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Predictive Equations for the Six-Minute Walk Test in Venezuelan Adults: Inclusion of a Novel Variable

Ecuaciones predictivas en la prueba de caminata de seis minutos en venezolanos adultos: inclusión de una variable novedosa

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ABSTRACT

Introduction: The six-minute walk test is simple, low-cost, and resembles daily physical activity. Multiple factors influence the test performance in different regions; therefore, predictive equations have been developed based on specific sociodemographic and anthropometric characteristics. To date, no reference equations exist for the Venezuelan population.

Objectives: To develop native predictive equations for the six minute walk test distance. To analyze and compare local data with equations derived from other countries.

Methods: An observational and prospective study was conducted between july 2024 and march 2025 with 247 venezuelan adults over 30 years old, of both sexes. Two tests were performed, selecting the longest distance walked for data analysis in order to identify variables with the highest predictive value.

Results: Independent variables with the greatest predictive power were sex, age, height, and waist circumference. The resulting equation, with an R^2 of 50%, was:
6MWT (m) = 278.7 – 58.6 × sex* – 1.2 × age + 3.24 × height (cm) – 2 × waist circumference (cm) + sex* × waist circumference (sex*: male = 1, female = 0).
On average, men walked 616.5 meters (m) and women 547.2 m.

Conclusions: Comparisons with foreign equations showed underestimations or overestimations when applied to our population. The inclusion of waist circumference as a predictive variable is novel and highlights the importance of visceral fat as a relevant factor in daily physical activity. A 20 minutes rest period between both tests is recommended.

Key words: six-minute walk test | reference equations | waist circumference | obesity

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RESUMEN

Introducción: La prueba de caminata de seis minutos es sencilla, económica y representativa de la actividad física diaria. Diversos factores influyen en el rendimiento de la PC6M; por tanto, se han desarrollado ecuaciones predictivas con características sociodemográficas y antropométricas regionales. Hasta la fecha, no existen ecuaciones de referencia para la población venezolana.

Objetivos: Desarrollar ecuaciones predictivas adaptadas a la población venezolana para la prueba de caminata de seis minutos. Analizar y comparar datos locales con ecuaciones de otros países.

Materiales y métodos: Se realizó un estudio prospectivo y observacional entre julio de 2024 y marzo de 2025 con 247 adultos venezolanos mayores de 30 años, de ambos sexos. Se ejecutaron dos pruebas, seleccionando la mayor distancia recorrida para el análisis de datos con el fin de identificar las variables con mayor valor predictivo.

Resultados: Las variables independientes con mayor poder predictivo fueron: sexo, edad, estatura y circunferencia abdominal. La ecuación resultante, con un R^2 del 50 %, fue la siguiente:

PC6M (m) = 278,7 – 58,6 × sexo* – 1,2 × edad + 3,24 × altura (cm) – 2 × circunferencia abdominal (cm) + sexo* × circunferencia abdominal (sexo*: hombre = 1, mujer = 0).

Los hombres caminaron un promedio de 616,5 metros (m) y las mujeres, 547,2 m.

Conclusiones: Las ecuaciones foráneas mostraron subestimaciones o sobreestimaciones al aplicarlas localmente. La circunferencia abdominal como variable predictiva es novedosa y resalta la importancia de la grasa visceral como un factor relevante en la actividad física diaria. El período de descanso de 20 minutos entre ambas pruebas es recomendable.

Palabras clave: Prueba de caminata de seis minutos | valor predictivo de la prueba | circunferencia abdominal | obesidad

INTRODUCTION

The 6-minute walk test (6MWT) is a simple and low-cost field exercise test that requires only basic equipment and adequate space. It allows assessment of functional capacity in healthy individuals and in patients with a variety of conditions, and it may also help estimate mortality risk in several diseases. The American Thoracic Society (ATS)[1] and Latin American working groups[2,3] have established guidelines for this test, and it is widely used as a prognostic and therapeutic variable in clinical trials involving chronic obstructive pulmonary disease (COPD),[4] pulmonary hypertension,[5] heart failure,[6] and many other diseases.[7]

Several studies have been published in the literature establishing reference equations for this test in different countries. However, the ATS recommends establishing reference values for the local population because of anthropometric, geographic, and ethnic differences among populations.

