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INVITED REVIEWS

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Heart-Rate Response to Exercise in the Water: Implications for Practitioners

Terri A. Lees

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Compared with the amount of research available on activities such as jogging, running, and swimming, research on aquatic exercise is still somewhat limited. In many cases it has been difficult to draw conclusions about water exercise in general because of the number of variables that affect exercise response in the water. Most of the studies that have been conducted have concentrated on discerning how exercise in the water compares with similar exercise on land. Investigators have looked at heart rate, ventilatory responses, oxygen consumption, respiratory-exchange ratios, and ratings of perceived exertion using various research protocols. Oxygen consumption and heart rates have been used frequently as indicators of metabolic workload. Heart-rate response to exercise is especially significant to practitioners if target heart rates are used to prescribe and monitor exercise intensity. An analysis of available research seems to indicate that exercise responses in the water vary with the temperature of the water, the depth of immersion, the intensity of the exercise bout (submaximal vs. maximal efforts), the exercise protocols (walking, running, calisthenics, step, cycle ergometry, use of the arms), and the skills and motivation of the participants involved in the study.

Water Temperature

The question of water temperature is a critical one, especially as it relates to heart-rate response in the water. The general consensus is that heart rates are lower in cooler water than in warmer water. Lower heart-rate responses have been reported at rest and during cycle ergometry at temperatures ranging from 18 to 25 °C (65–77 °F; Craig & Dvorak, 1969; McArdle, Magel, Lesmes, & Katch, 1976). Dressendorfer, Morlock, Baker, and Hong (1976) measured physiological variables during cycle-ergometer exercise to exhaustion in men and observed that heart rate was 8 beats/min lower in 30 °C (86 °F) water and 15 beats/min lower in 25 °C (77 °F) water than in 35 °C (95 °F) water. Avellini, Shapiro, and Pandolf (1983) also reported lower heart rates at a given oxygen consumption in their participants who trained on cycle ergometers at 20 °C (68 °F).

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Research conducted in water temperatures ranging from 31 to 35 °C (88–95 °F) has consistently shown that heart rates in the water are similar to those reported for similar land exercise (Connelly et al., 1990; Craig & Dvorak, 1969; Sheldahl et al., 1987). McArdle et al. (1976) observed oxygen consumption versus workload responses in thermoneutral water (water that approaches body temperature) similar to those on land. There are, however, conflicting results found in temperatures ranging from 27 to 31 °C (80–87 °F). In some studies heart rates were similar (Arboreliu, Balldrin, Liga, & Lundgren, 1972; Christie et al., 1990), and in other studies they were found to be lower (Lollgen et al., 1976; Rennie, 1971). Onodera, Yamaji, Kaneko, Sugimoto, and Miyashita (1983) found that heart rates were not significantly affected in water temperatures of 26–28 °C (78.8–82.4 °F). Rennie reported lower resting heart rates at 28–32 °C (82.4–89.6 °F) but found no differences in heart-rate response during exercise. It would seem from this discussion that, without considering other factors, it might be prudent to consider methods other than heart rates to monitor the intensity of an immersion workout (rating of perceived exertion, talk test). Nonetheless, using heart rates to monitor intensity in water warmer than 27 ° C (80 °F) might still be a viable option.

Depth of Immersion

Lower cardiovascular responses in the water have been attributed not only to water temperature but also to hydrostatic pressure (which increases with depth). During head-out immersion, hydrostatic pressure has been found to increase the blood volume in the central core, leading to an increase in the stroke volume of the heart. This decreases the heart rate at any given O_2 (Arboreliu et al., 1972; Blomqvist & Stone, 1983). It is conceivable then, that as the depth of immersion increases, one might expect a lower heart rate than in shallower water workouts. Several research studies have borne this out. Kennedy, Foster, Harris, and Stokeler (1989) compared the same water aerobics exercise in two different depths. They reported that heart rates were about 10 beats lower in the deeper water than in the shallow protocol. Most of the available research on deep-water running indicates that heart-rate response for any given O_2 is about 10–15 beats/min lower than on land (Frangolias & Rhodes, 1995; Kennedy et al.; Navia, 1986; Ritchie & Hopkins, 1991).

