Narrative Review

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Aquatic aerobic exercise and physical fitness: from scientific foundations to practical applications

Exercício aeróbio aquático e aptidão física: dos fundamentos científicos às aplicações práticas

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ABSTRACT

Introduction: The aquatic environment offers broad potential for physical training, providing an advantageous alternative, especially for individuals who have difficulties performing exercises on land. In this sense, the literature on aquatic exercise for health promotion has grown significantly. Objective: To present accessible knowledge related to the prescription of aquatic aerobic training in the vertical position, aiming to offer a comprehensive understanding from the scientific foundations to the practical applications for professionals who work with aquatic modalities. Development: In this review, we begin by summarizing the physical properties of the aquatic environment and their effects on the immersed human body. We discuss how buoyancy and drag force influence the biomechanics of movements in water and how hydrostatic pressure and thermal conductivity affect physiological parameters. Then, we address the main possibilities for prescribing aerobic exercises in the aquatic environment, highlighting the advantages and disadvantages of each intensity control parameter while considering differences from the land environment. Finally, we present the findings from aerobic training programs on physical fitness outcomes in young and older adults. The available evidence suggests that aerobic training in the aquatic environment may exhibit characteristics and adaptations similar to multicomponent training in previously inactive individuals. Final Considerations: We expect that aquatic professionals will "immerse themselves" into the knowledge related to aquatic exercise, as this will allow them to optimize the effectiveness of training programs in this environment, promoting health and well-being among practitioners.

Keywords: Water; Physical exercise; Immersion; Review.

RESUMO

Introdução: O meio aquático oferece um amplo potencial para o treinamento físico, sendo uma alternativa vantajosa especialmente para indivíduos com dificuldades em realizar exercícios no meio terrestre. Nesse sentido, a literatura sobre o exercício aquático para a promoção da saúde tem crescido significativamente. Objetivo: Apresentar o conhecimento relacionado à prescrição do treinamento aeróbio aquático na posição vertical de forma acessível, visando oferecer uma compreensão abrangente dos fundamentos científicos até as aplicações práticas para profissionais que trabalham com modalidades aquáticas. Desenvolvimento: Nesta revisão, primeiramente resumimos as propriedades físicas do meio aquático e seus efeitos sobre o organismo humano imerso. Discutimos como a força de empuxo e a força de arrasto influenciam a biomecânica dos movimentos na água, e como a pressão hidrostática e a termocondutividade alteram parâmetros fisiológicos. Em seguida, abordamos as principais possibilidades de prescrição de exercícios aeróbios no meio aquático, destacando as vantagens e desvantagens de cada parâmetro de controle da intensidade, considerando as diferenças com relação ao meio terrestre. Por fim, apresentamos os resultados de programas de treinamento aeróbio em desfechos da aptidão física de adultos e idosos. Nesse sentido, as evidências disponíveis sugerem que o treinamento aeróbio no meio aquático pode apresentar características e adaptações similares ao treinamento multicomponente em indivíduos previamente inativos. Considerações finais: Esperamos que os profissionais de modalidades aquáticas façam uma "imersão" no conhecimento relacionado ao exercício aquático, pois assim poderão otimizar a eficácia do treinamento nesse meio, a fim de promover saúde e bem-estar aos praticantes.

Palavras-chave: *Água; Exercício físico; Imersão; Revisão.*

Introduction

Physical exercise is widely recognized as fundamental for maintaining health and well-being. Different exercise modalities offer flexible options that match individual goals, limitations, and preferences, encouraging greater adherence to conditioning programs. In this sense, the aquatic environment presents several advantages related to water's physical properties, which make it an interesting option, especially for individuals who have difficulties while performing exercises on land[1,2]. However, it is crucial to understand that immersion in this environment provides different conditions compared to the land environment[3,4] and recognize that recommendations must be appropriate for aquatic exercise programs[5].

The scientific community has been striving to understand the acute and chronic effects of aquatic exercises, and as a result, the literature on this topic has grown significantly. A bibliometric review notably ranked Brazil second among the countries that have produced the most research on aquatic exercise for health promotion[6]. In addition, the review indicated that the four main researchers in the world on the subject are Brazilian[6].

It is worth noting that a large number of scientific articles are published in English in international journals, and this practice is fundamental for academic exchange and the advancement of scientific knowledge. On the other hand, it is important to recognize that language can be a significant barrier for interested individuals who are not proficient in English. According to the English Proficiency Index[7], Brazil ranks 70th in the world for English and is classified as having "low proficiency". Therefore, it is essential to find ways to overcome these challenges to ensure that scientific knowledge is accessible to a wider audience. Moreover, it is the responsibility of the scientific community to ensure that knowledge reaches those who are interested. In our case, we aim to promote a connection between researchers and professionals in the field of aquatic exercises since we share the same goal, namely, improving the health of those who practice this type of exercise.

In this review, our objective is to present the scientific knowledge related to the prescription of aquatic aerobic training performed in an upright position in an accessible way, aiming to offer a comprehensive understanding of the scientific foundations and practical applications for professionals working with aquatic modalities. We focused our approach on aerobic training programs due to the benefits this training model has demonstrated, which will be presented throughout this paper. First, we summarize the physical properties of water and their effects on the immersed organism. Then, we discuss the main possibilities for prescribing aerobic exercises in the aquatic environment. Finally, we present the results of aerobic training programs on the physical outcomes of both young and older adults. We hope this study assists professionals in prescribing training programs in the aquatic environment to promote health and well-being among practitioners.

Physical properties of water and their effects on the immersed body

Initially, it is important to understand that immersion in the aquatic environment creates different conditions from those in the land environment. Therefore, the benefits and advantages of exercising in this environment are related to the physical properties of water. Collectively, these characteristics of water induce unique biological effects that may favor specific physiological adaptations to exercise. Thus, understanding these characteristics is fundamental for a safe and effective exercise prescription. In the following subsections, some physical properties of water (density, buoyancy, drag force, hydrostatic pressure, and thermal conductivity) and their implications for exercise practice are presented.

Density and buoyancy

Density is the relationship between the mass and volume of a substance. In the case of a fluid, the greater its density, the greater the force it exerts on objects that are floating or immersed in it. We can observe that the density of fresh water at 4°C is approximately 1.0 g/cm^3, while the density of air is considerably lower, at approximately 0.001 g/cm^3. Based on specific density (i.e., the density of the substance divided by the density of water), we can determine whether a body will float or sink when immersed in water. Thus, bodies with densities lower than that of water float, while bodies with higher densities will sink. It is important to note that the density of the human body is slightly lower than that of water, with an average density of 0.97 g/cm^3, although this value varies according to sex, somatotype, and age[8]. In this context, lean mass, which includes bones, muscles, connective tissue, and organs, has a density of approximately 1.1 g/cm^3, while fat mass has a density of around 0.9 g/cm^3 [9].

Regarding buoyancy, it should be considered that it is a unidirectional force, directed from the bottom to the top, which a fluid exerts on a submerged body (Figure 1A). Archimedes' Principle is a key concept that states, "Any body, partially or totally immersed in a fluid, experiences a force equal to the weight of the displaced liquid volume, acting in the opposite direction to the gravitational force of the Earth". Therefore, an immersed body is subjected to two opposing forces, the force of gravity and the buoyant force.