In the specific case of Venezuela, to the best of our knowledge, there are no reference equations available for this test in the local adult population (born and residing in the country) that would allow comparisons in patients with various diseases. A previous multicenter study conducted across several Ibero-American cities included a small local sample, but it was not designed to derive equations specific to each region.[8]

The objectives of this study were to measure the maximum distance covered in two 6-minute walk tests, according to ATS guidelines, in a sample of Venezuelan adults older than 30 years of both sexes without limitations to

normal walking; to assess its association with potential predictive variables, including sociodemographic, anthropometric, and clinical factors; and to develop one or more equations that could serve as local reference standards. Additionally, similarities and differences with comparable reference equations from foreign populations were investigated.

METHODS

Over an 8-month period (July 1, 2024, to March 1, 2025), at the Instituto Clínico La Florida in Caracas, Venezuela, 263 native volunteers aged > 30 years, of both sexes, were screened and deemed eligible for the study according to predefined inclusion criteria. Of these, 247 agreed to participate in this prospective observational study. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Ethics Committee. All participants provided verbal and written informed consent after receiving a detailed explanation of the study procedures, before undergoing any testing.

Inclusion criteria were as follows: apparently healthy adults without disabilities that could interfere with test performance. Participants with controlled systemic hypertension or a history of stable, well-controlled asthma were also eligible.

Exclusion criteria: uncompensated chronic disease and any musculoskeletal, sensory, or neurological condition that could impair walking ability or comprehension of instructions; a cardiac ischemic event within the preceding 6 months; acute illness within 4 weeks prior to enrollment; resting systolic blood pressure > 150 mm Hg and/or resting diastolic blood pressure > 100 mm Hg; and resting heart rate < 50 beats/min or > 100 beats/min.

Data collection

The study procedures were conducted by experienced personnel under the supervision of three physicians and one nurse. Each participant completed a questionnaire before the walk that collected demographic and anthropometric data. A thorough medical history was obtained, including relevant comorbidities, smoking status, current medications, and vital signs. A cardiopulmonary examination was subsequently performed to verify eligibility criteria.

Anthropometric measurements included body weight (kg), height (cm), and body mass index (BMI), calculated as weight in kilograms divided by height in m^2. Neck circumference (NC) was measured in centimeters with the superior edge of the measuring tape positioned just inferior to the thyroid cartilage, parallel to the floor, and with the neck in neutral, erect position. Waist circumference (WC) was measured in centimeters at the level of the umbilicus at the end of normal expiration with the participant in a standing position.

The following equipment and instruments were used: a desk, two traffic cones, colored adhesive tape, a pulse oximeter, a digital sphygmomanometer, a stethoscope, a medical scale with an integrated stadiometer, a tailor's measuring tape in centimeters, a retractable tape measure, and the Borg Category Ratio 0–10 scale. Mobile phone stopwatches and lap counters were also used. The first three instruments were periodically calibrated against comparable reference devices.

Six-minute walk test (6MWT)

Each participant performed two 6-minute walk tests (6MWT1 and 6MWT2), separated by a randomized rest period of either 20 or 30 minutes. This approach allowed for the assessment of differences in the distance walked between the two tests relative to the duration of the rest interval. The tests were conducted in a straight, level indoor corridor exceeding 30 m in length, with ambient stable temperature of 23 °C. A 30-m walking course was marked, and two traffic cones were positioned at each end. The walking course was laterally marked every 3 m with adhesive tape in accordance with American Thoracic Society guidelines. Participants were instructed to walk as far as possible without running. Standardized encouragement was provided throughout the test. Participants were allowed to stop and rest if necessary, with instructions to resume walking as soon as possible. The supervising physician stood at the far end of the course, notified the participants of the elapsed time every minute while also providing verbal encouragement, such as "good job, keep up the pace." The total distance walked during the 6-minute period was recorded.

