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Characterization and Risk of Maximal Head-Out Aquatic Exercises

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Abstract: The present study aims to characterize maximal continuous and intermittent efforts in head-out of water aquatic exercise and to determine the risk associated with this type of exercises by healthy persons. Ten healthy women (38.3 ± 9.4 years; 160.2 ± 6.2 cm; 50.0 ± 8.5 kg) experienced in head-out aquatic exercise participated in this study. Two maximal exercises of (I) 7 min continuous and (II) 3x30 sec leg kick, with 30 sec interval were performed with a two days rest interval. The Rate of Perceived Exertion (I: 19.8 ± 0.4 and II: 19.4 ± 1.0) and the heart rate values (I: 184.9 ± 1.4 and II: 178.2 ± 10.4 bpm) confirmed that both exercises were maximal. The blood lactate concentration was high after exercise in both protocols (I: 12.0 ± 3.4 $mmol.kg^{-1}$; II: 10.7 ± 2.7 $mmol.kg^{-1}$). The systolic blood pressure was higher after both exercises (I: 119.9 ± 19.2 and II: 138.7 ± 15.5 mmHg) whereas diastolic blood pressure was lower (I: 52.6 ± 13.4 and II: 47.8 ± 9.7 mmHg). The mean blood pressure at rest (I: 88.8 ± 12.2 and II: 79.3 ± 8.1 mmHg) and after exercise (I: 83.4 ± 14.4 and II: 78.1 ± 9.8 mmHg) was similar. The higher diastolic blood pressure and double product (I: 26188.2 ± 3955.1 and II: 21899.1 ± 2696.4 mmHg.bpm) for maximal continuous exercise revealed high cardiac effort. Maximal intensity exercises could be safely used in head-out aquatic exercise classes with healthy participants.

Keywords: Cardiovascular risk, effort characterization, exercise mode, water based activities, maximal intensity, physiological parameters.

INTRODUTION

Head-out aquatic exercise performed in shallow water is a fitness activity (aqua fitness, also called aquagym, aquaerobics, and shallow-water exercise) mainly involving persons whose main goal is to maintain health. It has gained popularity in recent years [1-6]. Head-out aquatic exercise is described as an aquatic activity composed of several exercises done against water resistance [7]. Theoretically, the more the resistance is the more intense is the exercise.

A literature review has revealed that physiological response to head-out aquatic exercise still need to be studied and that the exact amount of effort produced is not clear [8, 9]. Physiological and training effects of water exercises have been investigated by several authors [2, 3, 5, 6, 8, 10-16]. Aqua fitness classes typically involve aerobic efforts, using moderate to vigorous exercises recommended to improve physical fitness [17]. Barbosa *et al.* [8] for example maintained that anaerobic system has only a small contribution for the energy supplying in head-out aquatic exercise. The anaerobic system has a larger contribution in maximal efforts beyond the guidelines of the ACSM for healthy non-athlete subjects [17]. Nevertheless, working under anaerobic regimens and at maximal intensities could be interesting to challenge the more fit practitioners and, eventually, to increase fitness more efficiently in the less conditioned.

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Aerobic efforts are considered [17] as the most important for developing cardiovascular resistance and improving practitioner's health status with lower or no risk. Cardiovascular risk is lowest in healthy adults during moderate intensity activities [17, 18] and slightly higher in vigorous activities. Although, according to some authors vigorous exercise has more benefits in reducing cardiovascular disease and early mortality than moderate intensity activities [19, 20]. Little is known on cardiovascular development for very hard and maximal head-out aquatic exercise, besides the fact that this could be dangerous for non-healthy practitioners. It can be pointed out that that those studies were mainly focused on the estimation of aerobic performance markers and that little attention was devoted to very hard and maximal exercise.

