Conconi test adapted to aquatic bicycle

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ABSTRACT

Physical exercise has been considered one of the mechanisms that improve health and quality of life. As a consequence of the enhanced demand for fitness centers, physical activities in liquid environment, especially aquatic cycling, have increased in the last years. However, methods of assessment and prescription of aerobic training in these equipments are still scarce. The objective of this study was to propose an adapted test of Conconi *et al.* (1982) to aquatic bicycle. 27 participants (24 ± 6 years, 171 ± 8 cm, 66 ± 12 kg), 15 male and 12 female, were assessed. The participants have been submitted to a graded test in aquatic bicycle, with initial load of 50 RPM and increments of 3 RPM each minute, until exhaustion. HR was registered during the entire test. For data analysis, descriptive statistics were used as well as Student "t" test for comparison between genders. HRDP was identified in 85% of the subjects. There were not significant differences in HR_{max} (181 ± 12 and 181 ± 10 BPM), HRDP (162 ± 10 and 172 ± 9 BPM) and $\%HRDP_{rpm}$ (91 ± 4 and 90 ± 3 $\%RPM_{max}$) between males and females, respectively. On the other hand, RPM_{max} (81 ± 6 and 72 ± 5 RPM), %HRDP (90 ± 5 and 93 ± 3 $\%HR_{max}$) and $HRDP_{rpm}$ (74 ± 6 and 66 ± 4 RPM) were significantly different. In conclusion, the adapted Conconi test can be performed in aquatic bicycle.

Keywords: Aerobic training. Cicloergometer. Heart rate.

INTRODUCTION

Regular practice of physical exercises is one of the factors which aids in health and quality of life improvement. Its benefits include physiological, (improvement in cardiorespiratory conditioning), psychological (improvement in self-esteem), and social factors (improvement in interpersonal relations)[1-5]. The search for these results has motivated the increase of the number of activities offered by health clubs. It is believed that countries such as Brazil, the United States and Australia are world leaders in the amount of establishments, in the number of practitioners and in the release of new exercise modalities created to fulfill the specific needs of their clients.

Hydro-gymnastics was created in order to provide an activity which was intense enough to cause physiological adaptations, especially in the cardiovascular system, and that at the same time, would impose low level of mechanical impact over the joints, preserving hence, the locomotor system. Due to its success, other activities originally developed in other environments have also been adapted to the water. Therefore, equipments usually used on the ground, such as treadmills, trampolines and bicycles, were developed in aquatic versions. However, due to the operational difficulty to measure the exercise intensity performed in the aquatic medium, and maybe due to the fact of this trend is relatively recent, procedures for prescription and load control of aquatic activities which can be applied to health clubs routine, especially for aerobic activities developed in aquatic bicycle, are still scarce.

In the trial to present a simple method for identification of the anaerobic threshold (Lan), Conconi *et al.*[6], presented a continuous running protocol with growing velocity in which the heart rate (HR), represented in Cartesian axis, presented a linear initial phase followed by a second curvilinear one. The authors verified that the transition point between these phases called cardiac deflexion point (HRDP), corresponded to the Lan. From its release on, the Conconi test has been successfully applied to different activities such as: swimming, canoeing, skiing, cycling, skating, rowing and athletic marching[7-8].

In the conventional cycle ergometer, the developed power is a product of the velocity (circumference x wheel rotation) by the resistive load applied over the wheel. On the aquatic bicycle, since the resistance is imposed by the water resistance, the workload manipulation occurs by alterations in the pedal rotation (RPM). Once the water resistance is proportional to the wheel velocity (in the aquatic bicycle, with paddles), the increase in RPM causes both increase in wheel velocity and resistance applied over it. Martins and Lima[9] used a protocol with increases of 10 RPM, at every 2 min. and observed that the HR curve, after an initial phase relatively linear with increases of approximately 23 BPM at each stage, presented in higher loads a tendency to curvilinear behavior similar to the one proposed by Conconi *et al.*[6].