Oxygen saturation, heart rate, and blood pressure were recorded immediately before and after each test. Values obtained within 30 seconds after

completion of the test were defined as immediate post-test vital signs. Participants were also asked to rate their perceived fatigue and dyspnea using the Borg scale. The same measurements were repeated at a mean of 3 minutes after completion of the test. Participants remained seated at rest for the randomly assigned interval of either 20 or 30 minutes (see Appendix), after which the same procedure was repeated. For purposes of calculation and derivation of the reference equations, the test with the greatest walking distance was selected for analysis, together with the corresponding Borg scale score and vital signs obtained during that test.

Data analysis

Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were expressed as percentages. Age and maximal walking distance were compared using the Welch variant of the Student t test. Maximal walking distance was compared across rest interval durations using the Student t-test for independent samples with equal variances. Finally, the distances walked during the two tests were compared using a paired-samples Student t-test. For all analyses, a two-sided p value < 0.05 was considered statistically significant.

The best-fitting reference multiple linear regression equation was obtained using a bidirectional stepwise selection procedure based on the Akaike Information Criterion, which ensures an optimal balance between goodness of fit and model complexity. Goodness of fit was assessed by residual analysis using different graphical methods for visual inspection. Cook's distance was also used to identify influential observations. In addition, analysis of variance was performed according to the principle of marginality using Type II sums of squares to summarize the results of the fitted model. The initial set of candidate predictors included sex, age, BMI, weight (kg), height, NC (cm), and WC (cm).

Sample size: After reviewing reference equation estimation studies from multiple countries, we determined that the final estimated equations would include a maximum of 8 parameters, comprising an intercept, 5 regression coefficients, and 2 interaction terms. According to Green's criterion,[10] a minimum sample of 114 participants would therefore be required. However, to obtain stable parameter estimates with small standard errors, a sample size of approximately 240 participants would be preferable. Accordingly, 263 individuals were recruited, of whom 247 ultimately completed the study protocol.

The multiple regression model providing the best fit according to the Akaike Information Criterion included 3 quantitative predictors, 1 dichotomous qualitative predictor, and 1 interaction term between the qualitative factor and one of the quantitative predictors. Thus, the final model required estimation of 6 parameters, for which a sample size of 180 participants would have been sufficient.[11]

Statistical analyses were performed using the R statistical programming language, version 4.5.0. URL of the website: https://cran.r-project.org/.

RESULTS

A total of 263 volunteers were assessed, of whom 16 were excluded for the following reasons: uncontrolled arterial hypertension (n = 12), invalid sociodemographic data (n = 2), acute respiratory symptoms (n = 1), and test interruption due to low back pain (n = 1). Consequently, 247 participants were considered eligible for the analysis (Figure 1, flow diagram).

Sex-stratified characteristics are shown in Table 1.

Overall, 61% of participants reported no comorbid conditions, whereas 24% reported cardiovascular disease, 9% respiratory disease, and 6% conditions of other etiologies. In addition, 63% of participants had never smoked, and 60% were sedentary. All anthropometric variables were lower in women (p < 0.001), with the exception of BMI (p = 0.097) (Table 2).

6MWT

The mean distance covered in the best of the 2 tests was 581 ± 70 m and was lower in women than in men (547 ± 54 m vs 615 ± 67 m, respectively). The mean difference was 69 m and was statistically significant (p < .001). On average, the distance walked during the first 6MWT was 19.3 m shorter than that recorded during the second test (p < .001). For both sexes, the distance walked was greater among participants who reported performing at least 1 hour per week of exercise (brisk walking or jogging), divided into two or more sessions, and

