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Cardiovascular and Perceived Effort in Different Head-Out Water Exercises: Effect of Limbs' Action and Resistance Equipment

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The aim of this study was to compare the cardiovascular and perceived effort of head-out water exercises selecting different limb strategies and using resistance equipment. Ten young women were randomly assigned to perform at 132 bpm during five minutes different head-out aquatic exercises: (i) horizontal arms abduction (Ab); (ii) horizontal arms abduction with dumbbells (AbD); (iii) frontal kick (Fk); (iv) frontal kick with leggings (FkLeg), and; (v) aquatic skiing (Ski). Cardiovascular effort was measured by monitoring the heart rate, blood pressure and double product. Perceived effort was assessed by the Borg's scale. Within-routines comparison was computed using repeated-measures ANOVA followed-up by the Bonferroni post-hoc test. Considering the percentage of the maximal heart rate, participants reached 72.88 ± 12.90% in the FkLeg, 65.99 ± 10.91% in the Fk, 62.62 ± 7.20% in Ski, 57.27 ± 11.58% in AbD and 57.12 ± 12.09% in Ab. Comparing exercises, higher heart rates were observed in the FkLeg (140.40 bpm) than Ab (110.30 bpm) or AbD (110.00 bpm). Significant differences were found in the systolic blood pressure when compared to the Fk (120.60 mmHg) and Ab (104.50 mmHg). Double product was higher in the FkLeg (16990) showing a meaningful difference when compared to Ab (11608) or AbD (12001). The highest perceived effort was found in the FkLeg (15.80) with meaningful variations compared to Ab (11.70), the Fk (13.70) and Ski (10.40). Thus, different head-out water exercises result in different intensities. The actions by lower limbs promote a higher cardiovascular response, whereas the upper limbs actions trigger a lower exertion. Moreover, exercising the four limbs concurrently seems to be less intense than using only two limbs with an aid.

Key words: *aquatic exercise, segmental action, buoyancy devices, heart rate, perceived exertion.*

Introduction

Head-out water exercises comprise a training programme that uses water properties to induce biological adaptations. In the last few decades, these programmes have gained popularity within the health system due to their benefits improving the fitness level of healthy subjects (Costa et al., 2014; Raffaelli et al., 2016) and rehabilitation of patients with chronic diseases (Alcalde et al., 2017; Suomi and Koceja, 2000). A literature review on head-out water exercises found that appropriate cardiovascular adaptations can be obtained depending on the type of exercise performed or the inclusion of training aids, such as buoyancy devices (Barbosa et al., 2009).

Head-out aquatic exercises are classified into six main groups (Sanders, 2000): (i) walking; (ii) running; (iii) rocking; (iv) kicking; (v) jumping; and (vi) scissors. Each of these exercises has several variants or extensions with increasing levels of complexity and exertion. For instance, increasing complexity results from the number of limbs in action (legs-only, arms-only or concurrent legs and arms actions). The scarce literature noted a higher acute cardiovascular

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response to a given exercise with an increasing number of limbs used (Costa et al., 2008; Darby and Yaekle, 2000). Nevertheless, it is still unclear whether cardiovascular effort may vary between water exercises using different limb strategies. The peak oxygen uptake seems to be significantly lower when comparing abductor hop and jumping jacks with the frontal kick and cross-country skiing (Antunes et al., 2015).

During head-out water exercise sessions, instructors select buoyancy equipment to vary the intensity of the exercise. There are several equipment commercially available to elicit more exertion. Despite having buoyancy features, equipment like dumbbells or leggings is mostly used as "resistance (or drag) devices" for strength and conditioning purposes. Literature shows little evidence on the acute adaptations when using dumbbells, whereas information on leggings is nonexistent. Costa et al. (2008) noted that performing the "rocking horse" exercise with dumbbells increased the rating of perceived exertion, heart rate and blood lactate concentrations when compared to the same exercise, but without those devices. Colado et al. (2013) reported unchanged neuromuscular responses when using different equipment performing shoulder extensions. As far as our understanding goes, the comparison of cardiovascular effort in head-out water exercises using different resistance equipment in different exercises remains unaddressed. In some populations, cardiovascular responses beyond a given intensity may impose serious health risks. Yet, if too low, it can decrease the effectiveness of the chronic adaptations over time.

The aim of this study was to compare the cardiovascular and perceived effort of head-out water exercises selecting different limb strategies and using resistance equipment. It was hypothesised that both cardiovascular and perceived effort would be greater in exercises involving two limbs, but using resistance equipment compared to a four limbs exercise without any device.