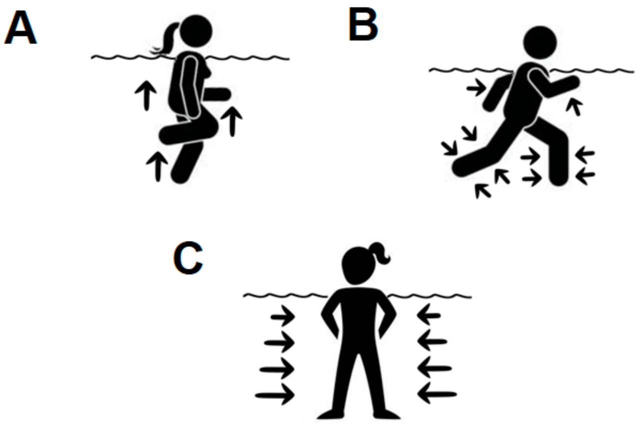

Figure 1 – Action of buoyancy force (A), drag force (B), and hydrostatic pressure (C) on the immersed body.
Source: the authors (2025)

Implications on apparent weight, ground reaction force, and use of floating equipment

Buoyancy reduces the apparent weight of immersed bodies compared to their weight on land, considering that apparent weight corresponds to the resultant difference between total body weight and buoyant force. This is the reason that carrying another person is much easier in a pool. It is important to consider that the immersion depth influences the reduction of the apparent weight, i.e., the greater the depth, the greater the reduction in apparent weight[10–12]. Regarding the reduction in apparent weight at the xiphoid process depth, which is typically used in water aerobics sessions, studies have shown a reduction of approximately 70% in eutrophic young adults[11,13,14]. Thus, during a water aerobics session, if we consider a person weighing 100 kg exercising at a depth of the xiphoid, they will only be carrying 30% of their body weight (i.e., 30 kg) rather than their full 100 kg, as it would be the case in a land exercise session.

Furthermore, reductions of 68% have been observed in patients with type 2 diabetes[15], 72% in children with obesity[16], 75% in postmenopausal women[17], 79.5% in older women[1], and 81% in women with obesity[2]. Such variations in the magnitude of apparent weight reduction among studies may be explained by differences in body composition (muscle mass, fat mass, and bone density) of participants[3]. Thus, individuals with different profiles will experience greater or lesser ease of floating and performing certain exercises.

Traditionally, exercising in an aquatic environment is recommended because it provides a low impact on the lower limb joints. This characteristic is a consequence of the reduction in apparent weight, which results in a lower vertical ground reaction force compared to the same exercise performed on land. These data were evidenced in different forms of exercise, especially in water aerobics exercises[13–19]. Due to the reduced mechanical load on the lower limb joints, the aquatic environment offers the advantage of greater osteoarticular safety, facilitating adherence to aquatic exercise programs for individuals who have difficulty performing exercises on land. In addition, the lower mechanical load on the joints in the aquatic environment is also advantageous because it allows for easier progress of the intensity and volume of aerobic training compared to land-based exercise.

On the other hand, it is important to demystify the idea that there is no impact in water aerobics exercises. Whenever the feet make contact with the ground during practice, impact forces are present, even if attenuated by water[14]. Therefore, unlike deep-water running, it is not appropriate to state water aerobics is completely impact-free; instead, it should be recognized as a low-impact activity due to buoyancy.

Another point that deserves attention is how floating equipment is used in the aquatic environment. As previously mentioned, buoyancy is a unidirectional force exerted from the bottom to the top, facilitating the buoyancy of bodies. Floating equipment, such as dumbbells and aqua tubes, is designed to increase resistance against buoyant force. Thus, using this type of equipment increases resistance when pushing them downwards, which can alter the muscle group involved in a given action when compared to performing the same movement on land, whose resistance is exerted in the upward direction due to gravity. Moreover, using these apparatus during exercise requires greater movement control, both in the ascending phase (moving the floating equipment towards the surface of the water) and in the descending phase (moving the floating equipment towards the bottom of the pool).

Drag force

Another advantageous biomechanical characteristic of the aquatic environment is the resistance imposed by water in all directions of movement (Figure 1B). As we previously discussed, water's density (ρ) and viscosity are much greater than those of air, making the resistance exerted by water during exercises in the aquatic environment greater than the resistance offered by air in land-based exercises[22]. Other factors also influence the drag force (F_{drag}), namely the drag coefficient (C_{drag}), the projected area (A), and the velocity of motion (V), as can be seen in the general fluid equation: $F_{drag} = 0{,}5 \cdot C_{drag} \cdot \rho \cdot A \cdot V^2$ [23].

- Projected area: the larger the projected surface area, the greater the resistance exerted by the water and, consequently, the force needed to move the body segment or piece of equipment through the water. This variable can be adjusted through different exercises using either segments with larger or smaller projected areas or aquatic equipment. Studies have observed greater cardiorespiratory responses during water aerobics exercises performed with resistance equipment (i.e., equipment that enhances the projected area) compared to the performance without equipment at the same rhythm/velocity of motion[24–26].
- Drag coefficient: it is related to the shape of the displaced object. For example, the drag coefficient of a cube is greater than that of a sphere, and the lower the coefficient, the better the hydrodynamics, meaning the resistance to movement will be reduced. This variable can be manipulated by the position of the body segments, such as the position of the hands (for example, open or closed), which substantially affects this coefficient, or by the shape of aquatic equipment.
- Velocity of motion: based on the equation, it is important to note that the drag force provided by water is strongly influenced by velocity, as it is squared and directly proportional to it. In other words, if the execution speed during an exercise is doubled, the resistance will increase fourfold. This must be considered when prescribing exercise intensity in the aquatic environment and when determining training load progression, especially at high intensities.
- Relationship between projected area and velocity: this aspect should be considered when prescribing aquatic exercises, especially when large-area equipment is used to increase the training load. This load increase will only occur when participants can use large-area equipment while maintaining the same velocity of motion as without its use. However, in most cases, using such equipment leads to a reduction in velocity of motion, resulting in a resistance equal to or even lower than in the condition without its use. Therefore, it is important to emphasize that the use of equipment does not necessarily imply an increase in water resistance.

Implications on the type of muscle contraction

The drag force has implications for the type of muscle contraction in the aquatic environment. On land, in an upright position, to work the biceps brachii, we can perform elbow flexion and extension, where the biceps brachii is activated concentrically during flexion and eccentrically during extension when using free weights against gravity. However, to work the triceps brachii, it is necessary to adjust the initial position, or the type of resistance used so that the triceps bracchi is activated concentrically and eccentrically. In the aquatic environment, the water resistance acts in all directions, allowing both muscle groups (i.e., agonist and antagonist) to be activated during the same elbow flexion and extension movement.

In the study by Pöyhönen et al.[27], when comparing two knee flexion and extension protocols in a seated position, they observed that during simple repetitions (i.e., only in one direction of movement), there was a low activation of the antagonist muscles, with a predominance of agonist muscle activity throughout the entire range of motion. For example, in knee extension, the quadriceps was the most activated muscle, while during the return to the initial position (i.e., during flexion), the hamstrings assumed predominant activation. In the second protocol, with multiple repetitions, the quadriceps femoris acted concentrically at the beginning of the knee extension movement, and the hamstrings were activated eccentrically to decelerate the movement at the end of the extension. During flexion, the hamstrings worked concentrically to accelerate the movement, while the quadriceps femoris acted eccentrically to break the motion at the end of the cycle. This pattern of acceleration at the beginning and deceleration at the end of the movement generates concentric and eccentric activation of both muscle groups (agonist and antagonist, respectively) in each phase of the movement. This continuous activation pattern of the agonist and antagonist muscles, with successive cycles of concentric and eccentric contractions, characterizes what is known as the stretch-shortening cycles.

Hydrostatic pressure and thermal conductivity

Immersion in an aquatic environment induces physiological changes in the body, resulting from the specific physical properties of water, particularly hydrostatic pressure and high thermal conductivity. Pascal's Law states that the pressure of a liquid is exerted equally on all areas of the surface of a body that is immersed and at rest at a given depth, and this pressure increases proportionally with depth and the density of the liquid[28] (Figure 1C). Thus, hydrostatic pressure rises with immersion depth, meaning that in a vertical position (commonly adopted in water aerobics sessions), its effect on the lower limb region is more pronounced than on the central region. This pressure gradient enhances venous return, propelling a large volume of blood from the peripheral to the central areas of the body, which increases intrathoracic blood volume[29]. Therefore, when immersed, the body experiences hydrostatic pressure over the submerged surface; consequently, physiological effects begin immediately after immersion.