Intensity of the Exercise Bout

There is evidence that heart-rate response is also related to the exercise intensity chosen for the research protocol. Heart-rate responses at maximal intensities have been consistently shown to be lower for water-immersion running (Butts, Tucker, & Greening, 1991; Svedenhag & Seger, 1992; Town & Bradley, 1991) and cycle ergometry (Bevegard, Holmgren, & Jonsson, 1963; Christie et al., 1990; Connelly et al., 1990; Dressendorfer et al., 1976; Sheldahl et al., 1987) than for similar exercise on land. Hoeger, Hopkins, Barber, and Gibson (1992) compared maximal exercise responses between treadmill running and water aerobics and found that exercise response for water aerobics was significantly lower than for treadmill running. Svedenhag and Serger reported that heart-rate responses with immersion running remained unchanged at lower intensities and were lower for

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higher intensity exercise bouts. Studies using a bicycle ergometer submerged in a tank or pool, when exercise intensity, water temperature, and depth of immersion (to the xiphoid process—slightly below level of the nipple) were controlled consistently, demonstrate similar exercise and training responses when compared with the same exercise on land using low or moderate intensities (Avellini et al., 1983; Christie et al.; Lollgen et al., 1976; Sawka, 1986). This evidence seems to indicate that as intensities approach maximal effort, heart rate is depressed. Low to moderate intensities, however, similar to those seen in a water aerobics program, might not elicit lower training heart rates.

Exercise Protocol

There is little doubt that exercising in the water has the potential to elicit a training effect. Not all water-exercise protocols are created equal. Much of the earliest research studied immersion running and cycle ergometry. These protocols are extremely limited in their biomechanics and should not necessarily be used to draw conclusions about the efficacy of the variations of water exercise that are predominant today. It would be equally dangerous to compare specific water aerobics protocols (waist-deep water running, aqua calisthenics, deep-water aerobics, step aerobics in the water, water aerobics) to each other to identify specific benefits or responses to the protocol. Take, for example, the use of traveling moves in the workout (traveling refers to moving across the workout area from Point A to Point B). Several studies have shown that traveling elicits higher oxygen consumption than stationary exercise (Beasley, 1989; Gleim & Nicholas, 1989; Town & Bradley, 1991; Whitley & Schoene, 1987). This is especially true in shallower water (thigh- to waist-deep). Traveling at faster speeds or in deeper water (chest-deep or more) could be problematic, however.

Napoletan and Hicks (1995) compared energy expenditure in a land treadmill walk–run protocol with water walk–run at two different depths. Participants walking in thigh-deep and xiphoid-deep water expended more energy than while walking on the treadmill at the same speed. When participants ran in thigh-deep water at 3.5 miles/hr they reached their highest energy expenditure. Energy expenditures at the xiphoid depth at 3.5 miles/hr, however, were not significantly different than treadmill running. The authors concluded that buoyancy created a "float phase" resulting in a rest period between strides. Gleim and Nicholas (1989) found an increase in energy expenditure for treadmill walking in the water until the speed increased to the point at which the participants had to jog. At jogging speeds, the participants spent more time in the nonsupport phase, assisted by buoyancy, and energy expenditure decreased.

Because most shallow-water aerobics programs occur in xiphoid-deep water, it is conceivable that individuals experience a float phase during travel activities. It is important to consider body position, the effects of buoyancy, and traction during travel sequences. For traveling to be effective, one must remain in a vertical position. Leaning forward too much reduces frontal drag (the resistance that is created by the form of the body that is perpendicular to the flow of the water) and increases the upward lift of buoyancy. The other issue that comes into play is traction. Without enough traction to accelerate through the water, resistance will be reduced. Participants should be encouraged to wear shoes to increase traction and to stay a little shallower to get more out of a travel format.