Methods

Participants

Ten young women were recruited to participate in this research. Table 1 presents the characteristics of the participants at rest. The inclusion criteria were: non-pregnant women, clinically healthy, physically active with at least one year of experience of attending head-out aquatic exercise programmes. Exclusion criteria were having any history of orthopedic, muscle-skeletal or neurologic disorders diagnosed in the last six months. All women were informed of the benefits and experimental risks prior to signing an institutional informed consent document to participate in the study. The Polytechnic Institute of Guarda Ethics Board also approved the research protocol. All procedures were in accordance to the Declaration of Helsinki in respect to Human research.

Design and Procedures

A randomised crossover design was selected for this study. Participants were randomly assigned to perform on different days the following head-out aquatic exercises: (i) horizontal arms abduction (Ab); (ii) horizontal arms abduction with dumbbells (AbD); (iii) frontal kick (Fk); (iv) frontal kick with leggings (FkLeg); and (v) aquatic skiing (Ski). Data collection was held at a conventional swimming pool (16.67 m length, 8 m width and maximal depth of 1.40 m). The water temperature was set at 30°C and relative humidity 75%. In Ab the participants maintained a static trunk with lower limbs fixed to the ground while performing simultaneously horizontal arms' abduction. The arms were fully extended during motion and the hands at a 90° angle of attack in concentric muscular action. In AbD the participants showed the same pattern of motion as in Ab, yet holding a dumbbell in each hand for resistance purposes. In the Fk the participants performed alternating leg kicking with a hop. While one leg was in the ascendant phase of the motion, the opposite leg was in the descendent phase. In the FkLeg the participants followed the same pattern of motion as in the Fk, but using a legging on each leg for resistance purposes. In Ski the participants hopped with legs extended forwards and backwards and a cross synchronised arms' swing.

All selected exercises and extensions are prescribed on a regular basis in head-out aquatic exercise programmes. Prior to testing participants performed a 3 min warm-up with low amplitude at low intensity in the vertical position. Immediately after the warm-up, each exercise was performed at least for five minutes to reach a cardiovascular steady state. Participants performed the exercises immersed up to the xiphoid process (i.e., breast level). Exercise cadence was set at 132 bpm and controlled electronically by a metronome (Korg, MA-30, Tokyo, Japan) connected to a sound system. The metronome was used to avoid any disturbance in the subjects' performance. All women were familiar with the concept of "water tempo" and followed the metronome beat throughout the test. Whenever necessary, the evaluators gave verbal and/or visual cues for participants to follow the appropriate exercise cadence, while maintaining the appropriate range of motion. The test was immediately stopped when failing to accomplish the set cadence.

Measures

Cardiovascular response was assessed by the heart rate (HR), systolic and diastolic blood pressures (SBP and DBP, respectively) and double product (DPr) (Gobel et al., 1978). The rest and exercise HR (in bpm) was assessed by a HR monitor (Polar S220, Finland). At rest the HR was obtained in the water with the participant standing still at least for five minutes. For each exercise the HR was recorded at a sampling frequency of 1 Hz and the peak value was selected for further analysis. The peak was considered the mean value from the three highest values during the exercise bout. The percentage of the predicted maximal theoretical heart rate (%HR_{max}) was determined according to the Tanaka et al.'s (2001) equation (HR_{max} = 208 – 0.7 x age).

Both SBP and DBP (in mmHg) were assessed at rest and immediately after each bout by an experienced health professional using a sphygmomanometer (Erka, model D-83646) and a Littman stethoscope (Littman Quality ™). At rest, blood pressure was collected with the participants seated on a chair and the arm on a table. After exercise blood pressure was measured with the participants in the water placing one arm on the pool's deck with the hand at the heart level.

The DPr was used as an additional health risk indicator and a measure for myocardial oxygen consumption. It represents the internal myocardial workload when the heart beats while the external myocardial work is a reflection of different modes of exercise (Formitano and Godoy, 2006). The DPr was estimated using the following equation: DPr = HR x SBP (Gobel et al., 1978).

Blood lactate concentrations ([La]) were measured as an estimation of metabolic response. Blood samples were collected immediately after the end of the protocol from the fingertip of the upper limb not used to measure blood pressure. Samples were then placed in an auto-analyzer (Lactate Pro 2, Kyoto, Japan) to determine [La].

