MHSalud
ISSN: 1659-097X
revistamhsalud@una.cr
Universidad Nacional
Costa Rica

Six-Minute Walk Test: Oxygen Uptake and Distance Predicted

Vásquez-Gómez, Jaime; Faundez-Casanova, Cesar; Souza de Carvalho, Ricardo; Chaverri, Diego; Castillo-Retamal, Marcelo

Six-Minute Walk Test: Oxygen Uptake and Distance Predicted
MHSalud, vol. 19, núm. 2, 2022
Universidad Nacional, Costa Rica
Disponible en: https://www.redalyc.org/articulo.oa?id=237070375014
DOI: https://doi.org/10.15359/mhs.19-2.11

Six-Minute Walk Test: Oxygen Uptake and Distance Predicted

Prueba de Caminata de Seis Minutos: Consumo de Oxígeno y Distancia Predicha

Teste de caminhada de seis minutos: consumo de oxigênio e distância prevista

Jaime Vásquez-Gómez
Universidad Católica del Maule, Chile
jvasquez@ucm.cl
https://orcid.org/0000-0003-0597-793X

Cesar Faundez-Casanova
Universidad Católica del Maule, Chile
cfaundez@ucm.cl
https://orcid.org/0000-0003-4501-4169

Ricardo Souza de Carvalho
Universidad Católica del Maule, Chile
rsouza@ucm.cl
https://orcid.org/0000-0003-1715-9213

Diego Chaverri
Universitat de Barcelona, España
dchaverri@gencat.cat
https://orcid.org/0000-0003-1885-2677

Marcelo Castillo-Retamal
Universidad Católica del Maule, Chile
mcastillo@ucm.cl
https://orcid.org/0000-0002-7482-1165

DOI: https://doi.org/10.15359/mhs.19-2.11
Redalyc: https://www.redalyc.org/articulo.oa?id=237070375014

Recepción: 20 Abril 2021
Aprobación: 05 Mayo 2022

Abstract:

Background: Maximum oxygen consumption is an indicator of cardiorespiratory fitness. **Aim:** The purpose was, first, to relate and compare the VO_2max as the dependent variable with the estimated distance in the six-minute walk test (SMWT) as the independent variable in university students and, secondly, to relate the distance (dependent) with demographic and anthropometric variables (independents). **Methodology:** A correlational, descriptive, and quantitative study with a non-experimental design was conducted on 110 university students. In the study, basic anthropometry and vital signs were measured. A direct method of VO_2max (Bruce test) on a treadmill was applied. Then, the distance covered in the SMWT was evaluated with two equations available in the scientific literature. Differences between men and women were measured in the tests, the correlation between the distances estimated with VO_2max and anthropometric variables, and repeated ANOVA measurement tests between VO_2max and estimated distance were analyzed with the SPSS v.22 program ($p<0.05$). **Results:** Significant correlations were found between VO_2max and estimated distances ($p<0.05$) in the total sample, men and women, and in some cases, the distance correlated with gender, age, weight, height, and BMI ($p<0.05$). However, there were differences between VO_2max and distances estimated in the SMWT ($p<0.001$). **Conclusions:** The VO_2max measurement method is different from the distance prediction equations, although they have a significant relationship.

Keywords: Oxygen consumption, walking, students.

Resumen:

Antecedentes: El consumo máximo de oxígeno es un indicador de la aptitud cardiorrespiratoria. **Objetivo:** El objetivo fue relacionar y comparar el VO_2máx. como variable dependiente con la distancia estimada en la prueba de caminata de seis minutos (PC6M) como variable independiente en estudiantes universitarios, a la vez relacionar la distancia (dependiente) con variables demográficas y antropométricas (independientes). **Metodología:** Estudio cuantitativo, no experimental, transversal, y descriptivo-correlacional en el que participaron 110 estudiantes universitarios. Se midió antropometría básica y signos vitales, y se aplicó un método directo de VO_2máx. (Test de Bruce) en cinta rodante, luego se estimó la distancia recorrida en PC6M con dos ecuaciones disponibles en la literatura. Diferencias entre hombres y mujeres en las pruebas aplicadas, correlación entre las distancias estimadas con el VO_2máx. y variables antropométricas, y la prueba de ANOVA de medidas repetidas entre el VO_2máx. y las distancias estimadas fueron utilizadas con el programa SPSS v.22 (p<0,05). **Resultados:** Se encontró correlaciones significativas entre el VO_2máx. y distancias estimadas (p<0,05) en la muestra, en hombres y mujeres, y en algunos casos la distancia se correlacionó con el sexo, la edad, el peso, la estatura y el IMC (p<0,05). Sin embargo, hubo diferencias entre el VO_2máx. y las distancias estimadas en la PC6M (p<0,001). **Conclusiones:** El método directo de VO_2máx. es distinto de las ecuaciones de predicción de distancia, aunque tienen relación significativa.

