Original Article

Measurement Precision of the Anaerobic Threshold by means of a Portable Calorimeter

Fernando dos Santos Nogueira and Fernando Augusto Monteiro Sabóia Pompeu
Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ - Brazil

Abstract

Background: **Many methods are used for determining the Anaerobic Threshold (AT) by means of sophisticated ergospirometer.**

Objective: **To test the AT variation, detected by mathematical models and visual inspection, when low cost ergospirometer is used and intended for clinical application.**

Methods: **Seventy nine apparently healthy subjects were volunteers in this study; from these, 57 men. The VO_{2max} and the ventilatory threshold were determined by indirect, open-circuit calorimetry. The electro-enzymatic method was used for analyzing the lactacidemia and direct determination of the Lactate Threshold (LT). The AT was determined by two mathematical methods (MM_{RSS} and MM_{slope}), based on the gases exchange, and by the log-log visual method, for determining the LT. Two independent investigators determined the AT through visual inspection of three graphs, considering two methods (AT_{-a}= V-slope, EqV; and AT_{-b} = V-slope, EqV and $ExCO_2$). The data were analyzed by means of parametric statistics for determining the differences between AT_{-a} *versus* $ExCO_2$, MM_{RSS} and MM_{slope}; AT-b *versus* MM_{RSS} and MM_{slope}; and LT *versus* AT_{-a}, AT_{-b}, MM_{RSS} and MM_{slope}.**

Results: **The MM_{slope} was the only method that presented a significant difference between the AT_{-a} and AT_{-b} ($p=0.001$), with CV% >15. LT *versus* MM_{slope} did not present significant difference ($p=0.274$), however, it was observed a high CV (24%).**

Conclusion: **It was concluded that with the low cost equipment, the MM_{RSS} and AT_{-a} methods can be used for determining the TAn. The MM_{slope} method did not present satisfactory precision to be employed with this equipment. (Arq Bras Cardiol 2010; 95(3): 354-363)**

Key words: **Exercise test, mathematical model, ventilatory threshold, ergospirometry.**

Introduction

The anaerobic threshold (AT) was initially proposed as tolerance index for cardiopaths[1] exercises. Currently, AT determination is of capital importance in the exercise science because it is a conditioning indicator in several groups of subjects[2-7]. For the indirect and bloodless determination of the AT, gas and ventilatory exchange measures were taken during an ergometric test with increments in the overload[8].

It is believed that the best adjust for detecting the AT is the flexion in the relation between the VO_2 *versus* VCO_2, with $b > 1.15$, which is obtained by means of the intersection between two line segments[9,10]. This detection is performed by means of visual inspection of dispersion diagrams, although mathematical algorithms and statistical calculations have been helping in the automatization and/or semi-automatization of this procedure[9-12].

The ergospirometers with computerized systems are broadly used in measuring the gases exchange and in the inference of the AT. Sophisticated and more expensive equipment is restricted to research labs. Simpler and cheaper ergospirometers were created for clinical and field investigation. Several studies validated the measurements of VO_2, VCO_2 and V_E by means of such clinical equipment[13-19], however a few studies determined the quality of the derived measurements such as AT[20].

Considering the low cost of the clinical equipment and the physiological relevance of the AT for several health professionals, the objective of this retrospective study was to analyze the accuracy of the AT detected by means of the measurements obtained by the indirect calorimetry system TEEM 100™ Total Metabolic Analysis System (Aerosport, Inc., Ann Arbor, Mich., USA)[17-20], determining the objectivity and the accuracy of the mathematical models of Beaver et al[9] adapted by Gaskil et al[21] and Vieth[10] and of the visual inspection methods V-slope[22], V_E/VO_2[23], $ExCO_2$[21] and lactate threshold[24].

Mailing address: Fernando dos Santos Nogueira •
Rua Conselheiro Paranaguá, 48/101 - Vila Isabel - 20551-150 - Rio de Janeiro, RJ - Brazil
E-mail: nogueira_ufrj@hotmail.com, mportomedicina@yahoo.com.br
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Methods

Subjects

The present investigation was divided into two assays consisted of two volunteer groups of both sexes, from 18 to 37 years old, apparently healthy, no smokers and no athletes, with or without experience in cycloergometer, engaged or not in aerobic training programs (tab. 1). In the first group, it was analyzed the discrepancy between the mathematical methods and the visual inspection ones to determine the AT. In another group, it was investigated the association between the ventilatory parameters and the gas exchange with the blood concentration of lactate to determine AT.

It was recommended, for the 24 hours before the test, absence of extenuating physical activities (> 5 METs) and no alcohol ingestion. It was also recommended to keep the mixed diet in the 48 hours before the test. It was also requested no ingestion of food and caffeine three hours before the effort. Each subject was informed regarding the risk associated to the adopted procedures. An informed consent was read and signed. All the procedures adopted were approved by the Local Ethics Committee on Research with human beings (Rio de Janeiro, CEP/HSE 000.021/99). This study was performed as per Declaration of Helsinki.

