Monitoring the Intensity of Aquatic Resistance Exercises With Devices That Increase the Drag Force: An Update

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SUMMARY

AQUATIC EXERCISE HAS GROWN IN POPULARITY BUT HAS BEEN MAINLY USED FOR REHABILITATION AND GENERAL AEROBIC TRAINING. IT HAS BEEN DIFFICULT TO CONTROL THE INTENSITY OF AQUATIC RESISTANCE EXERCISES, WHICH HAS LIMITED THEIR USE. RECENT RESEARCH STUDIES HAVE DEVELOPED METHODS FOR CONTROLLING AND MONITORING INTENSITY LEVELS DURING AQUATIC RESISTANCE EXERCISES, WHICH MAY INCREASE THEIR USE IN BOTH THE GENERAL AND ATHLETIC POPULATIONS.

INTRODUCTION

The responses and physiological effects of the practice of aerobic exercises in an aquatic environment are well known, as well as the methods of application. However, the same is not true for the use of resistance exercises in water, especially concerning the control of exercise intensity and progression of a training regimen to ensure an adequate stimulus for adaptation. Also, more research is necessary to determine all the physical effects resulting from this type of activity performed by recreational exercisers. The most recent resistance training guidelines that have been published in the last 10 years include position statements by well-respected exercise- and health-related organizations, but these do not adequately address the basic aquatic resistance exercise training recommendations for both recreational exercisers and athletes, even though there are now more investigations on the subject. Thus, to increase the knowledge and use of these training methods in both the scientific community and by the practitioner, the purpose of this review is to summarize the studies that have examined specifics about the control of intensity during aquatic resistance exercises and their use and the progression of aquatic resistance programs.

The guidelines for performing an aquatic resistance training program are similar to those for strength training in general (21,30,34). By definition, strength is the neuromuscular ability to overcome or oppose external resistance by means of muscular force production. This external resistance might be created when training, for example, with weights, elastic bands, air devices, or even with movements in water. Regardless of the material used, to gain improvements in physical performance or in health, it is necessary to create muscular tension so that the muscle groups involved are stimulated to adapt. However, this muscular tension must reach a minimum threshold to create enough physiological stress to produce the desired adaptations. The aquatic environment has not typically been considered as one for optimal training, possibly due to the lack of widespread availability of swimming pools for this type of use and the perception that water-based exercises may not be able to create an intensity of training similar to the one that is obtained by the same resistance exercises on dry land. However, recent studies have begun to investigate whether this is true, and the findings will be presented in this work.

KEY WORDS:
aquatic training; resistance training; muscular strength
immersion of both the body and the training device with the purpose of emphasizing some of the specific physical properties of water (buoyancy and drag force) and promoting positive adaptations at the neuromuscular level (34). There are 2 primary types of aquatic devices: flotation and surface. The use of flotation devices generates muscular tension (force) when moved in opposition to the flotation (buoyancy) force (34).

These devices are limited for general use because it is necessary to have a large variety of flotation devices for the different levels of strength of the different muscular groups in the same exerciser and for the different muscular fitness levels of all exercisers. This poses an important problem because an aquatic facility will likely not have enough financial resources for these training devices. In addition, there are some movements that are difficult to perform in a comfortable position. Thus, it is recommended that other surface aquatic devices be used for exercise and training (9). The use of surface devices generates muscular tension when moved in opposition to the water. Thus, the drag force is responsible for the resulting resistance during the use of the surface device and can be defined as a resistant force opposite to the direction of movement of an object, which can occur both in front of and behind the object that is moved (29,28). The magnitude of the drag force depends mainly on the surface area and the shape of the device but is also determined by the velocity of movement (cadence) such that an increase in the velocity of movement exponentially increases the drag force (24,29,28).

Aquatic resistance exercises have been used in programs of muscular rehabilitation for some time because of their intrinsic benefits, which include improving the range of motion and circulation and proprioceptive capacity (9,12,37,38). There is also evidence of some works that aquatic resistance exercises do have efficacy in the neural and structural adaptations of the muscular system (11,31,35,40). But the lack of methodological criteria that control for the objective performance of the exercises has resulted in these exercises not being heavily used in the fitness setting (26,30). In addition, the majority of research findings are primarily from individuals who were undergoing rehabilitation or who had minimal strength training background (1,6,35,36,40,41,43), and the results are not as easily applied to the recreational or athletic population as part of a regular strength training regimen. Overall, when compared with dryland resistance training, there is a lack of objective criteria for the control and progression of the intensity of aquatic resistance exercises. In addition, there are other factors, such as the stability of the body in the water, that increase the complexity of the prescription of these exercises (14,26,30).