The rate of perceived effort (RPE) was measured immediately after each 5 min interval by the Borg 6-20 scale (Borg, 1998). A board with the scale was shown to the participant.

Statistical Analysis

Kolmogorov-Smirnov and Levene's tests were used to assess normality and homocedasticity assumptions, respectively. Data were expressed as mean and standard deviation for each head-out aquatic exercise. The relative change (%) between rest and exercise was also computed.

Repeated-measures ANOVA (i.e., within-routines comparison) followed-up by the Bonferroni post-hoc test was conducted for all dependent variables. All assumptions to perform the ANOVAs were considered (i.e., independence, normality, and homoscedasticity). The level of statistical significance was set at $p \leq 0.05$.

Effect sizes were computed based on Eta-squared (η^2), and the following values were interpreted according to Ferguson (2009): without effect if $0 < \eta^2 \leq 0.04$, minimum if $0.04 < \eta^2 \leq 0.25$, moderate if $0.25 < \eta^2 \leq 0.64$ and, strong if $\eta^2 > 0.64$. Data were reported to have a *meaningful difference* if significant ($p \leq 0.05$) with a medium/moderate or large/strong effect size ($\eta^2 > 0.25$) and a *significant difference* if significant ($p \leq 0.05$) with a small effect size ($\eta^2 \leq 0.25$) (Winter, 2008).

Results

Figure 1 depicts the individual responses at %HR_{max} in each head-out water exercise. Subjects reached 72.88 ± 12.90% in the FkLeg, 65.99 ± 10.91% in the Fk, 62.62 ± 7.20% in Ski, 57.27 ± 11.58% in AbD and 57.12 ± 12.09% in Ab.

Figure 2 shows acute physiological responses across the head-out water exercises. There were significant differences in the HR when comparing the FkLeg (140.40 ± 25.50 bpm) with Ab (110.30 ± 23.75 bpm, $p = 0.03$, $\eta^2 = 0.32$) and AbD (110.00 ±

22.70 bpm, $p = 0.04$, $\eta^2 = 0.33$). There was also a trend toward lower values in the Fk (131.10 ± 27.14 bpm) and Ski (130.50 ± 40.29 bpm), but not significant. Significant differences were found in SBP when comparing the Fk (120.60 ± 15.20 mmHg) and Ab (104.50 ± 10.80 mmHg, $p = 0.05$, $\eta^2 = 0.18$), but not in AbD (106.80 ± 17.56 mmHg), the FkLeg (119.20 ± 15.44 mmHg) or Ski (117.20 ± 12.90 mmHg). The trend was to find unchanged DBP across routines with the highest value recorded in Ski (68.90 ± 5.00 mmHg) and the lowest in the Fk (63.60 ± 7.11 mmHg). A similar trend was found in [La] with the highest value recorded in the FkLeg (4.51 ± 1.73 mmol/L) and the lowest in Ski (2.67 ± 1.37 mmol/L). For the RPE, the highest value was found in the FkLeg (15.80 ± 1.93) with meaningful differences compared to Ab (11.70 ± 2.26, $p < 0.01$, $\eta^2 = 0.53$), the Fk (13.70 ± 1.83, $p < 0.01$, $\eta^2 = 0.27$) and Ski (10.40 ± 0.84, $p < 0.01$, $\eta^2 = 0.77$). There were also significant differences between the Fk and Ab ($p = 0.02$, $\eta^2 = 0.22$). The highest values of DPr found in the FkLeg (16990 ± 4655) showed a meaningful difference when compared to Ab (11608 ± 3138, $p = 0.01$, $\eta^2 = 0.42$) and AbD (12001 ± 3914, $p = 0.03$, $\eta^2 = 0.33$). There was also a meaningful difference when comparing the Fk (15963 ± 4328) with Ab (11608 ± 3138, $p < 0.01$, $\eta^2 = 0.31$).

Table 1

Characteristics of study participants.

