



Heart rate and perceived exertion at aquatic environment: differences in relation to land environment and applications for exercise prescription – a review*

Fabiane Inês Graef and Luiz Fernando Martins Kruel

ABSTRACT

The intensity in which effort is expended is essential to the elaboration and control of any exercise program. Whether an activity is performed on land or in water makes a whole difference, because aspects such as volume of immersed body, body position and water temperature result in body conditions different from those seen on land exercise and, thus, influence indicators of the intensity of effort. Considering that heart rate and perceived effort are the most frequently used indicators for the control of the intensity of effort in water exercises, the present review aims at analyzing the main changes that take place in those variables in immersion, comparing to land conditions, as well as the implications of these changes in the prescription of exercise. Therefore, the main changes resulting from situations of rest and exercise, in running and water biking, in water gym and swimming are described herein. Finally, some light is shed on the implications of these changes in the prescription of exercise, as well as on some strategies for the use of these variables in exercise performed in water. In relation to heart rate, one can conclude that occurs a reduction in heart beats during immersion, influenced by water temperature, immersion depth, absence or presence of effort, type and intensity of the exercise. Such reduction should be considered when using this indicator of intensity of effort in water. In relation to perceived exertion, Borg's scale seems to be a suitable option to control water exercises intensity, being considered its application recommendations.

INTRODUCTION

The essential prescription components, whenever elaborating an exercise program, include the sport selection, the effort intensity, the activity's duration and the weekly frequency in which it is conducted. Such components are applied when prescriptions are developed for individuals with different ages and functional abilities, independently of existence or lack of risk and disease factors⁽¹⁾. Therefore, the measurement of the suitable effort intensity constitutes in an aspect of great importance in the organization of an exercises session.

Many physiological indicators can be used to quantify the effort intensity, in activities both in and out of the water environment, namely the heart rate (HR), the oxygen consumption ($\dot{V}O_2$), the subjective perception of effort (SPE) and the ventilatory and lactate thresholds. These indicators have been widely studied on the

Keywords: Heart rate. Perceived exertion. Immersion. Exercise.

land environment. However, when establishing comparisons with the water environment, the exercises practice results in differentiated responses in the distinct environment⁽²⁻⁴⁾. This is an essential aspect for the professionals who deal with the prescription of exercises in water, since these differences influence the determination of the effort intensity, which affects all the other components of the prescription.

Due to the high level of specificity of the activities conducted in the water environment, controlling the effort intensity through simple excesses of the physiological indicators obtained on land to the aquatic condition may lead to rough prescription⁽⁵⁻⁶⁾.

Among the effort intensity indicators, the HR and SPE are the most practical and of lowest cost. Perhaps for this reason, they are the most used by professionals who prescribe exercises in the water environment. However, immersion, water temperature and different body positions adopted may affect the behavior of these indicators of effort intensity during the exercises performance, or even in its recovery⁽⁷⁻⁹⁾. The aim of the present study is to make a review on the literature about the main changes that occur in the HR and the SPE in immersion in the aquatic environment comparing to the land environment, and analyzing the implications of these changes in the exercise prescription.

HEART RATE

The HR is one of the most used variables in the effort intensity control. It mainly occurs due to the easiness of its measurement, which makes it quite practical, as well as its relation with the $\dot{V}O_2$ in a determined effort level. The HR behavior is differentiated in relation to the kind or intensity of exercise done in the land or water environment though⁽²⁾. In rest or water exercise situations, the alterations found in the HR are influenced by factors such as the body position, the immersion depth, the water temperature, the HR in rest and the decrease of the hydrostatic weight⁽⁹⁾. The great majority of the studies found in the literature points to the existence of a decrease in the HR during immersion^(2,4-5,9,28). According to Paulev and Hansen⁽²⁹⁾, the bradycardia due to the immersion is widely accepted, even with discrepancy about the origin, consistency and degree of decrease of this physiological alteration.

Swimming

Many comparative studies between on land treadmill running/walking and swimming have been conducted, being pioneers in demonstrating the occurrence of decrease in heart beating due to the immersion^(10-12,14-15,19,24). Magel and Faulkner⁽¹⁰⁾ used the tied swimming and reported significant decrease ($p < 0,05$) in the aquatic HR_{max} , with difference of 12 bpm. McArdle *et al.*⁽¹¹⁾ compared swimming and treadmill walking, reaching to the conclusion that, for different submaximal levels of $\dot{V}O_2$, the average HR in aquatic environment acted statistically different ($p < 0,05$) from the average HR on land, with lower values of 9 to 13 bpm. In the same exper-

* Laboratório de Pesquisa do Exercício – LAPEX/Grupo de Pesquisa em Atividades Aquáticas – GPAA, Universidade Federal do Rio Grande do Sul-UFRGS.

Received in 27/7/05. Final version received in 1/11/05. Approved in 24/4/06.

Correspondence to: Fabiane Inês Graef, Grupo de Pesquisa em Atividades Aquáticas – Laboratório de Pesquisa do Exercício – Escola de Educação Física – Universidade Federal do Rio Grande do Sul, Rua Felizardo, 750, Bairro Jardim Botânico – 90610 – Porto Alegre, RS. E-mail: fabianeGraef@gmail.com

iment, the HR_{max} obtained in swimming acted statistically different ($p < 0,01$) from the HR_{max} obtained in walking as well, being in average 22 bpm lower. Dixon and Faulkner⁽¹²⁾ compared treadmill running and tied swimming, finding HR maximum values in swimming reduced in 12 heartbeats (for the athletes) or in 20 heartbeats (for the non-athletes). Holmér *et al.*⁽¹⁴⁾ conducted tests of maximal effort in treadmill and swimming in flow pool (*swimming flume*), reporting values of HR_{max} , in average, 15 bpm lower ($p < 0,01$) in water. Another study by Holmér *et al.*⁽¹⁵⁾ involving submaximal and maximal tests in treadmill running and swimming flume showed that the HR in swimming was 12 bpm lower ($p < 0,05$) than in running, in submaximal and maximal tests as well.