In general, the limitations of the use of aquatic resistance exercises include the need to understand the specific properties of water and the manipulation of those properties and the guidelines for designing a resistance training program. If these variables are not properly understood, it can lead to the misuse of this type of exercise and improper training recommendations. For example, it has been suggested that swim training alone can be used for the improvement of strength, but there are studies that demonstrate that the maximum level of muscle activation when swimming at maximum velocity is only about 35% of maximum voluntary contractile strength (5,7,8), which is less than the minimum threshold of activation known to stimulate muscular adaptations in the general population (44). Although swim training is certainly beneficial for cardiorespiratory improvements and may improve strength in a rehabilitation or weak individual, it is not enough to improve strength in the recreational exerciser.

More recently, the use of aquatic training programs in a vertical position has often included aquatic resistance exercises but has failed to quantify the exercise intensity and volume, the progression of the exercise, and the variability of the exercises, which must be considered when performing long-term training programs (24,26). Although there are cases in which the recommendation of performing the resistance exercises to the maximum velocity has been made (35,39), this is still inadequate as it is too vague for a proper exercise prescription because the number of repetitions (reps), rest periods, and other specifics are omitted (9,26). Thus, there are few research studies and specific applications that objectively combine all the correct criteria for exercise prescription (31,40,41).

When compared with investigations and practical applications of resistance exercise on dry land, which are very specific regarding program design variables, aquatic resistance exercise program recommendations are very general. This can result in programs that are not safe or may not stimulate adequate physiological responses to training. The lack of a specific methodology has limited the increase in knowledge about and the application of aquatic resistance exercises because it is difficult to reproduce studies with vague methodologies, so the development of a program design with aquatic resistance exercises has been restricted.

**CRITERIA FOR CONTROLLING INTENSITY WITH DEVICES THAT INCREASE THE DRAG FORCE**

Using the fundamental criteria below, which are based on recent investigations (Table 1; (40,41)), it is possible to make objective recommendations for the design of programs using aquatic resistance exercises with devices that increase the drag force (DIDF):

1. **Aquatic strength training must be performed with DIDF.** Thus, it is necessary to have combined control of: (a) the movement pace or cadence, (b) the size of the DIDF, (c) the length of the extremity being used in the exercise, (d) the hydrodynamic position of the moving segment and the device used, and (e) the perception of effort at the predetermined number of reps. The perception of effort is the previously
determined rating of perceived exertion in the active muscles using the OMNI Resistance Exercise Scale for the active muscles (OMNI-RES AM) (17,18,23,32).

2. The exercisers must perform the movement with the DIDF at a pace that can be identified by a cadence of beats per minute. This pace must be predetermined as a function of the desired number of reps at the desired level of effort. This pace can be marked by using devices that emit sound or flashing lights and show the correct cadence (variations of a metronome). It is known that the resistance that is provided by the water is always the same when the movement is performed at the same pace, and the movement is executed in the same manner. If the pace of movement increases, the resistance of the water also increases in a quadratic manner.

3. If the prescribed reps and perception of effort are not met with a specific DIDF and the pace of movement, a larger DIDF can be used. The increase in the size of the DIDF should only be to the amount necessary to keep the prescribed pace of movement and reach the desired number of reps and level of effort. As the muscular fitness levels of the exerciser improve, the size of the device can be progressively

