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ORIGINAL ARTICLE

Two-Minute Walk Test Performance by Adults 18 to 85 Years: Normative Values, Reliability, and Responsiveness

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Abstract

Objectives: To provide (1) normative reference values for the 2-minute walk test (2MWT), (2) reference equations for the 2MWT, and (3) information on the reliability and responsiveness of the 2MWT across the adult lifespan.

Design: Cross-sectional study.

Setting: General community settings.

Participants: A population-based sample of adult participants (N=1137) contributed data to this study, which was part of the National Institutes of Health (NIH) Toolbox for the Assessment of Neurological and Behavioral Function Norming Project.

Interventions: Not applicable.

Main Outcome Measure: 2MWT.

Results: Overall, the distance participants walked ranged from 64.6 to 300.8m (mean, 180.9m). Men walked farther than did women (189.4m vs 176.0m; $t=6.8$; $df=1{,}135$; $P<.001$). Significant correlations were observed between the 2MWT and age ($r=-.41$), height ($r=.29$), weight ($r=-.16$), and body mass index ($r=-.32$). Age and body mass index were used in the linear regression modeling to predict the 2MWT distance ($R^2=.55-.56$). Test-retest reliability of the 2MWT as characterized by the intraclass correlation coefficient was .82 (95% confidence interval, .76−.87). Based on a standard error of measurement of 15.3m, the minimum detectable change for the 2MWT was 42.5m.

Conclusions: The study presents norms of the 2MWT established by the NIH Toolbox. The norms can be used to determine the presence of limitations in walking endurance across the lifespan.

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Tests documenting the distance walked over extended periods of time (1−12min) are widely used to characterize functional endurance in research and clinical practice settings. Originally directed at patients with cardiovascular or pulmonary problems,[1,2] the tests have since been more broadly applied.[3-6] In 2002, the American Thoracic Society specifically recommended the 6-minute walk test (6MWT) and provided instructions for its performance.[7] Normative reference values[8-11] and information on the reliability[10,12,13] and responsiveness[14] of the 6MWT are abundant. Notwithstanding the American Thoracic Society's recommendation and the availability of such information, the time required to conduct the 6MWT can be an impediment to its use in some settings.

The distance that can be walked over 2 minutes represents a practicable alternative. Because the distance covered during a 2-minute walk test (2MWT) has been shown to correlate highly with that covered during a 6MWT,[1,3,15] it should not be surprising that the 2MWT has been used increasingly over the past decade.[15-25] Despite escalating use, normative reference values for the 2MWT have only recently become available, and those values are

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from a relatively small sample of Brazilian adults (N=390 healthy participants).[21] Moreover, there is limited information on the test-retest reliability (individuals with stroke,[3,17] healthy adults in Brazil,[21] poliomyelitis,[22,26] neurologic impairment[27]) and responsiveness[17] of the 2MWT. If the 2MWT is to be advocated as an alternative to the 6MWT, additional reference values and information on the reliability and responsiveness of the test are needed.

The objective of this study was 3-fold. Specifically, we sought to provide (1) normative reference values for the 2MWT, (2) reference equations for the 2MWT, and (3) information on the reliability and responsiveness of the 2MWT across the adult lifespan.

Methods

The data for this investigation were collected from the Motor Domain of the National Institutes of Health (NIH) Toolbox for the Assessment of Neurological and Behavioral Function.[28] The intent of the NIH Toolbox is to develop an assessment battery that provides a standard set of royalty-free, brief, and comprehensive assessment tools that can be used by researchers and clinicians in various settings, with a particular emphasis on measuring outcomes in longitudinal epidemiological and prevention or intervention clinical research across the lifespan. Specifically used in this study were data from the norming phase of the project.[29] The project was approved by the Institutional Review Board of the Northwestern University, Chicago, IL, and all participants provided written informed consent.

Participants

A population-based sample of participants from 10 geographically diverse sites in the continental United States participated. To be eligible, individuals had to be community dwelling and noninstitutionalized, capable of following test instructions (English or Spanish), and at least 18 years old (a pediatric cohort was also collected and will be described in the future).

