Anaerobic Threshold in a Water-Based Exercise: Agreement Between Heart Rate Deflection Point and Lactate Threshold Methods

Cristine L. Alberton, Luana S. Andrade, Rochele B. Pinheiro, and Stephanie S. Pinto

Laboratory of Neuromuscular Assessment, Department of Sports, Federal University of Pelotas, Pelotas, Brazil

Abstract

Alberton, CL, Andrade, LS, Pinheiro, RB, and Pinto, SS. Anaerobic threshold in a water-based exercise: agreement between heart rate deflection point and lactate threshold methods. *J Strength Cond Res* 35(9): 2472–2478, 2021—The purpose of this study was to compare and assess the agreement of the heart rate (HR) and rating of perceived exertion (RPE) corresponding to the anaerobic threshold (AT) between HR deflection point (HRDP) and lactate threshold (LT) methods during a water-based exercise in young men. Sixteen young men (24 ± 6 years) performed the experimental protocol, which comprised the performance of a maximal incremental test during the water-based stationary running exercise. The initial cadence corresponded to 90 b·min^{-1}, with 10 b·min^{-1} increases every 3 minutes up to exhaustion. Heart rate was monitored every 30 seconds while blood lactate concentrations and RPE were measured at the end of each 3-minute bout. Anaerobic threshold was identified by HRDP and LT methods by experienced physiologists. Paired Student's *t*-test, Bland-Altman analysis, and Pearson correlation were used for data analysis (α = 0.05). As results, there was agreement between HRDP and LT methods for HR, while RPE presented significant higher values for the HRDP method, resulting in an absence of acceptable agreement between methods. In addition, strong relationships ($p \leq 0.001$) were verified between methods of AT determination for HR ($r = 0.786$) and RPE ($r = 0.916$). Therefore, based on the agreement between HRDP and LT methods, the HR determined by HRDP may be a valid parameter used for the intensity prescription of water-based stationary running exercise in young men during water aerobics programs and may be considered more reliable than RPE.

Key Words: rating of perceived exertion, water aerobics, stationary running, young men

Introduction

Water-based exercises are widely recommended for individuals of all ages and physical conditions with the purpose of rehabilitation and health promotion. Recent studies have shown that water aerobics promotes significant gains in cardiorespiratory conditioning and in additional health outcomes (18,19,33,34). However, water immersion exposes the body to several physiological adjustments because of the hydrostatic pressure and different thermal conditions (31,32), leading to primary reactions in the hemodynamic, neuroendocrine, and metabolic parameters. Therefore, the evaluation and prescription of water-based exercises used in water aerobics should consider these alterations to guarantee adequate control of training intensity in this environment.

Heart rate (HR) and rating of perceived exertion (RPE) outcomes have been investigated in water-based exercises at preselected submaximal intensities (5,7,36) and, more recently, along maximal incremental protocols (1,3,4,6,8,20,26). These latter studies have reported lower maximal HR (HRmax) and maximal oxygen uptake ($\dot{V}O_2$max) values for water-based compared with land-based exercises (1,3,26), with similar maximal RPE between the environments (1,3). Despite these changes due to water immersion, a recent study has reported a significant quadratic relationship between %HRmax and %$\dot{V}O_2$max throughout a maximal incremental aquatic protocol (20). In addition, a strong quadratic relationship has been observed between $\dot{V}O_2$ and RPE, as well as between HR and RPE, during maximal incremental aquatic protocols (4,20). Therefore, it is important to understand the pattern of cardiorespiratory parameters during specific water-based exercises to correctly prescribe the intensity in water aerobics.