Vilas-Boas⁽¹⁹⁾ comparing the HR_{max} in swimming and in treadmill running, showed that the swimming values were lower than the ones in running, being the difference lower among women. The average value of the HR_{max} in swimming was 7 bpm lower ($p < 0,05$) than the one in the treadmill running. For men, the difference corresponded to 12 bpm and for women, to 2 bpm. In research relating the HR_{max} in running, swimming and ergometric bicycle, Scolaro *et al.*⁽²⁴⁾ verified that the decrease in the HR during swimming represented 15 bpm for men and 14 bpm for women, compared to running. Concerning cycling, the decrease of the heart beating in swimming represented 3 bpm for men, not being reported the results for women. According to the authors, the lower values in cycling in relation to running are due to the differences in the resistance to the dislocation of the body weight. Thus, although the dislocation of the existing body weight in swimming and in running make them similar, and different from cycling, the implications resulting from the body position and the environment, cause greater influence, differentiating swimming from the other studied sports.

Generally, the HR during swimming is significantly reduced as compensation to the higher systolic volume caused by the decubitus body position⁽¹²⁾. According to the shown data, the existing decrease in the heart beating during swimming is between 12 and 15 bpm in the majority of the experiments. The greater differences found in non-athletes individuals are related to higher values of resting HR⁽²⁰⁾. The remarking differences between genders reported in one of the studies⁽¹⁹⁾ can also be explained by different values of resting HR, resulting from differentiated training levels, once, according to the authors of the mentioned study, women presented a higher training level.

Running in shallow or deep water

Other studies compared the running/walking outside water to exercises done on the vertical position, such as running on shallow or deep water and exercises of water gymnastics. Ritchie and Hopkins⁽²⁰⁾ compared running on deep water and treadmill running, in intense rhythm, with results pointing to an average HR 17 bpm smaller ($p < 0,05$) during running in deep water. Town and Bradley⁽²¹⁾ reported decrease slightly higher than 10% in HR_{max} during running on shallow and deep water, compared to running on treadmill, being the HR_{max} slightly higher in shallow water. The found differences were statistically significant ($p < 0,05$) and corresponded to approximately 21 bpm in running in shallow water and 26 bpm in running in deep water.

The comparative study between running on treadmill and running in deep water conducted by Svedenhag and Seger⁽²⁾ also revealed HR_{max} significantly lower ($p < 0,01$) in water, with average decrease of 16 bpm. It is important to highlight that in this study, for lower $\dot{V}O_2$ levels the difference between the HR values on land and in water was lower, and not significant. In submaximal effort intensities, the HR reduced from 8 to 11 bpm in water, with the highest reductions occurring in the lowest intensity. These data reinforce the idea that, in lower effort intensities, the differences in the HR tend to be smaller between the aquatic and on land environment.

Such fact possibly occurs due to differences related to the transmission of sympathetic nervous impulses, or to lower plasmatic concentration of noradrenalin in higher intensities⁽⁵⁾.

Frangolias and Rhodes⁽²³⁾ also conducted tests of maximal effort in treadmill outside water and in running in deep water, reporting average difference ($p = 0,001$) of 15 bpm in the HR, verified when the individual reached his $\dot{V}O_{2max}$. Similar results were pointed by Nakanishi *et al.*⁽⁴⁾, who observed HRmax reduced in 19 bpm in running in deep water, compared to running on treadmill outside water.

Relating HR and blood lactate production during running in deep water and running on track, Denadai *et al.*⁽⁵⁾ compared the HR corresponding to the aerobic and anaerobic threshold. The results of the research pointed that the aquatic HR was significantly lower ($p < 0,05$) for the two intensities. The average differences found, corresponding to 22 bpm in the aerobic threshold and 34 bpm in the anaerobic threshold, reinforce again the idea of the effort intensity over the magnitude of the decrease observed in the HR in aquatic environment.

According to the mentioned studies, when comparing the HR behavior during running in deep water and running outside water, a decrease in the HR_{max} occurs, during running in deep water that is between 15 and 20 bpm. Higher values for the reduction in the aquatic HR reported in two of the mentioned studies^(5,21) can be justified by the exercise with no use of floating device⁽²¹⁾, thereby imposing a bigger working load, or by the use of running on track⁽⁵⁾, which could lead to higher HR maximal values comparing to running on treadmill.

Water gymnastics

Some recent studies compared the HR during typical exercises of water gymnastics, performed in and out of the aquatic environment. Kruehl *et al.*⁽⁹⁾ observed average reduction of 9 ($p > 0,05$) and 25 bpm ($p < 0,05$) during water exercises in moderate intensity. Such variation depends on the immersion depth up to the umbilical scar level or the shoulder's, respectively. Heithold and Glass⁽²⁸⁾ also compared the HR during identical aerobic exercises in and out of the water, with velocity based on the subjective perception. The authors observed HR values of 20 to 29 bpm lower ($p < 0,05$) during water gymnastics, for the same effort intensity.

