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Review article

Physiological assessment of head-out aquatic exercises in healthy subjects: A qualitative review

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Abstract
In the last decades head-out aquatic exercises became one of the most important physical activities within the health system. Massive research has been produced throughout these decades in order to better understand the role of head-out aquatic exercises in populations' health. Such studies aimed to obtain comprehensive knowledge about the acute and chronic response of subjects performing head-out aquatic exercises. For that, it is assumed that chronic adaptations represent the accumulation of acute responses during each aquatic session. The purpose of this study was to describe the "state of the art" about physiological assessment of head-out aquatic exercises based on acute and chronic adaptations in healthy subjects based on a qualitative review. The main findings about acute response of head-out aquatic exercise according to water temperature, water depth, type of exercise, additional equipment used, body segments exercising and music cadence will be described. In what concerns chronic adaptations, the main results related to cardiovascular and metabolic adaptations, muscular strength, flexibility and body composition improvements will be reported.

Key words: Aquatic exercises, immersion, physical fitness, acute adaptation, chronic adaptation.

Introduction

In the last couple of decades head-out aquatic exercises became one of the most important physical activities within the health primarily prevention system (i.e., fitness context) and in the health thirdly prevention system (i.e., therapy and rehabilitation context). Massive research has been produced throughout these decades in order to better understand the role of head-out aquatic exercises in populations' health. Moreover, head-out aquatic exercises has become also a major component in therapy programs for a number of diseases or physical conditions (e.g., Koury et al., 1996), even for enhances sport performance of elite athletes (e.g., Robinson et al., 2004).

Such studies aimed to obtain comprehensive knowledge about the acute, as well as, the chronic response of subjects performing head-out aquatic exercises. Indeed, most of the relevant works published, at least in the first times, were dedicated to describe the improvement of physical fitness after programs of head-out aquatic exercises. However, chronic adaptations represent the accumulation of acute responses during each aquatic session. To promote these cumulative effects of acute responses over time, the use of appropriate means and methods of work during the sessions (i.e., mode or type of exercise, frequency of participation, duration of each exercise bout, and intensity of the exercise bout) are warranted. Some research groups are quite interested about the issue of the appropriate training means and methods (e.g. Colado et al., 2009a; Kelly et al., 2000). In this sense, presently, both the evaluation of acute responses and chronic adaptations has as much importance as the chronic ones. Although historically, aquatic research has been typically focused in competitive swimming, it seems that this tendency is shifting toward an interest in the effects of vertical exercises during aquatic therapy and exercise programs, as previously suggested elsewhere (e.g., Koury, 1996).

In order to describe and quantify such adaptations, the physiological assessment of several parameters is widely described in the literature. Acute adaptations are evaluated, on regular basis, using the rate of perceived exertion (RPE), heart rate (HR), blood pressure (BP), blood lactate ([La^-]), oxygen uptake (VO_2), energy expenditure (EE) and metabolic equivalent (MET) (e.g., Barbosa et al., 2007; Di Masi et al., 2007; Wilmore and Costill, 1994). On the other hand, aerobic capacity, body composition, flexibility, muscular strength and endurance are monitored to assess chronic adaptations (e.g., Wilmore and Costill, 1994).

The purpose of this qualitative review was to describe the "state of the art" about physiological assessment of head-out aquatic exercises based on acute and chronic adaptations of healthy subjects. With that aim, searches were done in several data bases (e.g., Index Medicus, MEDLINE, Science Citation Index, Scopus, SPORTDiscus) and in our departmental files, including conference proceedings (e.g., Biomechanics and Medicine in Swimming, Annual Congress of the European College of Sport Sciences, Symposium of the International Society of Biomechanics in Sports, Medicine and Science in Aquatic Sports, International Scientific Conference of Aquatic Space Activities) and official documents, statements and guidelines from several organizations (e.g., American College of Sports Medicine, Aquatic Exercise Association). The literature does not present a balance number of research papers for acute and chronic adaptations. So, the relative frequency of citations and references throughout the manuscript is somewhat proportional to the amounts presented in the literature.

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Acute adaptations

Effect of water temperature

Body temperature is the balance between heat production and heat loss. Changes in body temperature of subjects immersed in aquatic environments, as well as, those of aquatic instructors in the deck of indoor swimming-pools may occur.

