







Original Article (short paper)

The validity of Keiser-M3 stationary bicycle with standard ergometer for physiological measurements associated with maximum effort

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Abstract - Aim: This study aims to investigate the concordance between two cycle ergometers for variables measured in the test of maximum incremental effort. **Methods:** This correlation study enrolled 15 inactive women (19,2 ± 4,0 years old). At random, the participants performed two maximal effort incremental tests (MEIT), using cycle ergometers (Keiser-M3 and Ergo-167) on different days with a minimum interval of 72 hours. The test had stages of two minutes, and two-step increments were carried out at the end of each stage. Lactate concentration ([LAC]), and rated perceived exertion (RPE) were collected, in addition to monitoring oxygen uptake (VO₂) and heart rate (HR). The Paired t-test was carried out to compare physiologic variables, Lin's test was used for correlation, and Bland Altman was used to measuring concordances among variables. **Results:** The correlations between physiologic parameters were considered strong for HR on the anaerobic threshold (Keiser M3 = 146 ± 14 bpm; Ergo-167 = 149 ± 9 bpm; r = 0.762), greater blood lactate value (Keiser M3 = 9,97 ± 2,51 mmol/L; Ergo-167 = 9.71 ± 2.56 mmol/L; r = 0.820), VO_{2max} (Keiser M3 = 38,37 ± 6,97 mL/kg/min; Ergo-167 = 36.06 ± 8.4 mL/kg/min; r = 0,806) and HR_{max} (Keiser M3 = 186 ± 53 bpm; Ergo-167 = 188 ± 11 bpm; r = 0.716). **Conclusion:** The results show the feasibility of using the cycle ergometer Keiser, model M3, to perform the maximal effort incremental test, whereas there was high concordance in the physiologic responses in both ergometers for inactive women.

Keywords: validity study, exercise, incremental test, lactate threshold, oxygen uptake.

Introduction

Incremental tests were performed in different contexts since clinical and functional variables measured at rest are not capable to adequately identify an individual's ability to perform physical exercises^{1,2}. The results from these tests are used to obtain relevant information to the prevention and treatment of pathological conditions³, as well as for prescribing and understanding the physiological adjustments associated with physical training⁴.

In order to assess maximal oxygen uptake (VO_{2max}) and measures directly related to aerobic power such as anaerobic threshold (TAN), field tests⁵ using steps of different heights^{6,7}, using ergometers are highlighted^{8,9}. On the other hand, stationary bicycles structured for a daily routine of collective physical training classes - known as spinning - could be used to measure aerobic fitness. However, there is an absence of precise intensity control¹⁰.

Among the most usual physiological measures related to exercise, there are those associated with lactacidemic responses, given their relevance in the prescription of exercise intensity in cyclic sport modalities with aerobic predominance¹¹. These measures have also been con-

sidered appropriate to identify exercise intensity¹². TAN, minimum lactate, maximum stable lactate phase, and individual anaerobic threshold are procedures that evaluate, using the lactate concentration ([LAC]), the aerobic capacity¹³. In addition to [LAC] analysis, heart rate (HR), heart rate deflection point (HRDP), maximum ventilatory deflection point¹⁴, ventilatory threshold¹⁵, oxygen uptake (VO₂), and rating of perceived exertion (RPE) are considered during incremental tests¹⁶. Furthermore, the first ventilatory threshold is recommended as a submaximal physiologic index and has been used to determine functional measures, prescription, and training intensity control¹⁷, mainly due to its non-invasive characteristic¹⁸.

Cycle ergometers are commonly used in conducting research and laboratory tests and are frequently used as equipment for aerobic power measurement and other physiologic responses associated with maximal effort as well¹⁹. Although researches with physical exercise prescriptions are well established, the viability of spinning bicycles to carry out maximal effort incremental tests (MEIT) is insufficiently investigated.

In this sense, this study aimed to investigate the concordance between an electromagnetic cycle ergometer of

reference (Ergo-167) and a spinning bicycle (Keiser™ M3), for physiologic measures associated with a with maximal effort incremental test.

Methods

Experimental approach to the problem

For data collection, the participants visited the laboratory in two non-subsequent days, with a minimal interval of 72 h. Before the visits, each participant was instructed not to consume any alcoholic beverages or stimulants (such as caffeine and tea) in the 24 h period before the tests, to sleep at least 8hrs the night before the visit, to be hydrated and adequately fed during the hours before the procedures, and solid meals were prohibited 60 min before the tests, only water ingestion was allowed in this period.