Maximum test on the cycloergometer

Group 1 (G-1) - The continuous and maximum, scaled effort protocol[1] was used with a mechanical cycloergometer (Monark™, São Paulo, SP, Brazil). The height of the saddle was adjusted for each subject, so the knee could keep an angle close to the total extension (approx. 175º). The maximum power was previously estimated for each subject, in order to make possible 10% increments of the maximum load every minute[25]. After six minutes in rest, sitting on the cycloergometer saddle, the subjects pedalled with load for four minutes and, then, the scaled phase was started. The maximum duration of the exercise was of 10 ± 2 min. The subjects kept the fixed rhythm during the test (approx. 1.23 Hz). The rhythm was controlled by an audiovisual metronome (Wittner^{â} Junior Plast 826, Isny/ Allgäu, Germany).

The minute ventilation (V_E) and the oxygen and carbon oxide expired fraction were continuously measured by means of open circuit indirect calorimetry (TEEM 100™ Total Metabolic Analysis System, Aerosport, Ann Arbor, Mich., USA)[17-20]. The subjects used a nose clip and a medium flow pneumotachometer (Hans Rudolph™, Kansas City, MO, USA). The minute consumption oxygen (VO_2) as well as the carbon dioxide excretion, per minute (VCO_2) were presented every 20 seconds. The heart rate (HR) was monitored continuously during the test by means of telemetry (Vantage NV™, Polar Electro Oy, Kempele, Finland) and the perceived effort concept (PEC), in Borg scale of 6 to 20, was collected at the end of each stage.

Group 2 (G-2) - The ergospirometric protocol was the same of G-1, being added the blood lactate measurements. It was collected 25 μl of blood, by puncture of the ear lobe in hyperemia, as per the procedures described by Shephard[26]. The collections were performed during rest, two minutes before the test and every two minutes of effort. The samples were immediately analyzed by electroenzymatic method (YSI 1500 Sport L-Lactate Analyser™, Yellow Springs, USA). For determining the total blood lactate, the hemolytic agent Triton X-100 (YSI #1515 Agent Cell Lysing, USA) at 0.25% was added to the buffer solution. The blood collections were performed by an experienced evaluator between the 20 and 25 final seconds of every two minutes of effort.

Controls and calibration

The metabolic analyzer, the lactate analyzer and the cycloergometer were calibrated before each test. The ergospirometer was calibrated in closed circuit, by means of a certified mixture of gases containing 17.01% of oxygen, 5.00% of carbon dioxide and balanced with nitrogen (AGA™, Rio de Janeiro, RJ, Brazil). The flow was calibrated using a three-liter air syringe (Hans Rudolph™, Kansas City, MO, USA). At the end of each test, the measurement of oxygen and carbon dioxide percentage fractions in the gas mixture used for calibration was performed. The maximum error allowed was 16.16% to 17.86% for FO_2 and 4.75% to 5.25% for FCO_2. The lactate analyzer had the calibration confirmed before the test, by means of a standard solution of 5 mmol·l^{-1} (YSI #2327 Lactate Standard YSI™, USA) of lactate. Before each test, and at every hour of use, a new calibration was performed. The linearity of the equipment was confirmed at 15 mmol·l^{-1} of lactate. Before the beginning of the experiment, the precision of the equipment was checked by means of a calibration curve with standards of 1.0; 2.5; 5.0; 7;5; 12.0; 15.0; 18.0; 24.0 and

Table 1 - **Anthropometric characteristics and ergometric variables obtained in the maximum test in cycloer**

Variables	Group 1 (n = 70)		Group 2 (n = 9)	
Age (years)	25 ± 5	(18-37)	23 ± 4	(19-29)
Mass (kg)	70.9 ± 12.1	(47.9.0-106.6)	76.5 ± 17.2	(51.3-106.5)
Stature (cm)	173.0 ± 10.0	(148.0-194.0)	177.0 ± 10.0	(160.0-188.0)
VO_{2max} (l·min^{-1})	3.37 ± 0.90	(1.57-4.84)	2.73 ± 1.10	(1.36-4.97)
VO_{2max} (ml·kg·min^{-1})	47.3 ± 9.2	(29.4-64.8)	35.6 ± 11.6	(23.8-59.2)
W_{max}	253 ± 59	(135-363)	178 ± 59	(120-325)

*Average ± SD (minimum and maximum value). Difference between the groups determined by the Student's t test for independent samples. * Significant difference for p ≤ 0.05.*

30.0 mmol·l^{-1}, prepared by the dilution of standards supplied by the manufacturer (YSI #2327: 5 mmol·l^{-1}; YSI #2328: 15 mmol·l^{-1}, YSI#1530: 30 mmol·l^{-1} Lactate Standard YSI™, USA). The association between the measured and the expected values in the calibration curve was $r=0.999$, $y=0.9436x + 0.33011$ and $EPE=0{,}20$ mmol.l^{-1}. The cycloergonometer was calibrated by means of a 3 kg-ballast.

The tests were considered as maximum when at least three of the following criteria were observed[27]: a) plateau in VO_2 (increase ≤ 150 ml.min^{-1} or 2 ml.kg^{-1}.min^{-1}); b) respiratory exchange ratio (RER) ≥ 1.15; c) 90% of FC_{max} forecast by the age (220 - age); d) perceived effort concept ≥ 19 (6-20); e) blood lactate concentration ≥ 8 mmol·l^{-1}; and f) maximum voluntary fatigue with inability of keeping the pre-established rhythm. The VO_{2max} was determined as being the highest value found at the end of the test.