The findings by Martins and Lima[9], who observed a HR nonlinear behavior in aquatic bicycle point to the possibility of HRDP identification in this kind of ergometer, as proposed by Conconi *et al.*[6]. Considering the need to reach simple aerobic exercise prescription method which is able to be applied in practical situations, the aim of the study was to adapt the Conconi *et al.* test[6] for identification of the HRDP in aquatic bicycle.

METHODOLOGY

Subjects – 27 subjects were evaluated (24 ± 6 years, 171 ± 8 cm, 66 ± 12 kg): 15 males and 12 females. All individuals signed a consent form for studies involving humans. After weight and height measurements, all participants were submitted to the progressive test, performed in a swimming pool at least 1.2 m deep and water temperature ranging from 25 to 28°C.

Aquatic bicycle – the test was performed in an aquatic bicycle HIDROCYCLE® brand name. The used model had seat height regulation in relation to the pool bottom, so that it was possible for all individuals to perform the test with water at the umbilical scar level.

Pilot study – In the study by Martins and Lima[9], with increment of 10 RPM at every 2 min., HR increase of approximately 23 BPM was observed. Conconi *et al.*[10] suggest that, for identification of the HRDP, the HR increases are not higher than 8 BPM. As first trial to diminish the HR increases, in a pilot study increment protocols of 5RPM at every min were performed, which was not

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sufficient – the HR increments were in mean higher than 10 BPM. This fact suggests that increments should be lower than 5 RPM.

Test protocol – Before the test beginning, a standardized stretching which consisted of 5 min of exercise for lower limbs was performed. Afterwards, specific warm-up of 5 min cycling at 45 RPM was performed, followed by 2-min interval of passive recovery. The protocol consisted of initial load of 50 RPM and increase of 3 RPM at every min, until exhaustion. The pedaling cadence was set by a metronome, Quick Time® brand name.

HR monitoring – The HR was continuously registered by a Polar monitor, model S810. The values registered at the end of each stage were used for construction of the HR x RPM curves.

HRDP identification – From the HR x RPM curves, dispersion charts were elaborated in the Excel® program. The HRDP was identified by visual inspection, by two independent evaluators.

Statistical treatment – Descriptive statistics with values expressed as mean and standard deviation was used and for the comparison between sexes, the t-student test for independent samples was used ($P < 0.05$).

RESULTS

All subjects were able to satisfactorily complete the test, reaching HR_{max} of 181 ± 12 BPM, in the maximal load of 81 ± 6 RPM for men and 181 ± 10 BPM, in the 72 ± 5 RPM load for women. Significant difference was observed between men and women only in the maximal RPM (table 1). The mean curve of HR x RPM, presented tendency to curvilinear behavior in the higher loads. In the individual curves, such tendency has not observed in only 15% of the subjects (figures 1 and 2).

The mean growth of the HR during the test was of 4 BPM per stage for men and 6 BPM per stage for women, which is below the threshold recommended by Conconi *et al.*[10] for identification of HRDP. The first derivate of the HR x Stage which represents the mean growth of the HR of men and women during the test, adjusted by polinomy of third order, is presented in figure 3.

When using the proposed protocol, one may observe that the minimum recommendations suggested by the test's authors for the HRDP have been fulfilled: tendency to the HR plateau in the higher stages and mean growth of HR lower than 8 BPM per stage. After the protocol validation conditions have been fulfilled, the individual curves of HR x RPM were submitted to visual inspection by two independent evaluators who identified the HRDP in 85% of the subjects. Figure 4 shows the example of one of the subjects in whom the identification of the HRDP was possible. The HRDP was

TABLE 1
Variables identified in the progressive test

	Men		Women	
	Mean	**SD**	**Mean**	**SD**
HR_{max} (bpm)	181	12	181	10
RPM_{max}	81*	6	72	5
HRDP (bpm)	162	10	172	9
HRDP (rpm)	74*	6	66	4
HRDP (% HR_{max})	90*	5	93	3
HRDP (%RPM_{max})	91	4	90	3

* Significant difference between men and women ($p < 0.05$).