Palabras clave: Consumo de oxígeno, caminata, estudiante.

Resumo:

Antecedentes: O consumo máximo de oxigênio é um indicador de aptidão cardiorrespiratória. **Objetivo:** O objetivo é relacionar e comparar a VO_2 máx. como variável dependente com a distância estimada no teste de caminhada de seis minutos (TC6M) como uma variável independente em estudantes universitários, ao mesmo tempo, relacionar a distância (dependente) com variáveis demográficas e antropométricas (independente). **Metodologia:** Estudo quantitativo, não-experimental, transversal, descritivo-correlativo, no qual participaram 110 estudantes universitários. Antropometria básica e sinais vitais foram medidos, e um método direto de VO_2 máx. (teste Bruce) foi aplicado na esteira, então a distância coberta em TC6M foi estimada com duas equações disponíveis na literatura. Diferenças entre homens e mulheres nos testes aplicados, correlação entre distâncias estimadas com VO_2 máx. e variáveis antropométricas, e medidas repetidas teste ANOVA entre VO_2 máx. e distâncias estimadas foram usadas com SPSS v.22 (p<0,05). **Resultados**: Foram encontradas correlações significativas entre VO_2 máx. e distâncias estimadas (p<0,05) na amostra, em homens e mulheres, e em alguns casos a distância correlacionada com sexo, idade, peso, altura e IMC (p<0,05). Entretanto, houve diferenças entre VO_2 máx. e distâncias estimadas em TC6M (p<0,001). **Conclusões:** O método direto de VO_2 máx. é diferente das equações de previsão de distância, embora elas tenham relações significativas.

Palavras-chave: Consumo de oxigênio, caminhada, estudante.

Introduction

Oxygen consumption has a close relationship with aerobic-type exercise. In the face of a continued effort at a moderate and constant intensity, first, the anaerobic reserves are activated resynthesize ATP in a phase of oxygen debt; then, when the cardiopulmonary system finishes starting up, the contribution of O_2 is preponderant in the energy production, achieving a stable plateau, until the effort gives up (López-Chicharro & Vicente-Campos, 2017). A similar dynamic occurs at the beginning of the exercise in a staggered, progressive effort until exhaustion. Still, this time, as the exercise progresses, the O_2 consumption has a concomitant increase with the intensity (speed, watts, and treadmill inclination, among others) until reaching a point where VO_2 cannot continue to increase despite the increase in intensity itself, achieving a plateau characteristic of having reached VO_2max (Poole & Jones, 2017). In an intermittent dynamic exercise, the behavior of VO_2 is variable. On the one hand, a good cardiopulmonary capacity serves to withstand the duration of the effort (interval methods, HIIT, Split, etc.) and, on the other hand, to recover between high-intensity efforts that occur relatively frequently (Béres et al., 2021).

The most influential variables on VO_2max development are essentially those non-modifiable, such as gender or chronological age (Reyes & Soto, 2021), and those modifiable associated with lifestyle, such as physical activity practice, body composition, and smoking (Vásquez-Gómez et al., 2020). Thus, cardiorespiratory fitness has been considered a strong predictor of health and functionality (Mänttäri et al., 2018), and oxygen consumption is listed as the best indicator of this capacity (Costa et al., 2017). The evaluation can be done in laboratory ergometers, but this requires equipment of high economic cost and trained personnel to use and interpret the information. Another way to perform it is by using field tests, one of which is the SMWT (Costa et al., 2017), in which the distance traveled has been used to assess functional capacity and even morbidity and mortality (Britto et al., 2013). The applied test has been useful in healthy (Mänttäri et al., 2018) people and those with pathologies (Chetta et al., 2006).

To evaluate cardiorespiratory fitness in the SMWT was used the distance an individual can cover.. The distance covered was associated with variables such as age, gender, BMI, height, and heart rate (HR) (Britto et al., 2013; Chetta et al., 2006; Mänttäri et al., 2018). These variables correspond to the characteristics of the evaluated group and, therefore, in a specific context. Hence, the importance of generating instances of evaluations that are transferable from the laboratory to the practice field and are an alternative tool for professionals of physical activity and sports. Given this, the aim was to relate and compare the objective measurement of VO_2max as the dependent variable, with two prediction formulas of the distance traveled in SMWT, as the independent variables and, at the same time, to relate the distance (dependent variable) with basic demographic and anthropometric variables (independent) in university students of both genders.