Table 1
Summaries of recent studies which support methodological recommendations

<table>
<thead>
<tr>
<th>References</th>
<th>Brief description and important findings</th>
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<tr>
<td>Colado et al. (15)</td>
<td><strong>Aim:</strong> To examine whether monitoring of both the rhythm of execution and the perceived effort adjusted at a certain number of repetitions is a valid tool for reproducing the same intensity of effort in different sets of the same aquatic resistance exercise.</td>
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<td><strong>Methods:</strong> Muscle activation was recorded for 15 repetitions at maximum or near maximum effort by using surface electromyography in the pectoralis major and posterior deltoid.</td>
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<td><strong>Conclusion:</strong> The same intensity was achieved in an aquatic resistance exercise with different sets of the same exercise.</td>
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<td>Colado et al. (16)</td>
<td><strong>Aim:</strong> To analyze the effects of a short-term periodized aquatic resistance program (PARP) on maximum strength, power and body composition in fit young men.</td>
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<td><strong>Methods:</strong> The PARP was an 8-week supervised program performed 3 d-wk⁻¹. It consisted of a total-body resistance exercise workout using aquatic devices that increased drag force, with a controlled cadence of movement that was adjusted individually for each exercise and subject. The volume and intensity of the program were increased progressively.</td>
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<td><strong>Conclusion:</strong> The PARP produced significant improvements in strength, power and fat-free mass and thus appears to be a very effective form of resistance exercise.</td>
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<td>Colado et al. (12)</td>
<td><strong>Aim:</strong> To identify the effects of a periodized aquatic program for strength training (PAPST) on selected cardiovascular parameters in early-postmenopausal women.</td>
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<td><strong>Methods:</strong> The aquatic exercise group trained for 24 weeks with a periodized program for local muscular endurance based on OMNI perceived exertion scale for resistance exercise and with devices that increased drag force, which were sized to best allow each subject to adapt to the prescribed intensity.</td>
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<td><strong>Conclusion:</strong> The PAPST reduced the risk of cardiovascular disease by improvements in systolic and diastolic blood pressure, total cholesterol, LDL-cholesterol, glucose, apolipoprotein B, triglycerides, waist perimeter and total fat mass.</td>
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<td>Colado et al. (11)</td>
<td><strong>Aim:</strong> To investigate the effect on body composition of a periodized program for physical conditioning (PPC) carried out in deep water compared to an equivalent PPC carried out on dry land.</td>
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<td><strong>Methods:</strong> A 16-week PPC was performed with a frequency of 3 d-wk⁻¹. The aquatic group (AG) used flotation belts and the subjects were able to move and balance effectively while wearing them. The AG also used devices that increased drag force, which were sized to best allow each subject to adapt to the prescribed intensity.</td>
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<td><strong>Conclusion:</strong> The effect on body composition was the same, independent of whether the program was performed in deep water or on dry land.</td>
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increased to maintain the desired movement cadence and number of reps. If the pace of the movement is maintained but the size of the device is increased, then it is necessary for the exerciser to generate more muscular force to maintain this pace; thus, the intensity of the exercise is increased.

4. Another option for increasing the intensity of the exercise without increasing the size of the DIDF is to increase the pace of the movement. This solution temporarily avoids the need to change the DIDF to a larger size when the exercisers improve their muscular fitness because, in some situations, a larger device is not available. This option is attractive as a way of increasing exercise intensity that is more economical because a variety of DIDF are not necessary. However, there will be a point when it is necessary to increase the size of the device because the required speed of movement (to maintain intensity) with a given device will exceed the ability of the limb to mechanically complete the range of motion quickly enough, which is not due to a lack of force.

These guidelines are similar to those used in dryland resistance training, which often recommend a steady pace of movement and the adjustment of the weight used to reach a predetermined number of reps, often near to or at momentary muscular failure, for a specific training goal, such as hypertrophy, strength, muscular endurance, or power (17).

As a practical example, it is recommended that the following steps be taken to determine the intensity of the aquatic resistance exercises and their possible effects during a session of aquatic strength training:

1. Determine the desired rep range based on the training history and goals of the exerciser. As with dryland resistance training, lower reps (4–6) would focus more on strength development, whereas moderate reps (6,7,9,13,14,10,11) would focus more on stressing the metabolic and hormonal systems (potentially resulting in some hypertrophy) and the higher reps (11,12,17,15) would focus more on local muscular endurance (22). Similar numbers of sets and lengths of rest periods to

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Table 1 (continued)

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| Colado and Tella (13) | **Aim:** To verify whether the controlled use of water currents during aquatic strength training increases the muscular activity of certain trunk stabilizing muscles.  
**Methods:** A series of 15 repetitions at 9 to 10 on the OMNI perceived exertion scale for a resistance exercise of glenohumeral adduction and abduction movements on a horizontal plane with Hydro-Tone Bells was performed. After a 5-minute rest, subjects repeated the test while receiving water currents at 30 per minute at a force of 68.55 N from the front. Surface electromyography was used to determine the muscular activity of rectus abdominis, lumbar erector spinae, and medial fibers of the external oblique.  
**Conclusion:** The controlled use of water currents during aquatic strength training increases the muscular activity of the trunk stabilizing muscles. |
| Colado et al. (10) | **Aim:** To determine whether the level of activation achieved with aquatic resistance exercises in trained subjects is comparable to that achieved with their dry land exercise equivalents.  
**Methods:** Surface electromyography was used to determine the muscular activity of the agonist muscles of the movements of glenohumeral adduction and abduction on a horizontal plane, and certain muscles of the trunk.  
**Conclusion:** The activation of the erector spinae lumborum was significantly greater in the aquatic medium. However, these exercises should not be used with subjects who lack good exercise technique and whose stabilizing trunk musculature is not in excellent condition. |
| Colado et al. (14) | **Aim:** To verify if the cardiovascular and metabolic demands of an aquatic resistance exercise are comparable to the land-based equivalent.  
**Methods:** Subjects were evaluated using a horizontal shoulder adduction movement in water with a pair of Hydro-Tone Bells, and on land with an elastic band (EB). The movement cadence was determined, as well as the appropriate hand position on the elastic band, in order to achieve the desired number of repetitions for muscular fatigue, which was 25.  
**Conclusion:** The aquatic resistance exercise will produce a similar physiological response to that produced by performing the comparable land-based exercise. |
those used in dryland resistance training should be used.

