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Original Article

A SIX-MINUTE WALKING TEST: MAXIMUM OXYGEN CONSUMPTION IN PHYSICAL EDUCATION STUDENTS

TESTE DE CAMINHADA DE SEIS MINUTOS: O CONSUMO MÁXIMO DE OXIGÊNIO EM ESTUDANTES DE EDUCAÇÃO FÍSICA

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RESUMO
O teste de caminhada de seis minutos (SMWT) foi concluído em poucas ocasiões em indivíduos jovens aparentemente saudáveis e estudantes universitarios, enquanto que a predição máxima do consumo de oxigênio (VO_{2max}) não foi tomada em consideração. O objetivo deste estudo foi elaborar uma equação de predição para VO_{2max} a partir da recuperação da freqüência cardíaca (HRR) após a realização do SMWT. 127 jovens na primeira etapa completaram o SMWT eo Course Navette Test (CNT), 17 na segunda etapa (teste-reteste) completaram o SMWT e CNT, e 20 sujeitos na terceira etapa completaram o teste SMWT e Bruce test. Todos os estudantes de educação física (PES) completam o consentimento informado. Observou-se uma correlação significativa entre o $VO_{2máx}$ estimado pela CNT e a HRR após o SMWT (rho= -0,3; p= 0,001). A correlação entre as mesmas variáveis foi r= -0,72 (p= 0,001) na segunda etapa e observou-se uma correlação significativa (r= -0,65; p= 0,002) entre VO_{2max} medido diretamente no teste de Bruce e HRR após o SMWT. A partir da correlação foi elaborada uma equação de predição de y= 92,468-0,278*20-segundo-HRR) eo erro padrão de estimação (SEE) foi de 7,17 $ml \cdot kg^{-1} \cdot min^{-1}$. O HRR conseguido após o SMWT pode predizer VO_{2max} no PES.
Paravras-chave: Frequência cardíaca. Consumo de oxigênio. Teste de exercício. Coeficiente de correlação

ABSTRACT
The Six-Minute Walking Test (SMWT) was completed just in few times in apparently healthy young individuals and university students, while the maximal volume of oxygen consumption (VO_{2max}) prediction has not been taken into consideration. The aim of this study was to elaborate a prediction equation for VO_{2max} from the heart rate recovery (HRR) after completion the SMWT. 127 young in the first stage completed the SMWT and Course Navette Test (CNT), 17 in the second stage (test-retest) completed the SMWT and CNT, and 20 subjects in the third stage completed the SMWT and Bruce test. All physical education students (PES) completions an informed consent. A significant correlation was observed between VO_{2max} estimated trough the CNT and HRR after the SMWT (rho= -0.3; p= 0.001). The correlation between the same variables was r= -0.72 (p= 0.001) in the second stage, and a significant correlation (r= -0.65; p= 0.002) was observed between VO_{2max} directly measured in Bruce test and HRR after the SMWT. From the correlation a prediction equation was elaborated is *y*= 92.468–(0.278*20-second-HRR) and the standard error of estimation (SEE) was 7.17 $ml \cdot kg^{-1} \cdot min^{-1}$. The HRR achieved after the SMWT may predict VO_{2max} in PES.
Keywords: Heart rate. Oxygen consumption. Exercise test. Correlation coefficient.

Introduction

The VO_{2max} is quite a significant parameter for both health and fitness, as well as for quality of life[1]. However, its measuring has been complex, which in turn requires highly qualified personnel and brings about great economic costs. Heart rate (HR) performance[2] has become a non-invasive method to measure strength intensity as the living organism response when doing physical exercise. This has proved to be closely related to the VO_{2max}[3]. It has been found out that prediction the VO_{2max} has been done based on the HR and the rating of perceived exertion (RPE) under submaximal exercise. Tracking field tests get better

integrated to people's daily dynamics, in fact more than the submaximal tests that are carried out on steps or cycle-ergometers[4].

The SMWT it has usually been applied in clinic applications[5,6] and just in few times in the case of apparently healthy young individuals[7] and one study reports the distance covered in university students[8]. This test has been carried out with 20 to 80-year-old Chilean individuals. By doing so, distance that had been covered, age, mass and height were all connected. In addition to this, oxygen saturation, HR and RPE were all measured both at the beginning and at the end of the test[9]. With regards to this walking test, distance to be covered, age, sex and anthropometric variables have usually been assessed[6], while the VO_{2max} prediction has not been taken into consideration.