Methods for detecting AT by visual inspection

Three methods for detecting the anaerobic threshold for visual inspection were used:

Ventilatory equivalent method (EqV)[23] - Moment when there is an increase of the ventilatory equivalent for oxygen consumption (V_E/VO_2) without the concurrent increase in the ventilatory equivalent for carbon dioxide excretion (V_E/VCO_2).

Carbon dioxide excess method (ExCO$_2$)[21] - With the increase of the exercise intensity, it is observed an excess of carbon dioxide production calculated as $((VCO_2{}^2/VO_2)\text{-}VCO_2)$.

Simplified V-slope method (V-slope)[22] - In the Cartesian coordinates graph, having in the abscissa axis the consumption of oxygen per minute (VO_2) and in the ordinate, the excretion of carbon dioxide per minute (VCO_2), it was observed the moment when the points surpass the line parallel to the right angle bisectrix.

For each individual, the three methods of AT determination were analyzed visually by two experienced investigators.

AT analysis by mathematical method

Two functions of linear regression were described for the test from the relation between VO_2 *versus* VCO_2, as follows:

$y_1 = a_1+b_1.x_i$ $\quad x_i \le x_0$ $\quad$ (eq.01)

$y_2 = a_2+b_2.x_i$ $\quad x_i > x_0$ $\quad$ (eq.02)

where (x_0,y_0) represents the coordinate of critical point (AT).

On the first interaction, the observations x_1, x_2 and x_3 were included, estimating the parameters of the first regression line. The remaining observations n-3, $x_4,\ldots x_n$ were used to adjust the second regression line. In the following interaction, the first regression line was adjusted with the observations $x_1,\ldots x_4$ and the parameters of the second regression line were based on the observations n-4. At each interaction, an additional observation of the second part of the data was transferred to the first part and second regression line was adjusted with the remaining observations.

Vieth's mathematical method[10] (MM_{RSS}) - The estimate of the parameters was based on the least square methods. For the inference of the inflexion point, the residual sum of squares (RSS) was calculated for each regression line.

$$\text{SQR} = \sum_{x_i \le x_0}[y_i - (a_1 + b_1 \cdot x_i)]^2 + \sum_{x_i > x_0}[y_i - (a_2 + b_2 \cdot x_i)]^2$$

(eq.03)

The RSS is used as a criterium to determine the best adjust. The optimum adjusts of a_1,b_1,a_2,b_2 and x_0 are the values of the minimum RSS for the two lines.

Beaver's[9] *Modified mathematical method*[21] *of V-*slope (MM_{slope}) - The intersection between the two regression lines was employed for determining the AT. The solution was accepted when it is observed an increase in the inferior segment slope to the superior equal to one. This method, which originally employed an analysis of the collected gases at each respiratory incursion, was modified for the use of the incursions average at every 20 seconds[21].

Determination of lactate threshold

The results obtained by the blood lactate analysis were determined individually through the log-log method, described by Beaver et al[24]. The transformation of the data for the logarithmic method was performed for locating the inflexion point or the lactate threshold, which was understood as a crossing point between the two formed lines.

Statistical analysis

The statistical treatment was performed by means of the Statistical Package for the Social Sciences™ (SPSS, USA*)*, SigmaPlot™ (*Systat Software Inc.*, Alemanha) and Microsoft Excel™ applications for Windows XP™ (Microsoft, USA). The descriptive statistics was used, with average ± standard deviation (SD). It was used the grand average of the results obtained from the EqV and V-slope methods, by two evaluators, designating AT_{-a}. The grand average of the results obtained from the EqV, V-slope and $ExCO_2$ methods, used by two evaluators designated AT_{-b}. The values measured from AT_{-a} *versus* $ExCO_2$, MM_{RSS}, MM_{slope} and AT_{-b} *versus* MM_{RSS} and MM_{slope}, for G-1 and; LT *versus* AT_{-a}, AT_{-b}, MM_{RSS} and MM_{slope}, for G-2, were compared by means of variance analysis (ANOVA) with a factor and post-hoc test of Tukey-HSD. The limits of agreement of Bland-Altman[28] were employed. The association degree between the methods was determined by means of an intra class correlation coefficient (ICC). The error was also observed by measurement of technical error ($s = D.P._{dif} \div \sqrt{2}$) and of the variation coefficient (VC). It was also employed the above statistical treatment to evaluate the results obtained through two evaluators. It was compared the indices obtained of AT_{-a} and AT_{-b} *versus* Evaluator 1 and Evaluator 2 by means of ANOVA with two factors and *post-hoc* test of Tukey-HSD. All the statistical tests were performed at the significance level ≤ *0.05*.

