Comparative Analysis of Maximum Oxygen Consumption: A Verifiability of the Ergoespirometric Test Performed in the New Cycle® Ladder Simulator

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ABSTRACT

Santos Junior VM, Brighetti V, Lourenço JRM, Souza JCA. Comparative Analysis of Maximum Oxygen Consumption: A Verifiability of the Ergoespirometric Test Performed in the New Cycle® Ladder Simulator. JEPonline 2024;27(2):13-18. Maximum oxygen consumption is used to assess functional capacity. Ergoespirometry is performed on a motorized treadmill or an ergometric bicycle. There are currently no protocols with the Stair Climber Simulator in the literature, exposing a scientific gap related to the use of this ergometer. This study verified if a maximal test performed on a Stair Climber Simulator can be considered reliable when compared to the treadmill test with the Bruce Protocol. Data collection was carried out through acute evaluations on the treadmill and the Stair Climber Simulator, using an Inbrasport® treadmill and a New Cicle® SE01 Ladder Simulator. For the analysis of expired gases, a VO2000 gas analyzer from MedGraphics® controlled by Ergomet® software along with a HW model electrocardiogram were used. The subjects had an average age of 25.25 ± 5.26, weight of 72.41 ± 12.16, height of 171.38 ± 8.05, and BMI of 24.59 ± 3.32. The maximum oxygen consumption presented on the treadmill was 42.63 ± 11.29 mL·kg⁻¹·min⁻¹ and on the Stair Climber Simulator 42.59 ± 12.74 mL·kg⁻¹·min⁻¹, showing no significant difference. The data in both tests indicate that the Stair Climber Simulator is efficient for assessing aerobic power.

Key Words: Ergoespirometric Test, Ladder Simulation, VO₂ Max
INTRODUCTION

One of the variables that will be addressed in this study and considered the main one is the maximum oxygen consumption (VO$_2$ max), which is widely used for the detection of cardiovascular and pulmonary diseases, as well as for a training prescription, regardless of the individual's profile. VO$_2$ max refers to the highest oxygen consumption, that is, the uptake and delivery of oxygen to the muscle cells. This variable is commonly used and is considered by many researchers as the best for assessing cardiorespiratory conditions, including diagnosis and prognosis. One of the tests that can be used to collect data on this variable is ergospirometry, in which VO$_2$ max is determined (1,2).

Physical tests that require some effort, such as those following the principle of progressive overload are important because they can collect more reliable data than tests performed at rest. Therefore, the protocols used in this research are characterized by load progression. Conventional tests, such as the Bruce protocol used on a treadmill or the Cooper test are used for the assessment of functional capacity by ergospirometry that entails a high cost. Furthermore, the intensity indirectly prescribed revolves around 60% to 70% of estimated VO$_2$ max and 70% to 85% of measured maximum heart rate for healthy young individuals (3,6).

The ergospirometry test was used in the present study. It is comparable to the conventional ergometric test, containing electrical activity of the heart through the placement of electrodes on the chest, clinical analysis, and the collection of the ventilatory variables, expired gases, and oximetry (i.e., a way of measuring how much oxygen the blood is carrying) (8,11). The ergospirometry test is an examination used to assess the electrical activity of the heart, its health, and to estimate whether the individual's cardiopulmonary capacity is providing the blood and oxygen required by the body during physical exertion with aptitude. Also, the test provides the responses of clinical and hemodynamic variables that undergo alterations due to the disruption of homeostasis (1,2,5,8).

To understand if the two tests produced similar physiological results, data were collected on metabolic variables such as maximum oxygen consumption (VO$_2$) max, expired ventilation (V$_E$), carbon dioxide production (VCO$_2$), and heart rate (HR). The evaluation itself is rather common when performed on a treadmill or an ergometric bicycle. However, in the present study, this evaluation was carried out on a New Cycle SE01, the Stair Climber Simulator. It is worth noting that the Stair Climber Simulator is equipment that lacks research studies in the literature at the current moment, since it is still in a period of exploration.