Therefore, the objective of this research work was determine the relation between the heart rate recovery (HRR) of the SMWT and the VO_{2max} of the CNT, determine the reliability of the variables and to make an equation aiming at assessing the VO_{2max} as of the HRR that was obtained in the SMWT, in physical education students. The distance covered during the SMWT and the body mass had been correlated with VO_2 in a cardiopulmonary test, however, predictive equations in healthy subjects, such as PES, are lacking[10,11]. On the contrary, the relation between the SMWT and VO_2, and prediction formulas, have been already stablished in previous studies in elderly[12-14]. Thus, to help young people to stay healthy, regular assessments through submaximal testing (avoiding risk from maximal test), a prediction equation through the SMWT might be of value.

It is expected to find a high correlation between the post SMWT HRR and the VO_{2max} that had been obtained in a criteria-based test and, therefore, the equation to be derived from this should predict the VO_{2max}. Several studies had relate VO_2 only with the distance in the SMWT, founding low-medium relationship[15] or high[16], and others elaborated equations to predict distance[17]. However, scares studies had elaborate equations to predict VO_{2max} without consideration of HR[18]. Moreover, to our knowledge, prediction of VO_{2max} through the SMWT had never been performed in Chilean colleague subjects. The ability to perform the test, at submaximal intensity, and knowing their total time in the test, might be considered some strengths to perform such prediction in this population.

Methods

Participants

Those subjects or individuals who took part in the research work were both male and female PES, where the non-probabilistic sample was made up by 127 students in the first stage (22.8±2.2 years, 71.8±11.7 weight, kg; 1.71±0.05 height, m; 24.8±3 BMI, kg/m^2), 17 in the second stage (20.0±1.9 years, 70.4±12.1 weight, kg; 1.71±0.07 height, m; 23.9±2.7 BMI, kg/m^2) and 20 in the third work (22.4±1.8 years, 67.8±11.4 weight, kg; 1.66±0.06 height, m; 24.3±2.9 BMI, kg/m^2). Included participants were i) physical education students, ii) be apparently healthy (after PAR-Q administration), iii) free of orthopedic and cardiopulmonary disease.

Students completed the PAR-Q physical fitness questionnaire in the first stage, completed the PAR-Q, signed a reported consent were given an information document in the second stage. Finally, in the third stage, the students completed PAR-Q and signed a reported consent backed up by a scientific ethics committee of the San Sebastian University (approval number 01-2015-20) and were given an information document where they were told about the research work characteristics, physical exercise limitations, etc.

For to elaborate the prediction equation of VO_{2max}, the following were the criteria to choose the participants: having taking part in the first stage and/or in the second stage

(feasibility); participants were asked to i) avoid intense physical exercise, alcohol consumption or other substances that may alter heart rate 48 hours before testing, ii) to be well hydrated and to consume a meal rich in carbohydrate 2-3 hours before testing to avoid hypoglycemia and dehydration during testing. These requests was verified 15 minutes before testing, while subjects rested.

Procedures

In the first stage two measuring were carried out- SMWT and CNT (one session). Then, in the test-retest, three measuring on three days after least 72 hours passed; two measuring were carried out- SMWT and CNT, each day. In the third stage, two measuring sessions were carried out- SMWT was applied in the first one, where the distance to be covered, the RPE and the HRR were measured. After at least 72 hours had passed, a second session was held where height and body-mass were first specified, to further get the VO_{2max} measured by means of the Bruce test. HRR that had been obtained from the SMWT was matched with the VO_{2max} from the Bruce one, to further have a VO_{2max} prediction equation made.

SMWT[5] was applied in a gym over a 30-meter hallway that had been marked every 3 meters and where participants were asked to walk as much as possible by being orally stimulated every minute. The HR was measured during the test and when completing it, as well as the HRR by means of a Polar V800 monitor (Polar Electro, Finland); the latter was recorded in a bipedal position and in a stationary manner every 10 seconds until completing 3 minutes recovery. Besides, both the distance that was covered and the RPE were recorded. After a 5-minute-passive recovery, the CNT was applied, where a participant was asked to complete as many stages as possible and bringing the test to an end since he/she had failed to reach the 20-meter line two successive times, and where the HR should have been above 90% of the maximum[19] by the time the test was completed. Test initial speed was 8 $km \cdot h^{-1}$ with 0.5 $km \cdot h^{-1}$ increases after every phase.