The greater thermal conductivity of water also contributes to the increase in central blood volume[4,30]. The mechanisms of heat transfer in water and on land are different, since on land, heat transfer occurs predominantly through evaporation, while during immersion, this heat transfer occurs through conduction and convection, making water a more efficient conductor of heat, capable of transferring heat 25 times faster than air. Thus, at water temperatures typical for water aerobics (close to 30°C), the need to distribute blood from the central region (chest and abdomen) to the periphery is reduced. In addition, in contrast to what occurs during exercise on land, where evaporation and consequent water loss can lead to a reduction in blood volume, heat transfer through conduction and convection facilitates efficient heat exchange with the external environment while minimizing water loss. This results in an increase in plasma volume, which, together with the action of hydrostatic pressure, contributes to an increase in central blood volume[31].

Implications for physiological adjustments

The combination of the effects caused by hydrostatic pressure and thermal conductivity during immersion is responsible for central hypervolemia, requiring physiological adjustments due to this distinct hemodynamic condition. With the increase in plasma volume in the central region, the heart and central circulation vessels are distended, stimulating the volume and pressure receptors in these tissues. This leads to a readjustment in the cardiovascular system, increasing central venous pressure, stroke volume, and cardiac output while reducing heart rate (HR), which can be understood as compensatory[29]. It is worth noting that the magnitude of the HR reduction during immersion is influenced by several factors: water temperature[32–34], immersion depth[10,12,35], and initial HR[12,35] of each individual.

Regarding neuroendocrine adjustments, the atrial stretch resulting from increased venous return also leads to increased secretion of atrial natriuretic peptide. Consequently, there is an inhibition of sympathetic nervous system activity, suppression of the renin-angiotensin-aldosterone system, and reduced vasopressin secretion, leading to increased diuresis and natriuresis, which enhances urine flow to restore basal plasma volume[4]. This set of changes, especially the reduced release of vasoconstrictor hormones, leads to lower systemic vascular resistance[36] and attenuation of blood pressure[34].

Oxygen consumption (VO_2), which is the product of cardiac output and the arteriovenous oxygen difference, is also affected by immersion. At rest, as a consequence of the increase in cardiac output during immersion, some studies have observed similar VO_2 values between aquatic and land environments[37–38], while others have found a slight increase[39–41]. Blood redistribution, with an increase in blood volume concentration in the central region, results in an increase in blood flow through the heart and lungs, leading to greater oxygen uptake[41].

Concerning exercise, cardiac output increases on land due to the greater metabolic demand. However, exercises performed in water revealed a higher cardiac output than on land for an equivalent workload[30,37]. This increase in cardiac output does not imply a proportional increase in VO_2 as observed on land since the arteriovenous difference is smaller in water. Therefore, regardless of the blood redistribution to active muscles, this increase in cardiac output is not significantly directed to these muscle groups. In this regard, during incremental tests, studies have observed that maximal and submaximal VO_2 (at the intensity associated with the anaerobic threshold - AT) is significantly lower in the aquatic environment compared to the land environment[5]. Considering the changes caused by the physical properties of water, it is evident that the prescription of exercises in the aquatic environment should not be based on the behavior of the physiological parameters observed in the land environment. The next topic presents the parameters used for the prescription of aquatic exercises considering the characteristics of the environment.

Prescription of aquatic aerobic exercises in the vertical position

Intensity control deserves attention when prescribing aquatic aerobic exercise programs. As previously seen, water immersion exposes the human body to different conditions compared to the land environment, causing physiological changes due to the action of specific physical properties of water[4,30]. In this sense, various parameters can be used to prescribe aerobic exercises; however, it is essential to consider the characteristics of the environment to make the appropriate choice.

Another factor to consider is the availability of resources, as some parameters require sophisticated equipment that is impractical for large-scale use. For instance, although VO_2 is regarded as the gold standard parameter for prescribing aerobic exercises, its application is limited to research settings, as this parameter is not widely accessible in clubs and gyms. Thus, other parameters, such as HR, rating of perceived exertion (RPE), or cadence, can be utilized to prescribe and monitor aerobic exercise intensity. The characteristics, as well as the advantages and disadvantages of the different parameters that can be used during the prescription of aquatic exercises, are presented below.

Oxygen consumption and heart rate

Among several parameters to monitor intensity, traditional approaches have been to prescribe exercise intensity as a percentage of maximum oxygen consumption (VO_{2max}) or maximum heart rate (HR_{max})[42], due to their linear relationship with intensity during incremental tests[43–45]. VO_{2max} and HR_{max}, as well as the intensity associated with AT, are widely used indicators of intensity in the aquatic environment[46–50]. However, as seen previously, immersion in the aquatic environment influences the magnitude of these cardiorespiratory responses during exercise.

To summarize the differences between land and water and provide better guidance on the magnitude of responses in each environment, Andrade et al.[5] performed a meta-analysis (i.e., an analysis that uses a statistical method that combines results from two or more separate studies) comparing cardiorespiratory parameters in incremental protocols between environments. The results showed lower values in the aquatic environment compared to the land environment, with mean differences of -7.07 mL.kg^{-1}.min^{-1} for VO_{2max}, $-6{,}19$ mL.kg^{-1}.min^{-1} for VO_{2AT}, $-11{,}71$ bpm for HR_{max} and $-15{,}29$ bpm for HR_{AT}. These data demonstrate that cardiorespiratory responses during exercise, whether at maximal or submaximal effort, are significantly lower in the aquatic environment compared to the land environment.

It is important to note that using VO_2 and HR values measured on land to prescribe aquatic exercises may put practitioners at greater cardiovascular risk, as they overestimate the intensity of training compared to the same parameter on land. Thus, specific maximal incremental tests in the aquatic environment are recommended to adequately determine maximal and submaximal values for an adequate and safe prescription, if feasible and safe. When prescribing based on HR_{max} measured in the aquatic environment, it is suggested that the maximal test protocol consider the use of exercises involving large muscle masses, such as stationary running, widely used in water aerobics sessions, to avoid underestimated or overestimated percentage values.

Progressive testing is a relatively simple and cost-effective practice, as it only requires a HR monitor, a metronome (which can be easily downloaded as a mobile app), and a structured maximal incremental test for the aquatic environment. However, it requires extra time for individual performance and may require medical supervision in some clinical populations. Ogonowska-Slodownik et al.[51] reviewed the specific characteristics of cardiorespiratory fitness tests in the aquatic environment and observed that the protocols were highly diverse and there is no widely accepted protocol for assessing cardiorespiratory fitness. Based on the protocols analyzed, the authors suggested three key test characteristics for clinical use: water temperature of 28 to 30°C with a maximum difference of 1°C between participants and/or test sessions; water depth adapted to the participants' aquatic experiences and abilities; and increments in metronome cadence intensity of 10 to 15 beats per minute (b.min^{-1})[51].

Heart rate deflection point

Cardiorespiratory parameters associated with AT can be utilized as a more precise and individualized method for prescribing aerobic exercise intensity compared to parameters measured at maximum effort since AT represents the point where the aerobic system fails to meet metabolic demands[42,52]. It is important to note that the standard methods for determining AT, which include the ventilatory threshold (VT) and lactate threshold (LT) measures, are often impractical in clubs and gyms because they require sophisticated analyzers and trained personnel to conduct these measurements. In addition, determining LT involves an invasive procedure. As an alternative, the HR deflection point (HRDP) serves as a practical and non-invasive indirect method for determining AT, based on the curvilinear relationship between HR and exercise intensity[53]. Therefore, when the incremental test is performed in the aquatic environment, additional HR data are easily obtained for prescription, in addition to the HR_{max} data. Thus, the HRDP is determined based on the analysis through visual inspection of the HR versus intensity curve, considering the deflection point at which the linearity in HR behavior breaks with the increase in intensity (Figure 2).