Results

The characteristics of the subjects are in table 1. Table 2 presents the average and SD for AT_{-a}, $AT\text{-}_b$, $ExCO_2$, MM_{RSS}, MM_{slope} and LT, including comparative statistics between AT_{-a} $ExCO_2$, MM_{RSS}, MM_{slope} and AT_{-b} *versus* MM_{RSS}, MM_{slope} for G-1 and LT *versus* AT_{-a}, AT_{-b}, MM_{RSS} and MM_{slope} for G-2. It is noted that only MM_{slope} presents significant difference, when compared to AT_{-a} and AT-$_{b}$ (*p* = 0.001) and *CV* was above 18% in the two detection forms of AT. It was not observed a significant difference between AT_{-a} *versus* $ExCO_2$ and MM_{RSS} and AT_{-b} *versus* MM_{RSS}. In G-2, the visual inspection methods presented good correlation, as well as the MM_{RSS}, when compared to LT.

The dispersion diagrams of the left hand side of the figures 1 and 2 presented the relation between AT_{-a} *versus* $ExCO_2$, MM_{RSS}, MM_{slope} and AT_{-b} *versus* MM_{RSS}, MM_{slope}, respectively. In figure 3, there is a relation between LT *versus* AT_{-a}, AT-$_{b,}$ MM_{RSS} and $MM_{slope..}$ It is noted the proximity between the identity line and the trend lines for AT_{-a} *versus* $ExCO_2$ and MM_{RSS} and AT_{-b} *versus* MM_{RSS} and LT *versus* AT_{-a}, AT_{-b} and MM_{RSS}. The right hand side data in these figures refer to the limits of agreement of Bland-Altman[27]. Table 2 summarizes the values found for each analysis.

There was no significant difference for determining AT by means of visual inspection between the evaluators (p=0.757) and methods (p=0.700), and also there was no interaction between the evaluators *versus* methods (p=0.876). The evaluators presented for AT_{-a}: limits of agreement = 0.02 ± 0.29 $l.min^{-1}$, ICC = 0.92, *s* = 0.11 $l.min^{-1}$ and *CV* = 7%; and for AT_{-b}: limits of agreement = 0.01 ± 0.24 $l.min^{-1}$, *ICC* = 0.95, *s* = 0.09 $l.min^{-1}$ and *CV* = 6%.

Table 3 presents the reliability indices obtained from the previous studies of clinical equipment or for the lab use. High ICC indices were observed between the pieces of equipment for clinical use, with exception of MetaMax II. Similar indices are found in lab use equipment.

Discussion

The ergospirometric test and the AT analysis allow the integration study between the pulmonary, cardiovascular and muscleskeletal systems[29,30]. There are cases where this is the only means to understand the physiopathological mechanisms as in severe pulmonary vascular disease without right hypertension, in the open oval foramen with development of left-right shunt, during the exercise, in effort dyspnea, in effort hypoxemia, among others[31]. Its application in cardiopaths and pneumopaths groups is advantageous before the invasive or high cost procedures[30,31]. The present study proposal was to test the accuracy of the ergospirometric equipment that allows measurements with quality for the clinical application. Comparing the mathematical methods proposed by Beaver et al[9] and Vieth[10], with the V-Slope[22], Ventilatory Equivalent for VO_2[23], CO_2 Excess[21] and Lactate Treshold[24] methods for determining AT.

The sample of this study was consisted of non-athlete, healthy subjects, with or without experience in cycloergometer, engaged or not in aerobic training programs. Hereditary characteristics and the involvement in exercise programs can explain the large dispersion of VO_{2max} values. Even considering the experience of the individuals with the cycloergometer, this equipment can overload the inferior limbs, causing early fatigue[32,33]. The fatigue of the inferior limbs may result in low and relatively high AT (%)[31]. The AT can, also, certainly be super or subestimated in response to the overload increments[9]. The AT (%) found for the subjects during the progressive test was close to what was expected for non-obese, physically active and apparently healthy individuals[31]. Billat[34] demonstrated that the highly trained subjects are able to use more intensively the oxidative routes, therefore with lower lactate accumulation, with intensities of up to 90% of its VO_{2max}. Our results allowed to estimate the AT by the $AT_{-a,}$ $AT_{-b,}$ MM_{RSS}, MM_{slope} and LT methods, in percentage of VO_{2max} and, were close to the expected results for a test performed in cycloergometer[31].

Gaskill et al[21] studies the association between the several visual inspection methods and suggested that there are benefits in the analysis with the combination of the methods: V-slope, $ExCO_2$ and EqV. Another study[20], using the same equipment adopted in this study, also suggested the use of combined analysis of gas exchange and ventilatory parameters in order

Table 2 - VO_2 average ($l{\cdot}min^{-1}$) in AT obtained by means of the visual and mathematical inspection methods (Group 1, n = 70) and by means of visual, mathematical and lactate threshold methods (Group 2, n = 9) including comparative statistics

	Group 1					Group 2			
	AT_{-a} (1,49 ± 0,37 $l{\cdot}min^{-1}$) *versus*			AT_{-b} (1,51 ± 0,38 $l{\cdot}min^{-1}$) *versus*		LT (1,21 ± 0,46 $l{\cdot}min^{-1}$) *versus*			
	$ExCO_2$	MM_{RSS}	MM_{slope}	MM_{RSS}	MM_{slope}	AT_{-a}	AT_{-b}	MM_{RSS}	MM_{slope}
VO_2 ($l{\cdot}min^{-1}$)	1.55 ± 0.43	1.42 ± 0.43	1.93 ± 0.67*	1.42 ± 0.43	1.93 ± 0.67*	1.30 ± 0.43	1.32 ± 0.47	1.25 ± 0.57	1.77 ± 0.89
Limits of Agreement (± 1,96 SD)	-0.06 ± 0.43	0.07 ± 0.42	-0.45 ± 0.95	0.09 ± 0.38	-0.43 ± 0.88	-0.09 ± 0.37	-0.10 ± 0.32	-0.04 ± 0.44	-0.56 ± 0.98
ICC	0.85	0.85	0.61	0.88	0.66	0.91	0.94	0.91	0.75
S	0.15	0.15	0.34	0.14	0.32	0.13	0.12	0.16	0.35
CV%	10	11	20	09	18	11	09	13	24
P	0.877	0.851	0.001	0.574	0.001	0.997	0.996	0.999	0.274