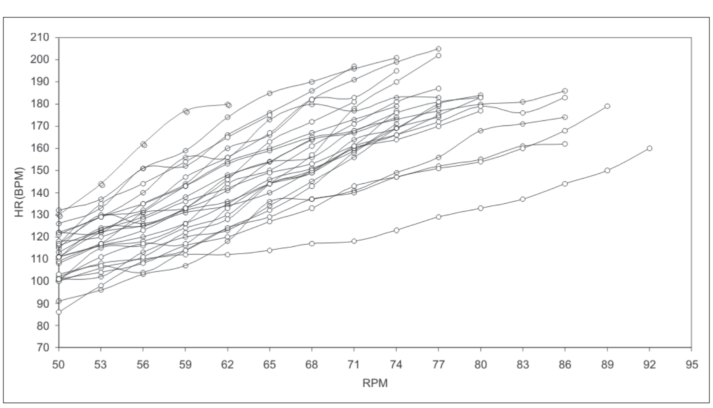

Figure 1 – *Heart rate individual curves in the progressive test*

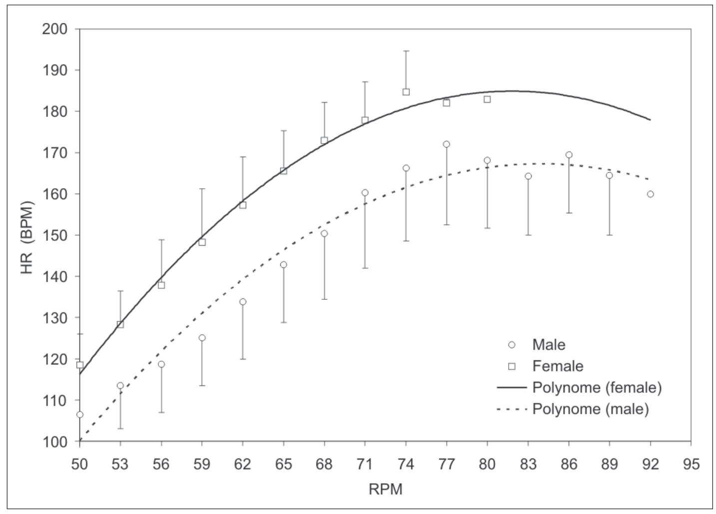

Figure 2 – *Heart rate mean curves in the progressive test*

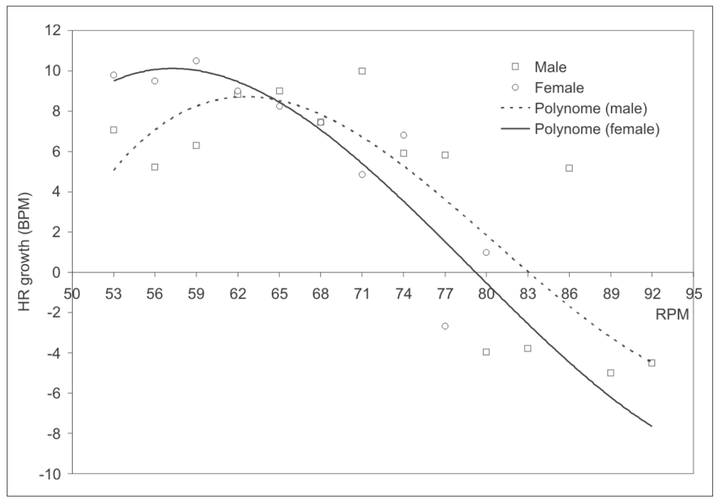

Figure 3 – *Heart rate increase per stage of the progressive test*

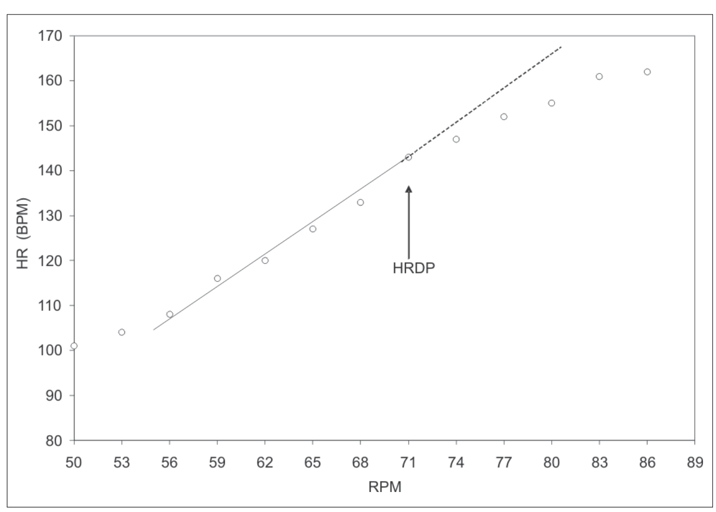

Figure 4 – *Identification example of the heart rate deflexion point of one of the individuals*

identified in similar HR, when men and women are compared (162 ± 10 BPM and 172 ± 9 BPM respectively), but in HR_{max} percentages significantly higher in women (90 ± 5% and 93 ± 3%). The men presented HRDP in loads significantly higher than in women, but which represented similar maximal load percentage (74 ± 6 RPM, 91 ± 4% and 66 ± 4 RPM, 90 ± 3%).

DISCUSSION

The performance of this study was motivated by the lack of instruments for evaluation of the aerobic capacity and prescription of exercise in aquatic bicycle. The cause of this lack may be partly attributed to the difficulty in quantifying the power developed in this equipment. In conventional mechanical cycle ergometers–ground ones, the power developed is given by the multiplication of the wheel velocity by the resistive load applied over it. The wheel velocity measurement is not a problem in water or out of the water, as long as its circumference is known and it is possible to count its rotations. On the determination of resistive load on the other hand, some problems are found. In the conventional cycle ergometer, the resistive load is applied by a tape which involves the wheel and its quantification can be done by a pendulum scale attached to it. In the aquatic bicycle, the resistive load is the resistance that the water offers to the dislocation of the wheel's paddles – greatness of difficult quantification.

