A Review on: Physiological Assessment of Aquatic Exercises in Healthy Subjects

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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: Acute Adaptation, Aquatic Exercises, Chronic Adaptation, Immersion, Physical Fitness

I. 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.

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. 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.

A. *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 35ºC (Drink water, 2008). Both the voluntary and evoked force development capacities of muscle are unimpaired until cooling is quite severe, such as, less than 27 ºC (Drink water, 2008). At least during sub maximal 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; VO2 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 VO2 was about 0.7 L·min-1in a 28-35 ºC water temperature, but increased in a 24-26 ºC temperature.

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 thermo regulation 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 VO2(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.

B. 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.

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); VO2 max 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 he 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.

C. 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.

II. CHRONIC ADAPTATION

A. 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 2 max 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 2 max for deep-water (Broman et al., 2006), aquatic stepbenching (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 sub maximal 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.

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. How ever, although after an endurance training program assessing BP at sub maximal 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.

B. 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.

C. 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 ofthe 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; Tsourlouet al., 2006) programs. All research groups reported improvements in the flexibility, comparing the pretest 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.

D. 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 headout 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 signifcant 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 ePlowman, 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.

III. 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.

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