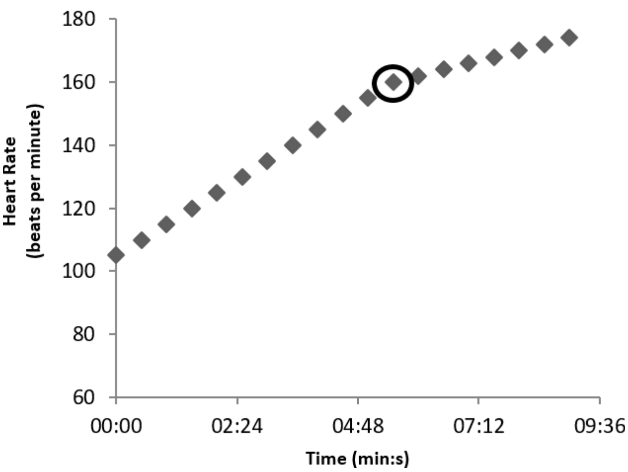

Figure 2 – Determination of the heart rate deflection point.

The HRDP was validated using the running modality on land[53], and in recent years, the application of this method for determining AT has been investigated in aquatic exercises[54–56]. Based on these studies, similar values and agreement of HR values corresponding to AT were observed between the VT (i.e., 2th VT) and HRDP methods during maximal incremental tests on an aquatic cycle ergometer performed by young men[55] and with stationary running exercise performed by older women[56], and between the LT (i.e., 2th LT) and HRDP methods in tests with stationary running performed by young men[54].

The use of HR associated with AT determined by the HRDP as a parameter for prescribing the intensity of aquatic exercises is an effective strategy to meet the principle of biological individuality since, based on the HRDP, it is possible to calculate percentages below or above the AT to prescribe the intensity of the desired training zone. It is noteworthy that studies have already verified the benefits of aerobic training in the aquatic environment prescribed by the HRDP in the health parameters of older adults, as well as those with diabetes and dyslipidemia[46,49,57–63]. In addition, the HRDP can be determined from a simple, economical, and non-invasive test, using only a HR monitor and a metronome throughout a structured maximum incremental test for the aquatic environment. On the other hand, this method has some limitations, such as the need for extra time to perform the tests and, in some cases, the requirement for medical monitoring, depending on the population evaluated.

Rating of perceived exertion

RPE is defined as the subjective intensity of effort, tension, discomfort, and/or fatigue felt or experienced during aerobic and resistance exercises[64]. This method is a practical possibility for controlling intensity directly associated with physiological parameters (VO_2 and HR), as demonstrated in different modalities and exercises throughout maximal tests in the aquatic environment[65–69].

The use of RPE as a prescription parameter in aquatic exercise programs has the advantage of greater external validity since it is an alternative for prescribing the intensity of training sessions performed by clinical populations, such as older adults, who frequently use medications (e.g., beta-blockers) that influence cardiovascular responses[70]. Furthermore, its application can be easily implemented for prescribing exercises in the aquatic environment, as it is a low-cost, simple, and easy-to-apply tool for group classes.

Likewise, no differences were observed between RPE values at maximum effort and AT intensity during incremental tests between aquatic and land environments; therefore, the RPE can be considered an interchangeable prescription parameter between the environments[5]. This characteristic can be considered an advantage of using RPE for intensity prescription in the aquatic environment, as this tool can help avoid the direct influence of the physiological effects of immersion and ensure an adequate intensity prescription without the need for specific tests. Considering the relevance of thresholds in exercise prescription, the literature has demonstrated values close to 12 and 16 on the

Borg scale (6-20) corresponding to the intensities of the first and second ventilatory thresholds, respectively, in water aerobics exercises for young and older women[56,65,71]. Thus, professionals can prescribe their exercise sessions using indexes above or below the AT, according to the objective and physical fitness of the practitioners. In addition, sessions can be structured either continuously, maintaining the same intensity throughout the session, or in an interval format, alternating the phases of greater effort with higher numerical anchors and phases of lesser effort, such as active recovery with lower numerical anchors.

The 6-20 scale proposed by Borg[72] is widely used in studies with aquatic exercise programs that use the RPE. It is important to highlight that studies have proven the effectiveness of the RPE exercise prescription using this scale[72], demonstrating increases in cardiorespiratory, neuromuscular, functional, quality of life, and blood pressure parameters after 12 to 28-week exercise programs[73–75]. On the other hand, for the method to be suitable to achieve the desired intensity and ensure the potential benefits of exercise programs, two points must be observed: 1) the scale must be positioned visibly for all participants during all sessions; 2) it is essential to spend time in the first training sessions so that sufficient information is provided on the application of this method, that is, individuals must be familiarized with the scale and, to this end, they must experience all the numerical anchors of the scale.

Cadence

Cadence is one tool some professionals use to control intensity during aquatic exercise sessions. This form of prescription is generally chosen to motivate participants, maintain synchronization, and achieve a certain intensity of effort[76]. Following this form of prescription, songs with the desired cadences are chosen to achieve a predetermined intensity of effort, and the tempo of the musical beat is synchronized with the execution of the segmental action during the aquatic exercise[76].

Increases in the cadence lead to increases in cardiorespiratory responses when we analyze the same exercise[17,77]. However, while it is possible to adjust the exercise load by using cadence, this approach does not consider individual differences in physiological responses to exercise, since a specific musical cadence may represent varying percentages of maximum effort for different individuals[65]. Observing the values reported by Alberton et al.[13] related to the mean and standard deviation for stationary running at the second ventilatory threshold (134 ± 13 b.min^{-1}), it can be observed that some participants in the sample reached the second threshold at approximately 121 b.min^{-1}, while others at 147 b.min^{-1}. Thus, when prescribing an exercise at a cadence of 130 b.min^{-1}, those who reached the threshold at 121 b.min^{-1} are likely in a predominantly anaerobic training zone, while those who reached the second threshold at 147 b.min^{-1} will be in a predominantly aerobic zone.

Another limitation of this method for controlling exercise intensity is that it does not take into account differences between exercises. Some studies have shown that different exercises at different pre-established cadences present different values in cardiorespiratory variables (VO_2, HR) and RPE in young[77], postmenopausal[78], and older women[79]. The results of these studies indicate that exercises with larger projected areas, both in the lower and upper limbs, lead to greater acute cardiorespiratory responses compared to exercises with smaller projected areas when performed at specific fixed cadences (60 - 140 b.min^{-1})[77–79]. Thus, it is observed that a specific musical cadence may correspond to different intensities when different exercises involving different ranges of motion and muscle groups are used throughout the session.

It is important to highlight that among the parameters used for prescribing aerobic exercises, cadence, although widely used in aquatic fitness worldwide, similar to aerobic gymnastics sessions in a land environment, has the least scientific evidence to justify its use. The evidence available in the literature mainly associates cadence with other parameters controlling the intensity of aerobic exercises (i.e., VO_2, HR, and RPE)[66,68,80] during incremental tests. Regarding the chronic effects of aquatic aerobic training prescribed by cadence, Raffaelli et al.[81] observed significant improvements in cardiorespiratory fitness, muscular strength, balance, and body composition in young women. However, it is worth noting that this study[81] has the limitation of having a pre-experimental design without a control group. Therefore, caution is needed when interpreting and generalizing the results, as pre-experimental studies may have their internal validity questioned. In addition, cadence is an external load marker, meaning that the choice of this parameter is based on personal preferences for musical rhythm. Therefore, in addition to this marker not being precise enough to generate effects, it also raises concerns about the safety of the prescription.

Based on this evidence, cadence is the least recommended parameter when the goal is cardiorespiratory conditioning, especially in heterogeneous groups, because it does not consider the principle of biological individuality. On the other hand, using music during aquatic exercise sessions may be relevant for coordination or cognition in choreographed classes or motivation during the sessions.