In rectilinear dislocations, the resistance offered by the water may be described by a quadratic function. In the aquatic bicycle, the wheel paddles in their circular movement find at each rotation the water already in movement, caused by the previous rotation. Such event makes the water resistance smaller than what would be expected in a rectilinear movement. Therefore, the linear increase of the numbers of rotations adds an increase approximately linear of the resistive load. The study by Martins and Lima[9] had already evidenced that, in a protocol with increments of 10 RPM at every 2 min., the HR X RPM curve was similar to what usually is found in tests performed in conventional cycle ergometer.

From the observation that the HR curve in aquatic bicycle with linear increments was similar to the one usually found in conventional cycle ergometer, it was hypothesized that it would be possible to perform the Conconi *et al.* test[6] in aquatic bicycle. Although there are still controversies concerning the physiological meaning of the HRDP, its identification is a datum concerning the Lan of the individual and may occasionally be used in the functional evaluation as well as prescription of aerobic training.

The literature shows that the HRDP is a phenomenon which really occurs in many subjects; however, the physiological mechanisms which trigger it are not completely clear yet[11]. According to Conconi *et al.*[6], this issue is strongly connected with the Lan; yet, the different methods used for identification of metabolic transitions thresholds may result in less convincing correlations. Pokan *et al.*[12] have suggested that there is a connection between the myocardial functions and the HRDP. In subjects where the HRDP was identified, the ejection volume of the left ventricle remained high until reaching the maximal aerobic load, allowing that the cardiac debt remained high with no great increase in HR. Lucia *et al.*[13] verified that the cardiac dimensions of professional cyclists may help in the HRDP explanation. The loss of linearity of the HR during the progressive test was predominantly found in cyclists who present thicker cardiac walls. Leprete *et al.*[14] defend that the lower increase of the Hr in high loads could be a cardiovascular strategy to preserve the systolic volume.