Variable	Mean	*SD*	Maximum	Minimum
Age (yr)	22.2	2.6	28	19
Body height (m)	1.63	0.08	1.72	1.48
Body mass (kg)	59.30	12.46	81.20	49.20
BMI (kg/m^2)	22.28	4.20	31.72	16.34

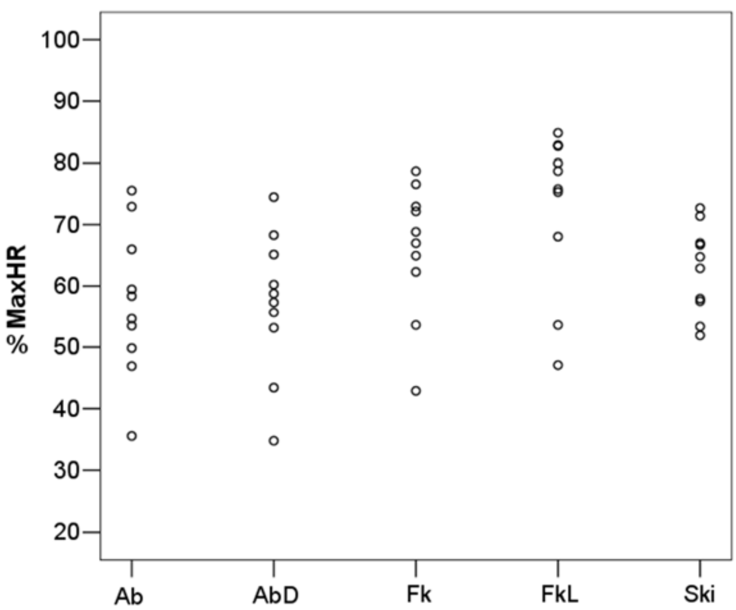

Figure 1

Percentage of the maximal heart rate while exercising: arms abduction (Ab), horizontal arms abduction with dumbbells (AbD), frontal kick (Fk), frontal kick with leggings (FkL) and aquatic skiing (Ski).