Nevertheless, there is some criticism for using either %$\dot{V}O_2$max or %HRmax when prescribing exercise intensity because these methods fail to account for differences in metabolic stress (22,25,28,38). By contrast, exercise prescribed relative to the anaerobic threshold (AT) would be expected to produce lower individual variation in metabolic responses and lower individual variation in time to exhaustion at a constant exercise intensity, providing a more homogenous training stimulus than training prescribed using %HRmax or %$\dot{V}O_2$max (27). It is also important to determine the AT during water-based exercises because this intensity demarcates the superior limit of the predominantly aerobic training zone and may be used to adjust the water aerobics training sessions (3). In fact, recent studies have used the prescription of aerobic training during water-based exercises based on the HR corresponding to the AT (33,34), finding significant improvements in cardiorespiratory parameters after 12 weeks of water-based concurrent training programs in young and postmenopausal women. However, the AT in both studies has been determined by the ventilatory method, using a gas analyzer, which has poor practical application in aquatic centers, sport clubs, and gyms.

The RPE value corresponding to AT has also been investigated in water-based exercises (1,4); however, its value was only determined by the ventilatory method. The overall perceived

Address correspondence to Dr. Cristine L. Alberton, tinialberton@yahoo.com.br.

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exertion integrates perceptions from several important cues, including physiologically local factors, such as the skin, muscles, and joints, and central factors, such as cardiovascular and pulmonary organs, and also psychological factors (11). Its use for exercise intensity prescription during water aerobics training sessions is simple and low-cost. A recent study using RPE for the prescription of a water aerobics training program based on the values corresponding to the AT (19) observed significant $\dot{V}O_2$max improvements after 12 weeks of training in women with dyslipidemia.

Ventilatory and lactate methods are considered gold standard for determining AT. However, such methods are expensive, and the blood lactate concentration ([lac]) is considered an invasive technique. In this context, Conconi et al. (17) developed a running protocol based on the relationship between HR and running speed. This relationship is curvilinear, and the speed at which this break in linearity occurs (deflection point) has been shown to be associated with AT. This method for determining the AT is called HR deflection point (HRDP), and its relationship with the ventilatory or lactate methods has been demonstrated on dry land protocols since the 80s (14,21,29,37).

Water immersion promotes several physiological adjustments, such as suppression of the renin-angiotensin system (39), reduction in the plasmatic renin activity (23), and increase in the secretion and release of atrial natriuretic peptide (24), which result in HR and blood pressure reductions during immersion at rest and during exercise (31,32). In addition, atrial natriuretic peptide is a powerful lipid metabolism regulator, which contributes to increased lipid oxidative capacity (30). Such alterations during water immersion could potentially alter the AT determination by HRDP and lactate threshold (LT) methods in aquatic protocols.

The occurrence of the HRDP in water-based exercises has only recently been reported, and its value has been compared with the AT based on the second ventilatory threshold (VT2) method (2,26,35). Kruel et al. (26) and Alberton et al. (2) verified similar HR responses at AT between HRDP and VT2 methods in young women during water-based exercise protocols. However, both studies did not investigate the agreement between methods using Bland-Altman plots, which are indicated to determine whether 2 methods agreed sufficiently well for them to be used interchangeably (9). In a more recent approach, Pinto et al. (35) observed similar HR values at the AT between HRDP and VT2 methods in young men during an aquatic cycling protocol. In addition, the authors reported agreement between methods using Bland-Altman analysis, which is the correct one to be used when a new method (i.e., HRDP) has to be compared with an already established technique (i.e., VT2).

Based on these studies, the validity of HRDP in relation to the ventilatory method was evidenced. However, to the best of the authors' knowledge, the LT use as gold standard method of comparison has not been investigated during water-based exercises used in water aerobics programs, and it may result in different responses than those found with the ventilatory method. The HR corresponding to this point is an important and practical indicator of intensity control, which is widely used to optimize water aerobics programs not only in the scientific area (33,34) but also in clinical or practical settings (i.e., aquatic centers, sport clubs, and gyms). In addition, the RPE parameter corresponding to AT may be a simple, useful, and practical tool to be used for individualizing the intensity. Therefore, the purpose of this study was to compare and assess the agreement of the HR and RPE at AT between HRDP and LT methods during a water-based exercise in young men. Based on the aforementioned literature, we hypothesized that both HR and RPE would be similar, resulting in acceptable agreement between the HRDP and LT methods.