When immersed, body heat is lost mainly by conduction and convection. Water has a thermal conductivity about 26 times greater than air and body loses heat four times faster, for the same temperature (Wilmore and Costill, 1994). The rate of heat loss is further accelerated, due to convection, if water is moving around the subject as it happens during aquatic exercises (Data et al., 2006). Heat lost to the water has a linear relationship with water temperature and the immersion duration (Craig, 1983). Cold water (i.e., 14 ºC) promotes a decrease of rectal temperature and an increase in *HR* of 5%, systolic *BP* of 7 % and diastolic *BP* of 8 %, when compared to controls at air temperature (Srámek et al. 2000). It has been reported that immersion at neutral temperature (i.e., 32 ºC) did not change rectal temperature and metabolic rate, but promoted a bradycardia of 15 %, systolic *BP* decrease of 11 % and diastolic *BP* decrease of 12 %. Physiological adaptations are mediated by humoral control mechanisms, while responses induced by cold water are mainly due to an increased activity of the sympathetic nervous system (Srámek et al. 2000). Immersed subjects at 40 ºC present an increased *HR* and an increased index of the cardiac parasympathetic system in comparison to a 25 ºC immersion and a control condition on land (Nahimura et al., 2008). For the 40 ºC environment, during and post exercise *HR* increased, although the index of the cardiac parasympathetic system decreased during exercise (Nahimura et al., 2008). While exercising, the slowed enzymatic processes and slowed nerve conduction that impair the rate of force development reduce local muscular endurance during dynamic contractions and impair manual dexterity until 35 ºC (Drinkwater, 2008). Both the voluntary and evoked force development capacities of muscle are unimpaired until cooling is quite severe, such as, less than 27 ºC (Drinkwater, 2008). At least during submaximal swimming significant changes in metabolic responses were reported according to water temperature. Comparing one hour breaststroke swim at 21 ºC, 27 ºC and 33 ºC, *HR* increased throughout the bouts; VO_2 was lowest at the warmest temperature; respiratory exchange ratio (*RER)* declined with time and was inversely related with temperature; [La^-] was higher in the coldest temperature and; no significant effect of temperature in insulin and glucose was reported (Houston et al., 1978). Once again, during light swimming VO_2 was about 0.7 $L \cdot min^{-1}$ in a 28-35 ºC water temperature, but increased in a 24-26 ºC temperature (Craig, 1983).

So, body temperature can be controlled by: (i) an increase of exercise work rate in order to promote heat production (Craig, 1983); (ii) an increase of body fat to decrease the heat lost and; (iii) the wear of wetsuits which reduced the decrease of the core temperature (e.g., Kang et al., 1983; Wakabayashi et al., 2006).

Even so, most of head-out aquatic exercises are performed in water temperatures of approximately 27 ºC. This temperature selection seems to be based in the knowledge gathered in competitive swimming and not in head-out aquatic exercises. Moreover, the water temperature selected for competitive swimming is not based on experimental results but in empirical decisions. Nonetheless, water temperatures around 27 ºC seem to be the most suitable for appropriate acute physiological responses during head-out aquatic exercises as well. However, different head-out aquatic exercise programs will induce different exercise intensities and, therefore, a need of appropriate water temperatures to stay comfortable and/or preventing thermo-regulation stress. For example, if the aim of the activity is the relaxation, the improvement of range of motion and/or flexibility workout, the water temperature should be increased to a thermo neutral value. Appropriate water temperature should also be considered according to the population special characteristics. Subjects should stay comfortable throughout the onset of exercise bout. For example, older subjects will need a higher water temperature in comparison to younger adults. In this sense, Aquatic Exercise Association (2008) state in their standards and guidelines water temperature ranging from 28-30 ºC for aquatic fitness programs.

When conducting head-out aquatic exercise sessions, most instructors are also exercising. Evaporation is the main way for heat dissipation during exercise (Wilmore and Costill, 1994). An indoor swimming pool is characterized by a high level of humidity, which affects the heat loss by evaporation. The already high quantity of water molecules in the environment affects the evaporation of sweat from the body. Consequently, body is under a thermoregulation stress. Moreover, indoor swimming pools also present a high temperature. When exercising, the aquatic instructor will present changes in the cardiovascular function, such as a reduction of stroke volume, since there is a reduction of returning blood volume to the heart. Hot environments sets up a competition between active muscles and skin for blood supply. The former to deliver oxygen, nutrients and remove metabolites; the latter to facilitate heat loss (Wilmore and Costill, 1994). Both phenomena, hot and humid environment, can explain the increase of acute response to exercise for aquatic instructors in what concerns to RPE, HR and VO_2 (Barbosa et al., 2007). Therefore, new highlights about physiological adaptations of aquatic instructors should be a priority in head-out aquatic exercises research in a near future.

Effect of water depth

There are several investigations about the influence of body immersion level during head-out aquatic exercises. Rate of perceived exertion is higher when exercising immersed by the hip, comparatively with immersion up to the breast (Barbosa et al., 2007). This perceived differences can be related to: (i) the higher intensity of drag forces acting in the lower limbs, as compared to those acting in the trunk and upper limbs, when partially immersed; (ii) an increasing ground reaction force, due to a reduction of the buoyancy (Nakazawa et al., 1994) and; (iii) changes in neuromuscular patterns of active muscles at different levels of body immersion (Fujisawa et al.

1998; Poyhonen et al., 1999; 2001).