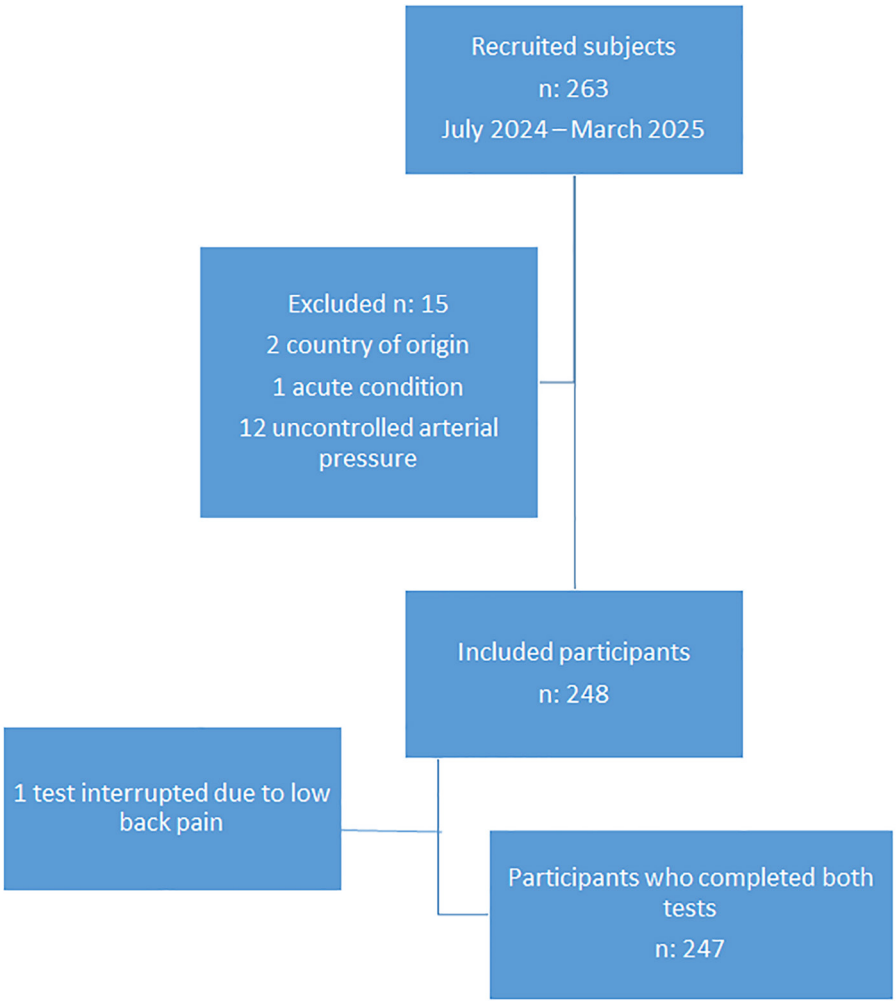

Figure 1. Flow chart

who were classified as physically active rather than sedentary ($p < .05$).

The maximum distance walked by participants with high school or university education was greater than that achieved by participants with lower educational attainment ($p < .001$) Regarding health status, participants who reported no medical conditions walked a greater average distance during the tests than those with controlled comorbidities ($p < .05$). No statistically significant differences were observed for the remaining sociodemographic variables.

The study also included a randomized experiment to determine whether a 20- or 30-minute rest period between the 6MWT1 and 6MWT2 influenced the distance walked. No significant differences were observed between the 2 rest intervals ($p = .981$).

Association between the 6MWT and study variables

Of all the variables analyzed, only age, sex, height, and WC were significantly and independently associated with the maximum distance walked during the 6MWT. The prediction equation for the maximum distance walked that best fit the data, with an R^2 of 50%, was:

$$6MWT = 278.7 - (58.6 \times Sex) - (1.2 \times Age) + (3.24 \times Height\ in\ cm) - (2 \times WC\ in\ cm) + (Sex \times WC\ in\ cm)$$

The sex regressor has a value of 0 for females and 1 for males; For a better interpretation, the equation can be specified for women as:

TABLE 1. Sociodemographic data of the participants

Sociodemographic data		Female (n)	%	Male (n)	%	Total	%
Volunteers	Excluded	9	3.4	7	2.7	16	6.1
	Participants	125	50.6	122	49.4	247	100.0
Participants	Mean age	51.7		53.3		52.5	
Geographic origin	Capital area	64	25.9	87	35.2	151	61.1
	Country interior	61	24.7	35	14.2	96	38.9
Ethnic group	Non-white	62	25.1	63	25.5	125	50.6
	Caucasian	63	25.5	59	23.9	122	49.4
Civil status	Married/Cohabiting	28	11.3	37	15.0	65	26.3
	Other	97	39.3	85	34.4	182	73.7
Academic level	Basic	23	9.3	19	7.7	42	17.0
	Superior	102	41.3	103	41.7	205	83.0
Health status	Healthy	70	28.3	80	32.4	150	60.7
	Controlled disease	55	22.3	42	17.0	97	39.3
Smoking habits	Never smoked	93	37.7	62	25.1	155	62.8
	Former smoker	20	8.1	42	17.0	62	25.1
	Active smoker	12	4.9	18	7.3	30	12.1
Physical activity	Active	43	17.4	55	22.3	98	39.7
	Sedentary	82	33.2	67	27.1	149	60.3

TABLE 2. Anthropometric data

	Female		Male		
Variables	Mean±SD	Min. Max..	Mean±SD	Min. Max.	*P value*
Weight (kg)	70.3 ± 14.3	44.5 134	80.3 ± 14.7	50 125	<0.001
Height (cm)	157.3 ± 6	144 173.3	171 ± 7.2	154 190	<0.001
Neck (cm)	34.4 ± 2.9	29 45	39.2 ± 3.1	32 47	<0.001
Waist (cm)	89 ± 11.7	62 125	94.9 ± 10.8	62 130	<0.001
BMI (kg/m^2)	24.4 ± 5.1	19.1 47.8	27.4 ± 4.3	15.2 40	<0.097

6MWT (m) = 278.7 – (1.2 × Age) + (3.24 × Height in cm) – (2 × WC in cm) For men:

6MWT (m) = 220.1 – (1.2 × Age) + (3.24 × Height in cm) – (WC in cm)

Among women, each 1-year increase in age was associated with a mean decrease of 1.2 m in maximum distance walked, whereas each 1-cm increase in height was associated with a mean increase of 3.2 m (Figures 2 and 3). Additionally, each 1-cm increase in waist circumference was associated with a 2-m reduction in maximum distance walked. Among men, the only difference compared with women was that each 1-cm increase in waist circumference was associated with a 1-m reduction in maximum distance walked (Figure 4).

DISCUSSION

This study shows that waist circumference should be considered, alongside sex, age, and