Methods

Experimental Approach to the Problem

To investigate the AT determined by HRDP and LT methods, a maximal incremental aquatic test was performed. For this purpose, an experimental session was performed by 16 young men, which consisted of a test during the water-based stationary running exercise performance with continuous data collection of HR, [lac], and RPE variables. Anaerobic threshold was identified for each subject by experienced physiologists using HRDP and LT methods. Heart rate and RPE corresponding to the AT in both methods were used for analysis.

Subjects

Sixteen young fit men (age: 24 ± 6 years, ranging from 18 to 35 years; body mass: 77.7 ± 10.8 kg; height: 1.77 ± 0.07 m) participated voluntarily in this study. Subjects were university students from the physical education department, who practice physical exercises at least twice a week. As inclusion criteria, all of them were free from acute or chronic cardiorespiratory and musculoskeletal disorders, and familiarized with the aquatic environment. All subjects were carefully informed about the potential risks and discomforts related to the study and signed a written informed consent form. This investigation was approved by the Research Ethics Committee of the Federal University of Pelotas (CAAE 38350414.3.0000.5313) and is in accordance with the Declaration of Helsinki.

Procedures

The experimental protocol started with anthropometrical measures. Body mass and height measurements were obtained using an analogic medical scale and a stadiometer (WELMY, Santa Bárbara d'Oeste–SP, Brazil). Then, a medical and exercise history screening was filled out. Subjects were asked to refrain from caffeine, alcohol, or any other stimulant and intense exercises 24 hours before the experimental session. After that, each subject entered individually in the pool and received standardized instructions about the Borg 6–20 RPE scale (13), which they were already familiarized with. After this, each volunteer was familiarized during 10 minutes with the water-based stationary running exercise, range of motion, and maintenance of movement into the rhythm of cadence, which served as a warm-up before the test performance.

The maximal incremental test was performed using the water-based stationary running exercise. This exercise was previously described in detail (4). It is widely used in water aerobics programs and has received attention in recent literature regarding cardiorespiratory responses along a maximal incremental test (1–4,20,26). Cadences were reproduced by a metronome (MA-30; KORG, Tokyo, Japan). The incremental aquatic protocol was performed barefoot, with the subjects immersed to the xiphoid process depth and the water temperature kept between 30 and 31° C.

The initial cadence of the maximal incremental test corresponded to 90 $b \cdot min^{-1}$, with 10 $b \cdot min^{-1}$ increases every 3 minutes up to exhaustion. This protocol was adapted from studies by Alberton et al. (1) and Kruel et al. (26), which analyzed variables associated to AT through ventilatory measurements. Tests were stopped when subjects indicated exhaustion or when they were not able to maintain the cadence proposed for the stage. Range of motion and technique of execution were visually controlled by an experienced instructor positioned at the edge of the pool, who gave constant feedback to the subjects along the test. Heart rate was monitored every 30 seconds using an HR monitor (POLAR, Kempele, Finland). Rating of perceived exertion and [lac] were measured at the end of each 3-minute bout. Blood was collected, with disposable lancets from the subjects' earlobe (15 μL of blood), and placed in reagent strips for [lac] analysis (ROCHE, Sao Paulo, Brazil). These analyses were performed in real time with a portable lactate analyzer (Accutrend Plus, Mannheim, Germany). The overall RPE was measured at the end of each stage during the test using the Borg 6–20 RPE scale (12,13). The scale (60 × 90-cm banner) was placed out of the pool in front of the subject, so that a value in this scale could be chosen.

Anaerobic threshold was identified for each subject by both HRDP and LT methods. Heart rate deflection point was determined based on HR-intensity graph, considering the point of deflection corresponding to the break in the linearity for HR outcome with intensity increase, as proposed by Conconi et al. (17). The LT was determined based on [lac]-intensity graph, considering the second breakpoint for [lac] outcome, i.e., the second point of inflexion in which an exponential increase of [lac] occurs as intensity is increased, according to Stegmann et al. (40). Both methods were analyzed by 3 experienced physiologists, who determined the AT in each graph by visual inspection, in a double-blinded procedure. Heart rate and RPE corresponding to the AT for both HRDP (HR_{HRDP} and RPE_{HRDP}) and LT (HR_{LT} and RPE_{LT}) methods were used for the analysis.