It has been observed that the *HR* decreased significantly with the increase of body immersion (Barbosa et al., 2007; Benelli et al., 2004; Town and Bradley, 1991). The lower *HR* with higher immersions during aquatic activities is a well-documented phenomenon and is believed to be related with: (i) the diving bradycardia with, or without, the face immersion (Andersson et al., 2003; Holmér, 1974; Shono et al., 2001); (ii) a higher volume of blood distribution in the trunk (Sheldahl et al., 1987); (iii) the improved conditions for heart filling during diastole, due to hydrostatic pressure and buoyancy, thereby promoting a higher stroke volume (Holmér, 1974) and; (iv) in some exercises, a horizontal body position, which improves the conditions for heart filling during diastole (Benelli et al., 2004; Bjertnaes et al., 1984; Holmér, 1974). Benelli et al. (2004) reported a decrease of the median value from land-based to shallow-water exercises of 7.5 $b{\cdot}min^{-1}$ and to deep-water exercises of 48 $b{\cdot}min^{-1}$. Barbosa et al. (2007) described a decrease of the mean heart rate from land-based to the breast immersion exercise of 21.2 and 9.3 $b{\cdot}min^{-1}$ for women and men, respectively. Yun et al. (2004) compared *HR* during rest on land, rest in water and exercising in water, in several groups. They reported a decrease from rest on land to rest immersed of 1.9 $b{\cdot}min^{-1}$ for young women and 4.7 $b{\cdot}min^{-1}$ for middle age women and 1.1 $b{\cdot}min^{-1}$ for professional women divers. So, it is questionable if the deduction of 11-17 $b{\cdot}min^{-1}$ when monitoring HR suggested by the Aquatic Exercise Association can be adjusted in order to increase prescription's accuracy.

Oxygen uptake and EE are lower at breast immersion when compared with hip immersion (Barbosa et al., 2007). The reduction of VO_2 and EE with increasing body immersion can be explained by: (i) the decrease of cardiovascular workout and the increase of hydrostatic pressure; (ii) the buoyancy force, as when totally immersed it reduces the neuromuscular activity of antigravitical/postural muscles (Butts et al., 1991) and; (iii) the extra difficulty to transfer body heat to the environment when exercising immersed to the hip, with subsequent increase in HR (Fink et al., 1975). On the other hand, VO_2 was reported as being higher during shallow water, compared with deep water running (Town and Bradley, 1991).

When comparing shallow-water versus deep-water exercises, the physiological demand seems to be lower for the second conditions. Indeed, HR and [La^-] (Benelli et al., 2004); VO_2max and HR (Dowzer et al., 1999; Town and Bradley, 1991) are higher during shallow-water exercitation. However, RER and [La^-] present non-significant differences between both depth conditions (Town and Bradley, 1991). While shallow-water practice is presumably an efficient method of maintaining cardiovascular fitness, some questions must be raised about the efficiency of deep-water exercises (Frangolias and Rhodes, 1996; Dowzer et al., 1999; Chu and Rhodes, 2001). Some explanations can be addressed for these results (Reilly et al., 2003): (i) the short duration of the water exercise protocols; (ii) the reliance on the subjects to control exercise intensity up to a perceived maximum; (iii) the changes in the kinematical and neuromuscular characteristics of the technique to be performed.

To understand differences in the physiological response according to the water depth, data comparing head-out aquatic with land-based exercises may also be considered. Most of the researches devoted their analysis to tasks performed in a gym (e.g., Benelli et al., 2004; Green et al., 1990; Shono et al., 2001). RPE is described as being higher during aquatic exercises than on land (Butts et al., 1991; Demaere and Ruby, 1997; Hall et al., 1998; Yu et al., 1994). On the other hand, HR (Barbosa et al., 2007; Benelli et al., 2004; Eckerson and Anderson, 1992; Town and Bradley, 1991; Yu et al., 1994) and [La^-] (Di Masi at al., 2007) are lower during aquatic exercises for the same reasons presented for its reduction with increasing body immersion. A conflicting issue is the bioenergetical profile. Several investigations reported that when exercising on land, VO_2 or EE were significantly higher comparatively with aquatic exercises (Barbosa et al., 2007; Butts et al., 1991; Hall et al., 1998; Yu et al., 1994). Contrarily, other studies observed that those parameters during aquatics were significantly lower or non-different from land-based exercises (e.g., Darby and Yackle, 2000; Green et al., 1990).

However, it is known that environmental conditions have a significant influence in the thermoregulation system and, therefore, in the physiological response to exercise (cf. "effects of water temperature" sub-chapter). That is why at least one paper compared aquatic exercises with land-based exercises performed in the pool-side, as done by aquatic instructors (Barbosa et al., 2007).

Effect of type of exercise

There are several types of exercises, drills and routines that can be performed during an aerobic head-out aquatic exercise session. From a technical point of view, those exercises are categorized in six main groups: (i) walking; (ii) running; (iii) rocking; (iv) kicking; (v) jumping and; (vi) scissors (Sanders, 2000). Each one of these exercises can be performed in several variants according to some guidelines described by the same author. In comparison to other aerobic aquatic activities, such as swimming, one of the main advantages of head-out aquatic exercises is the variety of exercises, drills and routines that can be performed throughout a session or a program. Even so, the question whether these exercises promote similar acute physiological adaptations is an issue that must be addressed.