*ICC - intra class correlation coefficient; s - typical error; CV% - coefficient of variation %; p - statistical significant; SD - standard deviation; AT_{-a} - grand average EqV and V-slope; AT_{-b} - grand average EqV, V-slope and $ExCO_2$; $ExCO_2$ - CO_2 excess method; MM_{RSS} - mathematical method of the residual sum squares method; MM_{slope} - mathematical method for V-slope; LT = Lactate threshold. Group 1 = AT_{-a} versus $ExCO_2$, MM_{RSS} and MM_{slope} and AT_{-b} versus MM_{RSS} and MM_{slope}. Group 2 = LT versus AT_{-a}, $AT_{-b,}$ MM_{RSS} and MM_{slope}. * Significant difference for p < 0.05 determined by ANOVA with a factor and post-hoc test of Tukey HSD.*

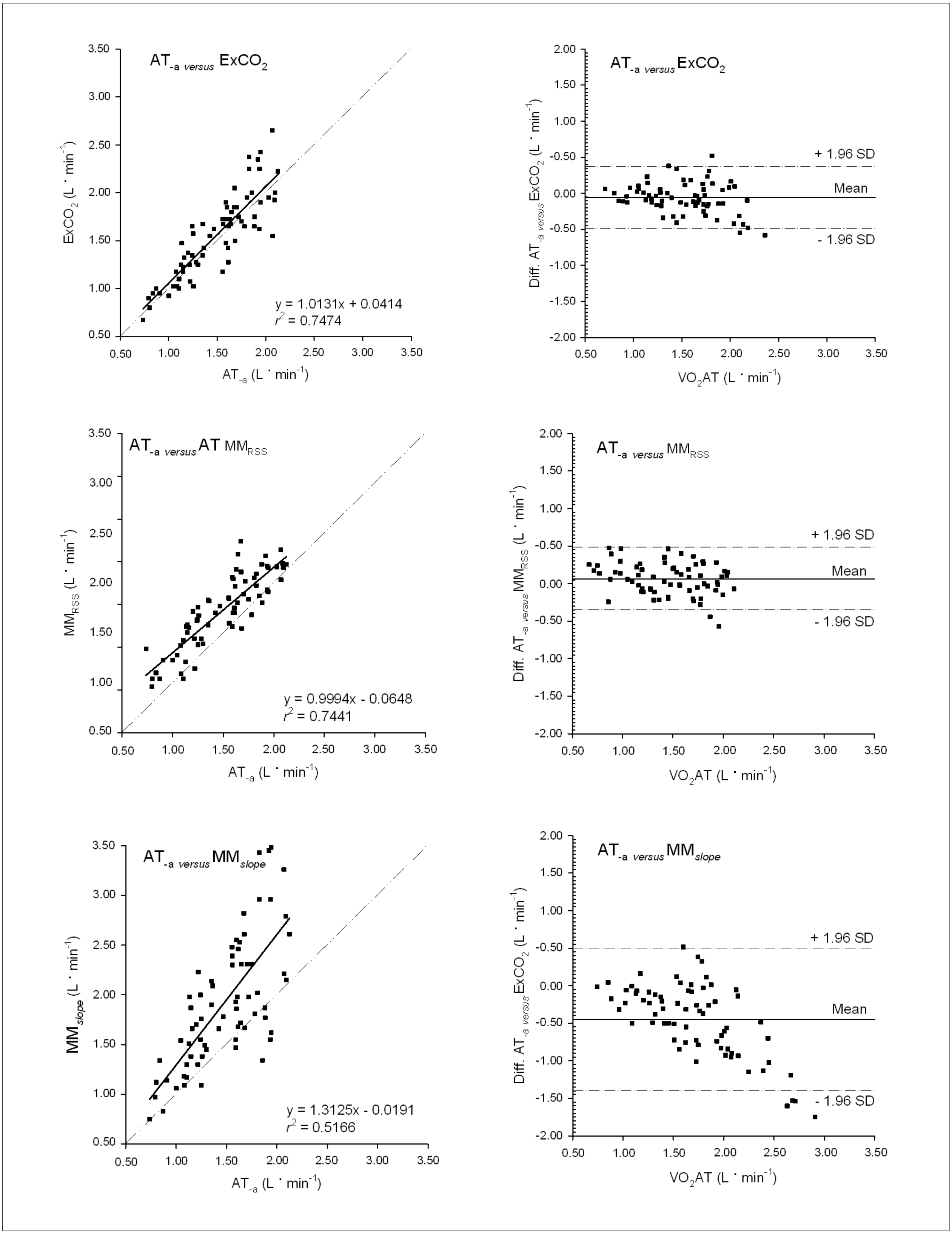

Figure 1 - *Validity test between the methods for male and female subjects (Group 1, n = 70). The graphs present the relation between AT_{-a} versus AT $ExCO_2$, MM_{RSS} and MM_{slope}. The graphs to the left present a relation between the methods by means of the identity line (intermittent), trend line (continuous line) and regression equation with determination coefficient (r^2). The graphs to the right present the limits of agreement of Bland-Altman. The dark lines refer to the differences average and the intermittent lines, the variation to ± 1.96 SD. The figures 2 and 3 follow the same format.*

