rhythm and temperature, the 6MWT was performed between 9:00 a.m. and 4:00 p.m. in a room maintained at 20–25 °C. The participants were instructed to avoid eating or engaging in vigorous physical activity for at least two hours prior to the test to ensure consistent conditions and minimize confounding factors. Each participant rested for at least 10 min near the starting point, during which initial physiological measurements such as oxygen saturation, blood pressure, and heart rate were obtained with calibrated devices, including oximeters and sphygmomanometers (Omron, China). Although metabolic data, such as the basal metabolic rate and energy expenditure, were not directly measured in this study, their potential influence was theoretically considered on the basis of the literature. We accounted for the impact of body mass and BMI, known to be strong predictors of metabolic rate and energy expenditure, in our statistical analyses by including them as covariates. The participants were provided with a comprehensive overview of the study procedure and objectives, with a focus on assessing the distance they could walk within a six-minute timeframe. Before and after the test, heart rate and perceived exertion were monitored with a pulse oximeter and the Borg dyspnoea scale, respectively, to evaluate cardiopulmonary response and fatigue levels [20]. The test was immediately stopped if the participant experienced severe discomfort, such as palpitations, chest pain, or dizziness to ensure their safety and well-being. A medical professional promptly assessed the participant's symptoms and vital signs, recorded the duration of discomfort, and called for emergency medical services if needed. To ensure consistency, standardized encouragement was given to all participants during the 6MWT. The test personnel followed a script to provide verbal support at regular intervals, such as halfway through the test and every minute thereafter. Phrases such as 'Keep going, you're doing great!' and 'Almost there, keep it up!' were used to offer consistent motivational support. The 6MWDwas recorded by measuring the total distance (in metres) walked during the 6-minute test and reflects the participant's endurance and cardiovascular capacity. The 6MWW was calculated from the best 6MWD in metres and body mass in kilograms. Two hours later, the participants completed a second 6MWT to assess results reliability and evaluation of test−retest consistency in the physiological responses.

Quality control measures

Several measures were implemented to ensure data consistency and accuracy, including the use of trained personnel, regular equipment calibration, standardized procedures, and thorough data validation.

Statistical analysis

The normality of the distribution of the data was confirmed with the Kolmogorov−Smirnov test. For variables that were found to be nonnormally distributed, appropriate transformations were applied in an attempt to normalize the data. Specifically, variables with notable skewness were log-transformed or square root-transformed as needed to approximate a normal distribution. For variables that could not be normalized, nonparametric tests were used in subsequent comparative analyses. Descriptive statistics, such as the means ± standard deviations (SDs) for measurement data, are reported to describe the subject characteristics. The independent-samples Student's t test was used to examine differences in the 6MWT outcomes and categorical variables between the two sexes. The paired-sample Student's t test was performed to compare the measured 6MWD with the 6MWD predicted with previously published reference Eqs. [15, 17–19]. To assess the repeatability of the two 6MWDs, we employed the intraclass correlation coefficient (ICC) and conducted Bland−Altman analysis [21].

One-way regression and multifactor stepwise regression analyses were conducted to derive reference equations for the 6MWD and 6MWW. To select predictor variables for the regression models, we first conducted Spearman correlation analyses to evaluate the associations between potential predictors (age, height, body mass, BMI) and the 6MWD and 6MWW. Variables showing significant associations with the outcomes ($p < 0.05$) were included in the stepwise regression analysis. Subsequently, forwards stepwise multiple regression analyses were employed to derive reference separate equations for the 6MWD and 6MWW for males and females. In the forwards stepwise regression process, variables were entered into the model in a stepwise manner. At each step, the variable with the highest statistical significance (lowest p value) was added to the model, and the procedure continued iteratively until no additional variables with p values below 0.05 could be identified. Variables with p values exceeding 0.05 were systematically excluded, ensuring that only the most relevant predictors remained in the final model. In this way, we identified the most significant variables for predicting the 6MWD and 6MWW, considering the unique characteristics of the study population.