Note that participants took the 2MWT as part of the entire NIH Toolbox battery under the Motor Domain. Detailed norming plans for the NIH Toolbox have been described.[29] Briefly, the recruiting process included poststratification adjustment calculated using iterative proportional fitting, and so the weighted sample would have the same distribution on key demographic variables (age, sex, and language preference) as the United States population described in the 2010 Census. The order of administration of the tasks was randomized by blocking (cognitive, motor, emotion, sensory domain). Within each domain, tests were presented in a fixed order.[29]

For this study, individuals were excluded if they did not complete the 2MWT, lacked height or weight documentation, or were determined to be outliers on the basis of extreme 2MWT distances (ie, >2.5SDs from the mean for their age category). For details, see figure 1.

List of abbreviations:

2MWT **2-minute walk test**
6MWT **6-minute walk test**
BMI **body mass index**
CI **confidence interval**
ICC **intraclass correlation coefficient**
MDC_{95} **minimum detectable change**
NIH **National Institutes of Health**

Procedure

Basic demographic characteristics (sex, age, height, and weight) were determined for participants before any performance-based assessments were undertaken. Thereafter, a series of motor assessments were conducted, including the 2MWT. The 2MWT was performed over a 50-ft (15.2-m) out-and-back course. Participants were instructed to walk as fast as they could until asked to stop. They were also told not to worry if they had to slow down or rest, but that if they stopped they should start walking again as soon as they felt ready to do so. When 1 minute had elapsed, they were told "You are doing well; you have 1 minute left." Participants stopped walking at 2 minutes, and the distance covered was documented. Because the NIH Toolbox norming plan was designed to obtain the test-retest reliability coefficient for each test being validated, a subset of 157 participants repeated the 2MWT 4 to 21 days later (mean, 8.6d).

Analysis

The determination of normative values began with an exploratory examination of factors identified by previous researchers to be determinants of performance on the 6MWT, that is, sex, age, height, weight, and body mass index (BMI).[8,30,31]

First, descriptive statistical analyses were performed using the entire sample and by sex. Second, to compare the effect of sex and age group on the 2MWT performance, we performed a multifactorial (sex×age group) analysis of variance, followed by Scheffe post hoc statistics. Third, to obtain the predicting equation, we used a forward stepwise multiple regression analysis. The dependent variable was the 2MWT performance (continuous

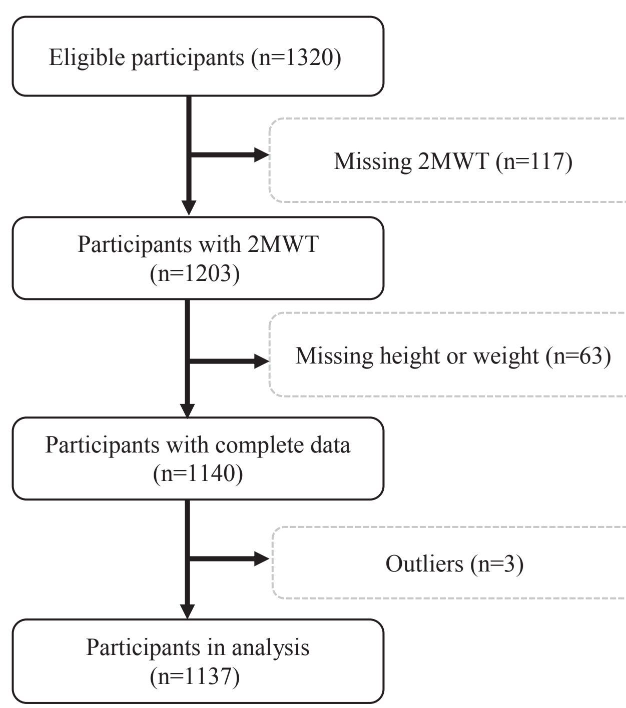

Fig 1 Data cleaning flowchart.

variable). The predicting candidate variables were sex, age, height, weight, and BMI. The exploration process involved scrutinizing scatterplots to check for a linear relation and calculating Pearson correlations to inspect the strength of the relation. The Durbin Watson test was used to check the assumption of independence of residuals. The variance inflation factor was used for multicollinearity diagnosis. We plotted standardized residuals to standardized predicted values to inspect the homoscedasticity. To check whether the residuals (errors) were approximately normally distributed, we plotted a histogram and a normal P-P plot and a normal Q-Q plot of the studentized residuals. In addition, outliers were inspected if the values were outside 3SDs.

