EFFECTS OF MUSICAL CADENCE IN THE ACUTE PHYSIOLOGIC ADAPTATIONS TO HEAD-OUT AQUATIC EXERCISES

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ABSTRACT

Barbosa, TM, Sousa, VF, Silva, AJ, Reis, VM, Marinho, DA, and Bragada, JA. Effects of musical cadence in the acute physiologic adaptations to head-out aquatic exercises. *J Strength Cond Res* 24(1): 244–250, 2010—The purpose of this study was to analyze the relationships between musical cadence and the physiologic adaptations to basic head-out aquatic exercises. Fifteen young and clinically healthy women performed, immersed to the breast, a cardiovascular aquatic exercise called the "rocking horse." The study design included an intermittent and progressive protocol starting at a 90 b·min^{-1} rhythm and increasing every 6 minutes, by 15 b·min^{-1}, up to 195 b·min^{-1} or exhaustion. The rating of perceived effort (RPE) at the maximal heart rate achieved during each bout (HRmax), the percentage of the maximal theoretical heart rate estimated (%HRmax), and the blood lactate concentration ([La-]) were evaluated. The musical cadence was also calculated at 4 mmol·L^{-1} of blood lactate (R4), the RPE at R4 (RPE@R4), the HR at R4 (HR@R4), and the %HRmax at R4 (%HRmax@R4). Strong relationships were verified between the musical cadence and the RPE ($R^2 = 0.85$; $p < 0.01$), the HRmax ($R^2 = 0.66$; $p < 0.01$), the %HRmax ($R^2 = 0.61$; $p < 0.01$), and the [La-] ($R^2 = 0.54$; $p < 0.01$). The R4 was 148.13 ± 17.53 b·min^{-1}, the RPE@R4 was 14.53 ± 2.53, the HR@R4 was 169.33 ± 12.06 b·min^{-1}, and the %HRmax@R4 was 85.53 ± 5.72%. The main conclusion is that increasing musical cadence created an increase in the physiologic response. Therefore, instructors must choose musical cadences according to the goals of the session they are conducting to achieve the desired intensity.

KEY WORDS basic aquatic exercises, music rhythm, rate of perceived effort, heart rate, blood lactate

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INTRODUCTION

Head-out aquatic exercises became a popular physical activity within the fitness context in the last few decades. Apparently, the number of head-out aquatic practitioners is increasing every day. For some instructors, one of the most important aspects when conducting such type of activities is to include music. According to the technical literature (e.g., 20) music has some basic functions: a) it is a way to motivate practitioners during a session; b) it allows for maintaining the synchronization of the subjects during specific routines and; c) it is used to achieve a given intensity of exertion.

Moreover, some instructors plan their sessions according to the music's characteristics. They choose a given music for a specific part of the session, according to its cadence or rhythm, to achieve a predetermined intensity of exertion. For this to be true, it is assumed that aquatic instructors are familiarized with the concept of "water tempo" and follow the music metric throughout the sessions. The "water tempo" is characterized by the countdown of only 1 beat in every 2 musical beats in the music tempo (20). The countdown of that musical beat is synchronized with the execution of a given segmental action of the full basic exercise being performed. This way, the movement frequency of the practitioners is related to the music's cadence. Increasing the music tempo will increase the movement frequency; decreasing the music tempo will therefore decrease the movement frequency.

For head-out aquatic exercises on regular bases, music cadences between 130 and 150 beats per minute (20) are suggested. However, this suggestion is based on the common sense or the author's experience and background. It appears that the number of investigations describing the relationship between musical cadence and the acute physiologic adaptations to head-out aquatic exercises is small.