The Bruce test[20] was applied in a SportArt model T652M treadmill (Industrial Co. Ltd., U.S.A.). Gestural signals were standardized in this test with the purpose of knowing individuals' exhaustion degree during the test that was performed on an 8-phase-basis and 3 minutes lasting, its speed ranging from 2.7 up to 10.9 $km \cdot h^{-1}$, and a 5.7 to 13.7 tilt grades. HR was measured during the last minute while recordings were taken every 15 seconds. RPE was registered at the end of the strength. VO_{2max} was measured by using the Fitmate PRO (Cosmed, Rome – Italy) unit, which is a metabolic analyzer that measures the oxygen that has been used up. It is furnished with a flow turbine that measures ventilation and a galvanized oxygen cell. In the case of aerobic performance recording, Fitmate v. 2.3 build 13 software was applied, which is compatible with the Cosmed Fitmate PRO unit. The Fitmate PRO unit was validated in earlier research works[21,22]. The following were the criteria used in order to define the VO_{2max}: increase in getting VO_2 lower than 100 $ml \cdot min^{-1}$ [23,24] and reaching a HR above 90% of the maximum[19], in turn to be assessed based on age.

Statistical Analysis

The statistical analysis was done by using the SPSS version 19.0 program (International Business Machines – IBM, New York, United States). In the case of descriptive data analysis, average values and standard deviations were applied; in turn, the Kolmogórov-Smirnov and Shapiro-Wilk was used for the inferential type in order to establish data normal distribution in the first and, second and third stage, respectively. ANOVA for repeated measures analysis was used to reproducibility for second stage. The Spearman (first stage) and Pearson, second and third stage, correlation was used to relate the SMWT HRR with the

VO_{2max} of the CNT and Bruce test (significance degree was set in $p<0.05$). Finally, Bland-Altman approach for limit of agreement in the third stage.

Results

A significant relationship was found between SMWR HRR and VO_{2max} in all stages. In the first stage, r =-0.3 (p=0.001) was obtained (with 15-second HRR); in the second stage, r=-0.72 (p=0.001) was obtained (with 15-second HRR) and there were no significant differences between the three measurements for absolute values the HRR post SMWT and the VO_{2max} of the CNT, described in Table 1 and Table 2.

Table 1. Stage two (test-retest): SMWT

Variable	Measure 1	Measure 2	Measure 3	ANOVA	Tukey
n	17	17	13		
Distance, m	701.5±36.2	710.3±33.6	718.1±27.7	*F*(2. 44)=0.93	0.401
RPE, 6-20	10.6±1.7	10.7±1.1	10.2±1.4	*F*(2. 44)=0.44	0.643
HR finished, b/m	130.4±22.7	140.5±23.3	127.7±23	*F*(2. 44)=1.33	0.273
HRR b/m, 0:15	122±22.4	132.4±22.6	120.2±20.8	*F*(2. 44)=1.41	0.253
HRR b/m, 0:30	110.7±22.8	122.3±21.9	109.4±20.5	*F*(2. 44)=1.67	0.199

Legend. b/m:beats·min^{-1}; ns: not significant differences
Source: The authors

Table 2. Stage two (test-retest): CNT

Variable	Measure 1	Measure 2	Measure 3	ANOVA	Tukey
n	17	17	13		
VO_{2max}, $ml{\cdot}kg^{-1}{\cdot}min^{-1}$	44.6±5.4	44.4±4.9	43.4±4.1	*F*(2. 44)=0.22	0.798
RPE, 6-20	14±2.2	14.1±2	14.4±1.7	*F*(2. 43)=0.11	0.891
HR finished, $beats{\cdot}min^{-1}$	194.6±10.7	193±12.4	187.1±9.4	*F*(2. 44)=1.81	0.176

Legend. ns: not significant differences
Source: The authors

A meaningful relation was found between SMWT HRR recorded after 20 seconds and VO_{2max} to be measured by Bruce test (r=- 0.657; p=0.002), thus being able to make an equation that predicts it. The achieved correlations are featured to be negative, which means that the lower the HRR, the greater the VO_{2max}. Table 3 shows yield in physical exercise tests.

The equation to assess the VO_{2max} reads as follows: y=92.468–(0.278*20-second-HRR), where y=VO_{2max} and 20 seconds HRR is the HR obtained once SMWT is over. The SEE is 7.17 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$, where r^2=-0.432, which means that the VO_{2max} can be understood as a 43.2% based on a 20-second HRR while the remaining percentage is due to other variables.