The samples were collected at the biochemistry and exercise physiology laboratory at the Federal University of Pelotas (UFPEl) with controlled temperature and humidity at 21° and 60%, respectively, and in each session, the participants performed MEIT in different cycle ergometers in random order and counterbalanced. One of the cycle ergometers often used in incremental tests exhibits electromagnetic characteristic (Ergo-FIT™, Ergo-167 Cycle model, Pirmasens, German), and has been employed in evaluations of different groups, such as sedentary women²⁰, diabetic subjects²¹ and, including, young people with obesity²². The other ergometer, Keiser™ M3 indoor Cycle (Keiser™, Chicago, USA), usually found in gyms and used for spinning classes, shows intensity manipulation from levers which present gears (from 1 to 24) associated with magnetic resistance on an LCD. In addition to estimating the power production based on rotations per minute (rpm), the Keiser™ M3 indoor Cycle presents similar ergonomics to the equipment used in cycling events¹⁴.

Subjects

This investigation is characterized as a validation study where fifteen women were enrolled with mean age, height, and weight of 19.2 ± 4 years, 169.6 ± 7.6 cm, and 61.7 ± 10.1 kg, respectively. The inclusion criteria of the participants were to be university students, not the practice of physical exercises systematically, not have experience with the use of cycle ergometers, and not on continuous therapy. After this phase, they read and signed the free and informed consent form (research project approved in the local ethics committee, protocol number 68577917.0.1001.5313).

Procedures

The heart rate was measured by using a Polar device (RS800CX™, Kempele, Finland) to register the heart rate

(HR). The gas exchange analysis was carried out using a VO2000 analyzer, previously calibrated according to the manufacturer instructions, and the Breeze software (Medgraphics™, Minnesota, USA), with a high flow pneumotachograph, neoprene™ medium size masks, with records of mean values for every three ventilations. The determination of blood lactate concentration ([LAC]) was performed using *Yellow Spring Instruments* (YSI) electrochemical analyzer, 2300 *Sport* model (Ohio, USA). RPE was collected with a 6-20 scale^{16,14}.

As baseline measures, the participants were instructed to sit for 10 minutes to be at resting heart rate (HR_{rest}), recording the mean value in 10 min^{24} . Gas exchanges were collected until the last 5 min of the resting phase. At the end of this period, 15 μL of blood was collected by a puncture on the fingertip, previously sterilized with 70% alcohol, using procedure gloves and disposable lancets (Softclick®), which were transported to an Eppendorf tube containing 30 μL of ethylenediamine tetraacetic acid (EDTA) for [LAC] analysis.

At the end of each stage and immediately at the end of the MEIT, HR, [LAC], oxygen uptake (VO_2), and RPE data were collected and registered.

Maximal Effort Incremental Test (MEIT)

After familiarization with the cycle ergometers, description and explanation of the procedures and adjustments related to body position as well (seat height, seat distance, and handlebar on each cycle ergometer), standardized heating was performed by pedaling in a controlled cadence of 55 to 65 rpm and using the same initial load of the test²⁵. After warming up, not using the gas exchange, 4min of recovery were granted, and then the VO2000 was installed during and after MEIT measurements.

To carry out MIET in both ergometers, each participant should pedal in a controlled cadence²⁵ for two minutes at each stage. In the ERGO FIT (MEIT-EF), the procedure started with 50 watts (W) of the initial load, and 25 W increments²⁰, which occurred until the interruption of the test. In the Keiser™ M3 (MEIT-M3), the wattage is calculated as the product of speed (rpm) for the gear (from 1 to 24), considering the time required (in minutes) for its 16.8kg wheel to travel one meter, and is presented on the display. A pilot study, carried out in our laboratory, identified that, for speed, varying between 55 and 65 rpm, two gear increments are associated with power production improvements near 25W. We would like to emphasize that during this pilot session, an independent sample ($n = 10$) was used to measure the intraclass correlation coefficient between the test and retest of the Keiser™ M3 ergometer ($ICC = 0.854$), considering the VO_{2max} as a variable. Thus, MEIT-M3 started with the ergometer in the fourth gear, and the progression occurred with increments of two gears every two minutes until its interruption. The MEIT interruptions occurred when the participant: i) reached

voluntary fatigue, losing the ability to keep the minimum established cadence; reported not being able to finish the subsequent stage; or iii) presented with sudden onset, identified by cyanosis, pallor or reported malaise. Exhaustion was verified using the result from the RPE.