Ergospirometry is a method used to assess VO$_2$ max. The purpose of the present study was to determine whether the ergospirometric test performed on a Stair Climber Simulator is reliable by way of a comparison between an adapted progressive effort test performed on a Stair Climber Simulator with the Bruce Protocol on a treadmill.

The Stair Climber Simulator is an ergometer that demands a lot from the lower limbs, mainly the quadriceps, considering the range of motion of the knee and hip joints that leads to a greater force production. With the emergence of this ergometer, it is common for many practitioners to opt for its use in studios and gyms worldwide. However, it is noteworthy to point out that only a few studies have been conducted with this type of equipment.
This study presents the validation of the Stair Climber Simulator as a new VO\textsubscript{2} max evaluation tool for aerobic fitness of individuals.

**METHODS**

**Subjects**

Eight subjects (6 men and 2 women between 21 and 37 years of age) participated in this study. They were studying and/or working at the University Center of Votuporanga/São Paulo – UNIFEV, Brazil, and were adapting to exercise training for at least 1 year.

The data collection in the ergospirometric tests consisted of acute evaluations on 2 ergometers, an Inbrasport® treadmill and a New Cycle® SE01 model stair climber. For the analysis of metabolic gases, a VO2000 gas analyzer from MedGraphics® brand was used, controlled by the Ergomet® software along with a HW model electrocardiogram from the same brand. The Bruce protocol was used in the Treadmill Test, which consisted of 6 stages of 3 minutes each, starting at a speed of 2.7 km·h\textsuperscript{-1} and reaching 9.6 km·h\textsuperscript{-1} with an increase of 2º at each stage until the end.

Due to the lack of research studies regarding the Stair Climber Test, an adapted protocol was performed that started at a speed of 1.5 floors with a progression of 0.5 floors every 2 minutes with a total of 8 floors that allowed for a total of 14 stages.

**Procedures**

The subjects were informed about the progressive exercise test they would undergo. After written consent was obtained and in accordance with Resolution 196/96 of the National Health Council - Research Involving Human Beings, the students agreed to participate in the maximum VO\textsubscript{2} test on the treadmill. Each subject signed the Informed Consent Form (ICF). The research project and the consent form were previously approved by the Research Ethics Committee of the University Center of Votuporanga under number 6.550.022. CAAE. 75019223.5.0000.0078.

**Statistical Analyses**

Regarding the statistics, data normality was assessed using the Kolmogorov-Smirnov Test, and the mean plus standard deviation was adopted to express the results obtained in the present study. The Student's \( t \)-test was employed to compare the mean values obtained on the Stair Climber Simulator with those obtained on the treadmill. All statistical analyses were conducted using the SPSS IBM® Version 24.0 software available for OS.

**RESULTS**

In the scope of this current research, the main variable assessed was maximum oxygen consumption (VO\textsubscript{2} max). On the treadmill, the mean and standard deviation were 25.97 ± 10.08 for the anaerobic threshold (AT), 35.79 ± 9.91 mL·kg\textsuperscript{-1}·min\textsuperscript{-1} for the respiratory compensation point (RCP), and 42.63 ± 11.29 mL·kg\textsuperscript{-1}·min\textsuperscript{-1} for the VO\textsubscript{2} max mL·kg\textsuperscript{-1}·min\textsuperscript{-1}. Meanwhile, on the Stair Climber, the means and standard deviations were 30.78 ± 10.78 mL·kg\textsuperscript{-1}·min\textsuperscript{-1} for AT, 36.43 ± 10.55 mL·kg\textsuperscript{-1}·min\textsuperscript{-1} for RCP, and 42.59 ± 12.74 mL·kg\textsuperscript{-1}·min\textsuperscript{-1} for VO\textsubscript{2} max.
The assessments also revealed a respiratory quotient (RQ = VCO$_2$ / VO$_2$) with a mean and standard deviation of 1.48 ± 0.36 on the treadmill and 1.33 ± 0.32 on the Stair Climber. For a comparison of the physiologic responses during the tests, the AT, RCP, VO$_2$ max, RQ, HR, and $V_E$ values are presented in Table 1.