Methodology

Participants

This was a correlational, descriptive, and quantitative study with a non-experimental cross-sectional design. The study was disseminated in the university community (library, virtual social networks, face-to-face courses) to attract students from various academic programs and all University semesters of day shift (not including Physical Education students). A non-probabilistic by convenience sample was used, and participants had to meet the following inclusion criteria: not having injuries, not performing a strenuous physical exercise the day before, not consuming substances that alter the HR and the body, and not consuming heavy meals prior to the evaluation. The final sample was of 110 students (51% women) means 21.9 ± 2.1 years old and BMI of 24.3 ± 3.1 kg/m^2, after giving their written consent (Scientific Ethics Committee, Universidad Católica del Maule, Talca, Chile, n° 17/2018).

Instruments and Procedures

The data of interest were collected in the same session. Blood pressure, HR (OMRON model BP760 series 7, Japan), and oxygen saturation at rest (Carewell model F1 oximeter, China) were recorded. Body weight and height were also recorded (DETECTO model 3P7044 capacity 140 kg, USA). Subsequently, the Bruce graduated exercise test (GXT) was applied, in which the intensity increased every three minutes based on the speed and inclination. The starting speed was 2.7 km/h to increase to 4, 5.4, 6.7, 8, 8.8 y 9.6 km/h and with a slope of 10, 12, 14, 16, 18, 20 y 22° on a treadmill, at each stage of 3 minutes, respectively. This test was applied on a motorized treadmill (3.3 kW) model h/p/cosmos mercury® (Germany). To do this, the participant had to wear comfortable sports clothing (sneakers, shorts, and a t-shirt, generally), a heart-rate monitor attached to the chest was installed, and a gas exchange analyzer was mounted. The analyzer had a mask covering the mouth and nose; it also had cells sensitive to O_2 and CO_2, a thermostat sensitive to temperature, and a turbine sensitive to air flows. The mask was fixed to the head with adjustable straps. The CORTEX ergospirometer model MetaLyzer® 3B (Germany) reported the data in real time, breath by breath, and was used to determine the VO_2max, under the following criteria: respiratory exchange ratio (RER) ≥1.11 (Hamlin et al., 2012; Web et al., 2014), an HR ≤ 10 beats$\cdot$min^{-1} or ≤ 5% in respects to the maximum estimated (220-age) (Poole & Jones, 2017). The RPE was also recorded at the end (Borg & Kaijser, 2006).

Then, aerobic endurance was estimated through the distance covered in SMWT with the equation by Britto et al. (2013) and Chetta et al. (2006). During the test, an individual has to cover distances as far as possible in six minutes. These equations were chosen due to the choice of the sample and its statistical analysis. The Britto et al. equation (2013) included healthy men and women. The independent variables of age, gender, BMI, and Δ HR were significantly related to the distance performed in the SMWT (r = 0.4 to 0.55; p<0.0001). A quadratic regression model showed that these variables, except Δ HR, explained 46% of the variability of the distance covered (R2 = 0.46; p<0.0001). The Chetta et al. equation (2006) also considered healthy men and women. The independent variables of age and height were significantly related to the distance covered in the SMWT (r = - 0.42 and 0.46; p<0.001) so that the regression model explained 42% of the variability of the distance performed ($R^2 = 0.42$; p≤0.05). Therefore, the formulas used to predict the theoretical distance were the following:

SMWT = 890.46 – (6.11 × age) + (0.0345 × age^2) + (48.87 × gender) – (4.87 × BMI) where male gender = 1, and female gender = 0 (Britto et al., 2013).

SMWT = 518.853 + (1.25 × height) - (2.816 × age) - (39.07 × gender) where height was in cm, and male gender = 0, and female gender = 1 (Chetta et al., 2006).

Statistical Analysis

The data were analyzed on average values and standard deviation. Normality was checked with the Kolmogorov-Smirnov test. The data between men and women were compared with the Student-T test or Mann-Whitney U test. The Pearson and Spearman test was used to evaluate the relationship between the different variables. On the one hand, the VO_2max was a dependent variable, and SMWT´s predicted distance was independent; on the other hand, SMWT's predicted distance was a dependent variable, and age, BMI, height, and weight were independents ones. The repeated ANOVA measurement tests were used to compare the VO_2max and the distances in SMWT, followed by the Tukey post hoc test. The SPSS v.22 program was used, and statistical significance was assumed when p<0.05.

Results

There were differences between men and women in VO_2max and in the distance calculated in SMWT; those were higher in men (Table 1).