Based on the presented data, during water gymnastics exercises, the HR seems to decrease more intensely than in swimming and running in shallow or deep water, being around 25 bpm to the immersion condition in the shoulder depth. Such evidence may be related to the presence or lack of dislocation, once a greater work amount and acting muscular mass is necessary to surpass the overload imposed by water during the frontal dislocation characteristic from swimming and aquatic running. Thus, the sports that involve dislocation would demand bigger blood storage to fulfill the acting muscular portion needs. Specifically comparing swimming to water gymnastics, another differential to be considered consists of the effects of the hydrostatic pressure over the immersed individuals in the vertical position. These effects include a bigger blood volume which returns to the heart, and consequently, a bigger volume ejected by systole, which allows the heart to decrease its bombing frequency.

Water cycling

Concerning ergometrical bicycle exercises performed in and out of the water, Sheldahl *et al.*⁽³⁰⁾ reported that the aquatic HR was not significantly different from the HR on land, for resting situations and moderate exercise. In the exercise with higher loads, the HR reduction in the water was bigger, corresponding to 10 bpm. Once again, the data shown in the literature reinforce the influence of the effort intensity in the HR reduction in aquatic environment. It seems that bigger differences between the HR responses in the water and on land environment are found whenever the

individuals are close to the maximal effort. Hence, equations that translate the differences of the HR_{max} of the land environment to the water environment should not be used since the HR_{max} is influenced, among other factors, by water temperature and by immersion depth. An interesting strategy for a suitable quantification of the HR_{max} in the water environment would be a conduction of a maximal effort test in the practitioner, respecting the specificities of the environment, namely temperature, depth and motor gesture, required during the usual training sessions.

Immersion depth

Concerning the influence of the immersion depth in the HR alterations, a gradual decrease in the HR is observed concomitantly with the immersion depth, during standing immersion in the water environment^(9,16,22,25-26). According to Risch *et al.*⁽¹⁶⁾, the HR decreases about 13 bpm from an initial position of immersion up to pubic symphysis for a second immersion situation up to the xiphoid appendix. However, starting from the same initial immersion situation up to the pubic symphysis to a immersion situation up to the neck, the average decrease of the HR corresponds to 16 bpm (statistically not significant differences). In another study by Risch *et al.*⁽¹⁷⁾, the average bradycardia found after rapid immersion up to the neck, in comparison to the condition outside water, was 17 bpm (statistically significant difference), being bigger for higher initial HRs. Later, Krueel⁽²²⁾ also analyzed the HR behavior during resting vertical immersion in different water depths, using a bigger number of immersion levels. The average bradycardia found in the different depths was of 2 bpm (knee), 9 bpm (hip), 13 bpm (umbilical scar), 16 bpm (xiphoid appendix and neck), 17 bpm (shoulder), 12 bpm (shoulder with arms out of water). Except for the immersion level up to the knee, the bradycardia was significant ($p < 0,05$) in all immersion depths analyzed. The author highlights that the growing bradycardia that follows the increase of the immersion depth is directly related to the increase of the hydrostatic pressure on the individuals.

Concerning the responses between genders, Krueel *et al.*⁽²⁵⁾ showed results similar to the ones in the study mentioned before⁽²²⁾, not revealing significant differences between genders or age groups. Likewise, Coertjens *et al.*⁽²⁶⁾ did not find significant differences between age groups or genders when analyzed individuals in vertical immersion in different depths. In this research, the bradycardia varied from 1 to 44 bpm, with the conclusion that both the immersion depth and the resting HR influence the aquatic bradycardia. Concerning the resting HR influence, the authors reported more remarkable bradycardia for higher resting HR values and less remarkable bradycardia for lower resting HR values.

Analyzing the HR behavior during water gymnastics exercises, out of water and in the immersion depths of umbilical scar and shoulder, Krueel *et al.*⁽⁹⁾ verified that the average decrease in the HR during exercises in the umbilical scar and shoulder depth, in relation to the same exercises performed out of water, was of 9 bpm and 25 bpm, respectively. In this study, the difference was significant ($p < 0,05$) only for the shoulder depth. Table 1 presents the values of the HR decrease reported by the mentioned authors in the different immersion depths of the body in water.

Water temperature

Some studies emphasize the influence of the water temperature in the HR behavior, in rest and exercise as well. Craig and Dvorak⁽³¹⁾ came to the conclusion that an increase in the HR of individuals immersed in the vertical position in temperatures of 36 and 37°C, and a decrease of the same in temperatures of 35°C or less is observed. Another important conclusion of this study was the discovery of the immersion temperature considered neutral in relation to the HR in rest, which was established between 35 and 35,5°C.

TABLE 1
HR decrease in different immersion depths of the body in water

Immersion depth	Decrease in the HR (bpm)				
	Risch <i>et al.</i> ⁽¹⁷⁾	Krueel ⁽²²⁾	Krueel <i>et al.</i> ⁽²⁵⁾	Coertjens <i>et al.</i> ⁽²⁶⁾	Krueel <i>et al.</i> ⁽⁹⁾
Neck	17**	16*	14*	13*	-
Shoulder with arms out of water	-	12*	13*	13*	-
Shoulder	-	17*	13*	13*	25*
Xiphoid appendix	-	16*	14*	13*	-
Umbilical scar	-	13*	11*	11*	9
Hip	-	9*	8*	8*	-
Knee	-	2	1	0	-

* statistically significant difference in relation to the condition outside water ($p < 0,05$).