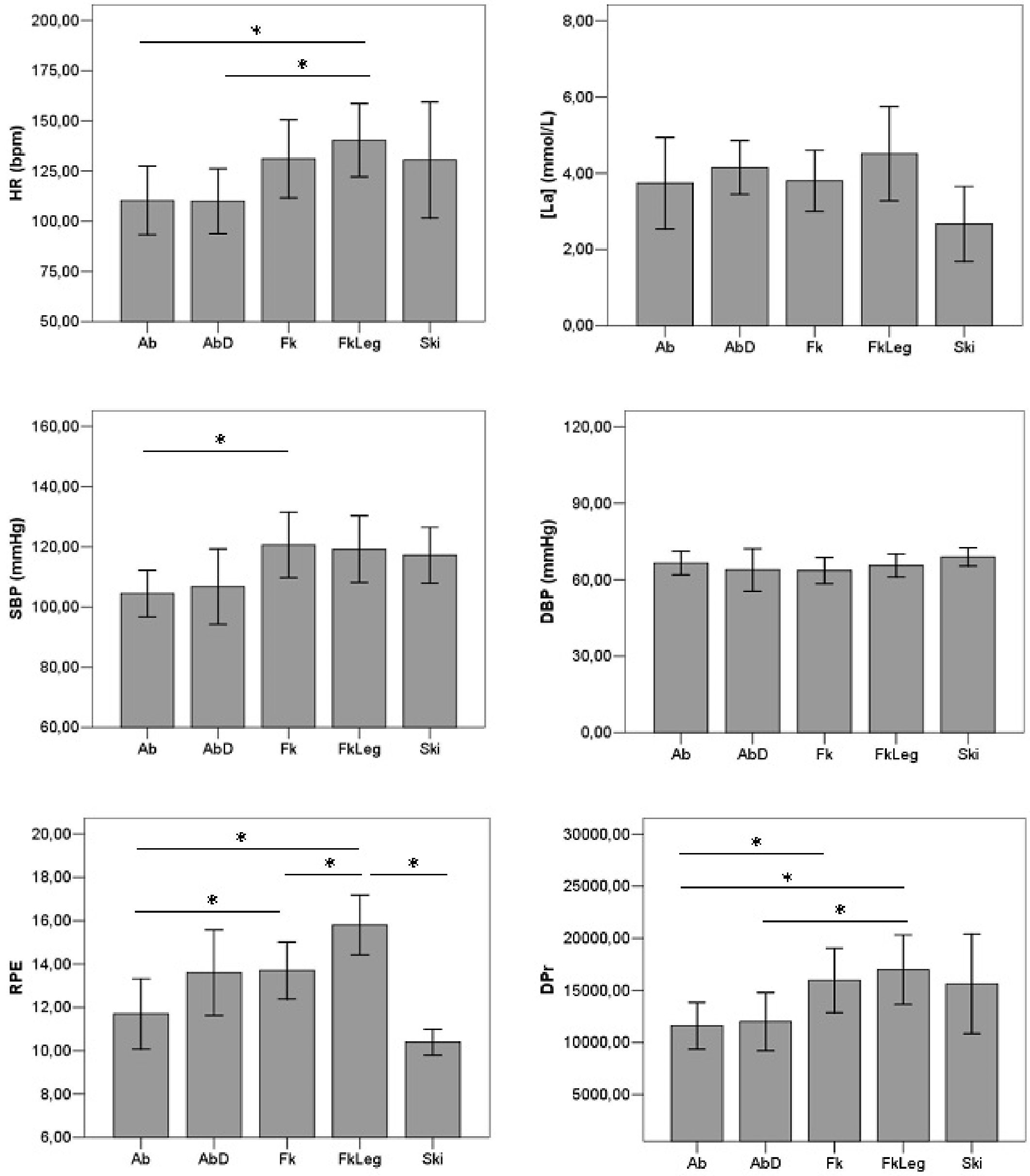

Figure 2

*Comparison of cardiovascular and perceived effort between horizontal arms abduction (Ab), horizontal arms abduction with dumbbells (AbD), frontal kick (Fk), frontal kick with leggings (FkLeg) and aquatic skiing (Ski). * p ≤ 0.05.*

Discussion

The aim of this study was to compare the cardiovascular and perceived effort between head-out water exercises with different limb strategies and using resistance equipment. It was found that actions by the lower limbs elicited a higher cardiovascular response, whereas actions using upper limbs resulted in lower exertion. Additionally, exercising the four limbs concurrently seemed to result in less exertion than when using only two limbs with a training aid.

General acute response

The values obtained in this study are within the standard guidelines described by the American College of Sports Medicine (Garber et al., 2011) for health promotion programmes, suggesting exercises at 60-90% of the HR_{max} using larger muscle groups. As depicted in Figure 1, participants reached an effort ranging from 57 to 72% of the HR_{max}. The Ab, AbD and Ski produced a light intensity, while the Fk and FkLeg yielded moderate intensity. Moreover, HR response during exercise reached values from 110 to 140 bpm, sustaining that intensity was within the threshold proposed. Indeed, those values match results from previous studies using subjects with similar background (Barbosa et al., 2007). SBP varied between 110 and 120 mmHg, while DBP remained relatively unchanged across exercises. Literature is not consistent on exercise-induced hypertension. However, Fagard and Grassi (2008) noted that exercise-induced hypertension was diagnosed when SBP values were equal or higher than 190 mmHg. Our values were well below that threshold point. The DPr was measured as an index of myocardial oxygen consumption reaching a 16,990 value. This value is off the limit of 21,000 suggested as an elevated hemodynamic response and a dangerous zone of stress for cardiac muscle during exercise (Formitano and Godoy, 2006). This suggests that the exercises used were appropriate and not too strenuous, as far as hemodynamic response is concerned. Previous studies suggested that music cadence ranging between 130 and 150 bpm was the most suitable to elicit the aerobic energetic pathway (Barbosa et al., 2010). In our study, the music cadence was set at 132 bpm, eliciting lactate within the limits of 2-4 mmol/L, and hence suggesting an external workload within the aerobic zone and targeting endurance development. Moreover, the RPE values were higher than 10 and less than 16 converging with a light to heavy perceived effort. Thus, when characterizing the acute adaptations, we can say that none of the head-out water exercises were too strenuous to compromise health and entail cardiac risk.

Our main goal was to discriminate between exercises by intensity, in order to give important feedback to head-out water instructors on the inclusion in their sequence/order within and between weekly sessions. Indeed, as shown in Figure 2, the cardiovascular and perceived effort were different between head-out water exercises.