The correlation of VO_2max of GXT, with the distance estimated in SMWT of both equations (Britto et al., 2013; Chetta et al., 2006) were significant in women (r = 0.535 [95% CI: 0.33; 0.68], p<0.001 and r = 0.268 [95% CI: 0.03; 0.46], p=0.046) and in men (r = 0.491 [95% CI: 0.29; 0.67], p<0.001 and r = 0.424 [95% CI: 0.21; 0.61], p=0.001), respectively. The estimated distance (Britto et al., 2013) was related to age, BMI, and height (r = -0.524 [95% CI: -0.07; -0.29]; -0.921 [95% CI: -0.95; -0.87]; -0.799 [95% CI: -0.88; -0.66], all p<0.001) in women, and age, BMI, and weight (r = -0.769 [95% CI: -0.88; -0.61]; -0.867 [95% CI: -0.91; -0.81]; -0.761 [95% CI: -0.85; -0.63], all p<0.001) in men. While in the other equation (Chetta et al., 2006) age, height and weight (r = -0.557 [95% CI: -0.74; -0.34]; 0.85 [95% CI: 0.76; 0.92], both p<0.001; r = 0.326 [95% CI: 0.15; 0.51], p=0.014) in women, and in men, age, BMI, and height (-0.646 [95% CI: -0.78; -0.43]; -0.386 [95% CI: -0.58; -0.18]; 0.722 [95% CI: 0.55; 0.84], all p<0.001) were correlated with the distance. Apparently, the distance (Chetta et al., 2006) underestimates and overestimates VO_2max, while BMI (Britto et al., 2013), weight, and height (Chetta et al., 2006) do so with distance (Figure 1) in women and men, respectively.

There were significant differences between the three methods [F (2, 327) = 22561.1; p<0.001)], when comparing the VO_2max with the estimated distance in both equations (Britto et al., 2013; Chetta et al., 2006), and also between these two methods (p<0.001). Similarly, it occurred in men [F (2, 159) = 36995.1; p<0.001)] and in women [F (2, 165) = 43679.4; p<0.001)].

TABLE 1.
Sample Characteristics, VO_2max, and predict distance covered.

Variables	Total (n=110)				Male (n=54)				Female (n=56)				p-value[a]
	Mean	Median	SD	IR	Mean	Median	SD	IR	Mean	Median	SD	IR	
Age (years)	21.9	21.6	2.1	2.3	22	21.8	2.5	2.7	21.8	21.5	1.6	2.1	0.606[b]
Weight (kg)	67.2	66.1	10.9	13.9	72.7	71.8	9.5	13.4	61.9	61.9	9.4	15.4	<0.001[b]
Height (m)	1.66	1.66	0.09	0.15	1.73	1.74	0.06	0.08	1.6	1.59	0.06	0.09	<0.001[b]
BMI (kg·m^{-2})	24.3	24	3.1	3.9	24.3	23.8	3	3.8	24.2	24.1	3.3	4.6	0.93[b]
SBP rest (mmHg)	116.1	113.5	14.1	16	123.1	122	12.4	18	109.4	110	12.3	14	<0.001[b]
DBP rest (mmHg)	71.3	71	9.7	11	71.6	71	8.8	11	71	71.5	10.5	12	0.735[b]
HR rest (beats·min^{-1})	75.4	75	10.7	15	72	74	9	13	78	78	11	15	0.002[b]
Saturation O_2 rest (%)	98.4	99	2.1	0	98.6	99	1.1	0	98.2	99	2.8	0	0.771[c]
GXT													
VO_2max (ml·kg·min^{-1})	40.1	40.1	7.9	10.1	44.7	44	7	9.6	35.7	35.8	6	8.9	<0.001[b]
VO_2max (L·min^{-1})	2.7	2.6	0.7	1.2	3.2	3.3	0.5	0.7	2.2	2.1	0.4	0.6	<0.001[b]
HR (beats·min^{-1})	193	193	8	10	195.2	194.5	7.5	12	191.2	193	8.4	9	0.01[b]
HR (%)	97.5	97.7	4.1	4.3	98.6	98.2	3.7	5.7	96.5	97.1	4.1	3.6	0.006[b]
RER	1.19	1.19	0.06	0.05	1.20	1.2	0.05	0.04	1.17	1.18	0.06	0.06	0.01[c]
RPE	16	15	2	2	16	15.5	2	3	16	15	2	2	0.829[c]
SMWT (Britto *et al.*, 2013), distance (m)	679.4	676.5	31.2	51	703.7	708	21.2	28	655.9	658.5	18.7	23	<0.001[b]
SMWT (Chetta *et al.*, 2006), distance (m)	645.3	637.5	29.3	55	673.4	673.5	10.3	11	618.3	618.5	8.8	12	<0.001[b]

Note. [a]differences between male and female; [b]Student-T test; BMI: body mass index; [c]U Mann-Whitney test; DBP: diastolic blood pressure; HR: heart rate; IR: interquartile range; RER: respiratory exchange ratio; RPE: rating of perceived exertion; SBP: systolic blood pressure; *SD*: standard deviation; SMWT: Six-Minute Walk Test.