Table 3. Physical performance in the SMWT and Bruce test

Variable	SMWT	Bruce
n	20	20
Distance, m	695.6±24.7	na
RPE, 6-20	11.2±1.6	18±1.3
Speed, km·h^{-1}	6.9±0.2	9.1±0.9
VO_{2max}, ml·kg^{-1}·min^{-1}	54.1±6	54±9.2
••HR, beats·min^{-1}	153.7±22.5	190.4±9.9

Legend. ••value achieves finish the test; na: not applicable
Source: The authors

The mean difference between two tests is -0.08 ± 6.97 ml·kg·min^{-1} (mean bias was close to zero) with the limits of agreement of -13.75 and 13.59, and there were no significant differences for values the VO_{2max} of SMWT and Bruce test (p=0.960) with 95% confidence interval -3.344 to 3.184, indicating that SMWT predicts the VO_2 max by between -3.344 to 3.184 ml·kg·min^{-1} (Figure 1). Finally, the agreement analysis showed that only one pairs (5%) of VO_{2max} lied outside the range of the limits of agreement.

Discussion

A research work[7] measured aerobic performance by means of the SMWT applied to 31 young men, where distances of 644±63.1 meters were recorded. Distances ranging from 600 to 800 meters have been found in the case of men and women, Chilean individuals, aged 20 through 29[9]. Distances covered by the PES in this current research work were 713.3±54 meters, which is within Chilean people range. A research work other than the latter[25] standardized sentences every 1 minute were used during the carrying out of the SMWT, while the time that had passed was reported to the participants, and measuring both HR and RPE right after the test was completed. This section of the protocol that has been described also matches with the PES procedures. However, the authors made use of a 50-foot-long hallway (15.24 meters) for a round way walk, while a 30-meter hallway was used in the case of the PES.

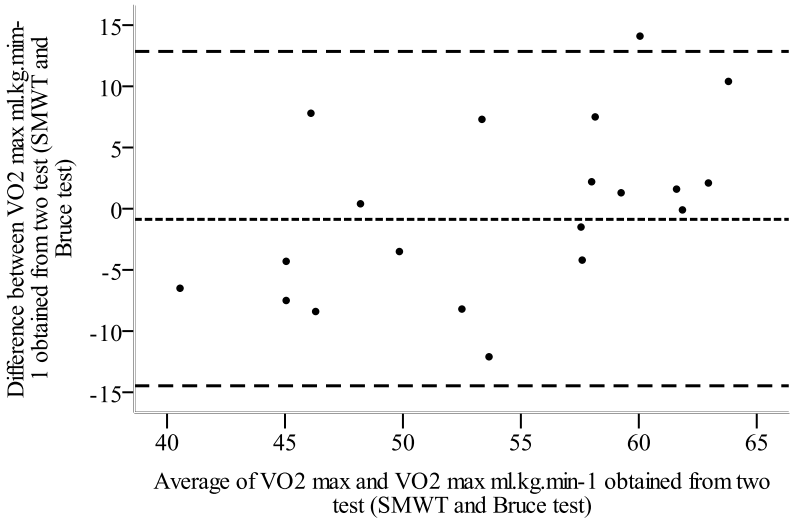

Figure 1. Plotting of difference between VO_{2max} values against their means
Source: The authors

With regards to the VO_{2max}, this has been measured applying indirect calorimetry in male and female physical education students, by using an 8-phase Bruce test[1]. In another research work, a group of physical education students were measured the VO_{2max} in the Bruce test[26], which has also been assessed[27] with a 6-phase Bruce protocol in fairly active men. VO_{2max} values were found in university students, six 20-year-old men and six 21-year-old women who were physically active[28]. 20-year-old trained and not trained women have also been measured their VO_{2max} by means of Bruce test[29]. As it can be found out from some earlier research works, Bruce test has been applied by using different numbers of stages, but VO_{2max} values have been the same for those young men who have taken part in the tests, featuring a 42 to 50 $ml \cdot kg^{-1} \cdot min^{-1}$ average range, which turns out to be lower when compared to what had been found in the PES, which was 61 $ml \cdot kg^{-1} \cdot min^{-1}$ while women reached a 46 average score in this current research work.