Most of the studies on this issue devoted their attention to the differences between immersed walking vs. running. Typically, an incremental protocol from a slow to a maximal speed was applied (e.g., Kato et al., 2001; Yu et al., 1994). Transition speed from walking to running in water happens at 1.67 $m{\cdot}s^{-1}$ (Kato et al., 2001). It was reported that speed had a significant effect in several physiological parameters, such as RPE, HR and VO_2 (Shono et al., 2001; Yu et al., 1994). Speed is related to drag force. So, as speed increases, subjects are submitted to an increasing drag force as well, and need a higher metabolic power to overcome such external force. By consequence, all physiological parameters increase as well. Moreover, it seems to exist a significant relationship between physiological and kinematical variations for immersed locomotion (Kato et al., 2001).

Physiological and even biomechanical assessment of the remaining types of head-out aquatic exercises is scarce. Some few exceptions are the works evaluating the squat jump (Hoshijima et al., 1999), single leg jump (Triplett et al., 2009), the rocking horse (Barbosa et al., 2007), the kicking (Poyhonen et al., 1999) and the arm's horizontal adduction and abduction (Colado et al., 2009a). No data is present in the literature about the physiological adaptations of other types of head-out aquatic exercises.

Effect of equipments

There are several equipments and apparatus commercially available for head-out aquatic exercise users. These equipments can be used in a given part of the session or throughout all session itself. Bench-stepping platforms, ergo-bicycles, rubber bands, flotation vests, ankle cuffs, treadmills, hydro-flumes or dumb-belts are some examples of such equipments. So, the question to be answered is what kind of acute physiological adaptations this apparatus promote during head-out aquatic exercises.

Costa et al. (2008) compared the same basic head-out aquatic exercise in young, healthy and physically active women: (i) only with legs actions; (ii) with simultaneous legs and arms actions and (iii) with simultaneous legs and arms actions using buoyancy dumb-belts. Practicing with dumb-bells promoted an increase in RPE, [La$^-$] and HR when compared with the remaining conditions (Costa et al., 2008). Authors suggested that practicing head-out aquatic exercises with both simultaneous legs and arms actions, matched with the American College of Sports Medicine guidelines (2000). However, when practicing with dumb-bells, the acute response was consistently above the target zone often suggested by this same organization (Costa et al., 2008). On the other hand, some research groups intended to analyze the neuromuscular effect of the head-out aquatic exercise with dumb-belts (e.g., Colado et al., 2009a). It can be suggested significant relationships between the physiological and the biomechanical adaptations during this kind of exercise. However, at least to our knowledge, there is no research about this interplay.

The bench-stepping platform (also known as aqua-step) is equipment often used. Evans and Cureton (1996) performed a physiological assessment of bench-stepping at the same cadence (0.48 Hz) in water and on land. HR and VO_2 were lower during water exercise, although RPE had no significant variation. Adding the arms to leg actions increased VO_2 demand as well. Therefore, the authors suggested that bench-stepping with the use of arms in water meets the American College of Sports Medicine guidelines (2000) for the improvement of aerobic capacity. In one other paper, this same group (Evans and Cureton, 1998) compared bench-stepping with platforms at different heights on land and in water (0.18 and 33 cm) using climbing movement with no arms (traditional step pattern) and straddle jumping involving arms and legs (modified step pattern). The intensity of traditional stepping in water was less than or equal to 50 % VO_2max recommended by the American College of Sports Medicine (2000) to increase fitness. The intensity for modified stepping in water was less than or equal to 50 % VO_2max recommended by the same organization at all bench heights (Evans and Cureton, 1998).

Although the re-new interest that ergo-bicycle is having, these types of equipments are not novel in the aquatic context. Indeed, since three decades ago there are some reports about the modification of standard ergo-bicycles for aquatic programs (e.g., Morlok and Dressendorfer, 1974). It seems to exist contradictory data about the effect of the ergo-bicycles in the acute adaptation: (i) after a maximal bout, there was no significant difference in VO_2max between aquatic and land-based exercise, but HR and ventilation exchange decreased significantly when exercising immersed (Dressendorfer et al., 1976); (ii) at similar ergometric workload, VO_2, tidal volume, breathing frequency and [La$^-$] levels were significantly higher in water than on land (Bréchat et al., 1999); (iii) at moderate intensity, there was no significant difference in HR, but systolic BP was significantly lower during water exercitation (Matsui et al., 1999). Di Masi et al. (2007) describe a faster [La$^-$] removal during immersed cycling when compared with land cycling. However, the amount of [La$^-$] during submaximal exercise was no different in the two conditions. Others have compared several aquatic ergo-bicycles models and verified significant differences in some physiological parameters (e.g., VO2 and HR) according to the model evaluated (Giacomini et al., 2007). Due to the commercial success that this equipment has, new highlights should be obtained about the physiological response with its use, such as the effects of: (i) the level of body immersion; (ii) several body postures; (iii) different pedalling rates; (iv) different resistance mechanics of the models used or; (v) aquatic resistance exercises, for arms and trunk, performed in the ergo-bicycle.