The required sample size for multiple linear regression analysis was determined with G*Power software (version 3.1). The analysis indicated that to attain a statistical power of 0.95 at a significance level set at 0.05 and a medium effect size ($f^2 = 0.15$), at least 129 samples would be needed with 4 predictor variables. However, to account for sex-based stratification and other potential confounders, the final sample size was increased to at least 300 individuals. Data analysis was conducted in SPSS for Windows, version 20.0 (SPSS Inc., Chicago, IL). Statistical significance was determined for all analyses with a p value less than 0.05.

Results

Participant characteristics

Among the initial 453 participants, 144 were excluded for a variety of reasons: 38 had cardiac disease, 20 had abnormal baseline heart rates, 42 had unstable hypertension, 13 had pulmonary disease, 6 had foot sprains, and 25 had encephalopathy. As a result, 309 participants (154 males and 155 females) completed the tests without early rest or termination. On average, the subjects were 44 years old, with a height of 164 cm, a body mass of 84 kg, and a BMI of 31 kg/m². Compared with females, males had significantly greater BMIs, heights, and body masses ($p < 0.001$) (Table 1).

6MWT results

This study established reference values for the 6MWD and 6MWW in a cohort of obese Chinese adults stratified by age and sex. The mean 6MWD and 6MWW for all the subjects were 550.7 ± 45.85 m and 46149.9 ± 6403.58 kg·m, respectively. For males, the mean 6MWD was 563.6 ± 46.45 m, and the mean 6MWW was 50394.5 ± 5271.22 kg·m. For females, the mean 6MWD was 537.8 ± 41.55 m, and the mean 6MWW was 41932.6 ± 4299.85 kg·m. The average distances walked during the initial and subsequent testing sessions were 536.5 ± 47.13 m and 542.4 ± 45.84 m, respectively. The two 6MWTs demonstrated good reliability (ICC = 0.84, 95% CI: 0.79, 0.88). The findings were significantly different between males and females ($p < 0.05$), indicating that reliable, sex-specific reference values for the 6MWD and 6MWW were obtained for obese Chinese adults (Table 1). Subgroup analyses were conducted by age in decades (18–29, 30–39, 40–49, 50–59, and 60–69 years) to examine the effects of age on the 6MWD and 6MWW ($p < 0.05$) (Table 2). As shown in Table 2, significant differences were observed in both the 6MWD and the 6MWW, demonstrating the influence of age on walking efficiency and overall functional capacity.

Associations of the study variables with the 6MWT results

The relationships between numerous variables and the 6MWT results of males and females were significant. Univariable linear regression analysis revealed significant correlations between age, height, and BMI and the 6MWD and between age, height, and body mass and the 6MWW. Age and BMI accounted for 35.3% of the variance in distance for males and 34.4% for females, while age and height independently explained 59.8% of the variance in the 6MWW in males and 61.4% of the variance in females. These findings illustrate the significant roles played by age, BMI, and height in predicting the 6MWD and 6MWW, as the variations in these factors

Table 1 Characteristics and 6MWT results

Characteristic	Males ($n = 154$)	Females ($n = 155$)	p-value*	All ($n = 309$)
Age, years	43.2 ± 15.33	43.7 ± 15.35	0.746	43.5 ± 15.32
Height, cm	169.4 ± 5.24	157.6 ± 4.73	< 0.001	163.5 ± 7.71
Body mass, kg	89.4 ± 5.86	78.0 ± 5.19	< 0.001	83.7 ± 7.96
BMI, kg/m^2	31.1 ± 1.10	31.4 ± 0.99	0.091	31.3 ± 1.05
6MWD test1, m	548.3 ± 48.45	524.9 ± 42.83	< 0.001	536.5 ± 47.13
6MWD test2, m	556.0 ± 46.63	529.0 ± 40.95	< 0.001	542.4 ± 45.84
6MWD best, m	563.6 ± 46.45	537.8 ± 41.55	< 0.001	550.7 ± 45.85
6MWW, kg·m※	50394.5 ± 5271.22	41932.6 ± 4299.85	< 0.001	46149.9 ± 6403.58

