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Physiotherapy Section

Original Article

Can the Six-Minute Step Test Predict the VO_2 Peak in Healthy Young Men?

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ABSTRACT

Introduction: The six-minute step test can estimate the oxygen consumption in patients with chronic obstructive pulmonary disease. However, the literature is scarce regarding to six-minute step test application to health and young subjects.

Aim: To correlate peak oxygen consumption (VO_2 peak) obtained in a Cardiopulmonary Exercise Test (CPX) with performance in the 6-Minute Step Test (6MST) in a group of healthy young men.

Materials and Methods: In a prospective observational cross-sectional study, thirty-one young healthy men (22.3±2.2years) were volunteers. The study was conducted during two non-consecutive days. On the first day, the VO_2 peak was obtained using CPX on a treadmill. After 72 hour, the 6MST (20 cm of height) was performed at a self-selected cadence. The reproducibility of the 6MST was tested in 14 subjects, 30 minute after the first 6MST.

Results: The 6MST demonstrated reproducibility (ICC=0.977; 95%CI 0.932 to 0.992). There was a significant correlation between the total number of steps and heart rate in the 6th minute of the 6MST (r=0.794; p<0.001). The multiple regression did not identify variables that could be associated with the VO_2 peak.

Conclusion: The 6MST has no power to estimate the VO_2 peak in healthy young men.

Keywords: Cardiorespiratory fitness, Exercise test, Peak oxygen consumption, Physical effort, Regression analysis

INTRODUCTION

Regular physical activity and exercise is associated with numerous physical and mental health benefits and a delay in mortality from all causesin both healthy individuals and patients with cardiovascular disease [1-3].

For the exercise to be performed safely, a prior full assessment of maximum oxygen consumption (VO_{2max}) is recommended, and the gold standard test is the Cardiopulmonary Exercise Test (CPX) [4,5]. However, CPX requires specific equipment, a suitable place, and trained personnel [4], in addition to being relatively expensive and time consuming [3]. In terms of practical application, when only an estimate of VO_{2max} is required, the use of simpler tests, applicable on a large scale, may be a viable strategy [6]. For example, step tests are low cost, can be easily transported, require little practice to perform, and usually have a short duration [7-9]. There are several step test protocols, with differences in the height of the step, test duration, frequency of cadence, and number of stages [9]. In patients with chronic diseases, a six-minute step test has been used, self-cadenced with a step height of 20 cm (6MST) [10-17].

On the other hand, in healthy individuals, the scientific literature demonstrates a predominance of the use of step tests with a pre-set cadence [9]. However, the self-cadenced test model, in the 6MST, may also be useful for healthy individuals, as it allows the frequency of the cadence to be individually adjusted during the total test time, so there is no need to choose a single step test protocol which may not promote the best work intensity, especially when evaluating individuals with different levels of physical fitness [9,18]. Nevertheless, further information on the applicability of the 6MST in healthy individuals can be obtained by comparing performance in the step test with direct oxygen consumption measured in a progressive test. To our knowledge, this information is not available in the literature and could allow VO_2 peak prediction through 6MST performance in healthy young people.

Thus, the objective of the present study was to verify the correlation between VO_2 peak obtained in the CPX and performance in the 6MST in a group of healthy young men, and analyse the power of the 6MST to predict VO_2 peak.

MATERIALS AND METHODS

Following a transversal design, this study was conducted during spring/summer (September-December of south hemisphere) of 2013 after being approved by the Ethics Committee on Human Research of the State University of Londrina, Brazil (243/2013). All subjects agreed to participate and all signed a written informed consent in accordance with Helsinki Declaration.

The calculation of sample size (two-tailed alpha = 0.05, beta = 0.20, and expected correlation of 0.50) showed requirement of a minimum of 29 subjects. For the sample selection, graduate students of Londrina State University, aged 18 to 27 years were invited. In total, 34 young males (healthy, normotensive and recreationally active) were included, not undergoing any drug treatment and without orthopedic or equilibrium alterations or any other conditions that could limit the tests.

Experimental Procedure

The tests were performed in a climatized laboratory (22°C to 24°C), in the evening to avoid alterations in circadian rhythm. The participants were instructed not to perform physical exercise in the 24 hours prior to the test, not to smoke or drink caffeine for three hours before the collections, not to drink alcohol for a period of 48 hours before testing and to wear sportswear and sneakers [7].