** statistically significant difference in relation to the condition outside water (p not mentioned).

Through the analysis of the effects of different temperatures during the immersion in resting and in exercising in the cycle ergometer, Rennie *et al.*⁽³²⁾ verified that in the immersion in resting, the average HR decreased 25% in temperatures below 34°C. In the aquatic temperature of 36°C, the average HR did not show significant alteration. In moderate exercise situation, the HR reduced 20 to 25% in water temperatures below 34°C. In an intense exercise situation, the HR did not reveal significant alterations. Holmér and Bergh⁽¹³⁾, while researching the relation between HR and $\dot{V}O_2$ during swimming in different temperatures (18, 26 and 34°C), reported that the HR for a given $\dot{V}O_2$ is lower in lower temperatures and higher in higher temperatures. The average HR in 18°C was 8 bpm lower than in 26°C and 15 bpm lower than in 34°C. Similar results were verified by McArdle *et al.*⁽³³⁾, during exercise in cycle ergometer in aquatic temperatures of 18, 25 and 33°C. The exercises performed in water with temperature of 33°C did not present relations between $\dot{V}O_2$ and FC significantly different from those on land. However, the HR found in the 18°C temperature was, in average, 5 bpm lower ($p > 0,05$) than in 25°C and 15 bpm lower ($p < 0,05$) than in 33°C, for a submaximal value of preestablished $\dot{V}O_2$. The difference of 10 bpm between the 25 and 33°C was also statistically significant.

Corroborating the studies mentioned above, another study⁽¹⁸⁾ reported differences in the HR values obtained during exercise in cycle ergometer in aquatic temperatures of 20, 25, 30 and 35°C, revealing increase or decrease according to respective increase or decrease in the water temperature. The variation was more remarkable in 30 and 35°C, with values significantly different ($p < 0,05$) from those found in 20°C. Concerning the HR in 35°C, the average values found in the temperatures of 30, 25 and 20°C presented reduced values in 6, 17 and 19 bpm, respectively. More recently, Müller *et al.*⁽²⁷⁾ analyzed the HR behavior during vertical immersion in rest, finding bradycardia in relation to the same position out of water corresponding to 17 bpm in the aquatic temperature of 33°C, 24 bpm in the temperature of 30°C and 33 bpm in the temperature of 27°C. These authors verified difference statistically significant ($p < 0,05$) only between the temperatures of 27 and 33°C. It is important to stress that the pools destined to water activities are usually within such range of thermal variation, and considering that the effort intensity increases the existing difference between the verified HR in and out of the water, one may speculate that during practice of exercises in the vertical position, the differences statistically significant occur in a temperature variation range lower than the one reported in the study mentioned above. Table 2 presents the values of the HR decrease reported by the mentioned authors, in the different water temperatures used.

TABLE 2
HR decrease during immersion in different water temperatures

Studies	Rest/Exercise	HR decrease
Holmér and Bergh ⁽¹³⁾	Swimming	From 34 to 26°C = 7 bpm From 26 to 18°C = 8 bpm From 34 to 18°C = 15 bpm
McArdle <i>et al.</i> ⁽³³⁾	Cycle ergometer	From 33 to 25°C = 10 bpm* From 25 to 18°C = 5 bpm From 33 to 18°C = 15 bpm*
McMurray and Horvath ⁽¹⁸⁾	Cycle ergometer	From 35 to 30°C = 6 bpm From 30 to 25°C = 11 bpm From 25 to 20°C = 2 bpm From 35 to 20°C = 19 bpm* From 30 to 20°C = 13 bpm*
Muller <i>et al.</i> ⁽²⁷⁾	Rest	From 33 to 30°C = 7 bpm From 30 to 27°C = 9 bpm From 33 to 27°C = 16 bpm*

* statistically significant difference (p < 0,05).

Conclusions

Although the mechanism responsible for the HR decrease during immersion is not totally clear, it is believed that one of the main explanations for it relies on the increase on the venous return. Thereby, one of the effects derived from the hydrostatic pressure action over the individuals consists in the increase in the venous return, which leads to increases in the central blood volume and in the cardiac pre-load⁽³⁴⁾. Another aspect to be considered is bigger water thermo conductivity when compared to air, causing lower aquatic temperatures to the thermoneutral condition to contribute to the blood redistribution. Thus, it moves the blood from the outer regions to the central regions in order to try to avoid the excessive loss of body heat. This central hypervolemia generates increases in the systolic volume and cardiac debt, promoting reflex bradycardia derived from the immersion⁽³⁵⁾. Moreover, the decrease of the sympathetic nervous activity also potentializes the bradycardic responses in the immersion⁽³⁶⁾. Besides that, a recent study⁽³⁷⁾ points to the decrease of the hydrostatic weight as factor equally responsible for the modifications in the HR during the immersion, contributing to the bradycardia due to the lower muscular recruiting and consequent reduction in the blood amount.

Relating to the data presented in the literature, it was verified that the magnitude of the differences in the HR responses in the aquatic and on land environment may greatly vary. Among the most important aspects that may impact this fact, we can mention the water temperature, the hydrostatic weight reduction, the body positioning and its immersion depth, the resting HR and the relative effort intensity. Thereby, for the exercise prescription in the water environment, the sum of these aspects should be taken carefully analyzed, once discreet variations in one or more aspects may cause important differences in the conduction of the exercises. This is specially important when dealing with risky, badly-conditioned or special care needs populations. From the practical point of view, for the real HR_{max} obtaining in water environment the ideal would be the application of a maximal effort test, which should be conducted in temperature conditions, immersion depth and motor gestures specific to the kind of exercise used in the training program. If the effort test conduction is impossible, the HR_{max} in the water environment prediction would be possible through the subtraction of the aquatic bradycardia of the HR_{max} value on land environment. Thus, in order to determine the value of the decrease of the heart beats during immersion, each individual should be analyzed in depth, temperature and body position conditions similar to the posed exercise in the training program, in comparison to the same position on land. A proposal for this aim would be the use of the following formula:

$$HR_{\max} \text{ in water} = HR_{\max} \text{ on land} - \Delta FC$$

where ΔFC = bradycardia derived from the immersion (in the depth, temperature and body position used in the exercise).