Although it appears that data about the relationship between musical cadence and acute physiologic response in head-out aquatic exercises are scarce, some similarities can be seen in other types of activities. A description of an increase of

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the rate of perceived effort (RPE) with increasing cadences (26) during progressive protocols (4,24,31,33) has been made. Some literature describes an increase of heart rate during incremental protocols while subjects are performing different tasks (9,10,18,19,24,26,27), but other reports show no significant differences (14). In at least in a couple of articles, the intensity was controlled with musical cadence (14,18). It is mostly agreed that an increase of blood lactate concentration ([La-]) happens with increasing intensity when exercising on ergometers (26,27), in competitive swimming (8,24), and in aquatic running (29).

Most aquatic instructors adopt the physical fitness guidelines for land-based activities (e.g., 1) to achieve the desired intensity of exertion. However, the aquatic environment is characterized by different mechanical aspects in comparison with the terrestrial environment. It is well documented in the literature that such differences promote specific physiologic adaptations at rest and exercising in total or partial immersion. For example, for the same intensity of exertion, the RPE is higher in aquatic activities than in terrestrial activities (3,5,11,28). Cardiac effort is higher on land than in water (3,5,12,17,23). Blood lactate decreases with an increasing volume of body immersion (5). Thus, it is questionable whether those guidelines are suitable for aquatic exercise programs.

Therefore, the purpose of this study was to analyze the relationships between musical cadence and physiologic adaptations to basic head-out aquatic exercises when immersed to the breast. It was hypothesized that increasing musical cadence will lead to an increase of the acute physiologic response because increasing rhythm is associated with an increasing movement frequency.

Methods

Experimental Approach to the Problem

The study included an experimental design comprising the evaluation of the interplay between musical cadence (as this is related to movement frequency) and the acute physiologic response. A group of 15 women completed the same basic aquatic exercise throughout an intermittent and progressive musical cadence (and, therefore, movement frequency) execution protocol to evaluate the response of several physiologic parameters. The study also included the analysis of the appropriate physiologic target zone for head-out aquatic exercises. It was hypothesized that increasing musical cadence will lead to an increase of the acute physiologic response.

Subjects

Fifteen young women (nonpregnant, clinically healthy, and physically active, holding a degree in Sports Sciences and with at least 1 year of experience conducting head-out aquatic classes) volunteered to participate in this study. They reported no previous history of orthopedic or muscle-skeletal injuries in the previous 6 months. Table 1 presents the characteristics of the subjects. All procedures were in accordance with the Declaration of Helsinki with respect to human research. The Institutional Review Board of the Polytechnic Institute of Bragança approved the study design. Women were informed of the experimental risks and signed an informed consent document before the investigation.

Procedures

Each subject performed the aquatic exercise "rocking horse." When included in a training program, the purpose of the exercise is to improve cardiovascular fitness (3). The "rocking horse" consists of standing on the left foot and lifting the knee from the right leg toward the chest. Simultaneously, the arms perform a horizontal adduction. Then, the subject hops forward to the right leg, kicking the left heel up and behind. At the same time, the arms perform a horizontal abduction. The "rocking horse" was always performed with the water surface at the level of the xiphoide process. Figure 1 illustrates the basic aquatic exercise studied.

The aquatic exercise was performed using the "water tempo" according to the standard recommendations from the technical literature (e.g., 20). During the first musical beat, the arms start the horizontal adduction and the hop (stance of the right leg). During the second musical beat, the subject finishes these 2 movements. During the third musical beat, the arms start the horizontal abduction and the hop (stance of the left leg). During the fourth musical beat, the subject finishes these movements. Therefore, the movement frequency is related to

Table 1. Characteristics of women studied.