In the development of the protocol for HRDP identification in aquatic bicycle, the outline used in a previous study was taken as a starting point, in which 10 RPM increments were used at every 2 min. Such protocol was proposed for identification of maximal aerobic load for the one which did not represent problem to the HR increase of 23 BPM per stage and the number relatively low of stages which were completed until the maximal load was reached. For the Conconi test, adaptations concerning increase in number of stages and decrease in mean growth of HR per stage were needed so that the recommendations by Conconi *et al.* for the HRDP identification were followed[10]. The solution found in this study (initial load of 50 RPM and increments of 3 RPM at every min.) was satisfactory, once it resulted in the conclusion of 11 ± 2 stages with growth of 4 BPM per stage for men and 8 ± 2 stages with growth of 6 BPM per stage for women. Despite being successful for women, the adopted protocol was very close to the threshold recommended by the authors for the test. A protocol with lower initial load and smaller increments would maybe be more suitable for them, though.

The HRDP was identified by visual inspection in 85% of the participants. The HR behavior during the test in the remaining individuals behaved in a linear way. These findings are similar to the ones reported by De-Oliveira[15] who has identified the HRDP in 87% in runners in a field test. The visual method used in this study, usually presents a certain degree of subjectivity in the data analysis. In the trial to improve the HRDP identification, Kara *et al.*[16] have adapted the Dmax model with polynomial adjustment of third order and reported to have identified the HRDP in all individuals in their study. Corroborating Piovezana and De-Oliveira[17] who have sued the Dmax method and found the HRDP in 100% of the Physical Education students tested in cycle simulator. These divergences are doubtful concerning the efficiency of use of the Dmax in this study in increasing the probability of identifying the HRDP. Nevertheless, the fact that the HRDP has been identified in 100% of the subjects is in agreement with the literature data, which also reports that the HRDP is found in approximately 90% HR_{max} regardless sex, age, physical capacity and kind of exercise[11].

The HRDP of men was identified in the same values of HR than in women; however, in higher loads which suggests that the test is able to discriminate the individuals with greater aerobic capacity. Concerning the HR_{max}, no significant difference was found either between men and women, suggesting hence that all individuals have reached similar relative maximal effort levels. However, the HR values reached at the end of the effort, show that the participants did not reach the HR_{max} predicted by age, as for instance by the equation $HR_{max} = 220 - age$[18]. The reached HR_{Max} (181 BPM) corresponds to 92% of what would be expected for 26 years old individuals (196 BPM). This value is within the interval in which the HR peak values are usually found in conventional cycle ergometers (90 to 95%) in non-cyclist individuals[19]. Additionally, we could speculate that the immersion in cold water could have triggered bradicardia[20], which was not the case in this study, once the water temperature was kept between 25 and 28° Celsius. We suggest that HRmax prediction studies in aquatic bicycle would be relevant.

CONCLUSION

Considering the results of this study, one may preview the Conconi test applications to aquatic bicycle classes or 'aquatic cycling' as they are commonly called. The HRDP evaluation with the use of the proposed protocol is very accessible, since it needs only a metronome and a HR monitor. The test is performed in approximately 12 min and it is of easy comprehension from the part of the evaluated subject. Once the HRDP is identified, the aerobic training can be prescribed based on the HR or on the RPM observed at this point. Thus, one may affirm that it is possible to identify the HRDP in aquatic bicycle with the use of a protocol of initial load of 50 RPM and increments of 3 RPM at every minute.

All the authors declared there is not any potential conflict of interests regarding this article.

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