Data are presented as the mean ± SD

* The p-value between males and females was assessed using the Student's t-test

※Values based on best 6MWD

BMI: body mass index; 6MWD: six-minute walk distance; 6MWW: six-minute walk work

Table 2 Age- and sex-stratified values for 6MWD and 6MWW

Age, years	Variable	Males ($n=154$)	Females ($n=155$)	p-value*	All ($n=309$)
18–29 ($n=73$)	6MWD, m	598.1 ± 34.79 m	569.3 ± 29.41	< 0.001	583.9 ± 35.15
	6MWW, kg•m	54204.8 ± 3713.17	45433.9 ± 3495.87	< 0.001	49879.5 ± 5685.96
30–39 ($n=62$)	6MWD, m	570.8 ± 36.86	551.8 ± 33.67	< 0.038	561.6 ± 36.35
	6MWW, kg•m	52170.3 ± 4320.08	43421.2 ± 4175.77	< 0.001	47936.8 ± 6099.53
40–49 ($n=59$)	6MWD, m	556.6 ± 41.72	531.1 ± 39.51	< 0.019	543.6 ± 42.26
	6MWW, kg•m	49511.1 ± 4608.03	40983.4 ± 3020.54	< 0.001	45175.0 ± 5770.72
50–59 ($n=55$)	6MWD, m	549.1 ± 45.59	521.6 ± 39.51	< 0.021	535.6 ± 44.54
	6MWW, kg•m	48336.7 ± 5757.49	40950.1 ± 3940.36	< 0.001	44710.6 ± 6159.43
60–69 ($n=60$)	6MWD, m	531.6 ± 46.35	509.3 ± 36.34	< 0.041	519.8 ± 42.46
	6MWW, kg•m	46302.8 ± 4030.77	38316.9 ± 2931.01	< 0.001	42043.6 ± 5300.06

Data are presented as the mean ± SD (range)

*P value between males and females

6MWD: six-minute walk distance; 6MWW: six-minute walk work

Table 3 Pearson correlations between the variables and the 6MWT results

6MWD, m				
Variable	**Males**		**Females**	
	***r*-value**	***p*-value**	***r*-value**	***p*-value**
Age, years	-0.515	< 0.001	-0.521	< 0.001
Height, cm	0.227	0.002	0.192	0.008
Body mass, kg	-0.004	0.481	-0.005	0.478
BMI, kg/m^2	-0.408	< 0.001	-0.370	< 0.001
6MWW, kg·m				
Variable	**Males**		**Females**	
	r-value	**p-value**	**r-value**	**p-value**
Age, years	-0.574	< 0.001	-0.573	< 0.001
Height, cm	0.709	< 0.001	0.722	< 0.001
Body mass, kg	0.613	< 0.001	0.641	< 0.001
BMI, kg/m^2	-0.098	0.112	-0.016	0.421

6MWD: six-minute walk distance; 6MWW: six-minute walk work; r value: pearson's correlation coefficients

accounted for a substantial proportion of the differences in performance (Tables 3 and 4).

Comparison with published regression equations

We compared the measured 6MWD values of our participants with the values predicted on the basis of previous reference Eqs. [15, 17–19]. However, these equations did not accurately predict the walking distances for our cohort, regardless of sex [15, 17–19]. Specifically, they significantly overestimated the distances walked by our participants within the same age group ($p < 0.05$) (Table 5). These findings underscore the need to develop population-specific reference equations to more accurately predict the 6MWD in obese Chinese adults.

Discussion

In this study, a critical gap in research was addressed through the development of new, sex-specific reference equations for predicting the 6MWD and 6MWW in obese Chinese adults aged 18–69 years. These equations improve the precision of functional capacity assessments, providing valuable tools for clinicians and public health professionals working with obese populations. The results revealed significant sex differences in walking distance, with males demonstrating greater walking capacity, attributed to greater muscle mass and better anaerobic capacity (Fig. 1). This finding emphasizes the need for sex-specific reference values for accurate functional capacity assessments.

Our study also highlights the significant role of body mass in walking efficiency, as indicated by a negative correlation between BMI and the 6MWD. These results reinforce the need for comprehensive measures, such as 6MWW, which accounts for both mechanical load and metabolic efficiency [11]. The inclusion of the 6MWW as a relatively novel metric in this study offers a deeper understanding of the functional limitations faced by obese individuals, which have not been fully addressed in previous studies. This is especially crucial in the Chinese population, where obesity-related gait changes, such as shorter stride lengths and increased energy expenditure, are pronounced [22]. The novel findings from this study suggest that the 6MWW, which considers both body mass and walking efficiency, provides a more accurate evaluation of functional capacity than the 6MWD alone does. These findings can have practical implications for tailoring interventions and improving outcomes for obese patients.