Based on the findings of these analyses, normative values of the 2MWT distance were presented in the form of descriptive statistics stratified by sex and age and regression equations. Reliability was examined using a paired t test, an intraclass correlation coefficient (ICC) (2-way random model with measures of absolute agreement), and a Bland-Altman plot. Using the test-retest ICC, responsiveness was characterized by calculating the minimal detectable change (MDC95) ($MDC_{95} = 1.96 \times \sqrt{2} \times \sigma\sqrt{(1 - \text{reliability})}$, where 1.96 represents the 95% confidence interval [CI] and σ is the SD of the 2MWT score). The IBM SPSS Statistics for Windows (version 20.0)[a] and MedCalc[b] programs were used for analysis.

Results

A sample of 1137 was available for analysis. Of these participants, 720 (63%) were women. The sample was racially diverse, with 890 (78%) whites, 168 (15%) blacks, 34 Asians (3%), 33 (3%) American Indians, 5 (0%) Pacific Islanders, and 27 (2%) undesignated. Ethnically, 364 (32%) were Hispanics. The distance participants walked in 2 minutes ranged from 64.6 to 300.8m (mean, 180.9m). Table 1 lists other basic demographic information such as age, weight, and height as well as the overall 2MWT performance for participants.

Overall, assumptions of linearity, multicollinearity, homoscedasticity, normally distributed errors, and uncorrelated errors were checked and met.

The Durbin Watson statistics were 1.96 and 1.92 for men and women, respectively, supporting the independence of residuals. The variance inflation factor value was close to 1, suggesting no significant multicollinearity between variables. There were no noticeable patterns for heteroscedasticity and no noticeable deviations from normal distribution in the histogram and the Q-Q plot. Five women were identified as outliers (>3SD) and thus were removed from the regression analysis.

Scatterplots illustrating the relation between independent variables (age, height, weight, BMI) and the 2MWT distance are presented in figure 2. The scatterplots were segmented by sex, and the patterns suggested the linear trends between independent variables and the 2MWT distance. Correlations between independent variables and the 2MWT distance are provided in table 2. All were significant ($P<.001$). Age correlated with the 2MWT distance the highest ($r=-0.41$), followed by BMI ($r=-0.32$).

Both the scatterplots and correlations demonstrated that men walked farther than women and that participants tended to walk farther if of younger age, greater stature, lesser mass, and lower BMI.

Results of the regression analysis are presented in table 3. The analysis showed, for both men and women, that age offers the best explanation of the 2MWT distance but that BMI makes an additional contribution to the explanation of the 2MWT distance.

Results of analysis of variance (controlling for sex) showed no difference in the 2MWT distance between age groups 18 and 29, 30 and 39, 40 and 49, and 50 and 54 years but showed differences in the 2MWT distance between age groups 55 and 59, 60 and 64, 65 and 69, 70 and 74, 75 and 79, and 80 and 85 years. Based on these findings, 2MWT norms are presented separately for men and women and for the following age groups: 18 to 54, 55 to 59, 60 to 64, 65 to 69, 70 to 74, 75 to 79, and 80 to 85 years. The norms are presented as distance and distance normalized against the BMI (table 4).

For the 157 participants who performed the 2MWT twice, the mean ± SD for distances walked during the 2 sessions were 175.9±35.5m and 180.3±36.7m, respectively. The distance walked during the second test session was significantly greater ($t=-2.54$; $df=156$; $P=.012$) than that walked during the first session. Using the entire sample, the test-retest reliability as estimated by the ICC for the 2 distance measures was .82 (95% CI, .76−.87). By sex, the test-retest reliability was .77 (95% CI, .66−.80) for men and .84 (95% CI, .76−.90) for women.

Figure 3 presents a Bland-Altman plot for the distances walked during the 2 sessions. Based on an SEM of 15.3m using the entire sample, the MDC_{95} for the 2MWT was calculated to be 42.5m. By sex, SEMs were 17.0 and 12.0 for men and women, and the corresponding MDC_{95} values for the 2MWT were 47.2 and 33.4m for men and women, respectively.

Discussion

Although the 2MWT is being used increasingly,[3,15,21] no study to date has provided normative values as well as information on both the reliability and responsiveness of the 2MWT. This analysis of the NIH Toolbox data did just that.