Variable	Mean	*SD*	Maximum	Minimum
Age (yr)	21.8	2.91	28	18
Height (m)	1.64	0.05	1.7	1.54
Body mass (kg)	58.49	8.14	72.3	47.2
BMI ($kg\cdot m^{-2}$)	21.69	2.64	26.3	17.3
Aquatic fitness classes ($min\cdot wk^{-1}$)	644	209	960	300

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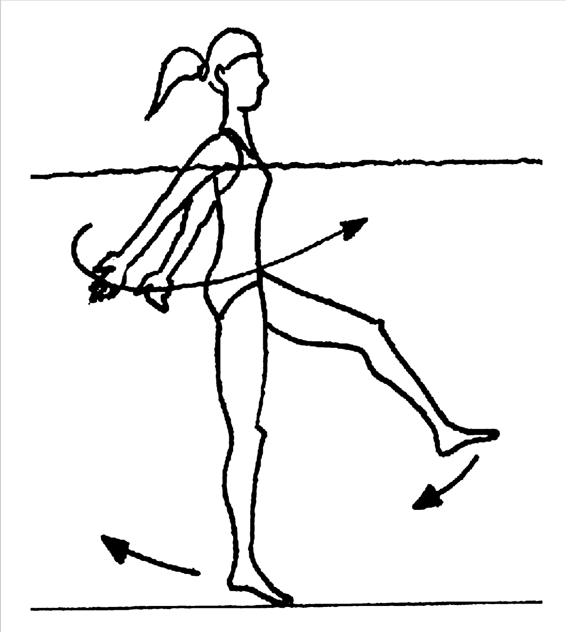

Figure 1. Basic aquatic exercise studied called "rocking horse."

the musical tempo. Increases or decreases of this tempo will lead to increases or decreases of the movement frequency, respectively.

The protocol is characterized as being an intermittent and progressive test. Protocol includes the performance of the "rocking horse" starting at a musical cadence of 90 beats per minute (b·min^{-1}), equivalent to 1.5 Hz, and increasing every 6 minutes by 15 b·min^{-1} (0.25 Hz), up to 195 b·min^{-1} (3.25 Hz), or sooner if exhaustion is evident. Musical cadence was controlled electronically by a metronome (Korg, MA-30, Tokyo, Japan) connected to a sound system. Therefore, the influence of music melody was controlled because the metronome only plays the musical rhythm. Exhaustion was defined as an incapacity to perform the aquatic exercise within the "water tempo" for a period of time above 30 seconds. The first bout was considered as being a warm-up rhythm. The last bout was assumed as being the maximal intensity supported by the subject within the "water tempo." Between bouts, subjects had a passive rest period of 30 seconds, or shorter, to collect blood samples. All women were familiarized with the concept of "water tempo" and followed the music metric throughout the test. However, when necessary, evaluators gave verbal encouragement or cues to subjects to maintain the appropriate synchronization