Participants attended the laboratory on two separate days with an interval of 72 hours between the applied exercise tests to allow relaxation of the muscles. On the first day, the subjects were instructed on how to respond to modified Borg CR10 scales on perceived exertion and fatigue of the lower limbs [19], they answered the short version of the International Physical Activity Questionnaire (IPAQ) [20], and performed the CPX. On the second day, the 6MST was performed.

The CPX was conducted on an electric treadmill (Super ATLInbramed, Porto Alegre, Brazil). The test was programmed to have an average duration of 10 min, oscillating between 8 and 12 minute [21,22], using an individualized ramp protocol [23]. The start of the CPX was preceded by a three minute warm-up at a constant speed of 5 km/hr to provide a drop in the respiratory quotient (≤0.80), considered an optimum value to begin the test, and cause the metabolic and functional modifications necessary for the realization of the CPX. For the test to be considered maximal, the subjects were required to meet at least three of the following criteria: maximum voluntary exhaustion; Heart Rate (HR) ≥90% of maximum HR estimated for age or lack of increase in HR through load increase at the end of the test; presence of a plateau in the VO_2 with the evolution of the loads to the end of the test; respiratory exchange ratio >1.1; value of perceived exertion scale ≥10 on the Borg CR10 scale [24]. Considering possible limitations to identifying the VO_{2max}, peak oxygen consumption was adopted (VO_2 peak), corresponding to the highest oxygen consumption obtained during the test. The VO_2 peak, pulmonary ventilation, carbon dioxide production, and HR were collected with an output frequency of 20 seconds, using an ULTIMA gas analyser (Medical Graphics, Saint Paul, United States). A medium flow pneumotachographwas used with a silicone mask (Hans Rudolph, Shawnee, United States). The HR was measured using a Polar V800 monitor (Polar, Kempele, Finland). The equipment was calibrated according to the manufacturer's instructions.

The perceived exertion was evaluated every minute of the test using the Borg CR10 Scale [19]. Due to the fact that the equipment used in the monitoring of ventilatory variables prevented verbalization of the scale values, a table was placed in front of the treadmill and an evaluator slid a ruler along the numbers, interrupting the movement at an indication from the participant.

The 6MST was performed on a step 20 cm high, 75 cm wide, and 40 cm deep, without a hand rest, and lasted for six minutes [10]. Before starting the test, all participants performed ascent and descent movements on the step a sufficient number of times to become familiar with the movement and step height. After familiarization, the participants remained in a sitting position for 15 minute. Then, they were required to ascend and descend the step as many times as possible for six minutes. If necessary, the individuals could sit down or decrease the speed of ascent and descent; however, the chronometer did not stop. Phrases of encouragement standardized by the American Thoracic Society for the six-minute walk testwere used [25]. The HR and number of ascents/descents were recorded every minute of the 6MST. The scales of perceived exertion and lower limb fatigue were responded to immediately after the end of the 6MST.

Finally, in order to test the reproducibility of the 6MST, 14 subjects (approximately half of the minimum sample size) were randomly chosen to perform a further 6MST 30 minute after the first. The reproducibility was used to avoid the false positive error regarding the 6MST data.

STATISTICAL ANALYSIS

Initially the Shapiro-Wilk test was performed to verify the normality of the data. Normal data are presented as mean and standard deviation. Pearson's correlation was used to verify the correlation between the number of steps and heart rate in the 6th minute of the 6MST and between the number of steps in the 6MST and VO_2 peak obtained in the CPX. Repeated measures ANOVA followed, when necessary, by the Bonferroni post-hoc was used to compare the number of steps from the 1st to 6th minute of the 6MST. The intraclass correlation coefficient was used to investigate the reproducibility of measurements between the first and second 6MST conducted in 14 subjects. A stepwise forward multiple regression model was used to examine associations of the variables heart rate in the 6MST, number of steps in the 6MST, the IPAQ, age, height, weight and BMI with the VO_2 peak obtained in the CPX. The significance level adopted was $p < 0.05$ and the data were processed in the program Statistica 15.0 (Statsoft, Tulsa, OK, USA).

RESULTS

Three participants were excluded (one did not perform the CPX and two did not perform the 6MST). Thus, the final sample consisted of 31 subjects. The characteristics of the sample, as well as results obtained in the CPX and 6MST are presented in [Table/Fig-1].