The flume is an ergo-meter where the subjects exercise stationary against a water flow. This apparatus has been developed in the late sixties and early seventies for competitive swimming (e.g., Holmér, 1972; 1974). Nowadays this apparatus has been also used for head-out aquatic exercises. At least free and flume swims presented similar values for VO_2max, R and VE (Bonen et al., 1980). However, significant differences between these two conditions of exercise have been reported other authors. Indeed, D'Acquisto et al. (1991) verified that flume swimming required higher VO_2max, HR and [La$^-$] than free swim. It can be speculated that the type of fluid flow around the subject in the ergometer is different from that in free swimming. This phenomenon has repercussions in the transfer of kinematical energy to the water and, therefore decreases the movement efficiency. Although there is no systematic study about physiological adaptations in a flume during head-out aquatic exercises, it can be hypothesized that data will be very similar. A single study about walking in a flume presented data quite similar (Yu et al., 1994).

Yet another possibility is to exercise in aquatic treadmill. Comparing submaximal walking in underwater and land treadmills, VO_2 and RPE were significantly higher in water (Hall et al., 1998). Thus, walking in chest-deep water yields a higher energy cost than walking at similar speeds on land. On the other hand, some data suggest that when exercising in underwater treadmill, EE (e.g., Shono et al., 2000) and VO_2, RPE, BP (Dolbow et al., 2008) are considerably lower than in free exercising. Migita et al. (1996) proposed that one half of the speed would be necessary in underwater treadmill to achieve the same physiological responses that land treadmill. Walking in an underwater treadmill inserted in a flume, no significant differences in the VO_2-HR relationships was found between land and water performances (Shono et al., 2007).

When exercising in deep-water the use of flotation vests and ankle cuffs is common. These equipments enable the subject to submerge still maintaining an upright position. Without the flotation vest, the subjects must relay in their ability to perform the skills, as well as their ability to maintain buoyancy. VO_2, VE, HR and RPE were significantly lower when running with the flotation vest than without it for a group of non-expert runners; however the same tendency was verified for expert runners but with no statistical meaning (Gehring et al., 1997). It seems that expert runners are able to elicit higher exercise intensities, both when practicing with or without the flotation vest. Contrarily, non-expert runners seem to rely in the buoyancy of the equipment rather than in the running technique during the bouts. On the other hand, when comparing tethered running with and without a flotation vest, evidences revealed that some kineanthropometrical parameters related to buoyancy force (e.g., fat-mass), to drag force (e.g., body surface area and height), to weight force (e.g., body mass) and to propulsive force (e.g., segmental strength) predicted (R^2 = 0.57, P = 0.01) the maximal horizontal propulsive force (Vila-Chã et al., 2007). This means that, besides physical fitness and technical level, often described in the literature, kineanthropometrical characteristics of the subject also affect significantly his performance during aquatic running exercises.

The scarce number of investigations about the utility of these equipments does not matched the variety of apparatus commercially available and its uses on regular basis in head-out aquatic exercise sessions. Therefore, the true repercussions in the acute physiological during head-out aquatic routines with such apparatus should be assessed.

Effect of segmental action

Acute response of aquatic exercises can be dependent from the number of body segments in action. Each head-out aquatic exercise has several variants. Some of those variants are based on the number of body segments in action during exercise (legs movement only, arms movement only and both arms and legs simultaneous movements). For a given basic movement, at the same music cadence, RPE, HR and [La^-] were significantly higher when exercising with simultaneous arms and legs actions, compared with leg exercise (Darby and Yaeckle, 2000; Costa et al., 2008). The same phenomenon was described for metabolic parameters, e.g., METs values during bench-stepping performed by women (Evans and Cureton, 1996). Therefore, it seems that increasing limbs in action will induce a significant increase in the acute response to exercise. This effect may be explained by: (i) the mechanical work done, once drag force also increases and therefore the RPE (Yu et al., 1994); (ii) the number of muscles in activity promotes a higher oxygen and nutrients demand, increasing HR and metabolite production (e.g. [La^-]).

Besides the arm actions, also hand and fingers positions may influence the biomechanical and physiological. Different hand position, e.g., attack and sweep angle (Silva et al., 2008a) and different finger's spread, e.g., fingers close together, little spread and large spread, leads to several drag force intensities (Marinho et al., in press) and therefore influences the physiological response. Drag force evaluated with "computer fluid dynamic" approach (e.g., Silva et al., 2008b) presented the minimum value near angles of attack of 0º and 180º and the maximum value was obtained near to 90º, when the hand is almost perpendicular to the flow (Silva et al., 2008a). Using the same methodology, for attack angles higher than 30º, as used in head-out aquatic exercises, when little distance between fingers is adopted higher values of drag coefficient are verified, rather than with fingers close together and with large finger spread (Marinho et al., in press).