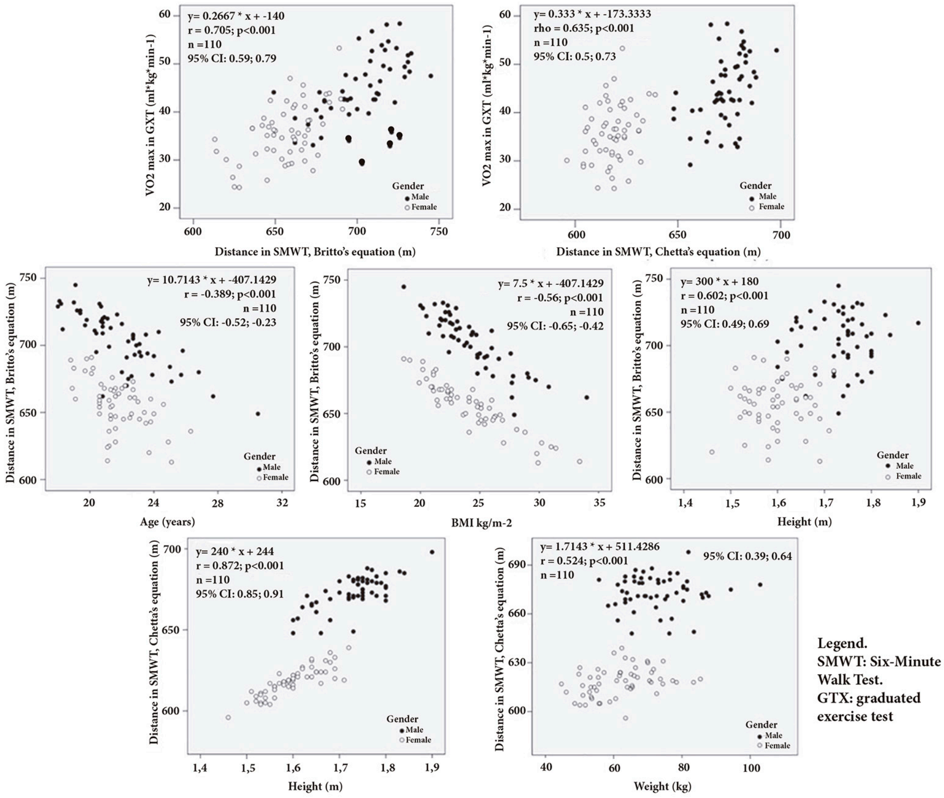

FIGURE 1.
Relationship between the distance in SMWT and VO_2max, age, and anthropometric variables

Discussion

When it comes to comparing different methods of evaluating aerobic resistance, some studies propose equations to evaluate the performance. The SMWT generally measured the distance traveled (Fleg et al., 2000; Harmsen et al., 2016), which has shown to correlate with the VO_2max (Harmsen et al., 2016) and, in some cases, this relationship (VO_2 – distance) has been studied in healthy individuals (Andersson et al., 2011; Andersson & Nilsson , 2011; Hill et al., 2011; Limsuwan et al., 2010; Ma et al., 2009). These findings are in line with the research conducted by the authors of this paper and reinforce their postulates.

The authors found an association between performance in the SMWT and the prediction of VO_2max in healthy people, in which distance traveled along with age, BMI, height, and HR accounted for 82% of the variation of VO_2max in men, and 79% in women, including weight, age, and distance for them (Mänttäri et al., 2018). Thus, the authors elaborated prediction equations of VO_2max for the SMWT. It has even been studied in people with heart disease, where gender, age, BMI, functionality status, and distance traveled in the SMWT were significantly related to the peak VO_2 estimated on a treadmill, giving way to an equation to predict this variable of interest, and there was no significant difference between the VO_2 observed and that estimated through the formula (Costa et al., 2017). Also, the SMWT has been used to relate to cardiopulmonary capacity in people with cerebrovascular (Pang et al., 2005) and pulmonary pathologies (Oudiz et al., 2006; Tueller et al., 2010; Zapico et al., 2016).

During the last decade, some studies have associated the distance covered in the SMWT with demographic variables and anthropometric characteristics. Osses et al. (2010) found significant correlations between distance and age, weight, and height in young adult subjects. Also, in young subjects, significant relationships have been found with body weight, height, and age, where the latter two explained the variability of the distance performed by 25% (Alameri et al., 2009). Finally, Dourado (2011) reports a series of studies in which the SMWT distance has various significant and non-significant correlations with age, height, weight, and BMI. These data do nothing more than confirm and support the associations found between the variables of interest (dependent and independent). Therefore, the measurements of the demographic variables and anthropometric characteristics must be evaluated and taken into account to develop predictive models.