The purpose of this research work was to make an equation to assess VO_{2max} in the SMWT, in turn based on HRR. The fact that research studies about the cardio-vascular system during recovery are not common[30] has been stated for a long time. Nevertheless, the submaximal physical exercise HRR has been used for the assessment of cardiovascular fitness and is based on the relation principle among work intensity, HRR and the VO_{2max}[31] ; in turn, it has been reported that HRR is inversely related with the VO_{2max}[32]. On the contrary, it has been stated that HRR might not be enough sensible to accurately and exactly predict the VO_{2max}, and that HRR might be more useful for a general characterization of the VO_{2max}[33]. However, there are several tests aiming at predicting VO_{2max} by means of the HR during physical exercise or post- physical exercise[34]. The only available references are the step-based tests, which point out that those equations that use just HRR to assess VO_{2max} have a high correlation, but are in turn negative; they range from – 0.58 to - 0.96, with SEE values between 0.3 up to 8.7 $ml \cdot kg^{-1} \cdot min^{-1}$ ($p<0.05$). These prediction-type equations that have been described also used the HRR that is recorded in an after physical exercise 20-second maximum time[23,24,33,35]. The correlation value featured by the equation that has been set up in this research work is also negative, statistically important, presenting a SEE within the range reported by the previously mentioned research works, while its HRR is recorded at 20 seconds. However, correlation is not that high.

An earlier research work[36] applied the SMWT to 617 individuals – both men and women – based on a 19 to 79-year age group. Equations were made in that research work in order to assess distance that had been covered. One of such equations included the HR delta (change from base HR up to the test final measuring), which correlated with the distance to be covered under a rho=0.43 ($p<0.0001$), but no prediction for the $VO_{2max}$was done, nor was this compared with a maximum strength test as criteria validation for the VO_{2max}. However, some walk tests have been compared with oxygen consumption tests; e.g., the 12-minute test ($r=0.9$) and the 6-minute test ($r=0.52$)[37].

SMWT is a choice for the assessment of cardio-respiratory fitness as a field-based test[25]. Similarly, applicability correctness of the walk test lies in the fact that it is a low cost choice for its setting up aiming at the measuring of aerobic resistance, thus being likely for massive application, while having a VO_{2max} prediction equation in its protocol, which turns out to be the most important parameter for cardio-vascular strength. Future study lines might be focused on the test applicability, thus standardizing walking speeds by means of an audible signal and building prediction equations for both men and women.

One study includes the evaluation by conventional treadmill exercise testing and not by cardiopulmonary exercise testing (directly measure of VO_{2max}) in patients with heart disease and concludes that peak oxygen uptake can be easily predicted by SMWT[18]. Finally, a significant correlation was found to predict VO_{2peak} in patients adults with pulmonary

hypertension[38] and univariate regression showed that the SMWT (distance) was strongly related to VO_{2peak} in individuals adults with aneurysmal subarachnoid hemorrhage[39].

Conclusion

It can be concluded that the suggested equation predicts the VO_{2max} measured in the Bruce test, for the 20 research individuals PES, although association among interest variables is not that high, but this can be put aside due to the degree of statistical importance that has been found. The model has a good performance to predict VO_{2max} and has potential value in the assessment of functional capacity in these students.