Physiological parameters associated with MEIT

Different physiologic values were obtained using concordance measurements between the cycle ergometers. Among them, blood ([LAC]), ventilatory (VO₂), and cardiac (HR) variables were considered to monitor the responses in both bicycles. Blood measurement for anaerobic threshold analysis considered Onset of Blood Lactate Accumulation (OBLA), assuming the beginning of [LAC] accumulation tends to increase abruptly, and the point of change was not analyzed based on a fixed number (4mmol), but at the moment of a relevant change in the [LAC] curve [26], identified by scatter plot. In addition, the peak lactate ([LAC]_{peak}) value, that is, the highest value of [LAC] obtained in the MEIT, was also considered.

Regarding the ventilatory component, the visual inspection method was used to determine VO₂TAn, where the deviation point was inspected and defined by two researchers and, in case of divergence, the participation of a third auxiliary researcher was requested¹⁵. A previous study found a strong association between VO₂, wattage, HR, and ventilatory threshold, the latter being a non-invasive measurement, and a facilitator for thresholds identification¹⁵. Relative VO_{2max} (mL/kg/min) values were also considered.

In respect to HR, from the immediate recording of each beat, a graphic line was observed, and with the increase of loads, the discontinuity point of the line was identified, indicating the anaerobic threshold (HRTAn)²⁷. This threshold is indicated to occur when, during exercise, the individual reaches VO₂ between 50 and 60% of the VO_{2max}, since there is a decrease in the vagal activity,

and there is a predominance of the sympathetic nervous system which indicates the respective physiological threshold²⁶, which tends to coincide with the first lactate threshold. Also, HRTAn, HRmean, and HRmax were considered during the test. In order to identify these HR markers, data recorded on the cardio-frequency meter were used, which were downloaded and analyzed using the Polar ProTrainer software (Kempele, Finland). Subsequently, the generated numbers were plotted and the HRTAn was identified using the HRDP method, which is the maximum point of distance from a curve described by the ventilatory variation values, with a straight line drawn by the start and endpoints of that curve¹⁴.

Statistical analysis

Firstly, descriptive data are shown as mean and standard deviation, and the comparisons between means of physiologic variables were performed with the paired T-test. Lin's test was used to measure the correlations, and Bland-Altman analysis was employed to measure the concordance among variables. The statistical routines were conducted with GraphPad Prism 7 (San Diego, California, EUA) and Stata 12 (Timbarlake, UK) software systems. A 5% significance level was adopted.

Results

Descriptive data, according to the ergometer and the group of variables, as well as the percentage of technical error measurement (TEM) are shown in Table 1. The Paired T-test did not identify differences in variables related to RPETAn (p = 0.609), HRTAn (p = 0.120) and [LAC]TAn (p = 0.728). The same occurs when the maximum responses are considered at the end of the test, being RPE_{max} (p = 0.371), VO_{2max} (p = 0.410), [LAC]_{peak} (p = 0.371) and effort time (p = 0.096).

Table 2 presents bias and standard deviation (sd), as well as limits of agreement (LoA), both obtained through

Table 1 - Descriptive data of the sample, considering each ergometer (n = 15).

Variables	Keiser-M3	Ergo-167	t (p-value)	Technical error of measurement
Anaerobic threshold measures				
RPE (u.a.)	14 ± 2	13 ± 3	t = 0.523 (p = 0.609)	6.76%
HR (bpm)	146 ± 14.44	149.8 ± 9.41	t = -1.656 (p = 0.120)	2.6%
VO ₂ (mL/kg/min)	14.62 ± 3.25	15.14 ± 2.70	t = 2.247 (p = 0.041)	3.55%
[LAC] (mmol/L)	3.26 ± 1.49	3.53 ± 1.50	t = -0.354 (p = 0.728)	8.28%
Measures at the end of the test				
RPE _{max} (u.a.)	19.66 ± 2.76	18.92 ± 1.20	t = 0.24 (p = 0.371)	3.91%
HR _{max} (bpm)	186 ± 53	188.4 ± 11.83	t = -2.102 (p = 0.719)	1.39%
VO _{2max} (mL/kg/min)	38.37 ± 6.97	36.04 ± 8.40	t = 2.247 (p = 0.410)	6.4%
[LAC] _{peak} (mmol/L)	9.97 ± 2.51	9.71 ± 2.56	t = 0.924 (p = 0.371)	2.67%
Effort time (min)	11.2 ± 2.11	9.86 ± 2.81	t = 1.784 (p = 0.096)	13.59%

RPE = Rated Perceived Exertion; HR = Heart Rate; VO₂ = oxygen uptake; [LAC] = lactate concentration; [LAC]_{peak} = lactate concentration peak.