The relevant element of the cited research is that it has shown correlations between the dependent variables (VO_2 and distance) and the corporal, demographic, and physiological characteristics, and health state, which makes the SMWT applicable in a real context of each group of people. In this research, there were significant correlations between the VO_2max and the distance predicted in the SMWT, which agrees with the comparative evidence; the correlations also indicated that this variable could be an indicator of cardiopulmonary capacity.

The main finding of this study is that the VO_2max was significantly different from the aerobic resistance expressed in the distance calculated in SMWT. As already mentioned in this discussion, some studies have shown that VO_2max has had a relationship with the distance performed in the SMWT; in turn, the distance covered has been associated with variables such as age, height, body weight, and BMI. Given these interactions, it can be inferred that the three methods used in this study (direct measurement of VO_2max and the two equations to estimate the theoretical distance in SMWT) can have a statistical association since, in practice, cardiorespiratory fitness activates the capacities functions of the cardiopulmonary and vascular system and involves large muscle groups (Gomes et al., 2018), characteristic aspects of the tests we investigate. However, there are contradictory findings regarding these results since, on the one hand, some reports in the literature state that there have been no significant differences between the objective measurement of VO_2max and prediction equations derived from the submaximal test (Song et al., 2019), and, between VO_2max and its prediction from a walk test (Lima et al., 2019). On the other hand, there have been differences between the measurement and estimation of VO_2max with the direct and indirect method, respectively (Bandyopadhyay & Pal, 2015).

The main strength of this research was that VO_2max was measured through an objective, direct, reliable, and valid method, using a gold standard such as ergospirometry. Another strength was the number of participants evaluated, considering other investigations that have worked with samples of 75 (Mänttäri et al., 2018), 81 (Costa et al., 2017), and 617 (Britto et al., 2013) people. At the same time, as a projection of this research, we intend to carry out the SMWT validation process as a predictor of VO_2max, as suggested by some studies (Britto et al., 2013; Mänttäri et al., 2018). On the other hand, a potential limitation was to use an indirect and theoretical method to predict the distance traveled in the SMWT. It was a potential limitation since this way of evaluating was raised within the objective of the research.

Conclusion

The GXT method of measuring VO_2max had low and moderate but significant correlations, with the equations of distance prediction in SMWT, for the total sample and separated by gender. In some cases, he distance predicted with both methods was significantly related to age, weight, height, and BMI. On the other hand, the VO_2max was significantly different from the two methods of distance prediction, both in the total sample and for each gender.

Future Recommendations and Practical Scopes

It is pertinent to elaborate a predictive model of either the VO_2max or the distance performed in the SMWT, both in the women and university men evaluated, or for the total sample that includes the gender variable in the said model. Because of that, an easy-to-apply and less-effort test would better represent the performance of students' daily life activities.

Acknowledgments:

To all university students who participated in the study.

Funding:

This research received no external funding.

Author contributions:

Conceptualization, J.V.G. (leaded), M.C.R. (equal) and C.F.C. (support); Methodology, J.V.G. (leaded), D.C. (equal) and M.C.R. (support); Formal analysis, J.V.G. (leaded), D.C. (equal) and C.F.C. (equal); Investigation, J.V.G. (leaded), R.S.C. (support), C.F.C. (equal) and M.C.R. (equal); Resources, J.V.G. (leaded), M.C.R. (support), R.S.C. (support) and C.F.C. (support); Data curation, J.V.G. (leaded), D.C. (equal) and C.F.C. (equal); Writing - original draft preparation, J.V.G. (leaded), R.S.C. (equal), D.C. (equal), C.F.C. (equal) and M.C.R. (equal); Writing - review and editing, J.V.G. (leaded), R.S.C. (equal), D.C. (equal), C.F.C. (equal) and M.C.R. (equal); Supervision, J.V.G. (leaded), C.F.C. (equal), R.S.C. (support) and M.C.R. (support); Project administration, J.V.G. All authors have read and agreed to the published version of the manuscript.

References

Alameri, H., Al-Majed, S. & Al-Howaikan, A. (2009). Six-min walk test in a healthy adult Arab population. *Respiratory Medicine, 103*(7), 1041-1046. https://doi.org/10.1016/j.rmed.2009.01.012

Andersson, E. & Nilsson, J. (2011). Can a six-minute shuttle walk test predict maximal oxygen uptake? *Gazzetta Medica Italiana, 170*(3), 163-170.