Statistical Analyses

Descriptive statistics were used for data analysis, and data are reported as mean ± *SD*. The Shapiro-Wilk's test was used for normality analysis. A paired Student's *t*-test was used to compare HR and RPE variables between HRDP and LT methods. To verify the agreement between methods, the differences were plotted against the mean value for selected variables as suggested by Bland and Altman (10). This analysis is based on the differences between measurements in the same individual by the 2 methods. The mean difference is the estimated bias, the systematic difference between methods, and the *SD* of the differences measures random fluctuations around this mean. The 95% limits of agreement were estimated by mean difference plus or minus 1.96 *SD*s of the differences, which explain how far apart measurements by the 2 methods were likely to be for most individuals (9,10). In addition, the Pearson product-moment correlation was used for verifying associations between variables determined by both methods. The significance level adopted was $\alpha = 0.05$, and the SPSS statistical software package (SPSS version 20.0, SPSS, Inc., Chicago, IL) was used to process all data.

Results

The descriptive data regarding the maximal HR, RPE, [lac], and cadence outcomes obtained during the maximal incremental test are presented in Table 1.

Heart rate corresponding to AT presented similar values between HRDP and LT methods is presented in Table 2. According to the Bland-Altman analysis, an acceptable agreement between HR_{HRDP} and HR_{LT} methods was verified (CI = 11.60; −17.14). Bland-Altman plots with estimated mean bias and 95% limits of agreement for differences in HR between HRDP and LT methods, as plotted against the mean value, are presented in Figure 1A. Based on this, it is estimated that for 95% of subjects, the HR_{HRDP} will be between 17.14 b·min^{-1} below the HR_{LT} and 11.60 b·min^{-1} above it. On the other hand, RPE presented significant higher values in the HRDP method in comparison with the LT (Table 2). Therefore, Bland-Altman analysis suggested that RPE_{HRDP} and RPE_{LT} methods did not present an acceptable agreement (CI = 2.10; −1.16) during the water-based stationary exercise, as the result from the paired *t*-test was significant ($p = 0.048$). Bland-Altman plots with estimated mean bias and 95% limits of agreement for differences in RPE between HRDP and LT methods, as plotted against the mean value, are presented in Figure 1B. With this, it is estimated that for 95% of subjects the RPE_{HRDP} will be between 1.16 below the RPE_{LT} and 2.10 above it. In addition, strong relationships were verified between HRDP and LT methods for HR (Figure 2A) and RPE (Figure 2B) corresponding to the AT.

Table 1
Descriptive statistics (mean ± *SD*) for heart rate (HR), rating of perceived exertion (RPE), blood lactate concentration ([lac]), and cadence corresponding to the maximal effort during water-based stationary running exercise.

	Maximal effort, mean ± *SD*
HR (b·min^{-1})	187.9 ± 6.9
RPE	19.5 ± 0.5
[Lac] (mmol·L^{-1})	8.9 ± 2.3
Cadence (b·min^{-1})	158.8 ± 10.9

Discussion

The purpose of this study was to compare and assess the agreement of the HR and RPE at AT between HRDP and LT methods during a water-based exercise in young men. The main findings revealed similar HR_{HRDP} and HR_{LT} values between both methods of AT determination, which is in accordance with our hypothesis. On the other hand, RPE corresponding to the AT presented significant differences between HRDP and LT methods, in contrast to our hypothesis. The Bland-Altman analysis suggests an acceptable agreement between methods only for the HR investigated during the water-based stationary running exercise performed by young men. Therefore, HR may be considered a more reliable parameter for intensity prescription during water aerobics programs for young men.