The subgroup analysis by age (in decades) revealed a notable decrease in the 6MWD and 6MWW with age; specifically, participants over 50 years exhibited significantly lower scores than younger participants did. These findings suggest that age may be a critical factor in determining functional capacity, with older individuals experiencing greater physical limitations in the context of obesity [23].

Table 4 Sex-based 6MWD and 6MWW reference equations derived from multivariable Stepwise regression

6MWD, m						
	Males			**Females**		
	B	**SE**	***p*-value**	**B**	**SE**	***p*-value**
Constant	1041.480	86.327	< 0.001	972.633	86.021	< 0.001
Age, year	-1.368	0.201	< 0.001	-1.275	0.179	< 0.001
BMI, kg/m^2	-13.447	2.812	< 0.001	-12.091	2.775	< 0.001
R^2	0.362			0.353		
Change in R^2	0.353			0.344		
6MWW, kg·m						
	Males			**Females**		
	B	**SE**	**p-value**	**B**	**SE**	**p-value**
Constant	-41767.720	9903.789	< 0.001	-38063.672	8104.019	< 0.001
Height, cm	574.451	56.317	< 0.001	534.044	49.576	< 0.001
Age, year	-119.051	19.231	< 0.001	-95.627	15.259	< 0.001
R^2	0.603			0.619		
Change in R^2	0.598			0.614		

Abbreviations: B, unstandardized coefficients

The reference equations for the sex-specific 6MWD and 6MWW are as follows

Male

6MWD(m) = 1041.480-[age(yr) x 1.368] - [BMI(kg/m^2) x 13.447];r^2 = 0.353

6MWW(kg m)=-41767.720 + [height(cm) x 574.451]-[age(yr) x 119.051];r^2 = 0.598

Female

6MWD(m) = 972.633 - [age(yr) x 1.275] - [BMI(kg /m^2) x 12.091];r^2 = 0.344

6MWW(kg m) = -38063.672 + [height(cm) x 534.044] - [age(yr) x 95.627];r^2 = 0.614

Table 5 The 6MWD was measured and predicted using previous equations reported

Study	**Measured (m)**	**Predicted (m)**	**Measured-predicted (m)**
Capodaglio et al. [14]	555.9 ± 43.45	625.2 ± 37.53	-69.3 ± 39.76*
Delbressine et al. [17]	532.9 ± 43.98	571.4 ± 46.37	-38.5 ± 48.86*
Ben Saad et al. [18]	531.9 ± 43.73	608.7 ± 93.51	-76.8 ± 86.34*
Iwama et al. [19]	550.7 ± 45.85	572.9 ± 42.20	-22.2 ± 42.27*

*$p < 0.05$ according to Student's t test

6MWD: six-minute walking distance

Height was included in the regression model for the 6MWW but not for the 6MWD because it plays a more significant role in determining the mechanical work and energy expenditure during walking, which are central to calculating the 6MWW. The 6MWW is a measure of the total work done and involves body mass and stride length. Taller people typically have longer strides, which increases the amount of mechanical work required to walk a given distance. This makes height a significant predictor of 6MWW, especially when accounting for the mechanical burden associated with walking. In contrast, while height can influence stride length to some extent, the total walking distance covered in a fixed time (6 min) is more heavily influenced by factors such as BMI, endurance, and overall physical fitness than just by stride length. As a result, when BMI and other variables were accounted for, height did not significantly contribute to the variance in the 6MWD and was therefore excluded from the final regression model for this value.

In our study, a BMI of 30 kg/m² was used as the threshold for obesity, in line with the classification system of the World Health Organization. This can serve as an initial reference for clinicians when determining treatment plans. However, clinicians should also consider other factors, such as comorbidities, functional limitations, and overall physical fitness, when making personalized intervention decisions.