Variables	Subjects (n=31) Mean (standard deviation)
Age (years)	22.3 (2.2)
Height (m)	1.74 (0.7)
Weight (kg)	73.3 (10.1)
BMI (kg/m²)	24.3 (2.7)
VO_2 peak (mL/kg/min/1)	43.6 (4.9)
Total time of the CPX (min)	10.5 (2.1)
IPAQ (n)	
Very active	14
Active	11
Insufficiently active	5
Inactive	1
6MST	
Total	209.0 (58.0)
1st min	35.0 (12.2)
2nd min	34.0 (9.8)
3rd min	34.0 (9.3)
4th min	35.0 (9.9)
5th min	34.0 (8.7)
6th min	36.0 (10.5)
6MST HR/CPX HR peak (%)	81

[Table/Fig-1]: General characteristics of the sample.
BMI: Body Mass Index; VO_2 peak: peak of oxygen consumption; CPX: Cardiopulmonary Exercise Test; IPAQ: International Physical Activity Questionnaire; 6MST: 6-Minute Step Test; 6MST HR/CPX HR peak (%): percentage of heart rate in 6MST in relation to heart rate peak in CPX

There was a strong correlation between the total number of steps and heart rate in the 6th minute of the 6MST ($r=0.79$; $p<0.001$), however, there was no significant correlation between VO_2 peak in the CPX and the number of steps in the 6MST ($r=0.11$; $p=0.57$). Furthermore, there was no significant difference in the comparison of the number of steps from the 1st to 6th minute of the 6MST ($p>0.05$). The reproducibility of the 6MST was tested in 14 subjects, who performed two 6MSTs with a 30-minute interval between tests. The mean number of steps in the first test was 258.6±37.6 and 257.0±32.5 in the second test, with no statistical difference ($p=0.46$). Performance in the tests, verified by the number of steps in the first and second 6MSTs demonstrated excellent reproducibility (ICC=0.977; 95% CI 0.932 to 0.992).

[Table/Fig-2] illustrates the multiple regression analysis with the stepwise forward method used to verify associations of the independent variables: heart rate, number of steps in the 6MST, the IPAQ, age, height, weight, and BMI, with the dependent variable VO_2 peak obtained in the CPX. There was no association of any independent variable with the VO_2 peak.

Parameter	Beta coefficient	R^2	F	p-value
HR 1st min	-0.21	0.04	1.29	0.27
HR 2nd min	-0.05	0.003	0.08	0.78
HR 3rd min	-0.08	0.01	0.18	0.67
HR 4th min	-0.15	0.02	0.69	0.41
HR 5th min	-0.20	0.04	1.19	0.28
HR 6th min	-0.20	0.04	1.24	0.27
Steps 1st min	0.02	0.0003	0.01	0.92
Steps 2nd min	0.12	0.16	0.45	0.51
Steps 3rd min	0.10	0.01	0.30	0.59
Steps 4th min	0.10	0.01	0.29	0.60
Steps 5th min	0.16	0.03	0.77	0.39
Steps 6th min	0.12	0.01	0.41	0.53
Total steps	0.10	0.01	0.32	0.58
IPAQ	0.05	0.002	0.07	0.79
Age	-0.03	0.001	0.02	0.89
Height	-0.17	0.03	0.84	0.37
Weight	-0.14	0.02	0.56	0.46
BMI	-0.05	0.003	0.07	0.79

[Table/Fig-2]: . Data from the multiple regression analysis (stepwise forward) to compare the independent variables with VO_2 peak in the cardiopulmonary exercise testing.
HR: Heart Rate in the Six-Minute Step Test; IPAQ: International Physical Activity Questionnaire; BMI: Body Mass Index

DISCUSSION

The aim of the present study was to verify the correlation between VO_2 peak obtained in the CPX and performance in the 6MST in a group of healthy young men and analyse the power of 6MST to predict VO_2 peak. The results showed no correlation or prediction power.

Some hypotheses have been raised to explain the results, and the first refers to the form of implementation of the 6MST. The 6MST had a self-cadenced execution model [10], allowing the participants to merge greater and lower efforts over the six minutes. Apparently, this did not occur since the mean number of steps per minute did not vary significantly over the six-minute test period [Table/Fig-1]. This was confirmed by the high test reproducibility. On the other hand, the mean steps per minute of the sample cannot be considered low, as it falls within cadences reported in the literature for healthy individuals (15 to 35 steps per minute) [9].