References

1. Romero-Fallas O, Soto-Arias M, Moncada-Jimenez J. Maximal oxygen consumption in college students is reliable following four consecutive trials. J Phys Ed Sport 2012;12(4):476-81. Doi:10.7752/jpes.2012.04069.
2. Lamberts RP, Swart J, Noakes TD, Lambert MI. Changes in heart rate recovery after high-intensity training in well-trained cyclists. Eur J Appl Physiol 2009;105(5):705-13. Doi:10.1007/s00421-008-0952-y.
3. Lubans DR, Morgan PJ, Collins CE, Boreham CA, Callister R. The relationship between heart rate intensity and pedometer step counts in adolescents. J Sport Sci 2009;27(6):591-7. Doi: 10.1080/02640410802676687.
4. Vilhena MG, Pereira FD. Between-day variability of net and gross oxygen uptake during graded treadmill walking: effects of different walking intensities on the reliability of locomotion economy. Appl Physiol Nutr Metab 2008;33(6):1199-1206. Doi: 10.1139/h08-109.
5. Gutiérrez-Clavería M, Beroíza T, Cartagena C, Caviedes I, Céspedes J, Gutiérrez-Navas, et al. Prueba de caminata de 6 minutos. Rev Chil Enf Respir 2009;25(1):15-24. Doi: 10.4067/S0717-73482009000100003.
6. Dourado, VZ. Reference equations for the 6-Minute walk test in healthy individuals. Arq Bras Cardiol 2011;96(6):1-11. Doi: 10.1590/S0066-782X2011005000024.
7. Fernandes DS, Ferreira AJ, Gonçalves LI, Varanda PB, Nogueira, Sentanin, AC, et al. Reprodutibilidade do teste de caminhada e do degrau de 6 minutos em adultos jovens saudáveis. Rev Bras Med Esporte 2014;20(3):214-18. Doi: 10.1590/1517-86922014200301714.
8. Grindrod D, Paton CD, Knez WL, O'Brien BJ. Six minute walk distance is greater when performed in a group than alone. . Brit J Sports Med 2006;40(10):876-77. Doi: 10.1136/bjsm.2006.027904.
9. Osses R, Yáñez J, Barría P, Palacios S, Dreyse J, Díaz O, et al. Prueba de caminata en seis minutos en sujetos chilenos sanos de 20 a 80 años. Rev Med Chil 2010;138(9):1124-30. Doi: S0034-98872010000900006.
10. Andersson E, Nilsson J. Can a six-minute shuttle walk test predict maximal oxygen uptake? Gazz Med Ital 2011;170:163-70.
11. Andersson EA, Lundahl G, Wecke L, Lindblom I, Nilsson J. Maximal aerobic power versus performance in two aerobic endurance tests among young and old adults. Gerontology 2011;57:502-12. Doi: 10.1159/000329174.
12. Maldonado-Martin S, Brubaker PH, Kaminsky LA, Moore JB, Stewart KP, Kitzman DW. The relationship of 6-min walk to VO_2peak and VT in older heart failure patients. Med Sci Sport Exer 2006;38:1047-53. Doi: 10.1249/01.mss.0000222830.41735.14.
13. Hill K, Wickerson LM, Woon LJ, Abady AH, Overend TJ, Goldstein RS, et al. The 6-min walk test: responses in healthy Canadians aged 45 to 85 years. Appl Physiol Nutr Metab 2011;36:643-9. Doi: 10.1139/h11-075.
14. Ingle L, Goode K, Rigby ASR, Cleland JGF, Clark AL. Predicting peak oxygen uptake from 6-min walk test performance in male patients with left ventricular systolic dysfunction. Eur J Heart Fail 2006;8:198-202. Doi: 10.1016/j.ejheart.2005.07.008.
15. Oudiz RJ, Barst RJ, Hansen JE, Sun XG, Garofano R, Wu XH, et al. Cardiopulmonary exercise testing and six-minute walk correlations in pulmonary arterial hypertension. Am J Cardiol 2006;97:123-6. Doi: 10.1016/j.amjcard.2005.07.129
16. Kelly JO, Kilbreath SL, Davis GM, Zeman B, Raymond J. Cardiorespiratory fitness and walking ability in subacute stroke patients. Arch Phys Med Rehab. 2003;84:1780-5. Doi: 10.1016/S0003-9993(03)00376-9.
17. Zou H, Zhang J, Chen X, Wang Y, Lin W, Lin J, et al. Reference equations for the six-minute walk distance in the healthy Chinese han population, aged 18–30 years. BMC Pulm Med 2017;17:119-28. Doi: 10.1186/s12890-017-0461-z.