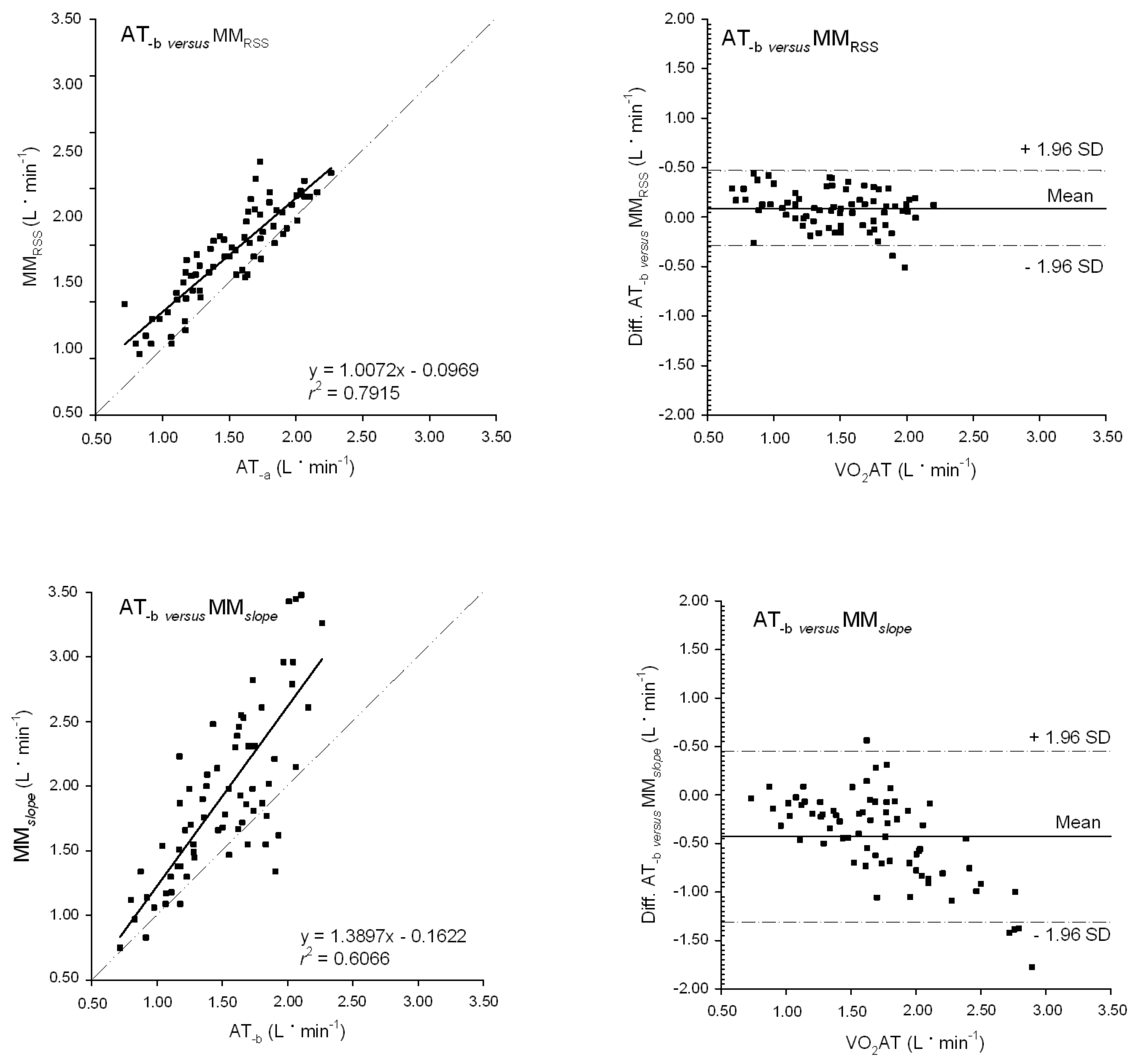

Figure 2 - Validity test between AT_{-b} versus MM_{RSS} and MM_{slope} (Group 1, n = 70).

to reduce the methodological error in determining the AT. The present investigation decided to make the comparisons with combined data (AT_{-a} and AT_{-b}) and tested only the $ExCO_2$ method separately. The statistical analysis showed a good association between the $ExCO_2$ and the AT_{-a} methods; however the increase of more than a detection method of AT did not reduce significantly the CV% from the one observed for MM_{RSS}, MM_{slope} and LT (tab. 2).