The intensity in which HRDP occurs has been shown to be associated to the AT by several studies performed on dry land (14,17,21,29,37). The pioneer studies regarding this analysis

Table 2
Descriptive statistics (mean ± *SD*) and *p* values for heart rate (HR) and rating of perceived exertion (RPE) corresponding to anaerobic threshold comparison between HR deflection point (HRDP) and lactate threshold (LT) methods during water-based stationary running exercise.

	HRDP, mean ± SD	LT, mean ± SD	*p*
HR (b·min^{-1})	168.2 ± 8.0	171.0 ± 11.7	0.198
RPE	15.5 ± 2.0	15.0 ± 2.0	0.048

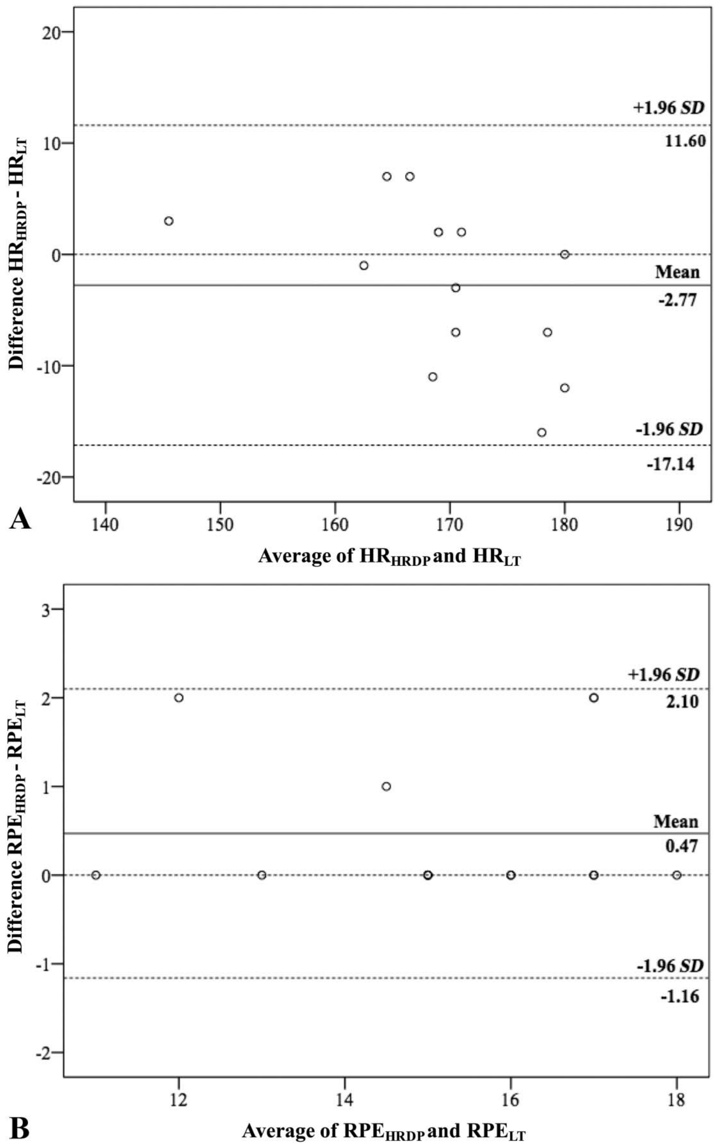

Figure 1. Bland-Altman plots with estimated mean bias and 95% limits of agreement for differences in HR (A) and RPE (B) data between HRDP and LT methods, as plotted against the mean value, during the water-based stationary running exercise. HR = heart rate; RPE = rating of perceived exertion; HRDP = heart rate deflection point; LT = lactate threshold.

were developed in the 80s, evaluating the relationship of the exercise intensity corresponding to AT between HRDP and LT methods in different modalities, such as walking, running, cycle ergometer, cross-country skiing, roller-skating, rowing, and cycling (17,21,37). In addition, Cellini et al. (16) observed a strong relationship for the exercise intensity (i.e., swimming velocity) corresponding to the AT between HRDP and LT methods while swimming, the first study developed with this purpose with individuals in water immersion. Recently, the relationship between HRDP and VT2 has also been verified for exercise intensity (i.e., HR) corresponding to AT during water-based exercises (2) and water-based cycling (35). In agreement with these studies, strong relationships were verified in this study for HR and RPE corresponding to AT between HRDP and LT methods during the water-based stationary running exercise. However, Bland and Altman (9) suggest that the use of correlation coefficient values between the results of 2 measurement methods as an indicator of agreement is inappropriate because a strong relationship does not mean that the 2 methods agree.