Despite the general acceptance that moderate to vigorous aerobic efforts are most adequate for non-athletes and the apparent absence of advantages in anaerobic stimulation, the use of very hard and maximal exercises with a strong anaerobic component is not unusual and exercise workouts for those intensities could be easily found in internet and observed in international aqua fitness conventions. This is nevertheless in conflict with the generalized idea that for non-competitive practitioners, aerobic stimulation is best and safer. The very hard and maximal exercise observed in practice seems to be used with the purpose of guiding more experienced practitioners to challenge their limits. This wouldn't be a problem if classes were homogeneous. According to Raffaelli, *et al*. [5] the standardization of exercise in a class is not always sufficient to obtain a homogeneous group response and using high intensities could be dangerous to some practitioners.

The American College of Sports Medicine (ACSM) [17] points out some risks associated to the use of very hard and maximal exercise, namely the possible occurrence of cardiovascular events in persons with unknown cardiopathy. For instance, it is known that arterial hypertension is considered one of the biggest risk factors for cardiovascular disease and mortality in developed countries [21]. The symptoms of arterial hypertension are silent however and most people ignore or are not aware of the presence of the disease.

This discussion raises important questions for the aquatic fitness instructor. How intense is the exercise performed by non-athletes in water? Aquatic exercises intensity could rise to dangerous limits for healthy as well as persons at risk? The risk of cardiovascular events associated with very hard and maximal exercises presents the aquatic fitness professional with a challenge in regulating intensity. This is not easy in water and especially during classes, as the gold standard (oxygen consumption) [VO2 consumption 6] is neither cheap nor practical. Although, alternative methods for intensity estimation such as Borg's Rating of Perceived Exertion Scale and heart rate (HR) direct measurements could help. As far as we know, a characterization of some very intense and maximal head-out aquatic exercises is still needed. Because they are often used in practice, the establishment of a clear relation between the intensity and health accident risk is required.

Additionally, the exercise mode, e.g. intermittent or continuous water exercise, must be studied to understand if different exercise modes could induce different physiological responses and therefore lead to different cardiovascular accident risk.

The simplest methods for cardiovascular risk evaluation seem to be the analysis of the blood pressure in response to exercise, namely systolic blood pressure (SBP), and the double product (DP), also known as the rate pressure product. This is the mathematical product of the HR and SBP (for key points interpretation of BP response to exercise see ACSM [17]). It has been suggested that the double product is a possible predictor of mortality but more studies are needed to confirm this [22].

The purposes of the present study were: (i) to characterize physiological responses to maximal continuous and intermittent head-out aquatic exercises (ii) to relate this with possible cardiovascular risk in healthy persons. A higher intensity and a higher risk associated to the maximal continuous exercise are expected.

METHODS

Participants were ten healthy women (38.3 ± 9.4 years; 160.2 ± 6.2 cm; 50.0 ± 8.5 kg) experienced in head-out aquatic exercise (more than one year practice; declared to have been screened before practice start). All participants gave their written informed consent for participating in the study and a health professional was present during data acquisition. The study was conducted in accordance with the Helsinki Declaration.

Two protocols were applied in shallow water with a two day rest interval. Prior to each protocol participants performed a 3 min warm up with low amplitude arms and legs movements of light intensity and in a stand-up position. Warm-up was immediately followed by 5 min of moderate to vigorous aerobic exercise, performed with the purpose of raising the HR and preparing the participant for the maximal effort. In this exercise bout stand-up position was kept and the amplitude of the movements was raised.

In the first protocol I, a maximal continuous effort of 7 min duration composed by four intense exercises was performed. To achieve the maximal intensity through the arm and leg movement's amplitude and velocity were raised. The first exercise was a cross country skiing movement jump with leg spread forward and backwards and a cross coordinated arm movement. The second exercise was an alternating leg kick with jump combined with alternated adduction of the arms at the chest high. The third exercise was a jumped jumping jack plus vertical adduction and abduction of the arms. The fourth exercise was jumping with simultaneous knees elevation and double backward vertical arm movement. The palms were always positioned perpendicular to the direction of movement. The four exercises were each performed for 1 min 45 sec consequently for a total of 7 min. All exercises were performed using music at 136 bpm and all participants worked on the same beat.

In the second protocol, after the same warm-up and 5 min of moderate to vigorous aerobic exercise, the participants performed a maximal short duration intermittent exercise of 3x30 s leg-kicking with the hands placed on the swimming pool wall, with 30 s active recovery (very slow low kick movements performed at very light intensity). Kicks were performed at maximal velocity, ignoring music bpm.