SUBJECTIVE EFFORT PERCEPTION

Considering the many physiological indicators which can be used in the effort intensity control, some are difficult to be applied to the water environment due to the high cost and measurement difficulty, such as, the blood lactate production and the $\dot{V}O_2$ ^(2,21). Hence, the choice for more practical indicators which present reduced costs has been adopted, especially in group work. Concerning the water environment exercises prescription, one of the most applied on a daily basis indicators is the Borg's *Rate of perceived exertion* scale. Such scale⁽³⁸⁾ was built and validated in exercises performed out of the water environment⁽³⁹⁻⁴¹⁾ and its application in water exercises has been investigated more recently. The literature presents some studies on this aspect, and the existing knowledge may be applied in the quantification of the effort intensity in exercises of this nature.

Maglischo⁽⁴²⁾ considers the Borg's scale a good instrument to evaluate the relative intensity of the exercise in swimming. Likewise, the *Aquatic Exercise Association – AEA*⁽⁶⁾ recommends the use of the scale in the estimate of the exercises intensity in water gymnastics. Some studies investigated the relation of the SPE responses with other effort intensity indicators in swimming, as well as in exercises performed out of water. Among them, the study by Ueda and Kurokawa⁽⁴³⁾ correlated the SPE with the HR, the $\dot{V}O_2$ and the blood lactate during the tied swimming. After the application of swimming submaximal tests, the authors verified high correlations between the investigated measures, coming to the conclusion that the SPE may be considered an effective measure of the effort intensity in this kind of exercise. It is important to highlight that swimming is characterized to be a cyclic activity, and the correlations were verified in situations of submaximal test, involving stable loads. Therefore, the high correlations verified in the study mentioned above should not be transferred to acyclic activities, in which varied muscular groups are required in distinct intensities.

In another study, when verifying the correspondent HR to some specific indexes in the Borg's scale during swimming, compared to the cycle ergometry or arms ergometry, Green *et al.*⁽⁸⁾ verified that, for the 12 index of the mentioned scale, the HR values were significantly different (p < 0,05) comparing swimming with ergometry as well as swimming with arms ergometry. The HR was higher during swimming. The HR values significantly differed (p < 0,05) for the 16 index of the scale, only when comparing swimming with arms ergometry, although when comparing swimming with ergometry, a tendency for higher values in swimming was kept. It is important to mention that the fact of no HR decrease being reported in the water environment clashes with the conclusions of most of the existing studies in the literature, including the studies that compared swimming to other exercise examples^(11-12,24), independently of the effort intensity indicator used as control. Such fact may be connected to the training level of the sample or to a higher adaptation to the exercises performed on land, factors that could justify the presented results. The authors did not correct the HR values in relation to an existing reduction in the water environment either, which could help in the consistency of results found in this investigation.

Other studies analyzed the SPE behavior in walking/running in and out of water. Denadai *et al.*⁽⁵⁾ compared the HR and the SPE corresponding to the aerobic threshold and the anaerobic threshold during running on track and running in deep water, in submaximal exercise intensities. The results indicated that the indexes obtained for the SPE, in the aerobic threshold (running in deep

water = 11,5; running on track = 11,2), and in the anaerobic threshold as well (running in deep water = 14; running on track = 15,2), were not significantly different ($p \geq 0,05$) between the exercise in and out of water. Similar results were found by Nakanishi *et al.*⁽⁴⁾, when comparing the SPE indexes during maximal effort tests in running in deep water and in treadmill outside water. The authors observed that the SPE was not statistically different ($p = 0,84$) when reaching the maximal effort, between exercises performed in and out of water (running in deep water = 9,60; running on treadmill = 9,65 – CR10 scale).

However, Denadai *et al.*⁽⁵⁾ did not find correlations between the obtained SPE in aquatic and on land environment ($r = 0,15$ for the aerobic threshold and $r = 0,38$ for the anaerobic threshold). Thus, although the results of the mentioned study point that the kind of exercise does not influence in the relation between SPE and blood lactate response, the fact that no correlations between the SPE of the two studied sports were found, show that the transfer of evaluations of the running on track to running in deep water may lead to inconsistent results. Therefore, besides the differences involving the water and the on land environment, there seems to be a specificity in the use of the scale, where little differences in the motor gesture may influence the SPE.

In another study, Shono *et al.*⁽⁴⁴⁾, examining the SPE and other physiological variables during water walking in treadmill, in the xiphoid appendix depth, revealed strong linear relation between HR and SPE ($r = 0,99$; $p < 0,01$). The authors came to the conclusion that the SPE may be considered a good index for walking on treadmill prescription, in water as well as on land. In another study, Lazari and Meyer⁽⁴⁵⁾ compared the HR and SPE responses during walking with waist depth to the walking on treadmill at the same velocity, in submaximal intensity. The PSE values found in the water walking were significantly higher when compared to values of the walking on treadmill, being the difference 30,2% in the first minute of test. According to the authors, such difference was expected due to the use of the same velocity in the different environment, once the aquatic environment offers more resistance to the body dislocation. Consequently, the energetic demand and the muscular work are also higher, reflecting in the SPE. Concerning the correlation between the HR and SPE values, it was considered weak, differently from the results pointed by Shono *et al.*⁽⁴⁴⁾. Such differences between the studies point to the lack of consensus concerning the relation between HR and SPE in the water environment, showing the need of new investigations.