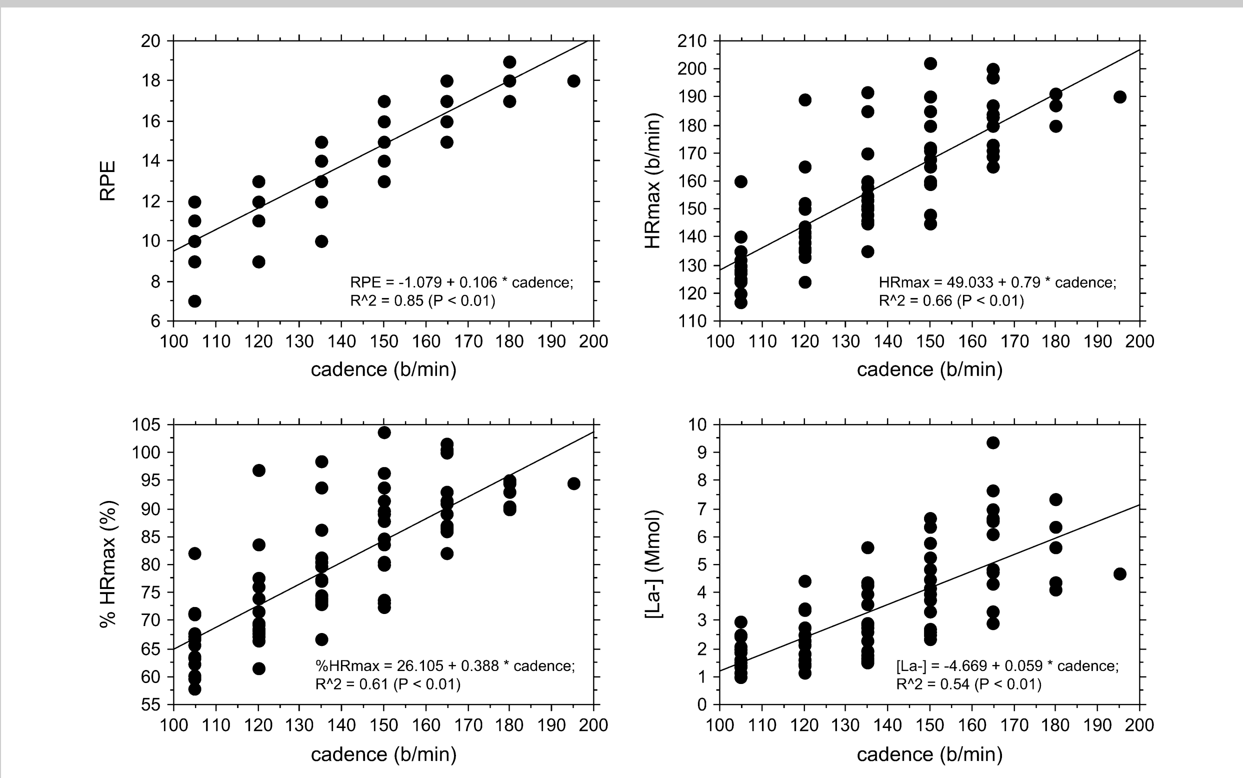

Figure 2. Relationships between music cadence and rate of perceived effort (RPE), maximal heart rate achieved during each bout (HRmax), percentage of maximal theoretical heart rate estimated (%HRmax), and blood lactate concentration ([La-]).

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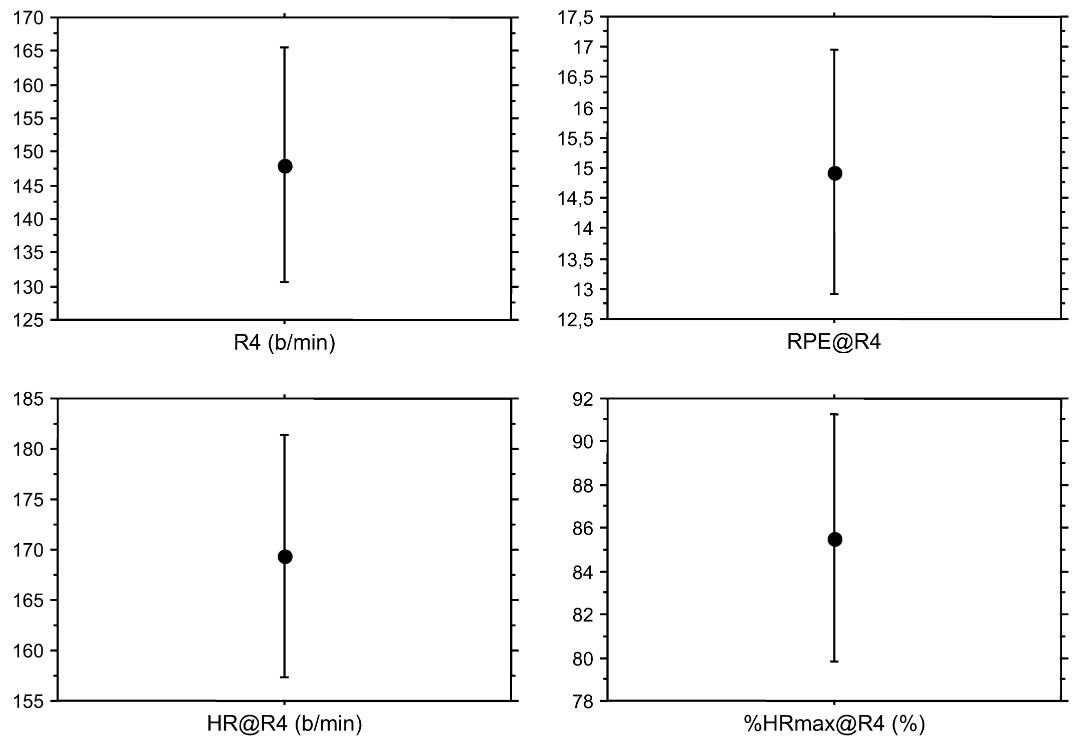