The rate of Perceived Exertion (RPE) was indicated by all participants at the beginning, middle and end of the first protocol. The scale used was the 6 to 20. This allows for a more intuitive relation with HR. In the second protocol the participants indicated the RPE immediately after every leg-kick bout. Prior to data acquisition, during eight sessions, participants were familiarized with Borg scale. The participants learned to reproduce the 11, 13, 15, 17 and 19/20 RPE.

The participants rest and exercise HR was checked with a HR monitor (*POLAR Vantage NV™*). Rest HR values were obtained both on land and in immersion, being the subject quiet for 10 min. Water depth was up to xiphoid process and temperature was 29º C. The HR values were expressed as a percentage of predicted maximal heart rate (HRmax) as determined according to the Tannaka *et al.* [23] equation (%HRmax= 208 – 0.7 * age). This equation was preferred once author compare it to others and concluded that currently used equations underestimates HRmax in older adults.

Blood pressure (BP) was evaluated at rest and after exercise by an experienced health professional using a sphygmomanometer (*Erka, model D-83646*) and a *Littmann* stethoscope (*Littman Quality ™)*. At rest, participants sat on a chair in a quiet place with the arm placed on a table (hand at waist level). After exercise the BP was taken with the participants in the water, with the arm placed over the swimming pool edge in a similar position as on land, but a little bit higher (hand at heart level). Mean BP was estimated using SBP and diastolic blood (DBP) pressure [MBP=1/3 (SBP-DBP) + DBP] and used as a health risk factor indicator. The DP was also calculated using HR and SBP (DP = HR x SBP x 10^{-2}). The DP as a measure of cardiovascular effort was used as an additional health risk factor indicator. DP values could rise until 5 times the rest value [17].

Capillary blood samples were taken from ear lobule at rest, on land, and after exercise, with participants in water. The maximal blood lactate concentration ($[La^-]$) was determined between minutes 3, 5, 7, 9 and 12 post exercise. A portable lactate analyser (LactatePRO, *Arkay, Inc*. Tokyo, Japan) was used.

To examine the distribution of data a *Shapiro-Wilk* test was first performed. When normality was assured a Paired Samples T-Test and *ANOVA* were applied to data. The significance level was set at 5%.

RESULTS

Fig. (**1**). shows the RPE expressed by participants in both maximal continuous and intermittent efforts performed in the two evaluation protocols. Effort was perceived to be similar for both protocols.

Fig. (**2**). shows the mean values of $[La^-]$ obtained in rest and after exercise, in both protocols. The $[La^-]$ values increased significantly after exercise and were similar in the end of both protocols.

Fig. (**3**). shows the mean resting HR values measured on land and during immersion. The rest HR values were lower when the participants were in water.

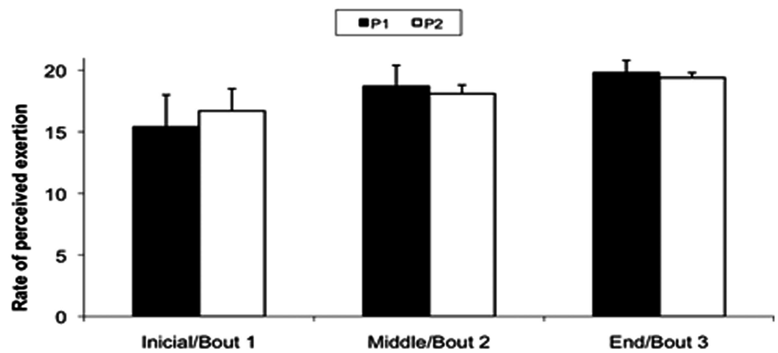

Fig. (1). Mean and standard deviation values of perceived exertion intensity expressed by participants at the beginning, middle and end of the 7 min maximal effort (P1) and after 30 sec leg-kick bouts - 1, 2, and 3 (P2).