Several research groups compared the acute response to exercises performed only with the legs or the arms. RPE was reported as being higher for arm's exercises, at least for land-based routines (Borg et al., 1987; Butts et al., 1995; Kang et al., 1999). One single study evaluated the MET's level for aquatic exercises performed either with arms or legs only. For both genders, MET value's for callisthenics exercises, were higher for legs actions (Cassady and Nielsen 1992). Indeed, at least for terrestrial and other types of aquatic tasks, it was already reported that an increasing number of limbs in action leads to a concomitant increase of the acute response (Butts et al., 1995; Robert et al., 1996; Darby and Yaeckle, 2000).

Effect of music cadence

For some aquatic instructors, one of the most important aspects when conducting their sessions is to include music in the routines with the aim to: (i) motivate practitioners during the session; (ii) maintain the synchronization of the practitioners during specific routines and; (iii) achieve a given intensity of exertion. In fact, some aquatic instructors plan their sessions according to the music characteristics. They choose a given music for a specific part of the session, according to its cadence or rhythm, in order to achieve a pre-determinate intensity of exertion. In this sense, the countdown of one musical beat in each two beats is synchronized with the execution of a given segmental action of the full exercise being performed (this is know as "water tempo"). So, movement frequency is related to music cadence. However, only a couple of papers attempted to understand the relationship between music cadence and acute physiological response in head-out aquatic exercises. Increases in the music cadence imposed significant increases in the acute physiological adaptation (RPE, HR, and [La^-]) of the subjects (Hoshijima et al., 1999; Barbosa et al., in press). Indeed, other researches reported that in several kinds of head-out aquatic tasks, increasing physiological responses were observed during incremental protocols (Darby and Stallman et al., 2006; Yackle, 2000). The increased physiological response may be explained by the fact that increasing music cadence will also increase movement velocity and frequency. Since drag force has a quadratic relationship with movement speed, an increased drag induces a larger energy demand.

Therefore, an issue that must be addressed is the understanding of the appropriate music cadence is in order to achieve the desired intensity of exertion. Usually, aquatic instructors adopt the physical fitness guidelines for land-based activities. However, it is questionable if those guidelines are suitable for aquatic exercise programs also. Head-out aquatic programs are moderate-vigorous activities, where it is presumable that [La^-] must be under or very close to its onset accumulation. Some researchers set a 4 mmol of lactate per liter as a reference value, expressing V4 as the exercise intensity (displacement speed) corresponding to that threshold (e.g., Heck et al., 1985). Barbosa et al. (in press) adapted the concept of V4 to head-out aquatic exercises, and defined it as being the music cadence achieved at a 4 $mmol \cdot l^{-1}$ of blood lactate concentration (R4), i.e., the rhythm in which is achieved the 4 $mmol \cdot l^{-1}$ of [La^-]. For young and active women R4 evaluated after an intermittent and progressive test was 148.13 ± 17.53 $b \cdot min^{-1}$ (Barbosa et al., in press).

However, these values are quite individual and hardly applicable to all subjects of an aquatic class group. So, the determination of a range of intensity (target zone) for young and active women was developed based in the 25 and 75 quartiles of the subjects' evaluated (Barbosa et al. in press). With that aim, the RPE at R4 (RPE@R4), the HR at R4 (HR@R4) and the percentage of the maximal theoretical HR at R4 (%HRmax@R4) were computed. Authors reported that R4 ranged from 136.03 $b.min^{-1}$ (quartile 25) to 158.28 $b \cdot min^{-1}$ (quartile 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 % to 89.75 %. Comparing these data with the American College of Sports Medicine guidelines (2000) they are appropriated but can be slightly adjusted for aquatic activities in order to promote a more accurate exercise prescription of young, healthy and physically active subjects.

Although these results may come as an advance in head-out aquatic exercises knowledge, this data is only suitable for young, healthy and active women. New investigations should be developed in order to determinate more accurately target zones for other specific populations. For instance, to evaluate it according to gender, physical activity level, age, mode or type of exercise, etc.

Chronic adaptations

Cardiovascular and metabolic adaptations

Cardiovascular and metabolic adaptations are one of the major interests in head-out aquatic exercises, since they are related to the prevention of several pathologies, such as, coronary artery disease, hypertension, stroke, obesity or diabetes. Most of the studies assessed the VO_2max adaptations in different head-out aquatic exercise programs. It is often reported that after one training program of at least 7-wks, a significant improvement in VO_2max for deep-water (Broman et al., 2006), aquatic step-benching (Gaspard et al., 1995), shallow-water walking and dancing (Tauton et al., 1996; Takeshima et al., 2002) is verified. However, in competitive runners, it was reported that cardiovascular and metabolic parameters, such as submaximal and maximal VO_2 or [La^-] threshold did not presented significant differences after a 4-week water running program (Bushman et al., 1997). The mechanisms behind the adaptations to aerobic fitness have been found primarily in peripheral skeletal muscles, with an increased arterial-venous difference, increased capitalization, and higher mitochondrial enzyme activities. At least for deep-water running, the hydrostatic pressure may raise the stimulus both for capillary proliferation and oxidative enzyme activities (Broman et al., 2006).