As in previous studies of the 6MWT and the 2MWT, age, sex, height, and weight were found to explain the 2MWT distance.[8,21,30,31] However, the correlations in this study were not strong and tended to be lower than those reported by Selman

Table 1 Descriptive statistics for study participants

Variables	All (N=1137)	Women (n=720)	Men (n=417)
Age (y)	46.2±17.6 (18−85)	44.3±16.7 (18−85)	49.7±18.6 (18−85)
Height (m)	1.68±0.10 (1.40−1.98)	1.62±0.07 (1.40−1.83)	1.77±0.07 (1.55−1.98)
Body mass (kg)	80.2±19.5 (40.8−195.0)	75.9±19.1 (40.8−195.0)	87.9±17.8 (54.4−156.5)
BMI (kg/m^2)	28.5±6.5 (16.5−58.3)	28.8±7.0 (16.5−58.3)	28.1±5.5 (17.9−50.9)
2MWT distance (m)	180.9±32.8 (64.6−300.8)	176.0±30.1 (64.4−260.6)	189.4±35.5 (88.9−300.8)
2MWT distance/BMI (m^3/kg)	6.71±2.07 (1.92−14.71)	6.53±2.09 (1.92−13.17)	7.02±2.01 (2.2−14.7)

NOTE. Values are mean ± SD (range). BMI (kg/m^2) is defined as the individual's body mass divided by the square of his or her height.