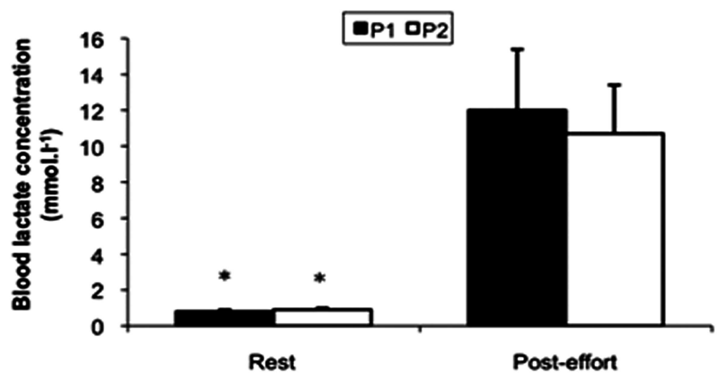

Fig. (2). Mean values and standard deviation values of blood lactate concentration at rest and after exercise, in the maximal continuous (P1) and intermittent (P2) protocols. *Different from post-effort.

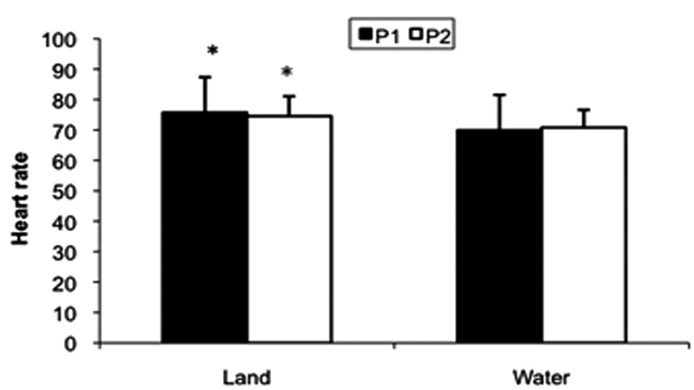

Fig. (3). Mean values and standard deviation of land and water rest heart rate values (bpm), measured before the beginning of the maximal continuous (P1) and intermittent (P2) protocols. *Different from water.

Table 1. Mean (HRmean), Maximum (HRmax) and SD Observed in First (P1) and Second Protocols (P2), at: a) 5 min Moderate Intensity Exercise; b) Maximal Exercise; c) 30 s Recovery

	Moderate Intensity Exercise (a)	Maximal Exercise (b)	Recovery (c)
HRmean (P1)	159.4 ± 16.8	179.3 ± 12.1 [a]	180.9 ± 13.2[a]
HRmean (P2)	152.7 ± 14.4	169.1 ± 10.2	165.3 ± 12.6
HRmax (P1)	171.0 ± 15.2[b]	184.9 ± 11.4[b]	182.6 ± 13.5[b]
HRmax (P2)	163.1 ± 14.9	178.2 ± 10.4	171.6 ± 11.4

Significantly different, $p \leq 0.05$, of: [a]HRmean (P2); [b]HRmax (P2)

Table 2. Percent of Maximal Heart Rate (HRmax) Achieved in First (P1) and Second Protocol (P2), at: a) 5 min of Moderate Intensity Exercise; b) Maximal Exercise; c) 30 s Recovery

%HRmax	Moderate Intensity Exercise (a)	Maximal Exercise (b)	Recovery (c)
%HRmax (P1)	88.1 ± 9.3	99.0 ± 5.3[a]	99.8 ± 5.6[a]
%HRmax (P2)	84.7 ± 8.9	93.8 ± 6.0	91.7 ± 7.4