Figure 3. Descriptive statistics (mean ± 1 *SD*) of music cadence at 4 mmol·L^{-1} of blood lactate (R4), rate of perceived effort at R4 (RPE@R4), heart rate achieved during exercitation at R4 (HR@R4), and percentage of maximal theoretical heart rate estimated at R4 (%HRmax@R4).

between musical cadence and movement frequency. The maximal number of bouts performed by each woman ranged between 4 and 7. An overall number of 78 bouts of 6 minutes was analyzed. The water temperature was 29°C, the air temperature was 31°C, and the relative humidity was 60%.

Data Collection

Rating of perceived effort was measured immediately after each 6-minute trial, using the most recent Borg's 6–20 scale (6,7). A sheet with the written scale was shown to each subject so that a value in this scale could be chosen. The RPE ranged from 6 (no exertion at all) to 20 (maximal exertion).

Heart rate was evaluated every 5 seconds during all bouts (Vantage NV, Polar, Kempele, Finland). The maximal heart rate achieved during each bout (HRmax) was measured. The percentage of the maximal theoretical heart rate was estimated (%HRmax) according to the procedures suggested by Wilmore and Costill (32):

$$\%\text{HRmax} = \frac{\text{HRmax}}{220 - \text{age}} \times 100 \qquad (1)$$

Blood samples (25 μL) from the ear lobe were collected to analyze [La-] (YSI 1500 L, Yellow Springs, OH, USA) before the protocol and after each 6-minute bout. The musical rhythm achieved at a 4 mmol·L^{-1} [La-] (R4) was calculated by interpolation. It was also computed using the same mathematical model, with the RPE at R4 (RPE@R4), the HR at R4 (HR@R4), and the %HRmax at R4 (%HRmax@R4).

Statistical Analyses

The normality of the distributions was evaluated with the Kolmogorov-Smirnov test. Descriptive statistics (mean ± 1 *SD*) from all dependent variables were calculated. The quartile values of some variables studied were also calculated (RPE@R4, HR@R4, %HRmax@R4, and R4). For each relationship, the mathematical model with the best adjustment and lowest standard error of the estimation was adopted. All relationships presented a better adjustment when linear regressions were computed. Therefore, linear regression equations were used to describe the relationships between musical cadence and physiologic variables (RPE, HRmax, %HRmax, and [La-]), as well as its coefficients of determination. The musical cadence achieved at a 4 mmol·L^{-1} of [La-] (R4) was assessed by an interpolation approach of the individual [La-] versus the cadence curve modeling method (least square method), and it was assumed to be the intersection point, at the maximal fit situation, when [La-] was equal to 4 mmol·L^{-1}. The level of statistical significance was set at $p \leq 0.05$.

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Table 2. Quartiles for music cadence at 4 mmol·L^{-1}of blood lactate (R4), rate of perceived effort at R4 (RPE@R4), heart rate achieved during exercitation at R4 (HR@R4), and percentage of maximal theoretical heart rate estimated at R4 (%HRmax@R4).