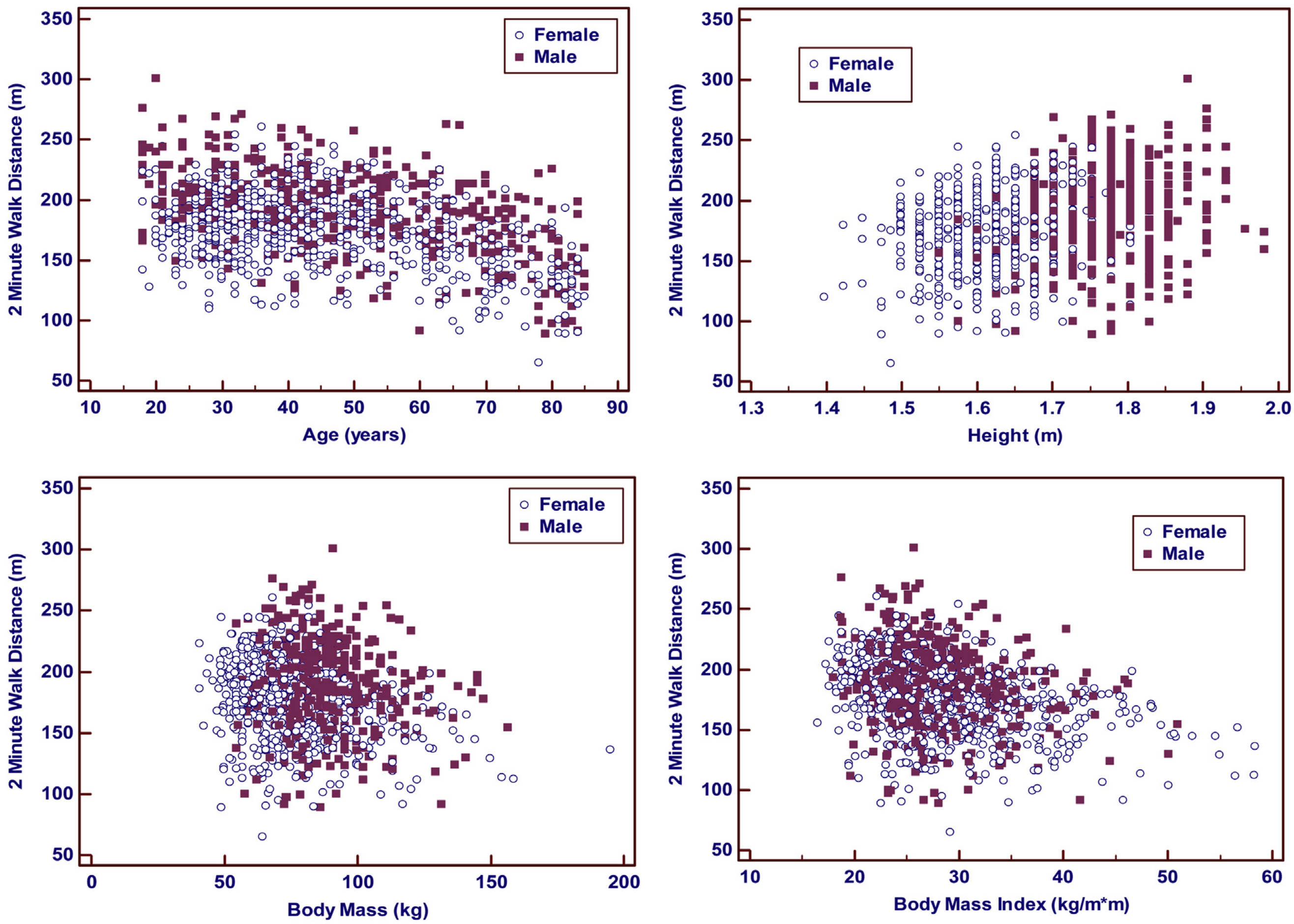

Fig 2 Scatterplots illustrating the relation between (age, height, weight, BMI) and the 2MWT distance.

et al[21] for the 2MWT. This study also showed that the BMI, which incorporates both height and body mass, was superior to either height or weight as an indicator of the 2MWT distance. Thus, we believe that it is practical to normalize the 2MWT distance against the BMI rather than height or weight.

On the basis of regression equations, a community-dwelling 66-year-old woman with a BMI of 29.5kg/m^2 would be expected to walk 159.7m [ie, (257.177−0.723)×(66−1.688)×29.5]. Using the norms (average values) presented in table 4, she would be expected to walk 155.2m (ie, women, aged 65−69y, would be expected to walk a distance of 155.2m, with a 95% CI of 140.6−169.8m). Supporting the known-groups validity of the normative distances reported herein is their relative comparability to distances reported by Selman[21] for Brazilian adults and their clearly greater magnitude compared with distances reported for patients who have a history of chronic obstructive pulmonary disease,[32] stroke,[3] transtibial amputations,[24] or cardiac surgery.[25]

In this study, we examined reliability by comparing the distance covered during tests performed days apart. Participants covered a greater distance during a second performance of the 2MWT than during the first performance of the 2MWT. The difference (4.4m) was greater than that reported by Selman et al[21] (3m), but their second walk test was within 30 minutes of

Table 2 Correlations (r)* between independent variables and the 2MWT distance

Independent Variables	All (N=1137)	Women (n=720)	Men (n=417)
Sex	−0.198 (−0.141 to −0.253)		
Age	−0.410 (−0.361 to −0.458)	−0.403 (−0.340 to −0.463)	−0.520 (−0.446 to −0.587)
Height	0.287 (0.233 to 0.340)	0.218 (0.148 to 0.287)	0.206 (0.112 to 0.296)
Weight	−0.157 (−0.010 to −0.213)	−0.299 (−0.231 to −0.364)	−0.127 (−0.032 to −0.221)
BMI	−0.322 (−0.269 to −0.373)	−0.383 (−0.319 to −0.443)	−0.217 (−0.123 to −0.306)

NOTE. Values are r (95% CI).
* All correlations are significant at $P<.0001$.

Table 3 Results of multiple regression analysis of independent variables explaining the 2MWT distance

Participant	Model	Coefficient B (β)	SE	*t* (*P*)	*R* (R^2 adjusted)
Women	Constant	257.177	4.528	56.795 (<.0001)	
	Age	−0.723 (−.406)	0.055	−13.235 (<.0001)	
	BMI	−1.688 (−.398)	0.130	−12.951 (<.0001)	.573 (.329)
Men	Constant	279.096	8.495	32.855 (<.0001)	
	Age	−0.998 (−.521)	0.078	−12.841 (<.0001)	
	BMI	−1.426 (−.220)	0.263	−5.414 (<.0001)	.564 (.315)

NOTE. The reference equations of the 2MWT were as follows:
- Women: $2MWT_{predicted} = 257.177 - (0.723 \times age) - (1.688 \times BMI)$
- Men: $2MWT_{predicted} = 279.096 - (0.998 \times age) - (1.426 \times BMI)$

  where BMI is weight (in kilogram) divided by height (in meter) squared.

Abbreviations: B, unstandardized coefficients; β, standardized coefficients; *t* (*P*), coefficients *t* statistics and *P* value.

the first[21] rather than days later as in this study. In any case, the finding of increased distance with repeated walk tests is well established.[33] In spite of the increase in walking distance in the second performance of the 2MWT of this study, the ICC was consistent with the good reliability even if lower than that reported by others (≥.90).[24,32] The difference might be explained by a variance between patients that exceeds the variance between healthy community-dwelling adults. The Bland-Altman plot did not reveal any systematic error between the distances covered during the 2MWT trials.