The data presented in table 2 and figures 1, 2 and 3 suggest a satisfactory approximation between the AT_{-a} and AT_{-b} methods. These methods presented an excellent correlation with MM_{RSS} and LT. A reasonable correlation was found between LT and MM_{slope}. Caiozzo et al[23] presented the EqV as the best isolated method for determining the AT (r = 0.93). According to these authors, the V-slope method does not produce a good estimate of AT. However, Gaskill et al[21] did not find a significant difference between the V-slope and EqV methods, when compared with the LT (± 5 ml·min^{-1}) indicating good agreement between the methods. Similar findings related by Santos et al[35] and by Granja Filho et al[20].

Beaver et al[9] proposed a method that eliminates the points that produce a regression line slope lower to 0.6 and values above the respiratory compensation point. The present investigation, based on a previous study[21], modified

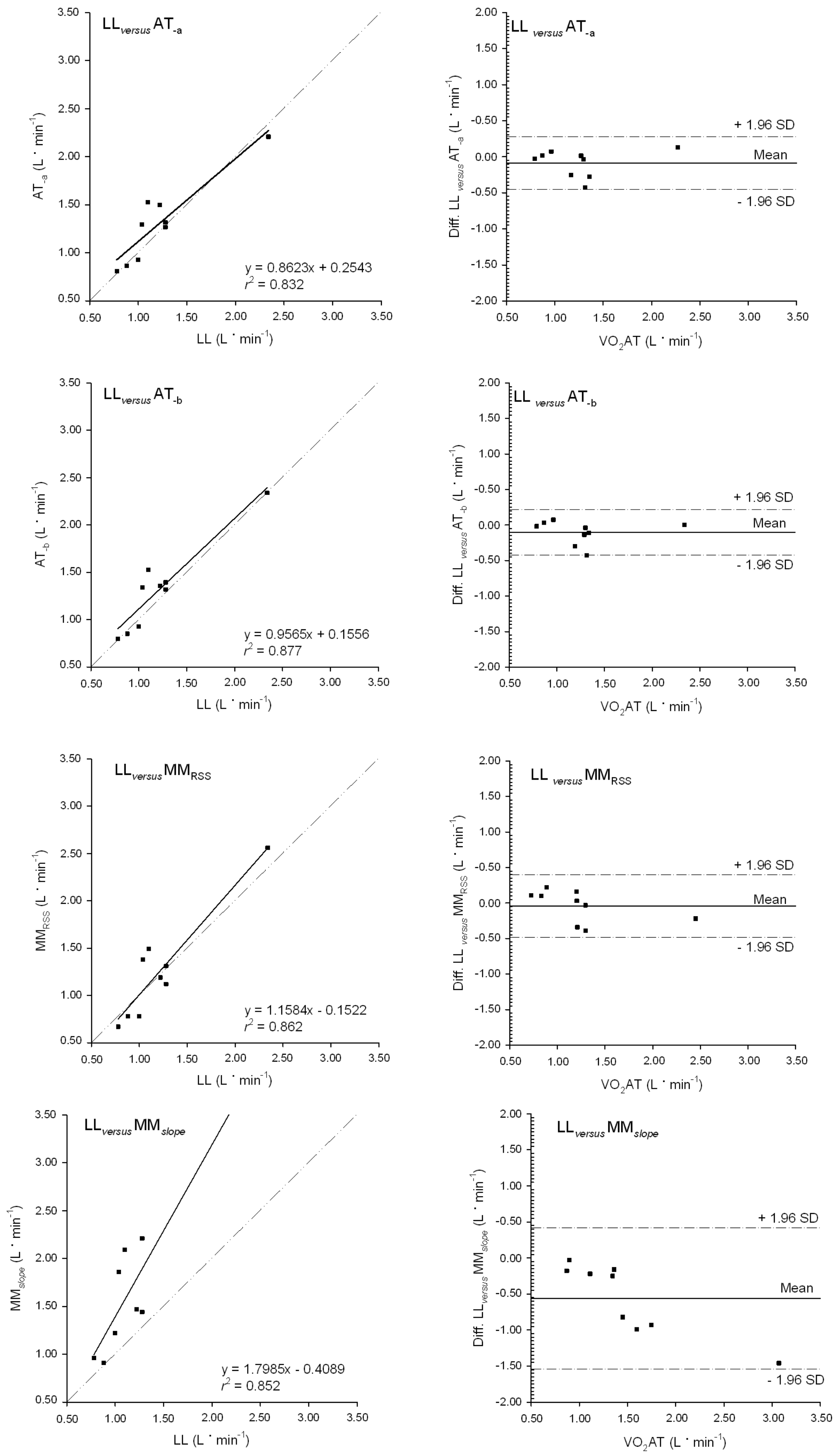

Figure 3 - *Validity test between LT versus AT_{-a}, AT_{-b}, MM_{RSS} e MM_{slope} (Group 2, n = 9).*

Table 3 - **Previous studies on reliability of portable and stationary equipment**