Stepwise multiple regression analysis indicated that age and BMI explained 35.3% of the variance in the 6MWD for males and 34.4% of that for females in our Chinese sample, comparable to findings in non-Chinese studies, whereas age and height independently explained 59.8% of the variance in the 6MWW for males and 61.4% of that for females, suggesting that while there are similarities, there are also population-specific nuances in the predictors of walking performance. Future studies could increase the predictive value of the reference equations by incorporating other factors, such as heart rate, muscle strength, and lifestyle habits, but their clinical utility also needs to be considered [16].

The 6MWW, which accounts for body mass, provides a more accurate measure of functional capacity than the 6MWD does by integrating metabolic efficiency with mechanical load. By incorporating both the mechanical

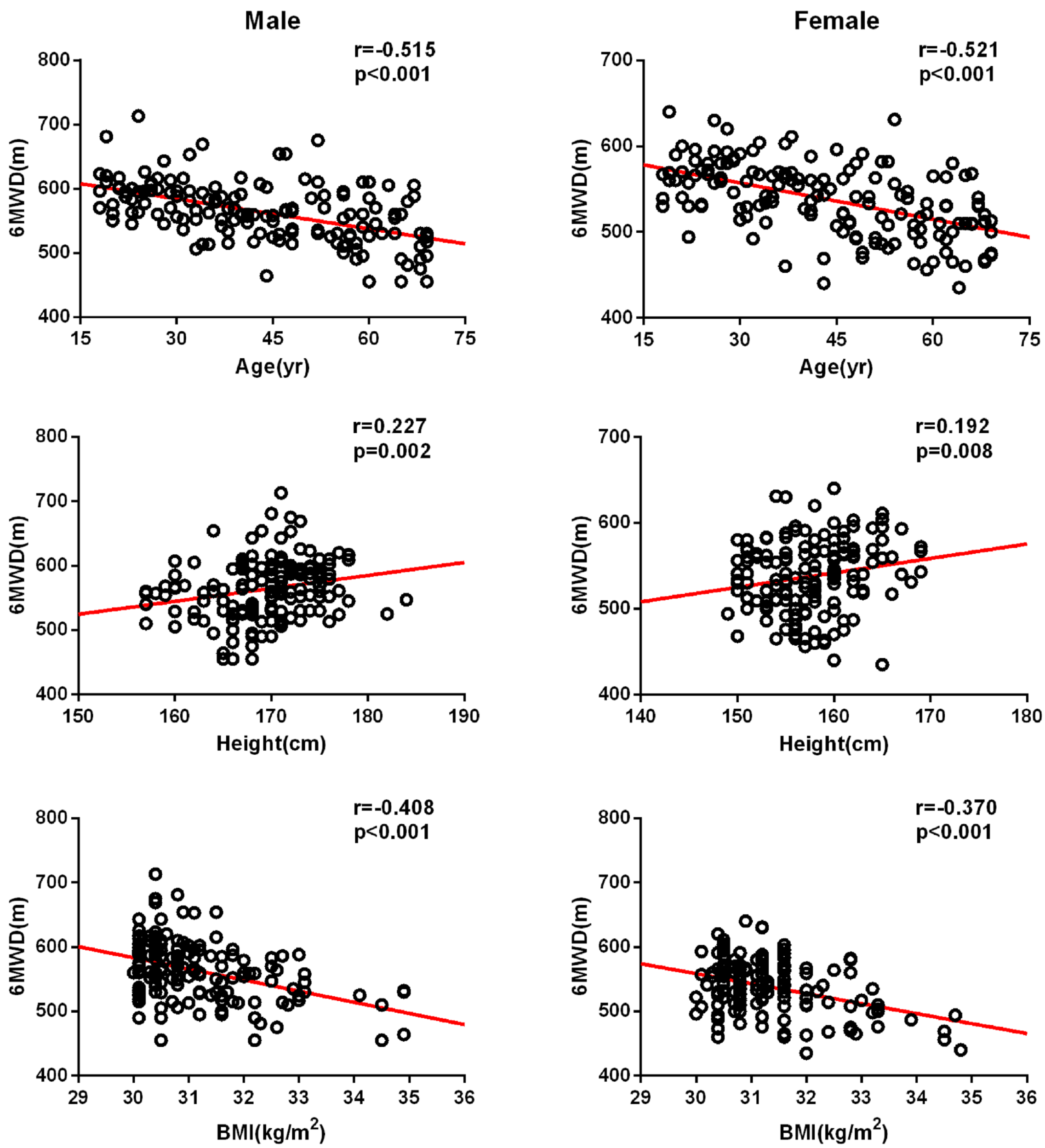

Fig. 1 Scatter plots depicting the relationships of the 6MWD with age, height, and BMI stratified by sex (males and females)