Hall *et al.*⁽³⁾ also conducted a comparative study between walking on treadmill in and out of water in the same velocity, including different water temperatures as influencing factors of the cardio-respiratory responses. Submaximal intensities for exercises performed in the chest depth and in the water temperatures of 28 and 36°C were used. The SPE was significantly higher ($p \leq 0,001$) during the exercises performed in water, confirming that the water walking on treadmill presents energetic cost higher than the walking on treadmill out of water in the same velocity. The results pointed PSE values corresponding to 11,4 and 14 during the water walking and 9,9 and 11 during walking out of water, for the 4,5 and 5,5 km/h velocities, respectively. In this study, the influence of the aquatic thermal variation in the SPE behavior was not reported. More recently, Fujishima and Shimizu⁽⁴⁶⁾ compared some physiological responses during walking on treadmill in and out of water to the same SPE index. No significant differences ($p \geq 0,05$) in the $\dot{V}O_2$ and the HR behavior and of the HR between walking out of water and in water in the temperatures of 31 and 35°C were found for the 13 index of the Borg's scale. A justification for such results may rely on the velocity of walking performance in the different environment, however, the authors did not report which were the used velocities. Another aspect to be considered is the higher tendency to the difference in the two variables mentioned between the out of water condition and aquatic temperature of 31°C. One

may speculate that such differences would be statistically significant if aquatic temperatures slightly lower were used. However, such fact should be confirmed through new experiments.

Concerning the training of water gymnastics sessions, some steps have already been taken in order to investigate the use of the Borg's scale in the quantification of the effort intensity. The study by Sá *et al.*⁽⁴⁷⁾ compared the SPE during water gymnastics exercises and ergometric test on treadmill out of water. The SPE was lower during the water gymnastics exercises for the same effort intensity, measured through the HR. In the intensities corresponding to 60 and 90% of the maximal effort, the found difference was statistically significant ($p < 0,05$). In the intensities of 70 and 80% though, only a tendency for lower values in the water environment was reported. The authors did not report a correlation based on the HR reduction in water environment in the percentage values of the HR_{max} used in the control of the exercise intensity, procedure that could alter the obtained results Hoeger *et al.*⁽⁴⁸⁾ conducted maximal tests in treadmill running and during the water gymnastics exercises performance. They came to the conclusion that the SPE when reaching the HR_{max} was lower during tests in water environment. The authors mentioned that the HR_{max} values as well as the SPE were significantly lower ($p < 0,05$) during the water gymnastics exercises.

In another study, Heithold and Glass⁽²⁸⁾ compared the SPE during the same aerobic exercises routine in and out of water. The routine duration was identical, being the velocity of performance of each exercise subjective. The found SPE indexes (between 12 and 14) were not statistically different ($p \geq 0,05$) between the two sports, although a tendency to lower values in the water environment has been observed, especially during exercises exclusively with the lower limbs. In the same study, the HR values were lower in water, showing that the HR did not affect the SPE. The authors came to the conclusion that the SPE is a reliable indicator of the effort intensity during water gymnastics practice.

Toner *et al.*⁽⁴⁹⁾ examined the interaction between thermal stress and SPE, through water exercises of low and high intensity performed in temperatures of 20 and 26°C. Despite the perceived effort being lower in the lower temperature during the high intensity exercise, the SPE did not significantly differ ($p > 0,05$) between the different temperatures and intensities. Therefore, the SPE is more related to cardiopulmonary variables than to the thermal sensation.

Conclusions

Although new studies are still necessary in order to clarify some disagreement about the SPE behavior in water exercises, the existing data show that it can be used as effort intensity indicator in water exercises. However, the adequate use of the Borg's scale needs further orientation and proper training, once the lack of familiarization with the instrument when performing motor gestures may alter the perceived effort results, and consequently the relation of this perception with the effort physiological indicators.

An interesting strategy to be tried out before Borg's scale application in the control of exercises sessions is to verify the reproducibility of its use among the individuals. Activities of different intensities are applied in different days, from a given motor gesture, being the individuals under the same conditions. Therefore, the individuals should attribute similar values from the scale to the same activities in the different days. In case these values are statistically different for the controlled situations, the individual may not be able to use the scale.

In addition, special attention should be dedicated to recent studies that relate the effort perception not only to the intensity used for the exercises, but also the factors such as the effort duration or even the expectation in relation to its intensity and duration⁽⁵⁰⁻⁵¹⁾. Thus, the responses of the effort perception represented by he

Borg's scale indexes seem to be partly influenced by psychological mechanisms that add to the physiological aspects.

FINAL CONSIDERATIONS

Concerning the HR behavior, one may come to the conclusion that a reduction in the heart beats, in rest or exercise condition, in the aquatic temperatures most used to the swimming practice, running and water gymnastics, that is, temperatures equal or lower to 32°C. Concerning the immersion depth, its increase intensifies the decreases that occur in the HR. Such decreases may be observed in exercises of submaximal and maximal characteristic as well during effort. Moreover, the magnitude of the difference in the HR between the water and on land environment increases from the rest condition to the submaximal and maximal exercise situations. Hence, one should be careful when adopting average values of difference between the HR values in the aquatic and on land environment, especially when considering distinct effort intensities.