Responsiveness in this study was characterized using a distribution-based measure, that is, the MDC_{95}. The MDC_{95} for the sample is large overall (42.5m); it is 23.5% of the first measure. This may be a function in part of the extensive variability associated with individuals who are either men or women and distributed over a wide range of ages.

Table 4 Norms for the 2MWT distance

Participants by Sex and Age Category, y (n)	Distance, m (mean [95% CI])	Distance, m/BMI (mean [95% CI])
Women		
18–54 (539)	183.0 (180.8–185.3)	6.82±0.09 (6.64–6.99)
55–59 (30)	176.4 (168.1–184.8)	6.41±0.35 (5.71–7.11)
60–64 (48)	166.4 (158.2–174.5)	6.26±0.26 (5.74–6.79)
65–69 (22)	155.2 (140.6–169.8)	5.48±0.45 (4.55–6.41)
70–74 (33)	145.9 (136.9–154.9)	5.01±0.31 (4.38–5.65)
75–79 (14)	140.9 (121.8–159.9)	5.58±0.54 (4.41–6.76)
80–85 (34)	134.3 (125.7–142.9)	5.01±0.19 (4.63–5.39)
Men		
18–54 (260)	200.9 (197.2–204.6)	7.40±0.13 (7.15–7.66)
55–59 (23)	191.0 (176.8–205.2)	6.92±0.38 (6.13–7.71)
60–64 (29)	179.1 (165.4–192.8)	6.43±0.33 (5.75–7.11)
65–69 (22)	184.2 (170.7–197.8)	7.08±0.35 (6.36–7.80)
70–74 (32)	172.4 (163.8–180.9)	6.50±0.26 (6.00–6.56)
75–79 (19)	157.6 (140.3–174.9)	5.78±0.44 (4.85–6.70)
80–85 (32)	144.1 (132.6–155.6)	5.74±0.30 (5.14–6.34)

Abbreviations: distance, mean 2MWT distance; distance/BMI, mean 2MWT distance normalized by BMI.

Study limitations

This study had several limitations. Because this study included data across 10 data collection sites, the researchers were not in control of the data collection procedures as in a study taking place at 1 site. Missing data were inevitable in large-scale studies across multiple sites. Subjects took the 2MWT as part of the NIH Toolbox battery; thus, the fatigue effect was unknown and may contribute to the biases that would affect the way practitioners use these data. Although this study had a relative large sample size, the study did not enroll a sufficient number of individuals within sex, age, and race strata to generate norms for racial strata and had no control for occupation and comorbid diseases, which warrant future study. Last, we did not perform cross-validation in this study. Future studies should examine the accuracy and predicting power of the reference equations reported in this study.

Conclusions

The study presented the norms of the 2MWT established by the NIH Toolbox. The norms can be used to determine the presence of impairments in walking ability, functional endurance, and overall functional status across the lifespan.

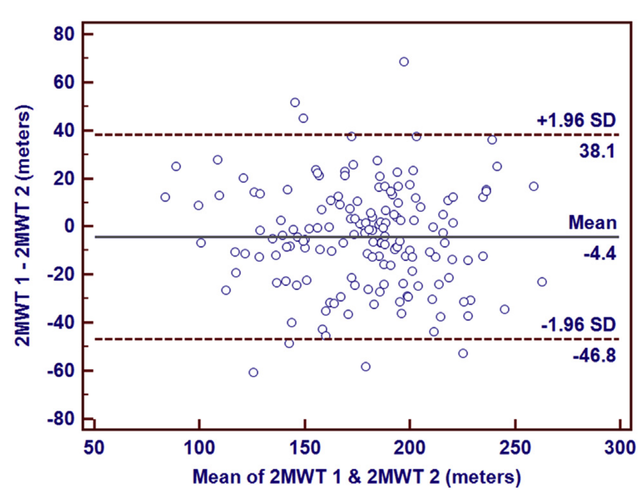

Fig 3 Bland-Altman plot for the distances walked during the 2 sessions.

Suppliers

a. IBM Corp.
b. MedCalc.

Keywords

Exercise test; Physical endurance; Psychometrics; Rehabilitation; Walking

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