burden of excess weight and its associated metabolic costs, the 6MWW offers a holistic assessment of the functional performance of obese individuals. In contrast, the 6MWD fails to account for the increased energy expenditure required to carry excess weight, making the 6MWW a better tool for evaluating functional capacity in obese individuals, particularly those with limited exercise tolerance. Obesity increases the energy costs of walking owing to the additional muscle effort required to overcome inertia and maintain balance, while excess fat mass impairs oxidative metabolism, reducing exercise tolerance [24]. Several studies have shown a stronger correlation between the 6MWW and peak oxygen uptake than between the 6MWD and peak oxygen uptake [12, 13, 25, 26]. In chronic obstructive pulmonary disease (COPD) patients, the 6MWW has been shown to be a better predictor of hospitalization and to be more effective in assessing carbon monoxide diffusion capacity [12, 14]. However, the maximal work rate correlations for both the 6MWW and the 6MWD in COPD patients are comparable. Current pulmonary rehabilitation guidelines recommend the use of the 6MWW to determine initial training loads for cycle ergometry [27]. The new 6MWW reference equation, which incorporates body mass, offers a comprehensive evaluation of functional capacity, which is particularly important for obese patients.

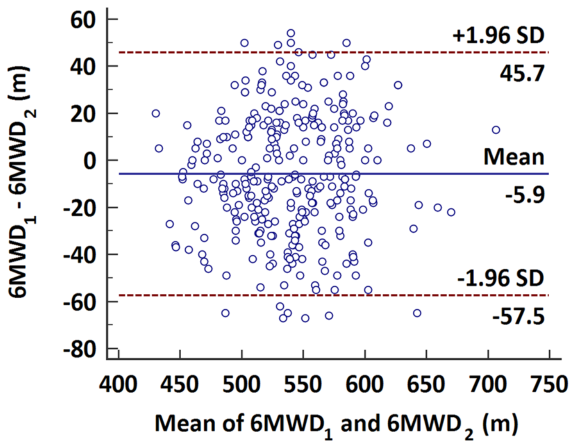

Fig. 2 Bland–Altman plot illustrating the agreement between the first and second 6MWT results, showing the mean difference and 95% limits of agreement

We also assessed test–retest reliability in this study (Fig. 2). The second 6MWT resulted in a greater walking distance than the first, likely due to the participants overcoming initial negative emotions, achieving improved coordination, and finding a better stride length. These factors may have contributed to the test–retest variability, and it therefore is important to consider their impact on performance between tests. The two 6MWTs demonstrated good reliability, confirming the consistency of the assessment as a measure of physical capacity. These findings are consistent with those of previous studies and suggest that further research should consider investigating additional factors that can influence test–retest reliability, such as the participant's psychological state and familiarity with the test procedure and environmental conditions (e.g., room temperature, time of day), to refine assessment protocols [28, 29]. Consistent and reliable testing methods are essential for accurately monitoring patient progress and treatment outcomes.

We compared the actual 6MWD with the values predicted with reference equations derived in non-Chinese studies; however, these equations did not accurately predict the walking distances in our subjects, both for the overall sample and within the sex subgroups [15, 17–19]. The equations from previous studies significantly overestimated the walking distances of subjects in the same age group. This discrepancy may stem from differences in sample characteristics, testing protocols, daily physical activity, mood, and psychological state [16, 30]. For example, the studies by Delbressine, Ben Saad, and Iwama mainly included healthy individuals from abroad, whereas our study included obese individuals from China [15, 18, 19]. Additionally, the Capodaglio and Delbressine study was conducted in a 20-metre corridor, and the Ben Saad study was conducted in a 40-metre corridor, whereas our study was conducted in a 30-metre corridor, as required by the ATS/ERS guidelines [15–18]. Moreover, Capodaglio's subjects performed the 6MWT only once, whereas our subjects performed the test twice [17]. The mindset and effort level of subjects can also influence the results of the 6MWT [16]. Our findings highlight the importance of developing population-specific reference equations to accurately predict the 6MWD in obese Chinese adults. Tailored reference equations are essential for providing precise evaluations and implementing appropriate interventions, allowing clinicians to better identify functional limitations and customize treatment plans for obese individuals.