After an aquatic training program, HR at rest decreased and BP was unchanged (Broman et al., 2006; Bocalini et al., 2008). The HR at rest can be expected to decrease by one beat per minute in each week of training for healthy but sedentary subjects (Wilmore and Costill, 1994). Training appears to increase parasympathetic activity while decreases sympathetic one in the heart. However, although after an endurance training program assessing BP at submaximal exercise is described as presenting a no-significant change, at rest it decreases. The decrease happened for both systolic and diastolic BP. Even so, the assessment of BP during head-out aquatic exercises of healthy subjects can be quite challenging and bring new highlights in a near future.

Muscular strength adaptations

A very high interest surrounds muscle strength training, since several health-related benefits are obtained with this type of training programs in fitness and therapy contexts.

It seems consistent an increase in the muscle strength after a program of head-out aquatic exercises that included in their sessions one section with that aim. Studies in the literature reported significant improvements after programs from 8-wks (Colado et al., 2009b; Hamer and Morton, 1990; Robinson et al., 2004; Hoeger et al., 1992), to 10-wks (Poyhonen et al., 2002), 12-wks (Bocalinni et al., 2008; Takeshima et al., 2002) and 24-wks (Colado et al., 2009c) with untrained women. Some of the most interesting researches assessed muscle strength with isokinetic machines (Hoeger et al., 1992; Poyhonen et al, 2002; Tsourlou et al., 2006). In such cases, muscle strength improved 7 % (Poyhonen et al, 2002), 10.5 % for knee extension and 13.4 % for knee flexion (Tsourlou et al., 2006). Moreover, at least one investigation suggests that aquatic resistance exercises, i.e., performed in water using special devices, have the advantage of increasing training intensity due to an increase of the drag factor (Colado et al., 2009a). Comparing a 24-wks program of aquatic exercises with a rubber-band exercise program, Colado et al. (2009c) reported that both programs are effective in order to improve muscular strength.

However, some limitations are still present in the literature and must be addressed: (i) the significant and high increases in muscle strength can be partially credited to the very low-medium fitness level of the subjects evaluated; (ii) some inconsistencies in the improvement values can result from differences in the strength programs design, i.e., different volumes, intensities, repetitions and sets numbers, rest interval, type of exercise, etc.

Flexibility adaptations

Flexibility exercises are usually supplementary to remain routines performed during the aquatic session. In the past, part of the flexibility routine was included at the end of the warm-up section. Nowadays, it is hypothesized that anatomical structures are more adaptable and responsive after the endurance conditioning section (Wilmore and Costill, 1994). Indeed, the original structure of a head-out aquatic exercise session included a stretching section after the warm-up. Presently most aquatic instructors do not perform this section and go directly from the warm-up to the cardiorespiratory conditioning section.

There are few studies about the trainability of flexibility, when included one specific section to its improvement in the head-out aquatic session (Bocalini et al., 2008; Colado et al., 2009c; Hoeger et al., 1992). Researchers used the land-based sit-and-reach test to assess flexibility in no-active healthy women after 8-wks (Hoeger et al., 1992) or 24-wks (Colado et al., 2009c; Tsourlou et al., 2006) programs. All research groups reported improvements in the flexibility, comparing the pre-test with the post-test. A significant improvement of 10.5 % (Hoeger et al., 1992) and 11.6 % (Tsourlou et al., 2006) for shallow-water aerobics and a 21 % significant improvement for aquatic resistance exercises (Colado et al., 2009c) were identified.

Water proprieties induce an increase in joints flexibility. Warm water reduces muscle spasticity, improving range of motion which is a benefit for some physical conditions and pathologies (Koury, 1996). So, it can be speculated that flexibility assessment with an aquatic-specific test might present results rather different from the ones described above. Another limitation of these conclusions is that only inactive or less-active subjects were evaluated. Probably the flexibility improvement would not present the same range with other type of subjects, such as for example, active subjects or even elite athletes.

Body composition adaptations

Physical activities, as head-out aquatic exercises, can substantially change body composition. That is why a large number of researches were performed in order to quantify such variations with this type of fitness programs. Body composition is one of the most assessed parameters in what concerns chronic adaptations of head-out aquatic exercises. Some authors did not found significant changes in body composition after a head-out aquatic exercise program (e.g., Quinn et al., 1994; Wilber et al., 1996). However, in both studies the time gap between the pre and the post-test was lower than six weeks. The 8-wks program seems to be the milestone to significantly change body composition. At least three papers reported significant decreases in body-fat of respectively 7.6 %, 2.7 % and 1.32% (Colado et al., 2009b; Hoeger et al., 1992; Michaud et al., 1995) in untrained healthy subjects after 8 weeks of training. Using the same duration for the exercise program, another paper found a 4.3 % decrease but with no statistical meaning (Kieres e Plowman, 1991). In programs with a higher duration, consistent and significant decreases of body-fat were reported (e.g., Abraham et al., 1994; Colado et al., 2009c; Miyashita et al., 2002; Tsourlou et al., 2006). Such decreases ranged between 6 % for an 11-wks program (Abraham et al., 1994) and 14.56 % for a 24-wks program (Colado et al. 2009c). At least one 13-wks program reported a decrease of body-fat of 3.7 % (Gappmaier et al., 2006) but a 12-wks program did not verified significant differences (Tauton et al., 1996). This non-significant improvement can be explain because the exercise program used was not specific enough or long enough to cause improvements in body composition (Tauton et al., 1996). Therefore, body composition adaptation seems to be independent from gender and age but not from the program design and its adjustments throughout its application.