Final considerations on aerobic exercise prescription parameters

Different parameters can be used to prescribe aquatic aerobic exercises. Although physiological parameters are more precise and individualized, they require attention since using VO_2 and HR values measured in a land environment to prescribe aquatic exercises may put individuals at greater cardiovascular risk by overestimating the intensity of the training due to the effects of immersion. Therefore, it is essential to emphasize the importance of specific maximal incremental tests in the aquatic environment, when feasible and safe, to adequately determine the maximal and submaximal values for an appropriate and safe prescription.

As a more accessible option, the RPE is an effective method for prescribing aquatic exercises and can be safely used in different populations. In addition, this tool can be easily implemented, as it is low-cost, simple, and easy to apply for groups. However, familiarization sessions with the scale are necessary to provide sufficient information before starting training programs so that the method is suitable for achieving the desired intensity. In contrast, cadence is not recommended for cardiorespiratory conditioning due to the lack of load individualization, which can put practitioners at cardiovascular risk.

Effects of aquatic aerobic exercise programs in the vertical position on health-related components of physical fitness in young and older adults

Studies on the effects of aquatic exercise programs on fitness components have been developed since the 1990s, with most focusing on combined (i.e., aerobic and strength) or multicomponent training models (i.e., exercises for three or more fitness components). However, research on the cardiorespiratory and neuromuscular adaptations of exclusively aerobic aquatic training has gained prominence, especially in the last decade[46,49,57,61,62,73–75,82–93].

A recent meta-analysis[94] summarized the effects of aquatic aerobic exercise programs compared to control groups (i.e., groups with no exercise, non-periodized activities, or health education) on physical fitness in older adults. The results indicated that aerobic exercises promoted a significant improvement in cardiorespiratory capacity, with an average difference of 5.18 $ml.kg^{-1}.min^{-1}$ in VO_{2peak}, muscular strength, with an average difference of 3.03 kg in the one-repetition maximum load in the knee extensors, and agility/dynamic balance, with a standardized difference of 0.63. However, no differences were found for flexibility. These additional adaptations in muscle strength can be attributed mainly to the overload imposed by the drag force generated by movement in the water[3]. Furthermore, aquatic aerobic exercises, associated with the buoyancy force, offer greater instability during exercises and appear to have provided sufficient stimulus to improve agility/dynamic balance in older adults.

In this context, it can be said that aerobic training programs in the aquatic environment can exhibit characteristics and adaptations similar to multicomponent training, aligning with exercise guidelines for older adults, which recommend exercise programs aimed at improving cardiorespiratory capacity, muscular strength, and balance[95]. It is worth noting that the study by Andrade[94] did not include results on the effects of aquatic aerobic training programs on the responses of young adults, as there were not enough original studies to perform a meta-analysis with this population. Table 1 presents the characteristics of aquatic aerobic training programs and the main results of the studies conducted with apparently healthy young and older adults.

Continuous versus interval aerobic training programs

Regarding different aerobic training models, some studies have compared continuous and interval training programs in the deep water running modality[75,92] and in water aerobics[73,74,82]. In deep-water running, Pasetti et al.[92] observed similar increases in cardiorespiratory capacity in obese women, with reductions in resting HR only after interval training. Reichert et al.[75] observed improvements after both training programs in cardiorespiratory capacity, upper and lower limb muscle strength, dynamic agility/balance, and lower limb flexibility in older adults, with no superiority of either model.

Table 1 – Characteristics of aerobic training programs in aquatic environment and the main results of studies carried out with apparently healthy young and older adults.

Study	Population/Intervention	Intensity	Main results
Andrade et al.[73,74]	**Population:** physically inactive older women **Mode:** water aerobics exercises **Duration:** 12 weeks **Frequency:** 2 times a week **Session duration**: 44 min (4 min – warm-up, 36 min – main part, 4 min – cool-down)	**Continuous Training:** Weeks 1-4 – RPE 13 Weeks 5-8 – RPE 14 Weeks 9-10 – RPE 15 Weeks 11-12 – RPE 16 **Interval Training:** Weeks 1-4 – 9 × (2 min RPE 16 + 2 min RPE 11) Weeks 5-8 – 12 × (1.5 min RPE 17 + 1.5 min RPE 11) Weeks 9-12 – 18 × (1 min RPE 18 + 1 min RPE 11)	Improvements in cardiorespiratory capacity, lower limb muscle strength and walking speed were observed after both training programs. No differences were observed for agility.
Bocalini et al.[83]	**Population:** physically inactive older women **Mode:** water aerobics exercises **Duration:** 12 weeks **Frequency:** 3 times a week **Session duration:** 60 min (10 min – warm-up, 45 min – main part, 5 min – cool-down)	70% age-predicted HR_{max}	Improvements in cardiorespiratory capacity, muscular strength of the upper and lower limbs, balance, agility, and flexibility of the lower limbs were observed.
Broman et al.[84]	**Population:** older women **Mode:** deep-water running **Duration:** 8 weeks **Frequency:** 2 times a week **Session duration:** 48 min (7 min – warm-up, 30 min – main part, 7 min – cool-down)	Block 1: 2 × 3 min 75% HR_{max} + 2 min 80% HR_{max} + (40 s stimulus: 20 s recovery) Block 2: 2 × 3 min 75% HR_{max} + 2 min 85% HR_{max} + (20 s stimulus: 20 s recovery) Block 3: 3 × 1 min 75% HR_{max} + 2 min 85% HR_{max} + (15 s stimulus: 15 s recovery)	Improvement in cardiorespiratory fitness parameters was observed.
Costa et al.[57]	**Population:** physically inactive older women **Mode:** water aerobics exercises **Duration**: 10 weeks **Frequency:** 2 times a week **Session duration:** 45 min (30 min – main part)	Weeks 1-5 – 6 × (4 min 90-95% HR_{AT} + 1 min 80-85% HR_{AT}) Weeks 6-10 – 6 × (4 min 95-100% HR_{AT} + 1 min 85-90% HR_{AT})	Improvements in cardiorespiratory capacity and lower limb muscle strength were observed.
Farinha et al.[82]	**Population:** older men and women **Mode:** water aerobics exercises **Duration:** 28 weeks **Frequency:** 2 times a week **Session duration:** 45 min (10-15 min – warm-up, 20-30 min – main part, 5-10 min – cool-down)	**Continuous Training:** 60-70% HR_{max}. **Interval Training:** 30 s stimulus at 70-80% HR_{max} + 1 min intervals at 60-70% HR_{max}.	Improvements in cardiorespiratory fitness and muscular strength of the lower and upper limbs were observed after both training programs. No differences were observed in agility and flexibility of the lower and upper limbs.
Häfele et al.[62] Silva et al.[49]	**Population**: physically inactive older women **Mode:** water aerobics exercises **Duration:** 12 weeks **Frequency:** 2 times a week **Session duration:** 24-27 min – main part	Weeks 1-3 – 85-90% HR_{AT} Weeks 4-6 – 90-95% HR_{AT} Weeks 7-9 – 95-100% HR_{AT} Weeks 10-12 – 12 × (1 min 105-110% HR_{AT} + 1 min 80-85% HR_{AT})	Improvements in cardiorespiratory capacity, lower limb strength, and agility/dynamic balance were observed.
Häfele et al. [63]	**Population:** physically inactive older women **Mode:** water aerobics exercises **Duration:** 16 weeks **Frequency:** 2 times per week **Session duration:** ≅ 45 min (5 min – warm-up, 36 min – main part, 5 min – cool-down)	Weeks 1–2 – 80–85% HR_{AT} Weeks 3–4 – 85–90% HR_{AT} Weeks 5–7 – 90–95% HR_{AT} Weeks 8–10 – 95–100% HR_{AT} Weeks 11–13 – 2 min 100–105% HR_{AT} + 1 min RPE 13 Weeks 14–16 – 2 min 105–110% HR_{AT} + 1 min RPE 13.	Improvements in cardiorespiratory capacity and lower limb strength were observed. No differences were observed for agility and lower limb flexibility.
Haynes et al.[85]	**Population:** physically inactive older men and women **Mode:** walking in a shallow pool **Duration:** 24 weeks **Frequency:** 3 times a week **Session duration:** 15-50 min.	15 minutes of exercise at 40%-45% HR_{res}, increasing to 50 minutes at 55%-65% HR_{res} throughout the study, with one interval exercise session and two continuous exercise sessions per week.	Improvement in cardiorespiratory capacity was observed.
Irandoust et al.[86]	**Population:** physically inactive older men and women **Mode:** walking and water aerobics **Duration:** 8 weeks **Frequency:** 3 times a week **Session duration:** 50 min (10 min – warm-up, 30 min – main part, 10 min – cool-down)	Weeks 1-4 – 50% HR_{max} Weeks 5-8 – 60% HR_{max}	Improvement in balance was observed.