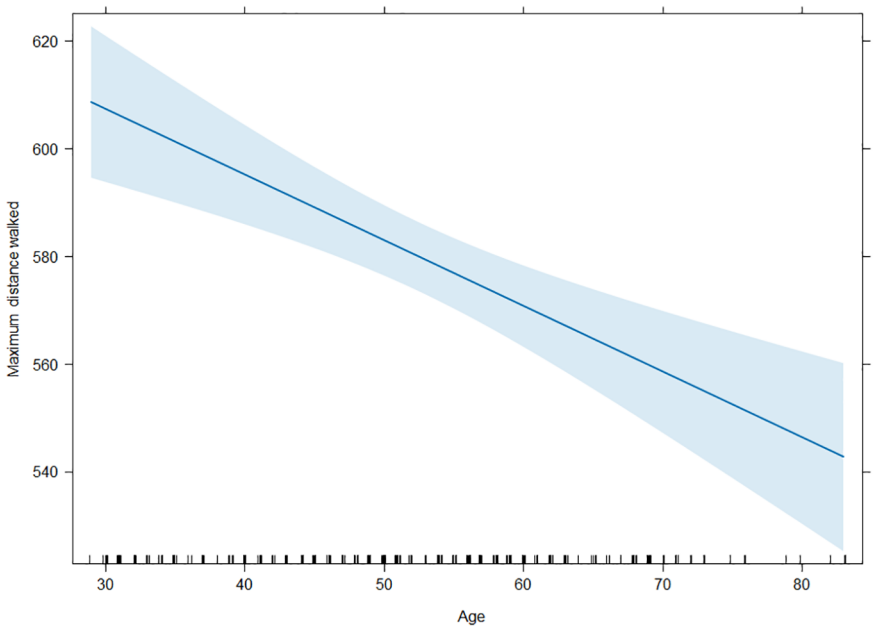

Figure 2. Effect of agen on maximum distance walked

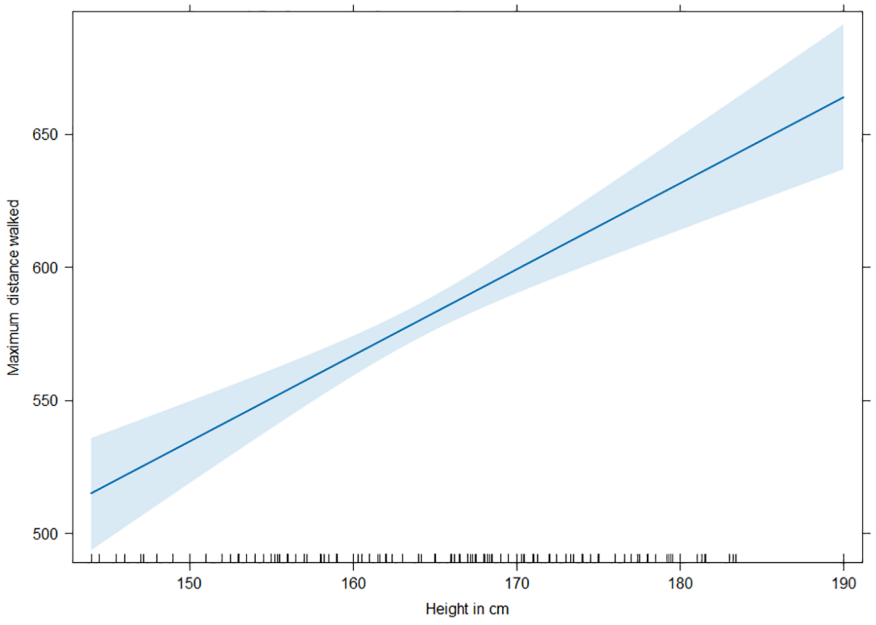

Figure 3. Effect of height on maximum distance walked

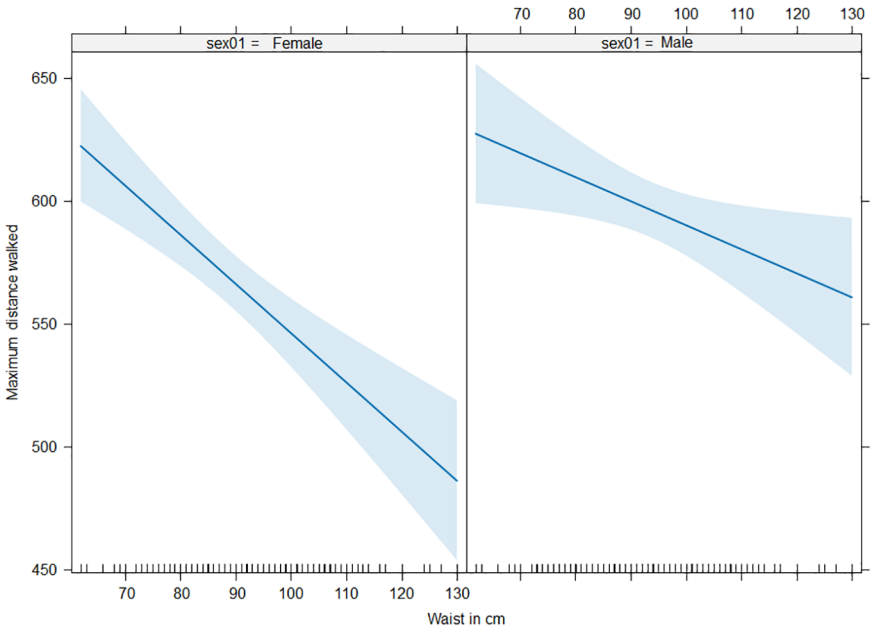

Figure 4. Effect of waist on maximum distance walked

height, as an important determinant of functional capacity. Collectively, these variables accounted for 50% of the variability in the 6MWT.