	R4 (b·min^{-1})	RPE@R4	HR@R4 (b·min^{-1})	%HRmax@R4 (%)
25	136.03	13.25	162.25	82.00
50	150.10	15.00	172.00	87.00
75	158.28	16.75	178.50	89.75

Results

Figure 2 presents the relationships between the musical cadence and the physiologic variables while subjects were performing the aquatic exercise "rocking horse." There were significant, positive, and strong relationships between the cadence and the RPE ($R^2 = 0.85$; $p < 0.01$), the HRmax ($R^2 = 0.66$; $p < 0.01$), the %HRmax ($R^2 = 0.61$; $p < 0.01$), and the [La-] ($R^2 = 0.54$; $p < 0.01$). Therefore, increases in the music cadence created significant increases in the acute physiologic adaptation of the subjects in all studied variables.

Figure 3 presents the central tendency (mean) and dispersion (1 *SD*) statistics of R4, RPE@R4, HR@R4, and %HRmax@R4. The R4 was 148.13 ± 17.53 b·min^{-1}, the RPE@R4 was 14.53 ± 2.53, the HR@R4 was 169.33 ± 12.06 b·min^{-1}, and the %HRmax@R4 was 85.53 ± 5.72%.

Table 2 presents the quartiles for R4, RPE@R4, HR@R4, and %HRmax@R4. Between quartile 25 and 75, R4 ranged from 136.03 b·min^{-1} to 158.28 b·min^{-1}, RPE@R4 from 13.25 to 16.75, HR@R4 from 162.25 b·min^{-1} to 178.50 b·min^{-1}, and %HRmax@R4 from 82.00% to 89.75%.

Discussion

The purpose of this study was to analyze the relationship between musical cadence and the physiologic adaptations to basic head-out aquatic exercises. The main reported conclusion is that increasing musical cadence created an increase in the physiologic response. Moreover, some guidelines that usually are taken into account in fitness activities can be slightly adjusted according to the aquatic environment and the subjects' specific characteristics.

There were strong relationships between the musical cadence and the RPE ($R^2 = 0.85$; $p < 0.01$), the HRmax ($R^2 = 0.66$; $p < 0.01$), the %HRmax ($R^2 = 0.61$; $p < 0.01$), and the [La-] ($R^2 = 0.54$; $p < 0.01$). Increasing the cadence corresponded to increases in all physiologic variables evaluated. For land-based routines, positive relationships between cadence and acute response during incremental cadence protocols have been described (26,27). In competitive swimming, increasing velocity promoted significant increases of several physiologic variables during progressive protocols (2,4,8,24,31). In several kinds of head-out aquatic tasks, increasing physiologic responses were observed during incremental protocols (10,18,29,33).

An important aspect to be mentioned is the fact that only 1 single head-out aquatic exercise was performed throughout the test. From an ecological point of view, this is a limitation of the study. During a real head-out aquatic session, the exercises performed are changed from time to time. Moreover, the continuous execution of the same exercise, stimulating the same muscle groups, can have an important role in early fatigue when compared with a real session. On the other hand, the adoption of a single exercise can guarantee that physiologic changes verified are only related to musical cadence. Continuous change in the type of exercise performed subjects the subjects to new mechanical external forces, such as inertia, propulsive, or drag forces, that might also promote changes in the physiologic profile obtained.

There is an obvious synchronization between musical cadence and the head-out aquatic exercises. The head-out aquatic exercises are performed using the "water tempo" (20). The "water tempo" is characterized by the countdown of only 1 musical beat in every 2 beats of the music cadence, which corresponds to the specific movement of the exercise. Therefore, musical cadence can be a useful way to achieve the desired intensity of exertion. In increasing the music cadence, the segmental frequency will increase and, therefore, the segmental velocity and the drag force (D) because it depends from a constant value (k) and velocity (v) as $D = k \cdot v^2$. As a consequence, an increasing physiologic acute response is verified.