Continue…

Contiuation of **Table 1 –** Characteristics of aerobic training programs in aquatic environment and the main results of studies carried out with apparently healthy young and older adults.

Study	Population/Intervention	Intensity	Main results
Kaneda et al.[90]	**Population:** older men and women **Mode:** walking and running in a deep-water pool **Duration:** 12 weeks **Frequency:** 2 times a week **Session duration:** 80 min (10 min – warm-up on land; 20 min – water walking exercise; 30 min – deep water running, 10 min – rest on land; and 10 min – recreation and relaxation in the water)	NR	Improvement in balance was observed.
Kanitz et al. [46]	**Population:** physically inactive older men **Mode:** deep-water running **Duration:** 12 weeks **Frequency:** 3 times a week **Session duration:** 45 min (30 min – main part)	Weeks 1–4 – 6 × (4 min 85–90% HR_{AT} + 1 min < 85% HR_{AT}) Weeks 5–8 – 6 × (4 min 90–95% HR_{AT} + 1 min < 85% HR_{AT}) Weeks 9–12 – 6 × (4 min 95–100% HR_{AT} + 1 min < 85% HR_{AT})	Improvements in cardiorespiratory capacity and muscular strength were observed.
Martínez et al.[88]	**Population:** physically inactive older women **Mode:** not specified **Duration:** 12 weeks **Frequency:** 5 times a week **Session duration:** 50 min (10 min – warm-up, 30 min – main part, 10 min – cool-down)	Weeks 1-6 – 40-50% HR_{res} Weeks 7-12 – 50-60% $HR_{res.}$	Improvement in functional autonomy was observed.
Pasetti et al. [92]	**Population:** women with obesity and physically inactive **Mode:** deep-water running **Duration:** 12 weeks **Frequency:** 3 times a week **Session duration:** 47 min (5 min – warm-up, 40 min – main part, 2 min – cool-down)	Week 1 – adaptation to the aquatic environment and familiarization with the deep water running. **Continuous Training:** Weeks 2-3 - 65-70% HR_{res}. Weeks 4-6 - 70-75% HR_{res}. Weeks 7-9 - 75-80% HR_{res}. Weeks 10-12 - 80-85% HR_{res}. **Interval Training:** 70-75% HR_{res} with 15s sprints and 30s active recovery: Weeks 2-3 - 2x4 sprints Weeks 4-6 - 2x5 sprints Weeks 7-9 - 3x4 sprints Weeks 10-12 - 3x5 sprints	Improvement in cardiorespiratory capacity was observed after both training programs.
Pernambuco et al.[89]	**Population:** physically inactive older women **Mode:** water aerobics exercises **Duration:** 8 months **Frequency:** 2 times a week **Session duration:** 50 min (five 7-min phases – main part, 5 min – cool down)	NR	Improvements in agility and functional autonomy were observed.
Raffaelli et al.[81]	**Population:** physically active young women **Mode:** water aerobics exercises **Duration:** 9 weeks **Frequency:** 2 times a week **Session duration:** 45 min (10 min – warm-up, 30 min – main part, 5 min – cool-down)	Weeks 1-2 – "moderate" intensity (i.e. musical cadence at 110-120 $b.min^{-1}$; 120-130 bpm; 130-140 $b.min^{-1}$) Weeks 3-5 – "moderate" to "strong" intensity (i.e. musical cadence at 120-130 $b.min^{-1}$; 130-140 $b.min^{-1}$) Weeks 6-9 – "strong" intensity (i.e. musical cadence at 130-140 $b.min^{-1}$).	Improvements in cardiorespiratory capacity, muscle strength, and balance were observed. No differences were observed in the flexibility of the upper and lower limbs.
Reichert et al.[75]	**Population:** physically inactive older women **Mode:** deep-water running **Duration:** 28 weeks **Frequency:** 2 times a week **Session duration:** 45 min (5 min – warm-up; 30-36 min – main part, 4-10 min cool-down)	**Continuous Training:** Weeks 1-4 – RPE 13 Weeks 5-8 – RPE 15 Weeks 9-12 – RPE 16 Weeks 12-16 – RPE 13 Weeks 17-20 – RPE 15 Weeks 21-24 – RPE 16 Weeks 25-28 – RPE 17 **Interval Training:** Weeks 1-4 – 10 × (2 min RPE 15 + 1 min RPE 11) Weeks 5-8 – 6 × (4 min RPE 17 + 1 min RPE 11) Weeks 9-12 – 7 × (4 min RPE 17 + 30 s RPE 11) Weeks 12-16 – 10 × (2 min RPE 15 + 1 min RPE 11) Weeks 17-20 – 6 × (4 min RPE 17 + 1 min RPE 11) Weeks 21-24 – 7 × (4 min RPE 17 + 30 s RPE 11) Weeks 25-28 – 12 × (2 min RPE 18 + 1 min RPE 15)	Improvements in cardiorespiratory capacity, upper and lower limb muscle strength, agility/dynamic balance, and lower limb flexibility were observed after both training programs. No differences were observed for upper limb flexibility.

Continue…

Continuation of **Table 1 –** Characteristics of aerobic training programs in aquatic environment and the main results of studies carried out with apparently healthy young and older adults.

Study	Population/Intervention	Intensity	Main results
Rica et al. [93]	**Population:** older women with obesity and physically inactive **Mode:** water aerobics exercises **Duration:** 12 weeks **Frequency:** 3 times a week **Session duration:** 60 min (10 min – warm-up, 45 min – main part, 5 min – cool-down)	70% age-predicted HR_{max}	Improvements in cardiorespiratory capacity and muscle strength of the upper and lower limbs were observed.
Silva et al. [91]	**Population:** older men and women **Mode:** water aerobics exercises **Duration:** 12 weeks **Frequency:** 2 times a week **Session duration:** 45 min (5 min – warm-up, 40 min – main part, 5 min – cool-down)	50%–60% HR_{max} or a Borg scale score of 13–14 points – 36 × (30 s with 10 s intervals)	Improvements in balance, agility and flexibility were observed only in the group with depression.
White & Smith[87]	**Population:** young men and women **Mode:** water aerobics exercises **Duration:** 8 weeks **Frequency:** 3 times a week **Session duration:** 50 min (5 min – warm-up, 40 min – main part, 5 min – cool-down)	70-75% HR_{res}	Improvements in muscle strength of the lower and upper limbs were observed.

RPE = rating of perceived exertion; HRmax = maximum heart rate; HR^{AT} = heart rate associated with the anaerobic threshold; HRres = heart rate reserve; NR = not reported; bpm = beats per minute.

In water aerobics, Farinha et al.[82] observed improvements in cardiorespiratory fitness and upper and lower limb muscle strength after both training programs with the continuous model showing superiority (increases of 16.8%) compared to the interval model (increases of 10.8%) for cardiorespiratory capacity. Conversely, Andrade et al.[73,74] observed improvements in cardiorespiratory capacity, lower limb muscle strength, and walking speed, with no significant difference between the models. Thus, there is still no consensus in the literature on the superiority of either the continuous or interval model in aquatic training programs, indicating an important gap to be investigated.