It is assumed that the decrease in the HR derived from different immersion situations may lead the individuals to exercise in different intensities from the desired, usually higher. Such decrease may occur due to the prescription of water exercises intensity based on HR values obtained during exercises on land, with no correction. Finally, we should stress that the differences between the HR behavior in and out of the water may greatly vary among the individuals, making it difficult to use average values for this difference, especially when considering different effort intensities. A

good alternative to professionals of the field would be the HR correction according to the conditions to be applied, such as: body positioning, water temperature, immersion depth, rest HR, kind and intensity of exercise. A maximal test is suggested in order to identify the real HR_{max} in the water environment, respecting the motor gesture and aquatic specificities. Another interesting strategy aiming the HR_{max} prediction in the water environment is the determination of the bradycardia during rest immersion in the position, depth and temperature used for the exercise practice, subtracting the obtained value from the HR_{max} on the land environment.

Concerning the SPE use, although future studies should be conducted in order to better consubstantiate its adoption as effort intensity indicator in aquatic exercises of varied nature, the available research suggests that the Borg's scale seems to be a reliable and practical option, due to its possibility of correspondence. In other words, the intensity control of swimming, water running and water gymnastics may be done through the SPE, in routine exercises prescriptions. However, caution should be taken concerning the familiarity with the scale's use. The individuals should be trained for the distinct motor gestures used in the different physical activities. Moreover, it is important to verify the reproducibility of the use of the scale among the individuals, for each water activity example adopted in the prescription of an exercises program.

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

REFERENCES

1. American College of Sports Medicine. Guidelines for exercise testing and prescription. 6th ed. Philadelphia: Williams and Wilkins, 2000.
2. Svedenhag J, Seger J. Running on land and in water: comparative exercise physiology. *Med Sci Sports Exerc* 1992;10:1155-60.
3. Hall J, Macdonald IA, Maddison PJ, O'Hare JP. Cardiorespiratory responses to underwater treadmill walking in healthy females. *Eur J Physiol Occup Physiol* 1998;3:278-84.
4. Nakanishi Y, Kimura T, Yokoo Y. Maximal physiological responses to deep water running at thermoneutral temperature. *Appl Human Sci* 1999;2:31-5.
5. Denadai BS, Rosas R, Denadai MLDR. Limiar aeróbio e anaeróbio na corrida aquática: comparação com os valores obtidos na corrida em pista. *Rev Bras Ativ Física Saúde* 1997;1:23-8.
6. Aquatic Exercise Association. Manual do profissional de fitness aquático. Rio de Janeiro: Shape, 2001.
7. Shimizu T, Kosaka M, Fujishima K. Human thermoregulatory responses during prolonged walking in water at 25, 30 and 35°C. *Eur J Appl Physiol* 1998;78:473-8.
8. Green JM, Michael T, Solomon AH. The validity of ratings of perceived exertion for cross-modal regulation of swimming intensity. *J Sports Med Phys Fitness* 1999;3:207-12.
9. Krueel LFM, Moraes EZC, Ávila AOV, Sampedro RMF. Alterações fisiológicas e biomecânicas em indivíduos praticando exercícios de hidroginástica dentro e fora d'água. *Revista Kinesis* 2001;nº especial:104-29.
10. Magel JR, Faulkner JA. Maximum oxygen uptakes of college swimmers. *J Appl Physiol* 1967;5:929-38.
11. McArdle WD, Glaser RM, Magel JR. Metabolic and cardiorespiratory response during free swimming and treadmill walking. *J Appl Physiol* 1971;5:733-8.
12. Dixon RW, Faulkner JA. Cardiac outputs during maximum effort running and swimming. *J Appl Physiol* 1971;5:653-6.
13. Holmér L, Bergh V. Metabolic and thermal response to swimming in water at varying temperatures. *J Appl Physiol* 1974;37:702-5.
14. Holmér I, Lundin A, Eriksson BO. Maximum oxygen uptake during swimming and running by elite swimmers. *J Appl Physiol* 1974;6:711-4.
15. Holmér I, Stein EM, Saltin B, Ekblom B, Astrand P. Hemodynamic and respiratory responses compared in swimming and running. *J Appl Physiol* 1974;1:49-54.
16. Risch WD, Koubenec HJ, Beckmann U, Lange S, Gauer OH. The effect of graded immersion on heart volume, central venous pressure, pulmonary blood distribution, and heart rate in man. *Pflügers Arch* 1978;374:115-8.
17. Risch WD, Koubenec HJ, Gauer OH, Lange S. Time course of cardiac distension with rapid immersion in a thermo-neutral bath. *Pflügers Arch* 1978;374:119-20.
18. McMurray RG, Horvath SM. Thermoregulation in swimmers and runners. *J Appl Physiol* 1979;6:1086-92.
19. Vilas-Boas JP. Valores máximos da frequência cardíaca obtidos em natação e em tapete rolante. *Revista Portuguesa de Medicina Desportiva* 1989;7:109-25.
20. Ritchie SE, Hopkins WG. The intensity of exercise in deep-water running. *Int J Sports Med* 1991;1:27-9.
21. Town GP, Bradley SS. Maximal metabolic responses of deep and shallow water running in trained runners. *Med Sci Sports Exerc* 1991;2:238-41.
22. Krueel LFM. Peso hidrostático e frequência cardíaca em pessoas submetidas a diferentes profundidades de água [dissertação]. Santa Maria (RS): Universidade Federal de Santa Maria, 1994.
23. Frangolias DD, Rhodes EC. Maximal and ventilatory threshold responses to treadmill and water immersion running. *Med Sci Sports Exerc* 1995;7:1007-13.
24. Scolfaro LB, Marins JCB, Regazzi AJ. Estudo comparativo da frequência cardíaca máxima em três modalidades cíclicas. *Revista da APEF* 1998;1:44-54.
25. Krueel LFM, Tartaruga LAP, Dias AC, Silva RC, Picanço PSP, Rangel AB. Frequência cardíaca durante imersão no meio aquático. *Fitness & Performance Journal* 2000;6:46-51.
26. Coertjens M, Dias ABC, Silva RC, Rangel ACB, Tartaruga LAP, Krueel LFM. Determinação da bradycardia durante imersão vertical no meio líquido. In: XII Salão de Iniciação Científica, Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, 2000;341.
27. Müller FIG, Santos E, Tartaruga LP, Lima WC, Krueel LFM. Comportamento da frequência cardíaca em indivíduos imersos em diferentes temperaturas de água. *Revista Mineira de Educação Física* 2001;1:7-23.
28. Heithold K, Glass SC. Variations in heart rate and perception of effort during land and water aerobics in older women. *Journal of Exercise Physiology* 2002;4:22-8.
29. Paulev PE, Hansen HG. Cardiac responses to apnea and water immersion during exercise in man. *J Appl Physiol* 1972;2:193-8.
30. Sheldahl LM, Wann LS, Clifford PS, Tristani FE, Wolf LG, Kalbfleisch JH. Effect of central hypervolemia on cardiac performance during exercise. *J Appl Physiol* 1984;6:1662-7.
31. Craig AB, Dvorak M. Thermal regulation during water immersion. *J Appl Physiol* 1966;5:1577-85.
32. Rennie DW, Di Prampero P, Cerretelli P. Effects of water immersion on cardiac output, heart rate and stroke volume of man at rest and during exercise. *Med Sport* 1971;24:223-8.
33. McArdle WD, Magel JR, Lesmes GR, Pechar GS. Metabolic and cardiovascular adjustment to work in air and water at 18, 25 and 33°C. *J Appl Physiol* 1976;1: 85-90.