In addition, the studies performed with water-based exercises (stationary running, frontal kick, cross-country skiing, and water-based cycling) also compared the HR corresponding to AT between HRDP and VT2 methods in young men (35) and women (2,26), and found no significant difference between them, also in accordance with the present findings. However, the studies by Alberton et al. (2) and Kruel et al. (26) did not investigate the agreement between methods. On the other hand, the study by Pinto et al. (35) analyzed and verified the agreement between HRDP and VT2 methods for HR corresponding to AT during water-based cycling using Bland-Altman analysis, which is indicated to determine whether 2 methods agree to be used interchangeably (9). This study corroborates with this analysis

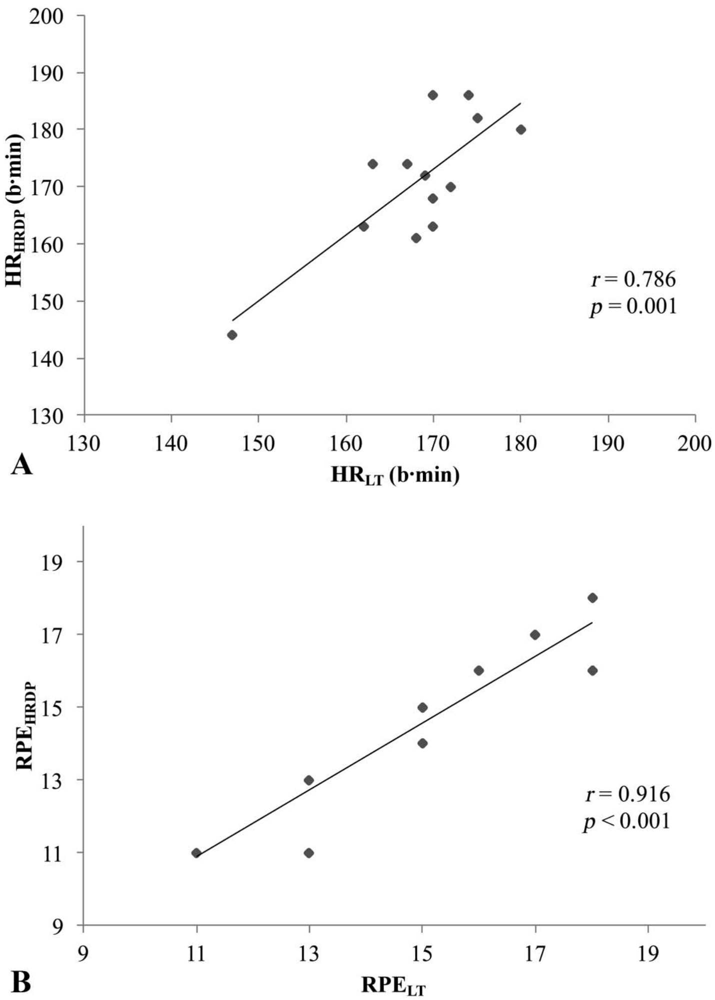

Figure 2. Correlation data between HR (A) and RPE (B) between HRDP and LT methods during the water-based stationary running exercise. HR = heart rate; RPE = rating of perceived exertion; HRDP = heart rate deflection point; LT = lactate threshold.

because, for HR outcome, the examination of the Bland-Altman plots reveals that, in 95% of cases, HR_{HRDP} may range between 18 b·min^{-1} below and 14 b·min^{-1} above the HR_{LT} (Figure 1A), suggesting an acceptable concordance between methods.