Table 2 - Concordance of Bland-Altman and Lin's correlation between ergometers (n = 15).

Variables	Concordance of Bland-Altman mean difference \pm sd (IC95%)	Lin's correlation r (classification)
Anaerobic threshold measures		
RPE (u.a.)	0.33 \pm 2.469 (-4.51 - 5.17)	0.17 (very weak)
HR (bpm)	-3.8 \pm 8.89 (-21.22 - 13.62)	0.76 (Strong)
VO ₂ (mL/kg/min)	-0.53 \pm 2.93 (-6.27 - 5.22)	0.59 (Moderate)
[LAC] (mmol/L)	-0.19 \pm 1.576 (-3.28 - 2.89)	0.42 (Moderate)
Measures at the end of the test		
RPE _{max} (u.a.)	-0.33 \pm 1.397 (-3.07 - 2.40)	0.23 (very weak)
HR _{max} (bpm)	-1.86 \pm 8.08 (-17.72 - 13.98)	0.72 (Strong)
VO _{2max} (mL/kg/min)	2.33 \pm 4.25 (-6.01 - 10.67)	0.81 (Strong)
[LAC] _{pico} (mmol/L)	0.26 \pm 1.50 (-2.68 - 3.20)	0.82 (Strong)

RPE = Rated Perceived Exertion; HR = Heart Rate; VO₂ = oxygen uptake; [LAC] = lactate concentration; [LAC]_{peak} = lactate concentration peak.

the Bland-Altman analysis (2000). Moreover, r values and the respective classifications are presented. A concordance was identified regarding the classification between HRTAn (r = 0.762) and HRmax (r = 0.719), which identified a strong correlation between cardiac variables. The lactacidemic responses during ([LAC]TAn r = 0.242) showed moderate correlation; however, [LAC]peak (r = 0.820) showed a strong correlation between ergometers. As well as blood responses, the threshold during MEIT showed a moderate correlation (r = 0.597). Nevertheless, a strong correlation was verified between ergometers in VO_{2max} (r = 0.809). About RPE at the anaerobic threshold, there was a very low correlation between the ergometers (RPE-TAn = 0.176), although a relatively small mean difference (0.33 \pm 2.47) was obtained in the Bland-Altman analysis.

Discussion

This investigation aimed to validate the Keiser™ cycle ergometer, M3 model, for physiologic evaluation in MEIT, comparing it with a previously validated cycle ergometer (Ergo-FIT™, Ergo-167 Cycle model). In this sense, the main findings indicate the following: i) there is a concordance between cardiac results obtained from HRmax and in the anaerobic threshold identification using HR during the test; ii) there is a strong concordance between the ergometers for [LAC]peak variable; iii) a strong correlation between bicycles used for VO_{2max} measurements was found; iv) the MEIT protocol, elaborated for tests in Keiser ergometer, is efficient when the aim is maximal physiologic measurements of HR, [LAC], VO₂ and RPE.

Among the measured physiological parameters, there is a strong agreement between ergometers for HRmax (r = 0.719), which is defined as the highest HR value that an individual can achieve in maximal effort until exhaustion is reached²⁸. In addition, an important indicator was considered to quantify maximum efforts

during the test in ergometers⁹, and the HRmax is widely used to aerobic exercise intensity prescription and is directly related to the VO_{2max}²⁹. HR increased in values according to the load progression in MEIT, and this response was similar in both considered instruments. The mean difference between ergometers for HR_{max} in this study was -1.86 \pm 8.08 bpm, which corroborates with the data observed in the study of Silva¹⁸, in which MEIT's were carried out using different cycle ergometers and, although a lower/upper difference was identified (182.05 \pm 12.39 bpm e 180.57 \pm 12.58 bpm), no significant differences were observed in this cardiac parameter (p = 0.127).

