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AQUATIC TRAINING – AN ALTERNATIVE OR A COMPLEMENT TO THE LAND-BASED TRAINING

TRENING U VODI – ALTERNATIVA ILI DOPUNSKA TRENING METODA KLASIČNOM TRENINGU SPORTAŠA

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SUMMARY

The aquatic training methods are all types of training while the body is immersed in water. The most important factor influencing the body is the low impact nature of the exercises. Thephysical characteristics of the water affect human body during standing or floating in supine or prone position. The level of immersion and the water temperature will affect human body in rest but also while doing aquatic exercise. In this review, the cardio-respiratory changes during the aquatic training are discussed, especially during the deep and shallow water running. Also, the changes in neuromuscular status during others types of exercise in water are analyzed. There are possible benefits, as improving the physical fitness of an athlete and accelerating the post-game or post-training recovery which might be obtained during aquatic training. Water environment is also favorable for injured athletes during rehabilitation and also for other athletes that are experiencing interruptions in training process and competition programs caused by illness or other factors such as postseason break. Therefore, it is important to identify the effects and mechanisms of the aquatic training that are associated with changes in physiological status and athletic performance in athletes.

Keywords: water immersion, conditioning, rehabilitation

SAŽETAK

Trening u vodi predstavlja niz oblika treninga koji se izvode s tijelom uronjenim u vodi i poznat je po smanjenim silama reakcije podloge te ostalim karakteristikama koje utječu na ljudsko tijelo bez obzira da li se tijelo nalazilo u horizontalnoj ili vertikalnoj poziciji. Dubina vode i temperature također različito utječu na ljudsko tijelo tijekom odmaranja, ali i tijekom vježbanja. U ovom preglednom radu promatrane su kardiorespiratorne promjene tijekom trčanja u dubokoj i plitkoj vodi te promjene u neuromuskularnom statusu tijekom drugih trenažnih oblika u vodi. Moguće pozitivne reakcije poput unapređenja tjelesnog statusa sportaša, brži oporavak nakon treninga i natjecanja, rezultat su treninga u vodi, dok trening u ovom specifičnom mediju također može pružiti ozlijeđenim sportašima odlične okolinske uvjete za rehabilitaciju. Također, koristan je i za sve ostale sportaše koji iz raznih razloga nisu u mogućnosti provoditi planirani trenažni i natjecateljski program, npr. bolest, završni period i ostali faktori.

Zbog toga je važno identificirati sve efekte i mehanizme treninga u vodi koji su povezani s promjenama u funkcionalnom i neuromuskularnom statusu te s izvedbom sportaša.

Ključne riječi: uron, kondicija, rehabilitacija, trening u vodi

WATER IMMERSION

The water immersion (WI) primarily presents a method of sport recovery (81), whether it is as active or passive. In the past few decades the athletes have been using WI and training in water for improvement as well as and maintaining of performance (9,80), motor abilities and cardiorespiratory function (5, 26, 72, 76) but lot of literature is based on anecdotal information while there is a small amount of research that actually research changes in performance.

WI may cause physiological changes within the body that are the result of physical properties of water such as buoyancy, viscosity, thermodynamics, hydrostatic pressure and fluid dynamics (6, 74). The buoyancy is defined as an upward thrust opposing to the gravity. It depends on specific gravity of body immersed in water. Wide variations in individual specific gravity led to a wide range of abilities to float (6, 36). However, many individuals have difficulty floating due to their body composition, stiffness and also because they are scared and feeling anxious in water. The viscosity is a friction during movement causing drag forces only while moving and providing greater resistance with an increase of movement. The hydrostatic pressure is proportional to the liquid density and immersion depth (6) and as Pascal's law states; the pressure is exerted equally on all surfaces of the body immersed in a liquid. It is known that water exerts 1 mmHg with every 1.36 cm, in other words, body immersed in 1 meter can experience almost normal diastolic pressure that is causing an squeezing upward action (6, 81). The physiological response of the body will depend on exercise or non-exercise mode. Using a different movement in water, with respect to the principles of water, could provide a creative tool for athletes during their recovery sessions, post-game or post-training. It could also be an useful tool for maintaining cardiorespiratory function in injured athletes.

The effects of the immersion depth

With every centimeter of depth, the external pressure increases by 0.74 mmHg (81). Different hydrostatic pressure in water elicits different physiological responses of the human body. . With an increase of the water level, the first change that occurs is an increase in stroke volume (SV). as observed in several studies that investigated the effects of the immersion level (5, 13). A higher SV is a result of the increase in central blood volume and right atrial venous pressure. With an increase in SV (35 %) the cardiac output also increases (10-15%), but heart rate (HR) decreases with graded immersion (4, 5, 7, 28, 58, 63, 76). There are several documented phenomena that are responsible for a decrease in HR, but accepted ones are a) the diving bradycardia reflex and b) mainly improved conditions for blood filling during diastole, but also c) a bigger water-thermo conductibility. The oxygen uptake (VO_2) and energy expenditure (EE) it also decreases with higher levels of immersion (4, 20). An explanation for that could be the increase of the hydrostatic pressure and buoyancy with depth, which then reduces the neuromuscular activity of the lower extremity muscles (45) and therefore, a greater use of smaller muscles results in smaller oxygen consumption then in bigger muscles (43). When designing an aquatic training program it is very important to know that the immersion depth will influence the weight bearing in water. Immersion within the seventh cervical vertebra level, the xyphoid, and the anterior superior iliac spine level provides bearing 8%, 35% and 54% of body weight, respectively (6, 50, 74). These values are reported for a non-exercise mode. If some kind of movement is included, the weight bearing will rise and because of those conditions in water, the athletes may undertake the same exercise with a possibility of increased load offering each time smaller depth of immersion.