Responses to exercise protocols are also related to the emphasis given to the arms and legs during the workout. It has been shown that leg exercise in the water requires more energy than arm exercise at the same cadence (Cassidy & Nielsen, 1992; Costill, 1971; Johnson, Stromme, Adamczyk, & Tennoe, 1977). This is primarily because the legs have a greater surface area and can generate more resistance. Arm work, however, elicits higher heart rates for any given O_2 than leg exercises (Sawka, 1986). Therefore, it is conceivable that protocols with heavy arm-resistance work might have higher heart-rate responses.

Studies using arm cranking reveal that it is not effective in eliciting cardiorespiratory-training responses. It might not be appropriate, however, to compare arm cranking with the types of arm activities possible in the water. For one thing, the biomechanics of arm cranking are totally ineffective in the water without the addition of large resistive equipment. Second, arm work in the water typically involves use of other muscle groups (chest, upper and lower back, abdominals including external and internal obliques) to stabilize the trunk and allow force to be produced by the arms. In other words, keeping the arms engaged in the water increases the energy cost of the exercise and, as an added bonus, activates the core muscles to stabilize the work.

And what of the protocols that use the arms overhead? In a study by Eckerson and Anderson (1992) the exercise protocol involved extensive arm movements over the head in combination with stationary jogging, knee lifts, and bobbing activities. The authors reported that, although the participants achieved heart rates that were 82% of the maximum attainable, oxygen consumption was below the minimum training threshold. This seems logical for several reasons. First, research has shown that arm work above the head results in higher heart rates relative to oxygen demand (Astrand, Guhary, & Wahren, 1968). Second, jogging and knee lifts use small surface areas and are somewhat assisted by buoyancy in the hip-flexion phase. Finally, bobbing activity involves a "rest phase" (similar to the float phase described previously) as the feet return to the bottom of the pool. This rest phase might be enough to reduce oxygen consumption.

Skill and Motivation of the Participants

There is growing evidence that exercise response somewhat depends on the skill and motivation of the participant. In one study in which participants performed deep-water running without a buoyancy device, researchers demonstrated that a high level of exercise intensity could be achieved by well-trained, competitive runners if they paid attention to technique and maintaining a hard pace (Ritchie & Hopkins, 1991). They also showed that runners did not achieve high training responses in their first attempt at deep-water running. Not until the third session did O_2 and effort match that found with treadmill running, indicating that technique and practice were definitely important in getting the most benefit from this form of exercise. Others have also observed that skilled and highly motivated individuals were able to reach and maintain higher training responses than individuals who were not skilled (Elder & Campbell, 1990; Frangolias, Rhodes, & Tauton, 1996; Ritchie & Hopkins; Ruoti, Troup, & Berger, 1994).

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In another study, by Gehring, Keller, and Brehm (1997), recreational (noncompetitive) and competitive runners were asked to replicate land-running intensities in deep-water running, both with and without a buoyant vest. In both protocols, recreational runners were unable to replicate land-training intensities. Competitive runners, on the other hand, were able to achieve their land-based training intensities in both instances. The authors suggested that the key difference was that the competitive runners were more highly motivated and willing to work harder than their noncompetitive counterparts.

Although the efficacy of any particular water-exercise protocol is contingent on a variety of factors, practitioners can still draw some valuable inferences that might help improve the quality of the exercise protocol that has been selected for the workout. To reach the greatest potential of the exercise, practitioners should consider the following:

- Never assume that heart rates are lower in the water. Average pool temperatures, exercise in shallow water (water below low sternum or xiphoid depth), and exercise at moderate intensities might elicit heart rates similar to those on land.
- Recognize that bouncing and jogging have a float phase that creates a "rest" and reduces the intensity of the exercise. To work harder, take out the bounce.
- Spend more time working the larger muscles in the legs without neglecting the potential of arm work to initiate spinal stabilization and increase the energy cost of the exercise, as well as working the core muscles.
- Travel for more intensity. Be certain to maintain a vertical position, stay a little shallower, and wear shoes to improve your traction.
- Remember that buoyancy increases with depth, so exercising in neck-deep water reduces heart rate, makes it difficult to travel, and supports movement.
- Finally, train your participants in purposeful movement. Realize that they will improve as their skill and motivation improve, and they will be able to reap the many rewards of exercising in the water.

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