The 6MWT provides valuable insights into a patient's functional capacity, making it ideal for monitoring disease progress in obesity and other chronic diseases and postsurgical rehabilitation [30]. This simple, low-cost, noninvasive test can help clinicians assess improvements or decreases in functional capacity, identify participant limitations, and evaluate pre- and postoperative function. The 6MWW, which considers both mechanical load and metabolic efficiency, improves the clinical value of the test, particularly for obese patients. Together, the 6MWD and 6MWW offer a comprehensive understanding of physical capacity, enabling personalized treatment plans. In the future, establishment of the minimum clinically important difference (MCID) for both the 6MWD and the 6MWW will be essential for assessing meaningful changes in patient performance. In this context, the MCID would provide a threshold for determining whether changes in the 6MWD and 6MWW are clinically significant, offering valuable guidance for clinicians in decision-making and treatment planning.

While the 6MWT is cost effective, successful implementation requires a safe, controlled environment, especially for patients with mobility issues or comorbidities. Standardized encouragement, accurate distance measurement, and attention to individual factors such as psychological state, fatigue, and comorbidities are crucial for ensuring consistency in the results. Proper training for personnel is likewise essential to ensure the correct administration and interpretation of results. The development of population-specific reference equations for the 6MWD and 6MWW in obese Chinese adults provides more accurate tools for assessing functional capacity in this group and has significant implications for prescribing exercise regimens. Understanding the relationships among BMI, age, and walking capacity allows the development of tailored rehabilitation strategies, such as lower-intensity, longer-duration walking exercises for individuals with higher BMIs or older individuals, and the refinement of exercise plans by incorporating the 6MWW and considering both mechanical load and metabolic efficiency.

Several limitations should be considered when interpreting the results of this study. The convenience sample used in this study may limit the generalizability of the findings to the broader obese population in China, as it may not capture the full range of demographic characteristics and health diversity of the country's citizens. Seasonal variations, such as changes in temperature, humidity, and daylight, could also influence performance, despite the use of a controlled environment for performing the test. Additionally, the single-centre design limits the applicability of the results, as local healthcare protocols and patient demographics may differ across institutions. To establish more robust, population-specific reference equations, multicentre studies involving larger and more diverse populations are needed. Furthermore, adapting the 6MWT and 6MWW for clinical populations with comorbidities, such as cardiovascular disease and diabetes, is essential. Future research should also refine the testing protocols for patients with mobility impairments or other health conditions to suit different clinical settings, including outpatient clinics and home healthcare. Integrating these tests with additional assessments, such as the Timed Up and Go test or muscle strength measurements, would allow a more comprehensive evaluation of functional capacity and improve clinical decision-making.

Conclusion

The new reference equations proposed for the 6MWD and 6MWW improve the assessment of functional capacity in obese Chinese adults by providing more precise and physiologically relevant predictions. Moreover, these equations can aid clinicians in understanding and managing obese patients' functional limitations, improving patient outcomes and quality of life. Future research should refine these equations and test their applicability in diverse populations.

Abbreviations

6MWT	Six-minute walk test
6MWW	Six-minute walk work
6MWD	Six-minute walk distance
BMI	Body mass index
ICC	Intraclass correlation
SD	Standard deviation
SPSS	Statistical Package for the Social Sciences
MCID	Minimum clinically important difference

Supplementary Information

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Supplementary Material 1

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Author contributions

LPW, HZ, XSC, JZ and XLW designed the research; LPW, HZ, XSC, JZ, XLW, CL, SXW and YZ performed the research; LPW, HZ, XSC, JZ and XLW were involved in analysing the data; HZ, XSC, JZ and XLW wrote the paper and edited the paper. All the authors read and approved the final manuscript.

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Data availability

Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Wenzhou People's Hospital (approval number: 2021.348). All participants provided written informed consent prior to enrolment in the study. The manuscript followed the STROBE guidelines for observational studies.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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