[a]Significantly different, $p \leq 0.05$, of P2

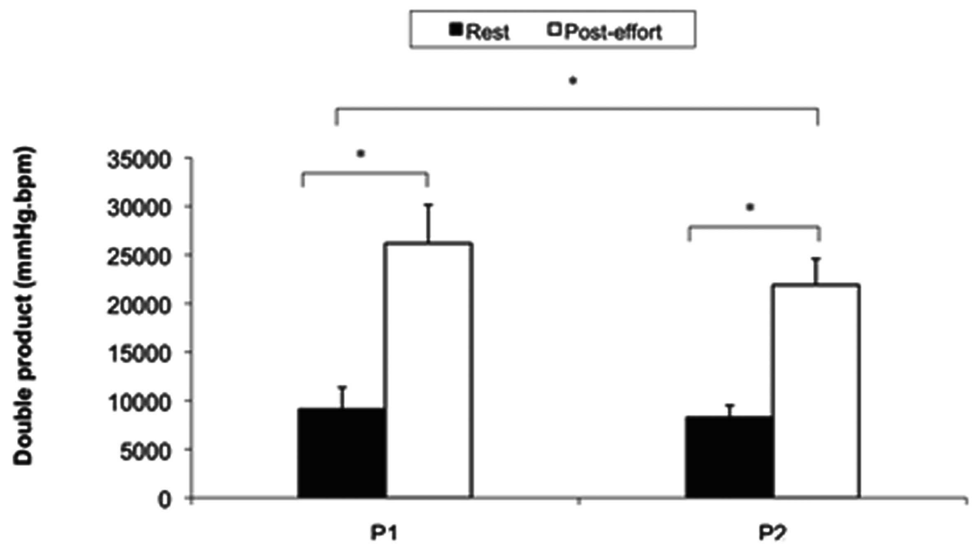

Fig. (4). Mean and SD of double product during rest and for maximal continuous (P1) and intermittent (P2) exercises.

In the Table **1** the mean and maximum HR values (HRmean and HRmax, respectively) achieved by participants during the two exercise protocols is shown. The maximal continuous effort produced a higher mean and maximal HR.

Table **2** lists the HR values as a percentage of predicted HRmax (HR= 208 – 0.7 * age). The maximal continuous exercise produced a significantly higher percentage of predicted HRmax. The HRmax values predicted by Tannaka equation underestimate the real HRmax for some participants.

The DP mean values are presented in Fig. (**4**). The two protocols leaded to a significant increase in DP after exercise. This indicates that cardiovascular effort was higher in the maximal continuous than in intermittent exercise.

Fig. (**5**). presents the mean and standard deviation values of SBP, DBP and MBP at rest and after exercise, attained in the maximal continuous and intermittent protocols. Rest BP values were different, but those differences disappeared after exercise. In both maximal continuous and intermittent efforts SBP rose whereas DBP decreased after exercise. Consequentially MBP remained similar at rest and after exercise.

DISCUSSION

The RPE values confirmed that both the continuous and intermittent exercises were performed at maximal intensity. The HR values, [La^-], and DP were higher after both maximal continuous and intermittent exercises. The BP followed the expected pattern for exercise. Systolic Blood Pressure rose, DBP decreased and mean BP remained stable after exercises. Higher values of HR and DP were found in the continuous exercise.

Among the various physiological parameters that can be used for exercise intensity control, Borg's Rating of Perceived Exertion Scale is the most economical and practical and it also has the advantage of being non-invasive. There is a positive correlation with other intensity indicators, such as HR, [La^-] and VO_2max [24]. In the present work, Borg's