2. Determine the desired level of exertion as indicated by the perception of effort using the OMNI-RES AM scale, which ranges from 0 to 10 or extremely easy to extremely hard (32). With some exercises or on some days, it may be desirable to perform the sets at different levels of effort perception (3). For example, in the beginning of a program or when performing a new exercise, a more appropriate level may be 4–5 (somewhat easy). After performing the exercises for several sessions, the level could be increased to 6–7 (somewhat hard), and with more advanced lifters, the level could reach 8–9 (hard). Variations in perceived level of effort could promote variation in the design of the training programs (42). If the OMNI Resistance Exercise Scale (OMNI-RES) value is attained but the targeted number of reps cannot be met, or the opposite, the exercise during a set must be stopped and adjustments made.

3. Once the level of perceived effort and the targeted number of reps has been determined, the appropriate DIDF must be selected. This process will likely involve some trial and error, in both DIDF selection and cadence determination, but this becomes easier as the exerciser progresses through a training program. The cadence should be the maximal possible, which still allows the lifter to complete the targeted number of reps with the selected device and at the desired OMNI-RES value without falling behind the pace. The pace of movement can be provided by a device that emits sound or flashing lights, and cadences are commonly between 44 and 64 beats per minute (depending on the exercise) when 10 reps are desired at a somewhat hard level, for example.

Table 1 shows a summary of the latest studies that have been performed by our research group to confirm the validity of the methodology that we show in this article for controlling the intensity during the performance of aquatic resistance exercises.

Other factors with aquatic resistance exercise include the lack of eccentric muscle actions and the difficulty in maintaining postural control in an environment where buoyant forces exist. Most common dryland resistance exercises have both concentric and eccentric muscle actions (2), but in aquatic resistance exercises with DIDF, there is a greater involvement of concentric muscle actions (28,30). Although this aspect casts doubt on the effectiveness of strength training programs that emphasize the use of concentric muscle actions to improve strength and muscle mass, one of the earliest studies performed with dryland resistance training showed that training exclusively with concentric–isokinetic muscle actions was effective in improving strength and muscle mass (20). Because aquatic resistance exercises are essentially speed controlled, they should show similar effectiveness. Subsequently, there have been many studies that have directly compared the 2 types of muscle actions and have been able to confirm that resistance training with only concentric muscle actions may cause adaptations that are similar in terms of strength and muscle mass to those obtained with training that only used eccentric muscle actions (4,19,25,33). However, there are scientific works that warn that there could be an increased susceptibility to eccentric dysfunction and injury when concentric-only training is prioritized (27), but this particular aspect has not yet been studied in the investigations that have used aquatic exercises with DIDF. As for the general aquatic exercise, there are numerous investigations that have compared dryland programs (with concentric and eccentric muscle actions) with aquatic programs (with concentric muscle actions), and the effectiveness and safety of the aquatic training have been demonstrated (6,16,31,35,40,41).

The difficulty in maintaining body posture increases the need for trunk stabilization during the performance of aquatic resistance exercises (13,10). By instructing the exerciser to stand in a more stable position to counteract some of the forces generated by moving the surface device through the water, some of this instability is alleviated. Finally, the application of this information has primarily addressed the training environment where only 1 exerciser is present with 1 trainer. In reality, aquatic resistance exercises are just as likely to be used in a class setting. For this, the cadence would have to be the same for everyone, and the only thing that can change between the participants is the size of the DIDF, which may not be optimal for maximum physiological adaptations for each person (9,40).

CONCLUSIONS

Resistance training in an aquatic environment has greater challenges with regard to the control of the intensity of the exercise. This has limited its use for both the general population and the athletes. Questions have arisen regarding how intensity can be maintained within a session and between sessions or how best to increase or reduce intensity, dependent upon the specific needs and training objectives of an individual. The strongest investigations using DIDF have combined the use of some type of standardized control of speed or reps with the subjective criteria of the exercisers.

It has been demonstrated that the intensity of the exercise can be controlled with the quantification of the pace of movement along with the perception of movement effort (OMNI-RES AM) adjusted to the targeted number of reps (15). With this combination, it is possible to control the intensity applied in each set, each exercise, and each workout. It is also possible that this methodology can be applied to more advanced training techniques for those individuals who desire greater results or a higher level of muscular fitness. This is very
beneficial for the exercise professional because it is an objective method of monitoring the intensity of aquatic resistance exercises.

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