Regarding submaximal measures, the results of this investigation agree with those obtained by Grazi et al.³¹, which verified concurrence in the points of deflection of the HR in different TIMS, showing similar linearity. The concordance between studies can be justified as both studies used test protocols with small increments in fixed-time stages, which follows the recommendations of Conconi et al.³². In addition, the values obtained on the HRTAn showed a strong correlation (r = 0.76). This finding is extremely important, as suggested by Grassl³⁸ since individuals with similar values of cardiorespiratory capacity presented different physiological responses during acute exercise performed in the same percentage concerning VO_{2max}.

The VO_{2max} is described as the higher rate of oxygen captured, transported, and used by the muscle during exhaustive work, and this variable is also used to describe cardiovascular and respiratory of oxygen transport capacity, making it one of the best indicators of cardiorespiratory function^{33,4}. In the present study, VO_{2max} showed a high correlation between ergometers (r = 0.809), with a mean difference of only 2.33 mL/kg/min. Thus, it is possible to assume that the measurement of VO_{2max} using the Keiser-M3 ergometer is accurate in relation to the Ergo-167 ergometer. These results are relevant, considering that VO_{2max} is one of the most essential mea-

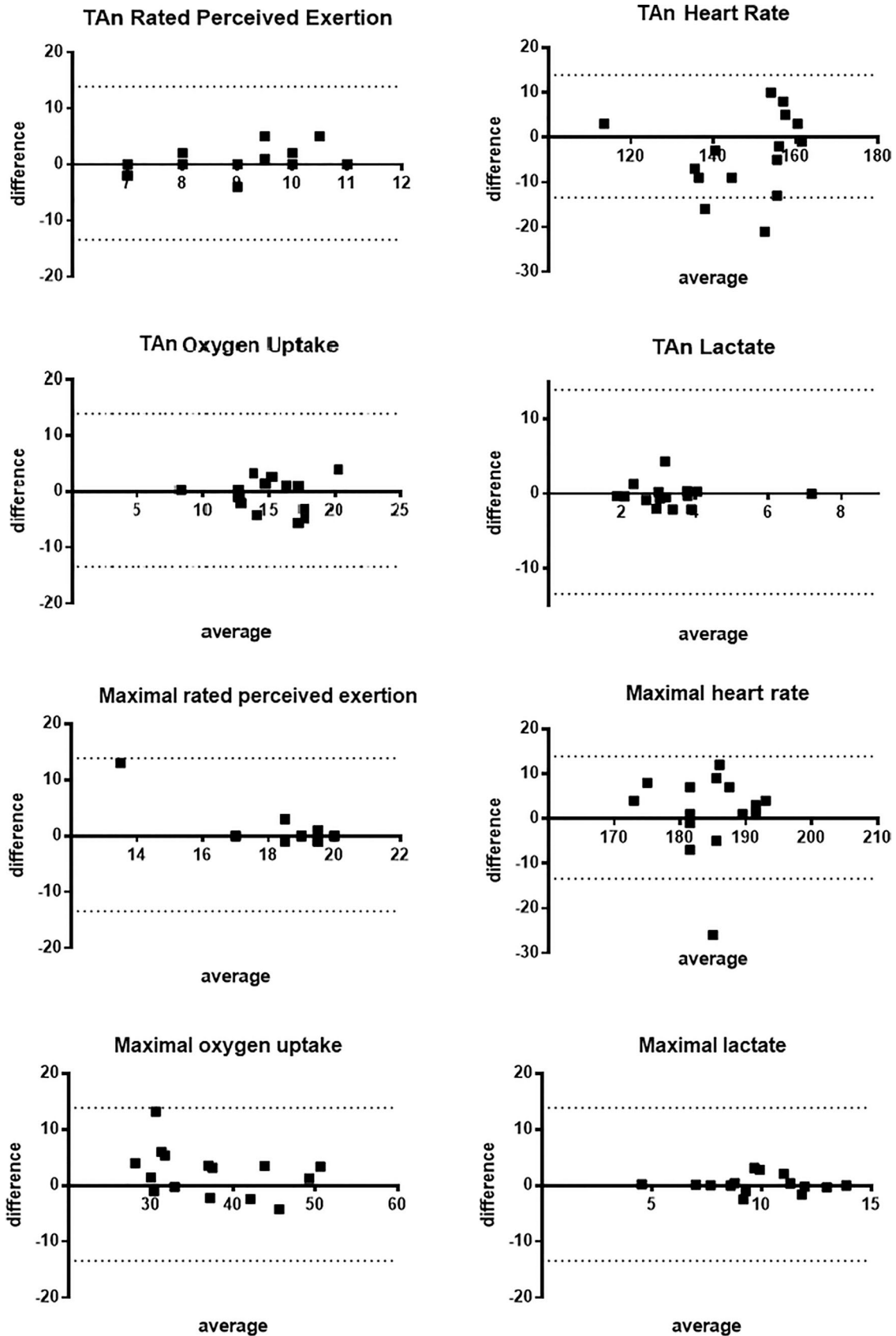


Figure 1 - Bland-Altman graphs for agreement between ergometers.