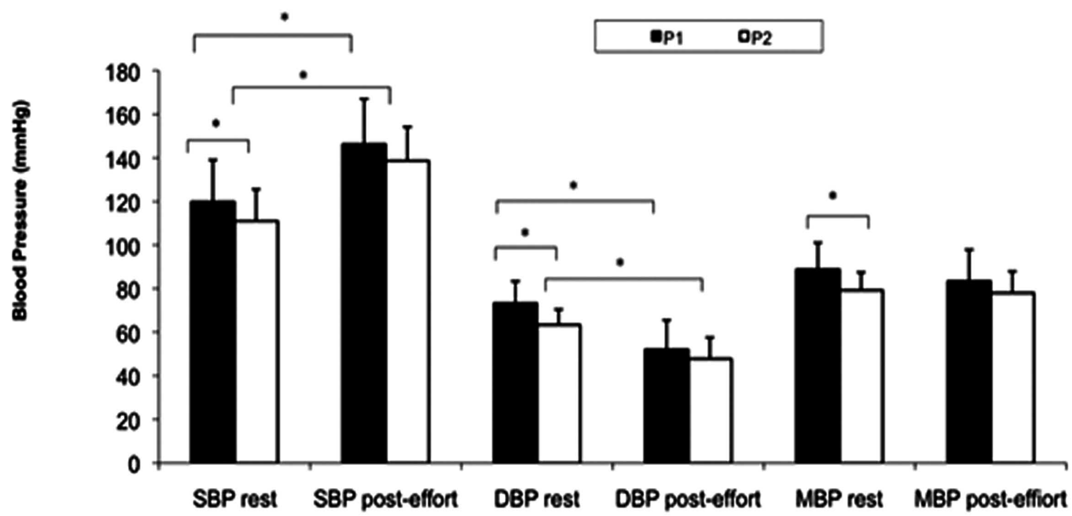

Fig. (5). Mean and standard deviation values of systolic (SBP), diastolic (DBP) and mean (MBP) blood pressure measured at rest and after maximal continuous (P1) and intermittent (P2) exercises. Significant differences are shown.

scale was used to check if maximal intensities were reached by the participants. Participants perceived an intensity increase between warm-up, moderate aerobic exercise and during the maximal efforts. At the end of the both efforts, the exercise intensity was similarly perceived by participants corresponding to the maximal intensity of Borg Scale (18-20). Additionally, the perceived intensity at the end of the effort seemed to be independent of the effort duration and type (continuous or intermittent), if it is maximal. Those results suggest that maximal continuous and intermittent efforts were really achieved by the participants in water exercise and validate our attempt to physiologically characterize these efforts and their eventual cardiovascular risk.

The maximal continuous and the intermittent head-out aquatic exercise efforts produced values of $[La^-]$ similar to swimming efforts of equivalent duration. No values were found in literature for shallow-water exercises. Bearing in mind that $[La^-]$ concentrations corresponding to swimmers anaerobic threshold are between 2 to 4mmol.l-1 [25, 26], $[La^-]$ concentrations obtained here in the maximal continuous effort suggested a high contribution of anaerobic metabolism to energy supply. The maximal continuous effort induced a lactate production that is similar to the obtained in the 400 m swimming events [27]. The continuous test here was of longer effort as compared to 400m swimming (4-5 min). Taking into consideration that the study sample was composed by non-athletes, the high intensity of the effort produced is clear. According to the duration of the maximal continuous effort it were expected maximal $[La^-]$ similar to those obtained in efforts performed at the VO_2max, that is between 4.5 and 10 $mmol.^{-1}$. In spite of the little difference between the values attained by swimmers and our participants and considering that participants were non-athletes, it seems clear that during the 7 min maximal continuous effort participants really attained VO_2max and overpass that intensity needing the anaerobic system for supplying the energetic demands. In short, the results confirmed that the participants made a continuous maximal aquatic effort with evident anaerobic participation.

Among the different swimming competitions, the 50 m seems to be the most similar, in duration and body position, to the peak effort performed by participants during the maximal intermittent exercise. According to literature, in 50 m swimming competitions the anaerobic system contributes 73% [28] to energy supply. The 50m post competitive $[La^-]$ concentrations founded for swimmers were between 12 and 14 $mmol^{-1}$ [29, 30]. Similar values were obtained after 50 m interval training bouts. In our study, the mean $[La^-]$ concentrations founded were slightly lower. These lower values are probably due to a lower maximal anaerobic capacity of our non-athlete participants. Additionally, in our intermittent exercise the arms were not used and the lower muscular mass involved in the exercise could have led to a decrease in fibbers recruitment. According to results, the maximal intermittent exercise performed by participants was clearly an anaerobic effort, although its total duration was not enough to exhaust the anaerobic system.

The risk level of the maximal continuous and intermittent cardiovascular efforts were studied using HR, BP and DP indicators. The bradycardic reflex associated with immersion in water seems to be well documented [31, 32]. Whole-body head-up immersion leads to a number of physiological responses (lower HR included), that could be beneficial even to patients with heart failure [33]. The results of our study showed lower rest HR values when measured in water what is in agreement to the literature.