On the other hand, this study revealed significant higher values for the RPE_{HRDP} (15.5 ± 2.0) in comparison with the RPE_{LT} (15.0 ± 2.0) method, despite the strong relationship between them. The Bland-Altman plots revealed that, in 95% of cases, RPE_{HRDP} may range between 1 units below and 2 units above the RPE_{LT} (Figure 1B), suggesting a nonacceptable concordance between methods. However, the difference in RPE between methods was only 0.5 units, which may have a small clinical relevance during water aerobics prescription. In fact, its use has been prioritized for special populations, especially those who are undertreatment with drugs that affect the HR response to exercise (15,41). To the best of the authors' knowledge, this analysis of the RPE corresponding to the AT between HRDP and a gold standard method had not yet been analyzed yet in the literature. Therefore, these results are new in the literature, and further research is needed to expand these findings.

The overall perceived exertion integrates much information, including various signals elicited from the peripheral working muscles and joints, from the central cardiovascular and pulmonary functions and from the central nervous system. It is indicated that an integration of central factors, such as HR, and peripheral factors, such as [lac], would better explain the psychophysical variation than any single physiological variable (11). These factors may be altered in water-based exercises in comparison with those performed on land, and this fact may compromise the agreement between methods for RPE in this environment. In addition, the difference in the RPE between methods, in contrast to the similar observed HR values, may be attributed to the different sample frequency between methods, since HR was collected every 30 seconds and [lac] at the end of each 3-minute bout. It is speculated that this fact may have influenced the breakpoint between methods, resulting in a light displacement of the AT to the next stage using HRDP (Mean cadence = 135.0 ± 12.6 b·min^{-1}) compared with the LT method (Mean cadence = 131.3 ± 13.6 b·min^{-1}), which presented a lower number of points. However, in contrast to the VT2, in which a higher sample frequency is obtained (i.e., breath-by-breath) for the gold standard measure, this is a characteristic of the LT during the maximal incremental test protocol.

To the best of the authors' knowledge, this is the first study investigating the agreement between HR and RPE corresponding to AT determined by HRDP and LT methods in a water-based exercise used in water aerobics programs. Heart rate is a fundamental parameter used for prescription of intensity during water aerobics. For this purpose, a maximal incremental test should be applied in the aquatic environment because the HR measured on dry land cannot be used as a parameter for intensity prescription in water immersion (3). In addition, based on the present results, HR_{HRDP} may be a valid control for intensity prescription during water aerobics, which can be determined by a simple method, noninvasive and aversive to some subjects as LT (27), using an HR monitor and a metronome along a maximal incremental test performed using a structured water-based protocol. Further investigations should be implemented in other populations to expand and support our findings.

Some limitations should be addressed in this study. First, a test-retest reliability of the water-based incremental protocol would benefit our design. Therefore, future studies are warranted. Second, because of the inclusion of young men in our sample, the findings should be carefully used considering other populations, such as elderly, obese, and individuals with musculoskeletal disorders, who are the main practitioners of water aerobics in practical settings. In addition, RPE data should be interpreted with caution because it integrates not only physiological, but also psychological factors.

In summary, based on our findings, it may be concluded that HR presented agreement and a significant relationship between HRDP and LT methods. On the other hand, RPE corresponding to the AT presented significant differences between methods, although a significant relationship between HRDP and LT methods has been observed. Therefore, HR_{HRDP} may be a valid parameter used for the intensity prescription of water-based stationary running exercise in young men and may be considered more reliable than RPE_{HRDP} during water aerobics programs.

Practical Applications

From a practical point of view, the results of this study provide an important and simple tool for the water aerobics instructors. The HR_{HRDP} determination during the water-based stationary running exercise attends to the biological individuality principle and can precisely determine the intensity corresponding to the AT using a noninvasive method. The maximal incremental test used in this study is specific for the aquatic environment, easy to perform, time-efficient (several practitioners can perform the test at the same time during the training session), and only requires an HR monitor. Based on the HR_{HRDP}, it is possible to calculate percentages below or above the AT to prescribe the target training zone intensity.

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