Aerobic training programs versus other training models

Some studies have compared the effects of aerobic training programs with strength[57] or combined[46,49,62,63,82] training programs on the physical fitness components of older adults. The meta-analysis cited above[94] also compared aerobic and combined training programs in the aquatic environment. The results demonstrated that aerobic training led to greater increases in cardiorespiratory responses, with similar improvements in lower limb muscle strength and agility/dynamic balance compared to combined training [94]. Meanwhile, Costa et al.[57] compared the adaptations induced by strength and aerobic programs and observed that aerobic training appeared to be more efficient than strength training in improving cardiorespiratory responses, while both training models produced similar increases in muscle strength.

In summary, aerobic exercises in the aquatic environment are most recommended to improve cardiorespiratory capacity and emerge as an effective modality for increasing muscular strength and agility/dynamic balance, especially in the first weeks of training. Furthermore, aerobic training offers a time-efficient alternative compared to combined training since it eliminates the need to include specific blocks of strength exercises in the initial training phase.

Final considerations

Collectively, the available evidence suggests that aquatic aerobic training appears to be an effective training alternative for improving different components of health-related physical fitness in young and older adults. This type of training may exhibit characteristics and adaptations similar to those of multicomponent training. However, for the benefits of aerobic training programs to be achieved effectively, the prescription must take into account the specificity of the environment. Throughout this review, we present several possibilities for prescribing the intensity of aerobic exercises in the aquatic environment. From the authors' perspective, no parameter should be considered the most appropriate in absolute terms; instead, we offer options so that professionals can choose the one that best suits the reality of their practice. For example, in individual sessions, where personalized work is possible, HR control may be a viable option. However, in group sessions, the RPE allows for a more pragmatic approach.

Furthermore, it is important to highlight that future studies should explore the therapeutic implications of the aquatic environment for other parameters related to health promotion for clinical populations. Similarly, other aquatic training models (e.g., strength, flexibility, balance, or combined programs) have distinct characteristics and can expand the benefits of the aquatic environment, offering diverse and effective options for different purposes. Finally, we emphasize that it is essential for scientific knowledge produced in all areas to be increasingly disseminated and applied in professional practice. It is important to encourage new studies that bring science closer to the target audience to ensure that these benefits are widely known and used in exercise programs aimed at promoting health.

Conflict of interest

The authors declare no conflict of interest.

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Author's contributions

Andrade LS: Conceptualization; Investigation; Data curation; Visualization; Writing – original draft; Approval of the final version. Alberton CL: Conceptualization; Investigation; Data curation; Supervision; Visualization; Writing review & editing; Approval of the final version.

Declaration regarding the use of artificial intelligence tools in the article writing process

The Grammarly AI writing assistance tool was used to review the English version of the article.

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The contents underlying the research text are contained in the manuscript.

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Reviewers' assessment

The reviews of this article were originally conducted in Portuguese. This version has been translated using ChatGPT and subsequently reviewed by the Chief Editors.

Reviewer A

Anonymous

Format

- Does the article comply with the manuscript preparation guidelines for submission to the Revista Brasileira de Atividade Física e Saúde?
  Yes
- Regarding formal aspects, is the manuscript well-structured, containing the following sections: introduction, methods, results, and discussion (with conclusion as part of the discussion)?
  Yes
- Is the language appropriate, with the text being clear, precise, and objective?
  Yes
- Was any evidence of plagiarism observed in the manuscript?
  No
  Suggestions/comments:
- The format is appropriate.

Abstract

- Are the abstract and resumo appropriate (including: objective, information about study participants, variables studied, main results, and a conclusion) and do they reflect the manuscript's content?
  Yes
  Suggestions/comments:
- The abstract is appropriate.

Introduction

- Is the research problem clearly stated and defined?
  Yes
- Is the research problem adequately contextualized in relation to existing knowledge, moving from general to specific?
  Yes
- Are the justifications (including the authors' assumptions about the problem) for the study's need well established in the text?
  Yes
- Are the references used to support the research problem current and relevant to the topic?
  Yes
- Is the objective clearly stated?
  Yes
  Suggestions/comments:
- It would be interesting to justify the choice of aerobic training over a broader approach to aquatic training prescription, considering its various possibilities such as strength training, balance, among others. Given that the primary outcome of the study is health, it would be pertinent to highlight that aerobic training often plays a central role in physical training and is frequently complemented by strength training, especially to improve cardiovascular and metabolic parameters.

Methods

- Are the methodological procedures generally appropriate for addressing the research problem?
  Not applicable
- Are the methodological procedures adopted for the study sufficiently detailed?
  Not applicable
- Was the procedure for selecting or recruiting participants appropriate for the problem studied and clearly, objectively described?
  Not applicable
- Were details provided about the instruments used for data collection, their psychometric properties (e.g., reproducibility, internal consistency, and validity), and, when relevant, the operational definitions of variables?
  Not applicable
- Is the data analysis plan appropriate and well described?
  Not applicable
- Are the inclusion and/or exclusion criteria for the sample described and appropriate for the study?
  Not applicable
- Did the authors provide information on the ethical procedures adopted for the research?
  Not applicable
  Suggestions/comments:
- These points are not applicable as the study is a narrative review.

Results

- Is the use of tables and figures appropriate and does it facilitate the clear presentation of the study results?
  Yes
- Is the number of illustrations in line with the journal's submission guidelines?
  Yes
- Are the number of participants at each stage of the study, as well as reasons for dropouts and refusals, presented in the manuscript?
  Not applicable
- Are participant characteristics presented and sufficient?
  Not applicable
- Are the results appropriately presented, highlighting the main findings and avoiding unnecessary repetition?
  Yes
  Suggestions/comments:
- The results are appropriate.

Discussion

- Are the main findings of the study presented?
  Yes
- Are the study's limitations and strengths presented and discussed?
  Not applicable
- Are the results discussed in light of the study's limitations and existing knowledge?
  Yes
- Do the authors discuss the potential contributions of the main findings to scientific development, innovation, or real-world application?
  Yes
  Suggestions/comments:
- The discussion is appropriate.

Conclusion

- Is the study's conclusion appropriately presented and consistent with the objective?
  Yes
- Is the study's conclusion original?
  Yes
  Suggestions/comments:
- The conclusion is based on the outcome "health-related physical fitness." In fact, the data presented—such as aerobic fitness, muscular strength, and balance—are related to this outcome. However, this information does not fully align with the outcome expressed in the title ("health promotion"), a broader term that encompasses other variables not discussed in the paper. Therefore, I believe it is important to either change the title or add information related to health in the manuscript.

References

- Are the references up to date and sufficient?
  Yes
- Are most references from original research articles?
  Yes
- Do the references follow the journal's format and quantity guidelines?
  Yes
- Are in-text citations appropriate, i.e., do they reference sources that truly support the statements made?
  Yes
  Suggestions/comments:
- References are appropriate.

Comments to the Author

- The article titled "Aquatic aerobic exercise for health promotion: from scientific foundations to practical applications" aims to present scientific knowledge related to the prescription of aquatic aerobic training, offering a comprehensive understanding from scientific foundations to practical applications for professionals working with aquatic modalities.
- The paper is extremely relevant for professionals in the field of aquatic training in Brazil, as it provides evidence-based guidance on how to prescribe aquatic exercises safely and effectively, promoting significant health benefits. Furthermore, the version in Portuguese enhances the accessibility of information from primary articles, which are often published in English and in restricted-access journals. Finally, the article serves as an excellent reference for teaching aquatic activity-related courses at the undergraduate level and is a valuable reading recommendation for students in these courses.
- I recommend only minor revisions for publication:
- Title: Specify that the exercises are performed in a vertical position.
- Introduction: Justify the choice of aerobic training over a broader approach to aquatic training prescription. Given that the study's outcome is health, highlight the central role of aerobic training and its

frequent complementarity with strength training, especially for improving cardiovascular and metabolic parameters.