To our knowledge, no previously published reference equation for the 6MWT derived in Western populations has identified waist circumference as a determinant variable of distance walked in healthy individuals. Waist circumference has previously been reported as a significant variable and incorporated into 6MWT equations in only one study involving healthy Japanese subjects[12] and another conducted in obese Asian patients with diabetes mellitus.[13] Unlike other published studies,[14-16] our exclusion criteria did not omit participants with out-of-range BMI values; rather, their inclusion was considered essential to ensure greater representation of the general population. Notably, the mean BMI of the study population was 27.9 ± 5.1 kg/m², corresponding to an overweight status.

In contrast to previous studies, BMI was not selected during the initial predictor selection procedure because its inclusion could have introduced multicollinearity into the model. Given the absence of BMI in our results –which has been significantly different from zero in other published studies– we repeated the selection procedure, forcing the inclusion of BMI. Although BMI remained in the resulting equation, it was not significantly different from zero (p = 0.8825).

We speculate that including overweight and obese participants in the study cohort may have driven the inclusion of waist circumference, offering greater predictive power for maximum distance walked than BMI. Some authors have suggested that body composition may be more informative than BMI when evaluating individuals, as BMI primarily reflects nutritional status rather than body fat distribution. [17,18] Most previous clinical trials used body weight[8,19-21] and body mass index[22,27] as predictors of distance walked in their reference equations, among other anthropometric variables. Only one clinical trial[12] included WC in the equation. In our study, both body weight and BMI were evaluated; however, WC demonstrated greater predictive power and was therefore retained in the final equation. Waist circumference, a surrogate marker of visceral adiposity, probably lacked relevance in the aforementioned studies simply because it was omitted from the anthropometric variables and not compared with other predictors. More recent

studies, such as that by Zhou et al,[23] using a metabolic score designed to assess abdominal obesity, demonstrated an inverse relationship between visceral fat and muscle mass in a large cohort of adults from the database of the National Health and Nutrition Examination Survey (NHANES). This association was more pronounced among overweight and obese individuals, which could help explain the inverse relationship between abdominal obesity and distance walked. Additionally, a physical rehabilitation program for patients with chronic heart failure (NYHA class II-III) without congestion showed that, independent of weight loss, decreases in visceral fat were directly associated with increases in the 6-minute walk distance.[24] We speculate that increased WC, as a surrogate marker of visceral adiposity, exerts a negative effect on gait performance. Potential mechanisms underlying this association have been attributed to chronic inflammatory response, insulin resistance, sedentary lifestyle, poor nutritional status, and hormonal changes associated with increased visceral adiposity. It is noteworthy that NC was also included among the anthropometric variables, as it is an easily obtainable measurement, representative of visceral adiposity, and has predictive value for cardiovascular mortality.[25,26] However, according to the statistical method used, it was not selected as a significant predictor of distance walked.

The mean distance walked observed in our cohort was statistically comparable to that reported in the multicenter studies conducted in Brazil[27] and Spain.[16] In the study conducted in a Chinese population by Zou et al,[28] a distinctive finding was observed: women achieved walking distances similar to those of men (mean difference < 50 m), with a significant difference observed for women ($p < 0.001$), but not for men ($p = 0.33$), when compared with our study population. We observed marked differences in walking distances compared with those reported in other populations[14,16,19,21,27-30], as well as in the predictive values obtained when applying foreign reference equations to our population (Table 3). Several factors may account for these differences beyond ethnic considerations, including the selected age range, inclusion of overweight or obese participants, comorbidities, regular physical activity, and academic level.