Nevertheless, some limitations are identified in the literature: (i) there was no diet control or manipulation in any study; (ii) different methodologies were used to evaluate body composition (e.g., skinfolds thickness, bioelectric impedance, etc.) which have different validity and accuracy levels; (iii) some studies (Quinn et al.,1994; Wilber et al., 1996) had a very short duration, lasting up to six weeks and; (iv) at least a couple of papers (Kieres e Plowman, 1991; Wilber et al., 1996) studied elite athletes, where significant changes in body composition are not expected. Moreover, consistent understanding of changes in body composition according to training program (e.g., shallow-water aerobics, deep-water aerobics or running, aqua-step, etc.) is not clear, since the quantity of studies devoted to each program is very limited.

Other adaptations

There are other important adaptations that have a significant interplay with the physiological behavior during an aquatic fitness program or aquatic session. The psychological adaptations are one of them. Some data indicate that subjects who participate in these type of programs reported lower state anxiety (e.g., Watanabe et al., 2000). Indeed, at least for low back pain patients, when participating in a head-out aquatic program, physiological variables related to anxiety (e.g., stress hormones such as salivary cortisol) decreased after an aquatic session (Sugano and Nomura, 2000).

Another topic is the hormonal response and the changes in the bone mineral density after an aquatic program. Ay and Yurtkuran (2003) assessed if moderate physical activity, such as aquatic exercise, has anabolic effects on bone evaluated with quantitative ultrasound and hormonal variables of 41 postmenopausal sedentary women. Authors stated that there were 36 %, 75 % and 54 % increases in the serum levels of insulin-like growth factor-1, growth hormone, and calcitonin, respectively. There were statistically significant differences between the control and the aquatic exercise groups for the 6 months relative changes in broadband ultrasound attenuation and speed-of-sound T scores, insulin-like growth factor-1, growth hormone, parathormone, and calcitonin. So, head-out aquatic exercises were determined as being effective to make an anabolic effect on the bone of the postmenopausal, sedentary subjects.

Cardiovascular, metabolic and body composition adaptations are strongly related to the subject's cardiovascular health and its rehabilitation. Exercise programs that combine resistance and aerobic exercise performed either on land or in water improved exercise tolerance, muscular strength and induce similar favorable adaptations on total cholesterol, triglycerides, and body composition in patients with coronary artery disease (Volaklis et al, 2007). However, cessation of the exercise program can reverse these adaptations (Tokmakidis et al., 2008). A 3 months water aerobic program results in favorable changes in glucose and lipid metabolism in obese subjects, even despite the lack of improvement in body mass (Nowak et al., 2008).

Conclusion

In conclusion, head-out aquatic exercise programs had an enormous expansion in the last decades because several benefits in the improvement of physical fitness are attributed to those programs. For each physical fitness component, consistent and significant improvements were reported for programs with durations of at least eight weeks. Nevertheless, chronic adaptations are the cumulative result of appropriate acute responses during the exercise session. So, exercise routines should be adjusted throughout the training program in order to improve physical fitness.

There are a large number of research groups with interests in the acute and/or chronic adaptation to head-out aquatic exercises within the fitness or therapy context. However, in comparison with other aquatic activities, e.g. competitive swimming, some lacks in comprehensive and consistent knowledge about head-out aquatic exercises are a reality.

In order to gather a more consistent knowledge about this physical activity, the submission of an increasing number of manuscripts in peer-reviewed and impact-factor journals should be promoted and the following criteria seem required: (i) statistical procedures and protocol design should be appropriate, e.g., randomized control trials; (ii) evaluation with larger samples of subjects; (iii) evaluation and comparison of samples with different profiles according to age, gender, fitness level and even pathology or physical condition; (iii) evaluate the acute and chronic effects of different modes of exercises, including the type of equipment used (e.g., treadmill, water aerobic, jogging, bike, bench-stepping, shallow and deep water, etc.); (iv) perform systematic revision and/or meta-analysis of the data published in the literature; (v) promote new biomechanical researches about aquatic exercises, since acute physiological adaptations are consequence of biomechanical ones; (vi) study the relationship between acute and chronic adaptations.

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Key points

- Several papers reported consistent and significant improvement in physical fitness (e.g., aerobic capacity, muscular strength, flexibility and body composition) after a program of head-out aquatic exercise with at least eight weeks.
- Chronic adaptations to head-out aquatic exercise programs are the cumulative result of appropriate acute responses during the exercise session.
- Appropriate acute adaptations can be obtained taking into account the water temperature, water depth, type of exercise and its variants, the equipment used and the segmental cadence according to the subjects' profile.

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