18. Costa HS, Lima MM, Alencar MC, Souza GR, Fiqueiredo PH, Nunes MC, et al. Prediction of peak oxygen uptake in patients with Chagas heart disease: value of the Six-minute Walk Test. Int J Cardiol 2017;1(228):385-7. Doi: 10.1016/j.ijcard.2016.11.259.
19. Hamlin MJ, Draper N, Blackwell G, Shearman JP, Kimber NE. Determination of maximal oxygen uptake using the bruce or a novel athlete-led protocol in a mixed population. J Hum Kinet 2012;31:97-104. Doi: 10.2478/v10078-012-0010-z.
20. García-Manso JM, Navarro-Valdivielso M, Ruiz-Caballero JA. Bases teóricas del entrenamiento deportivo: principios y aplicaciones. Madrid: GYMNOS; 1996.
21. Jung-Min L, Bassevf J, Thompson DL, Fitzhugh EC. Validation of the cosmedfitmate for prediction of maximal oxygen consumption. J Strength Cond Res 2011;25(9):2573-9. Doi: 10.1519/JSC.0b013e3181fc5c48.
22. Nieman DC, La Sasso H, Austin MD, Pearce S, McInnis T, Unick J. Validation of Cosmed's FitMate™ in measuring exercise metabolism. Res Sports Med. 2007;15(1):67-75. Doi: 10.1080/15438620601184380.
23. Chatterjee S, Chatterjee P, Mukherjee PS, Bandyopadhyay A. Validity of Queen's College step test for use with young indian men. Brit J Sports Med 2004;38(3):289-91.
24. Chatterjee S, Chatterjee P, Bandyopadhyay A. Validity of Queen's College Step Test for estimation of maximum oxygen uptake in female students. Indian J Med Res 2005;121(1):32-5.
25. Bohannon RW, Bubela DJ, Wang Y, Magasi SS, Gershon RC. Six-minute walk test vs. three-minute step test for measuring functional endurance. J Strength Cond Res 2015;29(11):3240-4. Doi: 10.1519/JSC.0000000000000253.
26. Machado Filho R. Nível de incompetencia cronotrópica em estudantes de educação física. Rev Bras Prescr Fisiol Exerc 2013;7(41):494-7.
27. Laurent CM, Meyers MC, Robinson CA, Strong LR, Chase C, Goodwin B. Validity of the VmaxST portable metabolic measurement system. J Sports Sci 2008;26(7):709-16. Doi: 10.1080/02640410701758685.
28. Willmert N, Porcari JP, Doberstein S, Brice G. The effects of oxygenated water on exercise physiology during incremental exercise and recovery. J Exerc Physiol 2002;5(4):16-21.
29. Roy JP, Smith JF, Bishop PA, Hallinan C, Minqi W, Hunter GR. Prediction of maximal VO_2 from a submaximal stairmaster test in young women. J Strength Cond Res 2004;8(1):92-9.
30. Redondo DR, Bone T. Central and peripheral circulatory responses during four different recovery positions immediately following submaximal exercise. J Exerc Physiol 1998;1(1):1-12.
31. Jinzhou Y, Yibing F, Ruipeng Z, Xi L, Gongbing S. The reliability and sensitivity of indices related to cardiovascular fitness evaluation. Kinesiology 2008;40(2):138-45.
32. Dimkpa, U. Post-exercise heart rate recovery: an index of cardiovascular fitness. J Exerc Physiol 2009;12(2):10-22.
33. Santo AS, Goldin LA. Predicting maximun oxygen uptake from a modified 3-minute step test. Res Q Exerc Sport. 2005;74(1):110-5. Doi: 10.1080/02701367.2003.10609070.
34. McArdle D, Katch FI, Katch VL. Fisiología del ejercicio: energía, nutrición y rendimiento humano. Madrid: Alianza Deporte; 1990.
35. McArdle WD, Katch FI, Pechar GS, Jacobson L, Ruck S. Reliability and interrelationships between maximal oxygen intake, physical work capacity and step-test scores in college women. Med Sci Sports 1972;4(4):182–6.
36. Britto RR, Probst VS, Andrade AD, Samora GR, Hernandes NA, Marinho PEM, et al. Reference equations for the six-minute walk distance based on a Brazilian multicenter study. Braz J Phys Ther 2013;17(6):556-63. Doi: 10.1590/S1413-35552012005000122.
37. Sivori M, Sáenz C. Prueba de caminata de carga progresiva (shuttle test) en enfermedad pulmonar obstructiva crónica grave. Medicina 2010;70(4):305-10.
38. Zapico AG, Fuentes D, Rojo-Tirado MA, Calderón FJ, Rosenzweig EB, Garofano RP. Predicting peak oxygen uptake from the 6-minute walk test in patients with pulmonary hypertension. J Cardiopulm Rehabil Prev 2017;36(3):203-8. Doi: 10.1097/HCR.0000000000000174.
39. Harmsen, WJ, Ribbers, GM, Slaman, J, Heijenbrok-Kal, MH, Khajeh, L, van Kootenc, F, et al. The six-minute walk test predicts cardiorespiratory fitness in individuals with aneurysmal subarachnoid hemorrhage. Top Stroke Rehabil 2017;24(4):250-5. Doi: 10.1080/10749357.2016.1260263.

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