34. Sheldahl LM. Special ergometric techniques and weight reduction. *Med Sci Sports Exerc* 1985;1:25-30.
35. Arborelius M, Balldin UI, Lilja B, Lundgren CEG. Hemodynamic changes in man during immersion with the head above water. *Aerosp Med* 1972;6:592-8.
36. Connelly TP, Sheldahl LM, Tristani FE, Levandoski SG, Kalkhoff RK, Hoffman MD, et al. Effect of increased central blood volume with water immersion on plasma catecholamines during exercise. *J Appl Physiol* 1990;2:651-6.
37. Alberton CL, Tartaruga LAP, Turra NA, Petkowicz RO, Müller FIG, Krueel LFM. Efeitos do peso hidrostático na frequência cardíaca durante imersão no meio aquático. In: XIV Salão de Iniciação Científica, Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, 2002;518.
38. Borg G. Borg's perceived exertion and pain scales. Champaign: Human Kinetics, 1998.
39. Borg G. Ratings of perceived exertion and heart rates during short-term cycle exercise and their use in new cycling strength test. *Int J Sports Med* 1982;3:153-8.
40. Pandolf KB. Advances in the study and application of perceived exertion. *Exerc Sport Sci Rev* 1983;11:118-58.
41. Kraemer WJ, Noble BJ, Clark MJ, Calver BM. Physiologic responses to heavy-resistance exercise with very short rest periods. *Int J Sports Med* 1987;8:247-52.
42. Maglisho EW. Nadando ainda mais rápido. São Paulo: Manole, 1999.
43. Ueda T, Kurokawa T. Relationships between perceived exertion and physiological variables during swimming. *Int J Sports Med* 1995;6:385-9.
44. Shono T, Fujishima K, Hotta N, Ogaki T, Ueda T, Otoki K, et al. Physiological responses to water-walking in middle aged women. *Appl Human Sci* 2000;2: 119-23.
45. Lazzari JMA, Meyer F. Frequência cardíaca e percepção do esforço na caminhada aquática e na esteira em mulheres sedentárias e com diferentes percentuais de gordura. *Rev Bras Ativ Física Saúde* 1997;3:7-13.
46. Fujishima K, Shimizu T. Body temperature, oxygen uptake and heart rate during walking in water and on land at an exercise intensity based on RPE in elderly men. *Appl Human Sci* 2003;2:83-8.
47. Sá CA, Sá AJPR, Benetti GMF, Krueel LFM, Sampedro RMF. Estudo comparativo da sensação subjetiva de esforço de universitários em aulas de hidroginástica e em teste ergométrico em esteira rolante. In: III Jornada de Pesquisa da Universidade Federal de Santa Maria, Santa Maria, Rio Grande do Sul, 1993:548.
48. Hoeger WWK, Hopkins DR, Barber DJ, Gibson TA. A comparison of maximal exercise responses between treadmill running and water aerobics. *Med Sci Sports Exerc* 1998;5:S96.
49. Toner MM, Drolet LL, Pandolf KB. Perceptual and physiological responses during exercise in cool and cold water. *Percept Mot Skills* 1986;1:211-20.
50. Hampson DB, St Clair Gibson A, Lambert MI, Dugas JP, Lambert EV, Noakes TD. Deception and perceived exertion during high-intensity running bouts. *Percept Mot Skills* 2004;3:1027-38.
51. Baden DA, McLean TL, Tucker R, Noakes TD, St Clair Gibson A. Effect of anticipation during unknown or unexpected exercise duration on rating of perceived exertion, affect, and physiological function. *Br J Sports Med* 2005;10:742-6.