The concept of training heart rate is based on a hypothetical linear relationship between heart rate and oxygen uptake with increasing rates of work (32). However, the exercise intensity necessary to achieve a given percentage of oxygen uptake results in a much higher heart rate than the expected %HRmax. Therefore, it appears more appropriate to establish exercise intensity by setting a heart rate range, rather than a single value (32). Almost every approach includes the HRmax in such prediction. Several mathematical models are described in the literature to estimate the HRmax (e.g., 13,25,30). Nevertheless, all published univariate equations and even multivariate equations present a large error in estimating the real HRmax (25). The conventional HRmax formula "220 - age" reported by several authors, such as Wilmore and Costill (32), presents some benefits: a) it is very easy to implement (25); b) it was previously adopted by several other research groups, allowing the comparison of our data with the literature (e.g., 3,5); c) it was described as having the same limitations of other age-predicted HRmax equations (22,25).

During light to moderate activities, [La-] remains only slightly above the resting level. With more intense effort, [La-] accumulates more rapidly. There is still much controversy about the issue of whether the lactate threshold is related to

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anaerobic activities. However, head-out aquatic programs are moderate-vigorous activities. Therefore, it is presumable that [La-] must be under or very close to its onset accumulation (OBLA). It is assumed that, in these kinds of activities, an [La-] steady-state must exist. Some researchers set 4 mmoL of lactate per liter as a reference value (e.g., 16,21). As such, it is important to assess the physiologic responses during the corresponding OBLA cadence in aquatic exercises. Because these values are quite individual, the determination of a range of intensity for a given population must be developed. With these data, a more accurate prescription of exercise intensity can be proposed in head-out aquatic exercises.

The R4 ranged from 136.03 $b \cdot min^{-1}$ (quartile 25) to 158.28 $b \cdot min^{-1}$ (quartile 75). For head-out aquatic exercises, music cadences between 130 and 150 bpm are suggested (20). Therefore, R4 was very close to the cadence range suggested by the technical literature. However, the present investigation evaluated clinically healthy and physically active females. Therefore, we can speculate that such a cadence range might be inappropriate for other types of practitioners.

Between the quartiles 25 and 75, RPE@R4 ranged from 13.25 to 16.75, HR@R4 from 162.25 $b \cdot min^{-1}$ to 178.50 $b \cdot min^{-1}$, and %HRmax@R4 from 82.00–89.75%. The American College of Sports Medicine and the American Heart Association recommend that all healthy adults aged 18 to 65 years of age should be engaged in moderate-intensity aerobic activity to promote and maintain health (15). A combination of moderate and vigorous intensity activity can be also performed to meet such recommendations (15). The American College of Sports Medicine (1) guidelines suggest that, for cardiovascular fitness improvements, an RPE between 14 and 16 and a %HRmax between 60% and 89% should be met. The range of the RPE@R4 computed in this investigation was slightly higher, and the %HRmax@R4 was within the upper and lower limits suggested by that organization. Therefore, it appears that these guidelines are appropriate but can be slightly adjusted for aquatic activities to promote a more accurate exercise prescription for healthy and physically active subjects. In addition, new investigations should be developed to determinate with more accuracy the range of R4, RPE@R4, HR@R4, and %HRmax@R4 for other specific groups of practitioners.

Practical Applications

To conclude, increasing musical cadence creates an increase in the acute physiologic response. In this sense, head-out aquatic exercise instructors must choose appropriate musical cadences according to the main goals of the session they are conducting and the intensity they would like to achieve. Moreover, some guidelines that instructors use on regular bases for the session's intensity control are appropriated but can be slightly adjusted when healthy and physically active subjects are involved. For healthy and physically active subjects, they should choose music cadences between 136 and 158 $b \cdot min^{-1}$, RPE between 13 and 17, heart rate between 162 and 179 $b \cdot min^{-1}$, and a percentage of the HRmax between 82% and 90%.

Acknowledgments

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