

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 universitários, 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 frequência 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_{2max} 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 $y = 92,468 - 0,278 * 20\text{-segundo-HRR}$ eo erro padrão de estimação (SEE) foi de $7,17 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. O HRR conseguido após o SMWT pode prever 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 $y = 92.468 - (0.278 * 20\text{-second-HRR})$ and the standard error of estimation (SEE) was $7.17 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. 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 life¹. However, its measuring has been complex, which in turn requires highly qualified personnel and brings about great economic costs. Heart rate (HR) performance² 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-ergometers⁴.

The SMWT it has usually been applied in clinic applications^{5,6} and just in few times in the case of apparently healthy young individuals⁷ and one study reports the distance covered in university students⁸. 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 test⁹. With regards to this walking test, distance to be covered, age, sex and anthropometric variables have usually been assessed⁶, while the $\text{VO}_{2\text{max}}$ 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 $\text{VO}_{2\text{max}}$ of the CNT, determine the reliability of the variables and to make an equation aiming at assessing the $\text{VO}_{2\text{max}}$ 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 established in previous studies in elderly¹²⁻¹⁴. 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 $\text{VO}_{2\text{max}}$ that had been obtained in a criteria-based test and, therefore, the equation to be derived from this should predict the $\text{VO}_{2\text{max}}$. Several studies had relate VO_2 only with the distance in the SMWT, founding low-medium relationship¹⁵ or high¹⁶, and others elaborated equations to predict distance¹⁷. However, scares studies had elaborate equations to predict $\text{VO}_{2\text{max}}$ without consideration of HR¹⁸. Moreover, to our knowledge, prediction of $\text{VO}_{2\text{max}}$ 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 $\text{VO}_{2\text{max}}$, 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 were 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.

SMWT⁵ 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 maximum¹⁹ by the time the test was completed. Test initial speed was $8 \text{ km} \cdot \text{h}^{-1}$ with $0.5 \text{ km} \cdot \text{h}^{-1}$ increases after every phase.

The Bruce test²⁰ 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 $10.9 \text{ km} \cdot \text{h}^{-1}$, 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 $100 \text{ ml} \cdot \text{min}^{-1}$ ^{23,24} and reaching a HR above 90% of the maximum¹⁹, 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
<i>n</i>	17	17	13		
<i>Distance, m</i>	701.5±36.2	710.3±33.6	718.1±27.7	$F(2, 44)=0.93$	0.401
<i>RPE, 6-20</i>	10.6±1.7	10.7±1.1	10.2±1.4	$F(2, 44)=0.44$	0.643
<i>HR finished, b/m</i>	130.4±22.7	140.5±23.3	127.7±23	$F(2, 44)=1.33$	0.273
<i>HRR b/m, 0:15</i>	122±22.4	132.4±22.6	120.2±20.8	$F(2, 44)=1.41$	0.253
<i>HRR b/m, 0:30</i>	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
<i>n</i>	17	17	13		
<i>VO_{2max}, ml·kg⁻¹·min⁻¹</i>	44.6±5.4	44.4±4.9	43.4±4.1	$F(2, 44)=0.22$	0.798
<i>RPE, 6-20</i>	14±2.2	14.1±2	14.4±1.7	$F(2, 43)=0.11$	0.891
<i>HR finished, beats·min⁻¹</i>	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: $y=92.468-(0.278*20\text{-second-HRR})$, where $y=VO_{2max}$ and 20 seconds HRR is the HR obtained once SMWT is over. The SEE is 7.17 ml·kg⁻¹·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
<i>n</i>	20	20
<i>Distance, m</i>	695.6±24.7	na
<i>RPE, 6-20</i>	11.2±1.6	18±1.3
<i>Speed, km·h⁻¹</i>	6.9±0.2	9.1±0.9
<i>VO_{2max}, ml·kg⁻¹·min⁻¹</i>	54.1±6	54±9.2
<i>••HR, beats·min⁻¹</i>	153.7±22.5	190.4±9.9

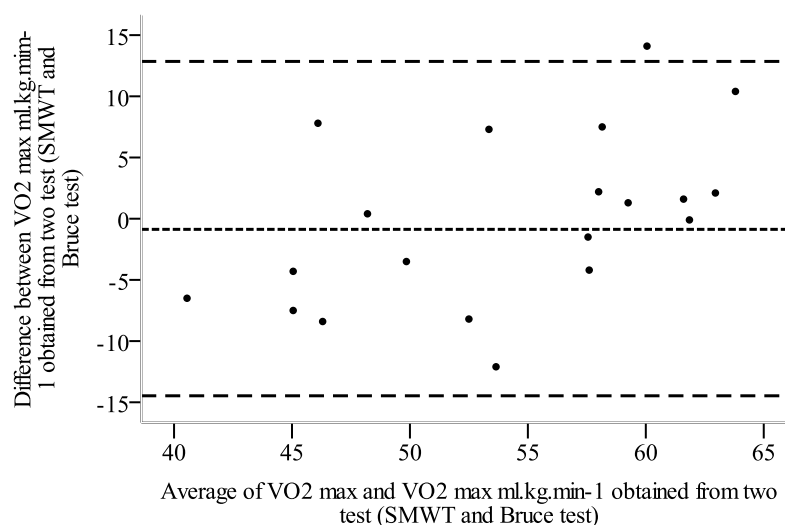
Legend. ••value achieves finish the test; na: not applicable

Source: The authors

The mean difference between two tests is $-0.08 \pm 6.97 \text{ ml} \cdot \text{kg} \cdot \text{min}^{-1}$ (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 $\text{VO}_{2\text{max}}$ of SMWT and Bruce test ($p=0.960$) with 95% confidence interval -3.344 to 3.184, indicating that SMWT predicts the $\text{VO}_2 \text{ max}$ by between -3.344 to 3.184 $\text{ml} \cdot \text{kg} \cdot \text{min}^{-1}$ (Figure 1). Finally, the agreement analysis showed that only one pairs (5%) of $\text{VO}_{2\text{max}}$ lied outside the range of the limits of agreement.

Discussion

A research work⁷ 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 29⁹. 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 latter²⁵ 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 $\text{VO}_{2\text{max}}$ 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 test¹. In another research work, a group of physical education students were measured the VO_{2max} in the Bruce test²⁶, which has also been assessed²⁷ 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 active²⁸. 20-year-old trained and not trained women have also been measured their VO_{2max} by means of Bruce test²⁹. 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 common³⁰ 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 exercise³⁴. 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 work³⁶ 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 test²⁵. 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 SMWT¹⁸. Finally, a significant correlation was found to predict VO_{2peak} in patients adults with pulmonary

hypertension³⁸ and univariate regression showed that the SMWT (distance) was strongly related to VO_{2peak} in individuals adults with aneurysmal subarachnoid hemorrhage³⁹.

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.

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