Andersson, E., Lundahl, G., Wecke, L., Lindblom, I., & Nilsson, J. (2011). Maximal aerobic power versus performance in two aerobic endurance tests among young and old adults. *Gerontology, 57*(6), 502-512. https://doi.org/10.1159/000329174

Bandyopadhyay, A. & Pal, S. (2015). Modification of Fox protocol for prediction of maximum oxygen uptake in male university students. *Work, 50*(2), 205-211. https://doi.org/10.3233/WOR-141824

Béres, B., Györe, I., Petridis, L., Utczás, K., Kalabiska, I., Pálinkás, G. & Szabó, T. (2021). Relationship between biological age, body dimensions and cardiorespiratory performance in young soccer players. *Acta Gymnica, 51*, e2021. https://doi.org/10.5507/ag.2021.001

Borg, G. A. V. & Kaijser, L. (2006). A comparison between three rating scales for perceived exertion and two different work tests. *Scandinavian Journal of Medicine & Science in Sports, 16*(1), 57-69. https://doi.org/10.1111/j.1600-0838.2005.00448.x

Britto, R. R., Probst, V. S., Andrade, A. F., Samora, G. A., Hernandes, N. A., Marinho, P., Karsten, M., Pitta, G. & Parreira, V. F. (2013). Reference equations for the six-minute walk distance based on a Brazilian multicenter study. *Brazilian Journal of Physical Therapy, 17*(6), 556-563. https://doi.org/10.1590/S1413-35552012005000122

Chetta, A., Zanini, A., Pisi, G., Aiello, M., Tzani, P., Neri, M. & Oliveri, D. (2006). Reference values for the 6-min walk test in healthy subjects 20–50 years old. *Respiratory Medicine, 100*(9), 1573-1578. https://doi.org/10.1016/j.rmed.2006.01.001

Costa, H. S., Lima, M. M. O., Alencar, M. C. N., Sousa, G. R., Figueiredo, P. H. S., Nunes M. C. P., Ribeiro, A. & Rocha, M. O. C. (2017). Prediction of peak oxygen uptake in patients with Chagas heart disease: value of the six-minute walk test. *International Journal of Cardiology, 228*(1), 385-387. https://doi.org/10.1016/j.ijcard.2016.11.259

Dourado, V. Z. (2011). Reference equations for the 6-minute walk test in healthy individuals. *Arquivos Brasileiros de Cardiología, 96*(6), 128-1398. PMID: 21359481.

Fleg, J. L., Piña, I. L., Balady, G. J., Chaitman, B. R., Fletcher, B., Lavie, C., Limacher, M., Stein, R., Williams, M. & Bazzarre, T. (2000). Assessment of functional capacity in clinical and research applications - An advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association. *Circulation, 102*(13), 1591-1597. https://doi.org/10.1161/01.cir.102.13.1591

Gomes, A. L., Mendonça, V. A., Dos Santos Silva, T., Pires, C., Lima, L. P., Silvia, A., Camargos, A., Neves, C., Lacerda, A. & Leite, H. R. (2018). Cardiorespiratory and metabolic responses and reference equation validation to predict peak oxygen uptake for the incremental shuttle waking test in adolescent boys. *PloS One, 13*(11), e0206867. https://doi.org/10.1371/journal.pone.0206867

Hamlin, M., Draper, N., Blackwell, G., Shearman, J., & Kimber, K. (2012). Determination of maximal oxygen uptake using the Bruce or a novel athlete-led protocol in a mixed population. *Journal of Human Kinetics, 31*, 97-104. https://doi.org/10.2478/v10078-012-0010-z

Harmsen, W. J., Ribbers, G. M., Slaman, J., Heijenbrok-Kal, M. H., Khajeh, L., van Kooten, F., Neggers, S. & van den Berg-Emons, R. J. (2016). The six-minute walk test predicts cardiorespiratory fitness in individuals with aneurysmal subarachnoid hemorrhage. *Topics in Stroke Rehabilitation, 24*(4), 250-255. https://doi.org/10.1080/10749357.2016.1260263

Hill, K., Wickerson, L. M., Woon, L. J., Abady, A. H., Overend, T. J., Goldstein, R. S. & Brooks, D. (2011). The 6-min walk test: responses in healthy Canadians aged 45 to 85 years. *Appl Physiology, Nutrition, and Metabolism, 36*(5), 643-649. https://doi.org/10.1139/h11-075

Lima, L. P., Leite, H. R., Matos, M. A., Neves, C., Lage, V., Silva, G., Lopes, G., Chaves, M., Santos, J., Camargos, A., Figueiredo, P., Lacerda, A. & Mendonça, V. A. (2019). Cardiorespiratory fitness assessment and prediction of peak oxygen consumption by incremental shuttle walking test in healthy women. *PloS One, 14*(2), e0211327. https://doi.org/10.1371/journal.pone.0211327

Limsuwan, A., Wongwandee, R. & Khowsathit, P. (2010). Correlation between 6-min walk test and exercise stress test in healthy children. *Acta Paediatrica, 99*(3), 438-441. https://doi.org/10.1111/j.1651-2227.2009.01602.x

López Chicharro, J. & Vicente Campos, D. (2017). *Umbral láctico: bases fisiológicas y aplicación al entrenamiento*. Médica Panamericana.