Another hypothesis relates to the height of the step, which may have been insufficient to cause higher physical stimulus. The protocol employed in the 6MST used a 20 cm step, contrasting with other protocols, such as the YMCA Step Test (30.5 cm) [4] or the Canadian Home Fitness Test (seven stages for men, six for women, carried out with two steps of 20 cm each) [8]. Thus, some studies using step heights greater than 20 cm have shown significant correlations between performance in the step test and VO_2 in the CPX [3,24,25].

For example, one study used the YMCA Step Testin a sample of 97 healthy individuals, finding a strong correlation between the VO_2 peak obtained in the CPX and the step test in participants who failed to complete the step test (exercise capacity less than 9 METs) [3]. On the other hand, in the group of individuals who completed the trial (exercise capacity ≥9METs and VO_2 peak of 37.8±9.0 mL/Kg/min) a moderate correlation was found between the VO_2 peak values obtained in the CPX and the step test. The authors attributed these results to the ceiling effect, since the step test was a submaximal exercise in this group. These results are consistent with the results observed in the present study where participants presented a higher exercise capacity (VO_2 peak=43.6±4.9 mL/kg/min) and no significant correlation was found (r=0.105; p=0.57) between the VO_2 peak in the CPX and the 6MST.

In another study, which used the Chester Step Test (composed of four height options and five stages), a strong correlation was observed (r=0.92; p <0.001) between the VO_2 in the CPX and the VO_2 estimated in the step test [24]. However, some important methodological differences were observed when comparing the sample and protocol of the above experiment with the presentstudy. Firstly, when validating the Chester Step Test, the sample was found to be very heterogeneous, consisting of men and women aged 18 to 52-year-old with a VO_2 peak between 25 and 68 mL/Kg/min, different from the sample used in the present study, composed of young men (22.3±2.2 years) with a VO_2 peak ranging from 34.2 to 52 mL/Kg/min.

In addition, in the Chester Step Testprotocol, the individuals were instructed to ascend the step in progressive rhythms with the evolution of the test, unlike the protocol of the present study, whose rate of increase was self selected by individuals. The Chester Step Test was interrupted when the volunteers reached an intensity corresponding to 80% of the maximal HR expected for age. On the other hand, in the present study, the test duration was fixed at 6 minute. Therefore, the sum of these aspects may have influenced the different correlations observed in these both experiments.

The characteristics of the sample may also have influenced the results. The sample of the present study was composed of young, healthy men, with a reasonable level of fitness (VO_2 peak=43.6±4.9 mL/kg/min). As the 6MST was self cadenced and the cadence did not vary, the mean steps per minute may have been insufficient to generate significant physiological modifications in the sample. On the other hand, in studies with other populations, such as obese women [26] and individuals with respiratory diseases [10,11,27], the 6MST appears to be a test model that presents power to estimate the fitness level.

The present experiment was based on the initial assumption that a step test with a self-selected ascent cadence, in which participants individually regulated the rate of ascent, could better estimate VO_2 peak in relation to tests with predetermined ascent rhythms. It was believed that a predetermined rate of ascent could represent a strong effort for the less conditioned individuals and a weak effort for the most conditioned individuals, negatively affecting the correlations between the variables obtained in the bench test and the VO_2 peak in the CPX. However, this hypothesis was not confirmed and the results showed that the adoption of a self-selected pace did not represent a useful strategy to implement the protocol when the variables obtained in the test were correlated with the VO_2 peak in the CPX. Other strategies should be sought to better correlate the data in the step test with VO_2 peak in healthy young individuals.

LIMITATION

Some individuals were not familiar with using a treadmill and it was not possible to submit these individuals to adaptation sessions on the treadmill prior to application of the CPX. Therefore, it is unclear to what extent the lack of familiarity of these individuals may have influenced the CPX results. However, it is important to note that the majority of individuals in the sample were used to walking and running on a treadmill and even those who were unfamiliar had previously conducted a CPX on an ergometer.

CONCLUSION

Performance in the 6MST, despite presenting high reproducibility in healthy young men, has no power to estimate the VO_2 peak based on the values obtained in the CPX.

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