Effect of limbs' action

This research demonstrated that actions of the lower limbs elicited a more intense response than exercising the upper limbs only. This was the case of leg kicking that was more intense than arm abduction. This finding is in accordance with previous research. When analysing callisthenics exercises, Cassady and Nielsen (1992) reported increased oxygen uptake for leg actions when compared with arm actions. This more intense effect while exercising in the water may be explained by: (i) higher muscle size in the legs that promotes a higher oxygen and nutrient demand when contracting, an increasing HR and metabolic production (e.g. [La]); (ii) an increased drag force due to greater leg dimensions that culminated with a higher mechanical work influencing the RPE. Interestingly, the concurrent use of arms and legs (e.g. Ski) promoted a more vigorous response than arms-only (e.g. Ab), but not more than legs-only actions (e.g. Fk). Literature has been consistent that the exclusive use of legs is associated with a lower cardiovascular response compared to the concurrent action by arms and legs (Barbosa et al., 2007; Costa et al., 2008; Darby and Yaekle, 2000). This may be suitable when increasing the number of limbs in action considering the same water exercise. However, the present study focused on different exercises characterized by different mechanical strategies. Probably a different range of motion in various exercises added to the exercise mechanics may help explain differences between exercises. The Fk comprised an alternating extended leg action which, in part, was opposed to buoyance force. Buoyancy force is a water property that has an ascending direction. So, any attempt to bring the legs fully extended near the ground (e.g. downward) will impose higher buoyancy and drag forces, leading to an increased concentric muscular action and a more intense motion. On the other hand, Ski used a leg extended forwards and backwards and a cross coordinated arm movement where arm and leg motions were performed in a parallel trajectory in relation to the ground axis. In this case, there was only active drag force to meet imposing less intensity than the Fk. Antunes et al. (2015) also found that the Fk was the exercise that triggered the higher cardiorespiratory response from a group of six different water-based routines. Thus, exercises comprising a higher number of limbs in action do not necessarily represent higher intensity. For this reason technical literature (e.g. Kinder and See, 1992) proposes some exercises using the four limbs for the warm-up, while some legs-only and arms-only exercises are included in more intense parts of the sessions.

Effect of resistance equipment

Considering cardiovascular data, our study showed that exercising with four limbs (e.g. Ski) seemed to be less intense than exercising only two limbs (arms or legs) with the aid of resistance equipment (e.g. FkLeg or AbD). The resistance equipment aims to increase active drag force in order to get a vigorous response from specific body segments. This will help work specific muscle groups in order to reach one of the desired effects of head-out water sessions, the development of muscle strength. Previous studies agree that adding resistance equipment increases physiological response to selected water exercises (Costa et al., 2008; de Souza et al., 2012; Pinto et al., 2011; Pöyhönen et al., 2001). Our findings agree with this even when analysing different types of exercise at the same time. For a legs-only (FkLeg) or arms-only exercise (AbD), the inclusion of devices with floating/resistance properties greatly increased buoyancy force acting on that body region. This effect was more intense for a two limb mode, than exercising the four limbs simultaneously (Ski). Two factors help explain such a phenomenon: (i) the higher drag forces acting on the resistance device due to a higher cross-sectional area; (ii) the higher density of segmental body regions that are able to easily perform the four limb exercise. This supports technical literature that exercising with the aid of resistance equipment should be planned for the more intense segments of the sessions. Interestingly, Ski reflected lower RPE values in comparison to the remaining exercises. This suggests that the perceived exertion by the participants may not necessarily represent the cardiovascular acute response triggered by each exercise. One might claim that the need of synchronising both arms and legs in Ski makes it more challenging to perform, leading to a drop in the perceived effort. Perhaps, the participants adapted their motor actions changing the range of motion to follow the pace set. This may lead to a lower perceived exertion regardless of the cardiovascular response achieved. As shown by the lower inter-subject variability for the RPE, decreases in the range of motion can be a common trend when analysing exercises synchronising the four limbs as shown at least while performing jumping jacks (Costa et al., 2011). In this sense, further studies should add and control the range of motion considering its influence on changing the RPE and cardiovascular output.

Some additional limitations of our research can be addressed: (i) uncontrolled effect of several external factors (i.e. lack of sleep, smoking, diet) that can influence cardiovascular variables; (ii) the absence of oxygen uptake data to serve as a more reliable measure of acute response; (iii) the unaccounted comparison of the energy expenditure of different exercises.

Conclusions

These findings show that different head-out water exercises, encompassing different limb strategies or with the aid of resistance equipment, induce a different cardiovascular response and perceived effort. Actions by the lower limbs are the most intense, while upper limbs elicit a lower exertion. Exercising the four limbs (e.g. aquatic ski) seems to be less intense than using only two limbs, but with the aid of resistance equipment. Head-out water instructors should plan carefully their weekly sessions. While planning, they should breakdown the workout intensity based on the number of limbs in action with or without resistance devices, always underpinned by the exercise mechanics rational. As seen, there were exercises with a fewer number of limbs in action, but with resistance equipment that imposed a higher intensity. Those can be prescribed for the more intense part of the sessions. Other exercises triggered lower effort and can be used for warm-up purposes.

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