Ma, M., Lin, Q. & Qin, H. (2009). Correlation between 6-minute walking test and oxygen uptake. *Journal of Clinical Rehabilitative Tissue Engineering Research, 13*(50), 9909-9912.

Mänttäri, A., Suni, J., Sievänen, H., Husu, P., Vähä - Ypyä, H., Valkeinen, H., Tokola, K. & Vasankari, T. (2018). Six - minute walk test: a tool for predicting maximal aerobic power (VO. max) in healthy adults. *Clinical Physiology and Functional Imaging, 38*(6), 1038-1045. https://doi.org/10.1111/cpf.12525

Osses, R., Yáñez, J., Barría, P., Palacios, S., Dreyse, J., Díaz, O. & Lisboa, C. (2010). Prueba de caminata en seis minutos en sujetos chilenos sanos de 20 a 80 años. Revista Médica de Chile, 138(9), 1124-1130. PMID: 21249280. http://dx.doi.org/10.4067/S0034-98872010000900006

Oudiz, R., Barst, R., Hansen, J., Sun, X., Garofano, R., Wu, X., & Wasserman, K. (2006). Cardiopulmonary exercise testing and six-minute walk correlations in pulmonary arterial hypertension. *The American Journal of Cardiology, 97*(1), 123-126. https://doi.org/10.1016/j.amjcard.2005.07.129

Pang, M., Eng J. & Dawson, A. (2005). Relationship between ambulatory capacity and cardiorespiratory fitness in chronic stroke - Influence of stroke-specific impairments. *Chest, 127(*2), 495-501. https://doi.org/10.1378/chest.127.2.495

Poole, D. C. & Jones, A. M. (2017). Measurement of the maximum oxygen uptake VO_2max: VO_2peak is no longer acceptable. *Journal of Applied Physiology, 122*(4), 997-1002. https://doi.org/10.1152/japplphysiol.01063.2016

Reyes Amigo, T. & Soto Sánchez, J. (2021). *Fitness cardiorrespiratorio en la infancia y la adolescencia*. Universidad de Playa Ancha.

Song, J. R., Lee, S. H., Kim, Y. J., Kim, S. J., Park, H., Kim, J. S., Kwak, H. B., Kang, J. E. & Park, D. H. (2019). Assessing agreement of step test equations to estimate VO2 max in Korean male and female youths aged 13-18 years. *Exercise Science, 28*(1), 66-73. https://doi.org/10.15857/ksep.2019.28.1.66

Tueller, C., Kern, L., Azzola, A., Baty, F., Condrau, S., Wiegand, J., Tamm, M. & Brutsche, M. (2010). Six-minute walk test enhanced by mobile telemetric cardiopulmonary monitoring. *Respiration, 80*(5), 410-418. https://doi.org/10.1159/000319834

Vásquez-Gómez, J. A., Garrido-Méndez, A., Matus-Castillo, C., Poblete-Valderrama, F., Díaz-Martínez, X., Concha-Cisternas, Y., Cigarroa, I., Martorell, M., Martínez-Sanguinetti, M., Leiva-Ordoñez, A., Petermann-Rocha, F. & Celis-Morales, C. (2020). Fitness cardiorrespiratorio estimado mediante ecuación y su caracterización sociodemográfica en población chilena: Resultados de la Encuesta Nacional de Salud 2016-2017. *Revista Médica de Chile, 148*(12), 1750–1758. https://doi.org/10.4067/S0034-98872020001201750

Web, C., Vehrs, P., George, J., & Hager, R. (2014). Estimating VO_2max using a personalized step test. *Measurement in Physical Education and Exercise Science, 18*(3), 184-97.

Zapico, A., Fuentes, D., Rojo-Tirado, M., Calderón, F., Rosenzweig, E., & Garofano, R. (2016). Predicting peak oxygen uptake from the 6-minute walk test in patients with pulmonary hypertension. *Journal of Cardiopulmonary Rehabilitation and Prevention, 36*(3), 203-208. https://doi.org/10.1097/HCR.0000000000000174