- Page 7 – Define the term "apparent weight."
- Page 8 – After the sentence on joint safety in aquatic environments, highlight that reduced joint overload allows for easier progression in training volume/intensity compared to land-based exercise, which is important for health outcomes.
- Page 8 – Replace "up" and "down" phases with "ascending phase" (moving the floating equipment toward the water surface) and "descending phase" (pushing the floating equipment toward the pool bottom) for better clarity.
- Page 8 – Complement the sentence: "… resistance imposed by water is greater" with "... than the resistance imposed by air in land-based exercises."
- Page 9 – Consider a brief discussion on the relationship between projected area and speed. Clarify that using equipment does not necessarily increase water resistance if movement speed decreases.
- Page 13 – Replace "durantes" with "durante".
- Pages 12–13 – Since the paper focuses on "health promotion," include physiological effects of hydrostatic pressure and thermal conductivity that relate to health, e.g., reduced blood pressure, suppression of the renin-angiotensin-aldosterone system, and increased atrial natriuretic peptide.
- Page 14 – Write out the acronym IEP (presumably "Índice de Esforço Percebido") on first mention.
- Page 14 – Replace "influência" with "influencia".
- Page 17 – Replace "em parâmetros de saúde em idosos, indivíduos diabéticos e dislipidêmicos" with "em parâmetros de saúde de pessoas idosas, com diabetes e com dislipidemia."
- Page 17 – Correct: "associada à parâmetros" to "associada a parâmetros".
- Page 18 – Clarify that "16" refers to the Borg scale (6–20). Also, consider discussing the relationship between the first ventilatory threshold and perceived exertion found in Alberton et al.'s study.
- Page 20 – In "cadence of music increases cardiorespiratory responses," clarify that this applies when comparing the same exercise with different cadences.
- Page 20 – In "ventilatory (134 ± 13 bpm)...", clarify that "bpm" here refers to musical beats per minute. Use "$b.min^{-1}$" for clarity and explain it in the text.
- Subheading – In "Effects of aquatic aerobic exercise programs on physical fitness components in adults and older adults," consider referencing "health" explicitly to align with the article's title.
- Page 22 – When discussing cardiorespiratory and neuromuscular adaptations, add minimum and maximum improvement percentages observed across studies.
- Page 23 – Review the sentence regarding Andrade et al.'s study and clarify why meta-analysis on young adults wasn't included.
- Table 1 – Why were only apparently healthy populations selected? Note that some included studies (e.g., Costa et al., Pasetti et al., Rica et al., Silva et al.) involved participants with dyslipidemia, obesity, or depression.
- Page 23 – Replace "mulheres obesas" with "mulheres com obesidade".
- Page 25 – Correct "aptidão física relacionados a saúde" to "aptidão física relacionados à saúde".
- Final Considerations – The conclusion is based on "health-related physical fitness," but the title suggests a broader concept of "health promotion." Consider modifying the title or including broader health-related information.
- Table 1 – Replace "obesas" with "pessoas com obesidade".
- Figure 2 – Add axis labels.

Final decision

- Minor revisions required

Reviewer B

Rochelle Rocha Costa
University of Brasília, Brasília, Federal District, Brazil.

- The study entitled "Aquatic aerobic exercise in health promotion: from scientific foundations to practical applications" aims to present knowledge related to the prescription of aerobic training in an aquatic environment in an accessible way, seeking to provide a comprehensive understanding from scientific foundations to practical applications for physical education professionals working with aquatic modalities. This is an article carefully crafted in terms of content and writing, clearly addressing basic concepts such as the effects of the physical properties/characteristics of water on the immersed body and their relationship to bodily movement in aquatic environments. In fact, the Portuguese-language literature on this topic is scarce, and there is a demand to be met regarding the dissemination

of knowledge to those prescribing aquatic aerobic exercises. Furthermore, as written, the article constitutes a text that is understandable even to individuals who practice these activities.
- I recommend a few adjustments to improve the manuscript. In general, I suggest making it clear that this study is limited to addressing issues related to vertical-position aquatic aerobic training, considering that it does not cover content related to swimming or other aquatic exercise modalities performed in the horizontal position.

Title
- Page 1, line 1: At the end of the title "às aplicações práticas," add a grave accent (à with crase in Portuguese – not applicable in English but important for the Portuguese version).

Abstract
- Page 1, lines 11 to 14: To better align the title with the objective, I recommend addressing "health promotion" in the objective as well, or possibly including the term "prescription" in the title, depending on the focus the authors wish to emphasize. It is also worth considering replacing "health promotion" in the title with "health-related physical fitness." In my opinion, keeping "health promotion" in the title as an expected outcome may lead readers to expect that the text will discuss outcomes beyond physical fitness, such as cardiometabolic, bone health parameters, etc.—which are not covered. In fact, in the final considerations, the text aligns more closely with the scope of "health-related physical fitness."
- Page 1, line 19: The phrase "...de cada parâmetro" is vague. I suggest clarifying by specifying the type of parameter. Example: "of each intensity prescription parameter."
- Page 1, lines 22 and 23: I recommend adding a clarification at the end of the sentence: "...in special situations (e.g., older adults, previously sedentary individuals, clinical populations)" or something similar that corresponds to the existing literature.
- After making these changes to the Abstract, ensure the same adjustments are reflected in the English version.

Introduction
- The introduction is well written, both in terms of content flow—guiding the reader from a more general topic to a more specific one—and in justifying the need for the study.
- Page 3, line 8: I suggest replacing "em contrapartida" (which indicates opposition) with a word that suggests caution, such as "no entanto" (however).
- Page 4, lines 2 and 3: At the end of the sentence, the verb "ajudar" (help) needs clarification. I suggest adding an object to complete the sentence meaningfully.

Main Body
- The chapter "PHYSICAL PROPERTIES OF WATER AND THEIR EFFECTS ON THE IMMERSED BODY" is well written and clearly and succinctly addresses the main characteristics of the aquatic environment and how they affect the human body during immersion and movement.
- This chapter includes both classical references from the field of physics and current studies that apply this knowledge.
- I only suggest adding, on page 11, lines 3 to 7, the increase in the secretion and release of atrial natriuretic peptide (ANP), which has great clinical relevance, especially when aiming for health promotion in people with overweight, obesity, dyslipidemia, and metabolic syndrome.
- The chapter "AEROBIC EXERCISE PRESCRIPTION IN THE AQUATIC ENVIRONMENT" addresses the main parameters for prescribing aerobic training intensity in water. It summarizes each prescription method and supports its recommendations with specific and up-to-date literature.
- Page 12, lines 9 to 11: I suggest including a reference to support the statement that intensity control is directly related to the effectiveness and safety of the exercise program. If none is available, consider softening the statement.
- Page 14, line 18: The authors state that "Cardiorespiratory parameters associated with lactate threshold (LT) can be used as a more accurate and individualized way to prescribe the intensity of aerobic exercises." I suggest clarifying: more accurate in comparison to which other parameters?
- In the chapter "EFFECTS OF AEROBIC EXERCISE PROGRAMS PERFORMED IN THE AQUATIC ENVIRONMENT ON PHYSICAL FITNESS COMPONENTS OF ADULTS AND OLDER ADULTS," the term "training" is often

used to refer to the training program. I recommend using caution and possibly replacing the word, since "training" can imply a single session rather than the entire program. Regarding the content covered, I consider the chapter adequate and complete.

Final Considerations

- Page 23, lines 11 to 13: Concluding about safety implies that it was addressed throughout the text. Therefore, there are two options: (1) remove the word "safe" from this sentence; or (2) ensure that safety in aerobic training programs is discussed throughout the text.
- I find it relevant that the authors, in this chapter, state their position on the best (or most recommended) intensity prescription parameter for adults and older adults—even if this involves briefly mentioning key considerations.

Decision

- Minor revisions required