The 247 subjects included in this study reflect the proportions reported in the most recent Venezuelan National Population and Housing Census.[31] In particular, the sex distribution was similar, comprising 51% women and 49% men. The mean age of participants, ranging from 30 to 83 years, was 52.5 ± 12.5 years. Skin color distribution was also consistent with the 2011 census, with 49% White individuals and 51% mixed-race and Afro-descendant individuals.

In the present study, the distance walked was greater among participants with higher educational attainment than among those with only basic education. In addition, individuals who reported engaging in physical exercise for more than 1 h per week, distributed across two or more sessions, achieved greater walking distances than those who did not. Several studies have demonstrated these relationships with educational attainment, as well as with higher socioeconomic status, which has been linked to regular physical exercise. [32,33]

The study randomly assigned participants to either a 20- or 30-min rest interval between the two tests. No differences were observed between protocols; therefore, we recommend the use of a 20-min rest period, as it shortens the overall study duration.

We acknowledge several limitations of this study. First, this research was conducted at a single center and utilized a convenience sample, similar to pioneering studies in this field across other countries; therefore, our findings cannot be extrapolated to the general population. However, nearly 40% of the participants were from cities or towns in the country's interior. Second, the minimum age of recruited participants was 30 years; consequently, the equation cannot be applied to individuals younger than this age. Third, 19% of included subjects had well-controlled systemic hypertension, 12% were otherwise healthy smokers, and 7% had well-controlled asthma. However, all of these participants were clinically stable and considered healthy, thereby representing real-world individuals.

CONCLUSIONS

The present study, conducted in a native adult Venezuelan population with a broad age range and an adequate sample size, demonstrated that

Table 3. Distance walked during the 6MWT (m) across different populations and estimated distance obtained by applying Venezuelan data to foreign equations

Country (*)	Distance walked	Estimated distance	Distance- Venezuela	Reference	*p value*
EE UU	576♂ 494♀	576♂ 539♀	617♂ 547♀	Enright (19)	<0,001
Chile	644♂ 576♀	637♂ 578♀	617♂ 547♀	Osses (21)	<0,05
Brasil	614♂ 560♀	578♂ 529♀	617♂ 547♀	Britto (27)	NS
Saudi Arabia	409 (Δ)	474	581	Alameri (30)	<0,001
India	512♂ 457♀	486♂ 444♀	617♂ 547♀	Fernandes (29)	<0,001
China	623♂ 578♀	605♂ 554♀	617♂ 547♀	Zou (28)	NS ♂ - <0,001♀
Portugal	658♂ 605♀	615♂ 559♀	617♂ 547♀	Oliveira (14)	<0,001
España	615♂ 557♀	670♂ 605♀	617♂ 547♀	Gimeno-Santos (16)	NS

(*) Clinical trials with a sample size greater than 100 participants and a 30-meter corridor. In the Spanish study, 61% of the sample performed the 6MWT in a 30-meter corridor.
(Δ) Reports an equation not stratified by sex.

the values obtained from the 6-minute walk test (6MWT), estimated using the following equation: 6MWT = 278.7 − (58.6 × Sex) − (1.2 × Age) + (3.24 × Height in cm) − (2 × WC in cm) + (Sex × WC in cm), where Sex = 1 for men and 0 for women, differ from the results obtained when applying foreign reference equations to our population. In this study, waist circumference contributed independently to functional capacity, as measured by the distance walked during the 6MWT. The study also demonstrated that a 20-min rest interval provides results comparable to those obtained with a 30-min interval, thereby reducing the total time required to complete the two mandatory walks recommended by current guidelines.

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Conflict of interest.

None

AC reports receiving professional fees from Laboratorios La Sante for statistical analysis, which didn't have any interference in the conduct of the study or interpretation of the results.

Author contributions

HS and MG conceived the study. AC and HS designed the study with the collaboration of SG and MG. AC performed the data management and statistical analysis. G, MG, and HS conducted the fieldwork. HS, AC, SG, and MG contributed to the discussion and critical revision of the manuscript.

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