Table 1. Mean and Standard Deviation Values of the Ventilatory Variables from the Treadmill Test and the Stair Ladder Simulator Test.

<table>
<thead>
<tr>
<th>Ventilatory Variables</th>
<th>Treadmill</th>
<th>Ladder Simulator</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT</td>
<td>25.97 ± 10.08</td>
<td>30.78 ± 10.78</td>
<td>0.067</td>
</tr>
<tr>
<td>RCP</td>
<td>35.79 ± 9.91</td>
<td>36.43 ± 10.55</td>
<td>0.567</td>
</tr>
<tr>
<td>VO$_2$ Max (mL·kg$^{-1}$·min$^{-1}$)</td>
<td>42.63 ± 11.29</td>
<td>42.59 ± 12.74</td>
<td>0.979</td>
</tr>
<tr>
<td>RQ</td>
<td>1.48 ± 0.36</td>
<td>1.33 ± 0.32</td>
<td>0.120</td>
</tr>
<tr>
<td>HR</td>
<td>193</td>
<td>187</td>
<td>0.890</td>
</tr>
<tr>
<td>$V_E$</td>
<td>98.9</td>
<td>99.57</td>
<td>0.456</td>
</tr>
</tbody>
</table>

AT = Anaerobic Threshold, RCP = Respiratory Compensation Point, VO$_2$ Max = Maximum Oxygen Consumption, RQ = Respiratory Quotient, HR = Heart Rate, $V_E$ = Expired Ventilation

**DISCUSSION**

The purpose of this study was to determine whether the ergospirometry test carried out on a Stair Climber Simulator can be used as an evaluation in the search for data to understand the health status or cardiorespiratory performance of a patient and/or student.

As for the evaluation performance of the subjects, the comparison of the tests was found to be positive since there was no significant difference in VO$_2$ max between the ergospirometry test and the Stairs Climber Simulator (1,4,5,6). This is important for understanding the similarities between these two pieces of equipment in fitness assessments and scientific research. Both devices are popular for providing a controlled environment for aerobic exercise tests, although they have distinct characteristics that would appear to influence the physiological outcomes (7,10,11).

In terms of movement mechanics, the Stair Climber Simulator simulates the act of climbing stairs, primarily involving the lower limbs, especially the quadriceps, hamstrings, and gluteal
muscles. On the other hand, the treadmill provides a running or walking motion that requires a wider range of muscle groups, including both the lower and the upper limbs as well as the core. Therefore, the choice between the two types of equipment may depend on the availability of the equipment and/or the subject's preference (3,5,12). As to exercise intensity, the Stair Climber Simulator tends to require greater lower limb overload due to the vertical movement. This can result in higher muscle recruitment and a increased sense of fatigue while the treadmill allows for greater flexibility in adjusting speed and incline, thus enabling exercise adaptation according to the participant's fitness level (8,9,10).

Regarding safety and comfort, both types of equipment offer stable and safe exercise surfaces. However, the stair climber may pose a greater challenge for individuals with balance issues or lower limb injuries due to the vertical movement nature and the requirement of motor coordination. On the other hand, the treadmill may be more accessible and easier to use for a variety of populations, including the elderly and individuals with physical limitations (2,4,12). With regards to validity and reliability of the obtained data, the present study demonstrates that the stair climber is effective in assessing physiological variables such as maximum oxygen consumption (VO\textsubscript{2} max). However, it is important to consider the specific characteristics of each type of equipment when interpreting the results and comparing the data across different studies (6,7,13,14).

CONCLUSIONS

The results from both tests indicate that the Stair Climber Simulator is efficient for assessing aerobic power.

ACKNOWLEDGMENTS

We thank Lion Fitness\textsuperscript{®} and New Cycle\textsuperscript{®} companies for their support throughout the development of this study. Gratitude to the Educational Foundation of Votuporanga for providing the necessary structure for the tests' development in this study.

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