tures in the exercise physiology area, mainly if they are analyzed for maximum aerobic power and aerobic exercise prescription³⁰. Barbinou et al.³⁴ found that there may be a difference between the same test and retest gas analysis system, suggesting that tolerable differences for VO₂max in repeated measurements may reach 4%. In addition, Hodges et al.³⁵ stated that changes between 3-10% are acceptable and have been cited in the literature. Yule et al.³⁶ reported differences of 15% between three equal gas analyzers but belonging to different laboratories. Considering the obtained data from the same gas analyzer during the collections, a variation of 3.5% was found, that is, lower than the variation indicated in the aforementioned studies. Moreover, regarding VO₂TAn values, despite showing statistical difference ($p = 0.041$), the correlation test found moderate values ($r = 0.59$) between ergometers. Also, the Bland-Altman concordance test demonstrated that the values obtained are within the limits of the agreement provided by the analysis. In a study by Hirakata³⁹, it was indicated that these measures of agreement and correlation may have limitations when used in isolation, highlighting the need for complementary use between them. Thus, observing the results provided by the statistical treatment, it is possible to highlight the feasibility of using Keiser-M3 for VO₂TAn measurements.

Regarding [LAC], its kinetics exhibits two distinct post-effort phases, one when there is a rate of increase and another when there is a rate of decrease³⁷. When considering the [LAC]peak, the obtained results show strong concordance ($r = 0.820$) between the compared instruments, showing its usefulness for the realization of maximum efforts tests. This accumulation in [LAC] can be evidenced by the high energy required by the anaerobic system, which increases blood rates of this metabolic product¹³. Gross et al.³⁸, when investigating cyclists, found that all subjects, even when they did not have a maximal stable phase of [LAC], on reaching fatigue, concomitantly presented similar maximum values of [LAC], making the findings of the present study valid. This investigation also verified the applicability and consistency of the mathematical model HRDP on the identification of the anaerobic threshold. It is also accepted that the MEIT protocol used in the course of this study becomes replicable since the organic responses induced in the two tests were comparable. Another vital point among ergometers is comfort. According to the women participating in this research, the Ergo-167 is uncomfortable and encourages interruption of the test, while the Keiser-M3 is more similar to a conventional bicycle, making it the preferred bicycle among participants. Regarding VO₂TAn values, no statistical differences were found ($p = 0.728$) between MEIT's, with a moderate correlation ($r = 0.42$) and an average difference of 0.2 mmol/L between tests. In a study conducted by Okano et al.¹⁵, it was possible to find inter-individual variation between 1.9 and 5.04 mmol/L, high-

lighting the feasibility of using the Keiser-M3 ergometer in conjunction with the proposed protocol for MEIT. The difference between the values of the studies may be associated with the fact that the authors of the previously mentioned study used frozen samples for analysis, whereas the samples used in this study were immediately analyzed after collection.

Based on the findings of the present study, it was observed that parameters about RPE presented low reproducibility, although they did not present differences between averages. On the other hand, HRTAn, HRmax, VO₂max, and [LAC]peak showed a high level of agreement between ergometers. Thus, the reproducibility of using the Keiser stationary bicycle, model M3, for the realization of MEIT is highlighted, considering that both ergometers may cause physiological stress of similar magnitude for this sample.

The findings in this study are relevant since accurate assessments, both in laboratories and in gyms, are necessary for the planning and monitoring of physical exercise programs. This study demonstrates that stationary bicycles, easily found in different locations, laboratories, or not, may provide a reliable analysis of parameters obtained through MEIT. In the present study, a high correlation was found between the maximum variables and the use of Keiser-M3. Therefore, when the focus of the incremental test is maximum parameters, the Keiser-M3 cycle ergometer is an efficient alternative instrument, without compromising data obtained at the end of the session.

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