The HRmax values attained both in the maximal continuous and intermittent efforts were above the ACSM guidelines for exercise prescription (70 to 94% of HRmax) to this population, which could point to an eventual risk of cardiovascular events. The maximal HR values attained in the maximal continuous protocol confirmed the high intensity of the effort performed and Tannaka equation seemed to underestimate, for some participants, the real HRmax. In fact, the HRmax attained during maximal continuous exercise was 94 to 104% of the predicted HRmax. Despite this no, risk reaction was observed. In maximal intermittent exercises perhaps a protective option was better.

The HRmax attained in the maximal intermittent exercise was significantly lower than the attained in the maximal continuous protocol. This is probably due to factors such as duration, rest interval, body position and total muscular mass involved in exercise. According to the literature, the HR decreases from between 9 and 22 bpm in exercises performed in horizontal position compared with that performed in vertical position [34]. Furthermore, in some studies carried out in water (head-out aquatic exercise) and in land the exclusive use of legs is associated with lower values of HR compared to the simultaneous use of legs and arms [35]. Finally, in anaerobic exercises commonly a rise in HR occurs immediately after exercise followed by a drop after 5 to 10 sec rest [36].

It is clear in literature that the anaerobic efforts lead to an increase in BP, a risk factor for hypertensive persons or others with cardiovascular risk. This rise in BP is normal and innocuous for athletes, but must be carefully analysed when exercise is performed by non-athletes and especially unhealthy persons. Through the estimation of MBP it is possible to diagnose the cardiac overload induced by the exercise and determine the associated danger for participants with clinical history of cardiac problems [37]. The risk is evident when the SBP rises without a parallel drop in DBP [38]. After both maximal continuous and intermittent exercises the SBP increased and the DBP decrease [39] as expected. Consequently, the MBP correspondent to rest and to post-effort must be similar. Our results showed that the maximal continuous and intermittent exercises performed were safe, as no differences were found between rest and post-effort MBP.

Our healthy non-athletes demonstrated normal BP behaviour after performing maximal continuous and intermittent efforts. The exercises could even attenuate the BP differences observed in rest between the maximal continuous and intermittent protocols. These rest differences were probably due to higher levels of anxiety of the participants felt before the first protocol, due to the lack of experience in being evaluated. This is a positive result for healthy participants, not supporting some conservative approaches to exercise with non-athletes. The greatest danger could be to those participants with no evident or silent diseases. For instance, participants with a long history of hypertension develop alterations of blood vessels with a debilitation of its structure [For references see 40]. These structural alterations associated with a high peak of effort could eventually lead to a cardiovascular event during an aquatic fitness session were efforts similar to the induced in the present study were performed.

The results of DP estimation demonstrated a high increase of myocardial oxygen consumption between rest and post-effort. There is a relationship between myocardial oxygen consumption and coronary flow, because in exercise the intensification of myocardial oxygen consumption is counterbalanced by an increase in the coronary blood flow. However if a participant has an obstructive coronary disease the blood flow might not be enough to supply the myocardial metabolic needs. Considering the positive correlation described in literature between DP and myocardial oxygen consumption, DP is considered as an indicator of cardiac overload. In the present study DP increased after both the maximal continuous and intermittent exercises, but cardiovascular effort was higher in the maximal continuous exercise. The higher DP observed in the maximal continuous exercise is mainly due to the higher HR induced by this kind of exercise. If we want to make a conservative approach to aquatic exercise, maximally reducing the risk of cardiovascular events, maximal intermittent exercises use seems to be preferable. Nonetheless, no cardiovascular risk events could be found in our healthy participants when maximal continuous and intermittent exercises were performed.

CONCLUSION

The HR, [La$^-$], and DP rose after both continuous and intermittent maximal exercises, and the mean BP remained stable. The higher values of HRmax, %HRmax, HRmean and DP in the maximal continuous exercise indicated to higher cardiac effort associated to the continuous exercise. The analysis of the BP and DP results led to the conclusion that both maximal continuous and intermittent efforts, with a strong anaerobic participation, could be safely used in head-out aquatic exercise classes with healthy participants.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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None declared.

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