Reference	n	Conditions	System		ICC	CV(%)	Average difference (± 95%)
Portable system							
Lothian et al[13]	1	Treadmill: INC	Cosmed K2	VO_2		3.0-14.0	
				VCO_2			
				V_E			
Lucia et al[14]	20	Treadmill: SUBMAX e MAX	Cosmed K2	VO_2			0.01 (NR)
				VCO_2			
				V_E			1.05 (NR)
Meyer et al[15]	23	Cycloergometer: INC	MetaMax I	VO_2	0.98		0.05 (± 0.30)
				VCO_2	0.99		0.05 (± 0.30)
				V_E	0.97		1.00 (± 9.00)
Larsson et al[16]	19	Cycloergometer: SUBMAX 100 W (n= 9) 200 W (n= 10)	MetaMax II	VO_2	0.56-0.90		
				VCO_2	0.66-0.88		
				V_E	0.43-0.84		
Melanson et al[17]	22	Treadmill: SUBMAX	TEEM 100	VO_2	0.96		0.00 (± 0.17)
				VCO_2			
				V_E	0.86		1.90 (± 1.37)
Granja Filho et al[20]	14	Cycloergometer: INC	TEEM 100	VO_2	0.97	5.5	0.14 (NR)
				VCO_2			
				V_E			
Crouter et al[37]	10	Cycloergometer: INC	VO2000	VO_2	0.99	14.2	-0.04 (± 0.33)
				VCO_2	0.99	15.8	-0.02 (± 0.37)
				V_E	0.98	8.8	-1.22 (±11.04)
Online system stationary							
Lothian et al[13]	1	Treadmill: INC	Quinton	VO_2		1.1-3.9	
				VCO_2			
				V_E			
Meyer et al[15]	23	Cycloergometer: INC	MetaLyzer 3B	VO_2	0.97		-0.01 (± 0.40)
				VCO_2	0.96		-0.01 (± 0.40)
				V_E	0.95		0.01 (± 13.00)
Carter et al[38]	10	Cycloergometer: SUBMAX 100 W 150 W	Douglas Bag	VO_2		3.3-5.1	
				VCO_2		3.9-5.0	
				V_E		5.1-5.7	
Carter et al[38]	10	Cycloergometer: SUBMAX 100 W 150 W	Oxycon Alpha	VO_2		4.5-6.3	
				VCO_2		4.8-5.3	
				V_E		6.1-7.3	
Carter et al[38]	10	Cycloergometer: SUBMAX 100 W 150 W	Pulmolab EX670	VO_2		26,8-33,6	
				VCO_2		33,1-45,8	
				V_E		7,6-12,5	
Carter et al[38]	10	Cycloergometer: SUBMAX 100 W 150 W	Oxycon Pro	VO_2		4,7-6,5	
				VCO_2		5,3-7,1	
				V_E		6,6-7,4	
Crouter et al[37]	10	Cycloergometer: INC	TrueOne 2400	VO_2	0,99	4,7	-0,04 (± 0,23)
				VCO_2	0,99	5,7	-0,03 (± 0,28)
				V_E	0,96	7,3	-1,34 (± 10,56)
Crouter et al[37]	10	Cycloergometer: INC	Douglas Bag	VO_2	0,99	5,3	-0,05 (± 0,28)
				VCO_2	0,99	6,0	-0,05 (± 0,33)
				V_E	0,97	8,5	-1,36 (± 11,22)

n - número de sujeitos, ICC - coeficiente de correlação intraclasse, CV - coeficiente de variação, INC - teste de incremento, SUBMAX - teste SUBMAXimo de carga fixa, NR - não relatado.

the original method so all the data could be used in the linear adjust. Such adaptation was necessary due to the temporal resolution of the measurements by means of the equipment used in this study. Kelly[36] observed that the results obtained by the original mathematical method of Beaver et al[9] presented a major estimate standard error, when compared to MM_{RSS}. Santos et al[35] found for this method, percentage indices of 83% of VO_{2max}. In our study, we observed high intensities of AT[31] by means of MM_{slope}, indicating a possible method inaccuracy.

There are few studies related to the reliability of the metabolic analysis system of low cost, The table 3 presents some indicators for clinical and scientific use equipment. The equipment used in this study presents a test-retest reliability of 5.5% for VO_{2max}, according to Granja Filho et al[20]. Melanson et al[17] found ICC of 0.96 for VO_2 and 0.86 for V_E. On the same study[17], the equipment was validated comparing it with a computerized reference system, and Pearson's correlation coefficients of 0.91 to 0.97 were found for V_E and 0.88 to 0.97 for VO_2. Wideman et al[19] found differences of 2% to 11% for VO_2 and 5% to 17% for VCO_2 in several intensities. An average difference of 3.9% for VO_2 was found by Novitsky et al[18] when compared to Sensormedics 2900™. The indices presented in table 3 related to the validity and reliability of VO_2, VCO_2 and V_E of TEEM 100, and other clinical equipment were found a little under the ones observed for the most sophisticated equipment for the scientific investigations.

Considering the AT importance as exercise tolerance índex and conditioning indicator in several groups of individuals[1-7], we conclude that MM_{RSS}, as well as the visual inspection methods of AT_{-a} and AT_{-b} are satisfactorily accurate and objective for the determination of that metabolic reference. The inclusion of another visual inspection method ($ExCO_2$) did not reduce significantly the error. We also conclude that MM_{slope} did not present significant accuracy for determining the AT in the equipment adopted in this study[38].

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Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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