The effects of the water temperature

Water is an effective conductor that can transfer the heat 25 times faster than air (Becker 2009), so utility of water depends on both retaining heat and ability to transfer heat. Immersion temperature will depend on purpose of use. The recommended water temperature for intense training and vigorous exercise should be between 26 and 29C to prevent any heat-related complications (6, 74). The cold plunge tanks (10-15C) are often used for athletic recovery and for decreasing muscle pain and soreness. Thermo neutral pools (32-35.5C) are used for typical aquatic therapy and exercise, and the last option arewarm and hot pools (36C>) which are used for relaxation and sometimes for some stretching exercises, although very high temperatures are rarely comfortable for more than a few minutes.

Testing of cardiorespiratory responses during deep and shallow water running is mainly tested in cool conditions (9, 10, 22, 25, 57, 61, 80) but also in thermo neutral water conditions (56). The cold water immersion (CWI) is generally used for decreasing the cellular metabolism, reducing inflammation, for controlling pain and edema formation, for enhancement of performance (42, 68), an isometric strength training (8) and functional strength performance at higher movement velocities (37). Nevertheless, some studies concluded that there was no larger beneficial effect of CWI on physical performance than there was in a thermo-neutral water immersion (66). Hot water immersion (HWI) is mainly used for relaxation causing vasodilatation and shifting blood to the periphery, but also for passive increase of the body temperature and also as a possible ergogenic aid for improving anaerobic performance. Though, some researchers didn't report that kind of effect (71).

The water immersion as a recovery method

The recovery process is and important phase and it should be given a great amount of time and attention as it is given to programming the training itself. Because of the hydrostatic pressure and buoyancy, every immersion in water has an effect of pushing blood to the central body parts, and therefore inducing a clearance of accumulated metabolic products that are affecting muscle cell function and creating peripheral fatigue. Therefore, WI can be considered as a favorable option during the sport recovery, but the effects of cold, hot and contrast water immersion are not equal, so not every method of WI should be considered a good way for recovery.

The cold water immersion causes the reduced heart rate and cardiac output, and induces vasoconstriction (8). It also lowers peripheral blood flow which could help in reducing acute inflammation from muscular damage (3, 35, 42). the slower transmission along neurons, caused by cold temperature, affects muscle contractile speed and inhibits a performance shortly after immersion, but on the other hand it could lower the level of pain perception (37, 68, 81).

The hot water immersion is not used as frequently as cold water immersion because of the peripheral vasodilatation which causes an inflammatory response and swelling, and prolongs the recovery time. It may also cause dehydration (71, 81). Due to the lack of research about hot water immersion and recovery, its ergogenic effects are still unclear.

The contrast therapy mimics mechanisms and effects of the low intensity active recovery, alternating pumping and squeezing smooth muscle action but without excess energy demand. The changes in temperature which occur every 30-120 seconds is probably not strong enough to change the deep tissue temperature (14, 33, 54, 55, 81) which is necessary for the vaso-pumping effect, so this contrast method needs to be researched more and maybe revised. In the study of cold water immersion by Ingram et al. (38) the recovery effects that were observed were better than during the contrast water immersion which only showed to provoke the significantly lower muscle soreness than in a control group after 24 hours. Kinugasa and Kindling (40) compared different methods of post-match recovery in youth soccer players and concluded that CWI with an active recovery has more positive effect on perceived recovery than the contrast recovery method or the passive method.

In summary, comparing literature involving performance and perceived recovery after CWI, HWI and contrast WI, it could be concluded that CWI, as a single recovery method is probably the best option of all WI methods for recovery, as long as the specific needs of the athletes are looked after and the strategies which provide achieving greater recovery in all kind of situations are applied.

THE AQUATIC TRAINING

The aquatic training presents an effective cardiovascular and musculoskeletal training for athletes that are competing in sports with longer season or are in some kind of injury recovery process (74). Those athletes that are overscheduled and with less time to taper, competing often, frequently suffer from injuries such as tendinitis, bursitis and stress fractures, and with training cessation and without competing those athletes are becoming detrained (47, 52, 53, 74). A rapid decline in maximal oxygen uptake and blood volume, a decrease in maximal cardiac output and impaired ventilatory efficiency and endurance performance are some characteristics of a short term detraining (52). Because of such losses, many athletes use benefits and advantages of the water based programs during the "active" recovery. Not only injured athletes, but also the healthy ones recognize the benefits of aquatic training and consider it to be a good prevention and also an alternative to some kind of on-land training. Most commonly used methods are the buoyancy-assisted deep water running, shallow water running, cross-country skiing, aquatic treadmill running, upper and lower extremity work with resistive devices, aqua-plyometric drills and other kind of workouts in water. The main advantage of water exercise is a lower weight bearing. The immersion up to the seventh cervical vertebra level, the xyphoid and the anterior superior iliac spine level provides bearing of 8%, 35% and 54% of body weight, respectively (50, 74). It is necessary to know that with an increase of speed the weight bearing also increases. These differences provide the possibilities for creating various progressive exercises with decreasing the water depth. the physiological response will depend on the kind of program that is used. In the next sections, the effects of different water programs will be presented.

The aquatic cardiorespiratory training

The cardiorespiratory training in water may be described as a type of swimming and deep or shallow water running. For a non-water athlete, the deep or shallow water running is a better form of training cardiorespiratory system because of the several limitations during swimming, such as a specific position and coordination, breathing pattern, learning process, etc. These programs give alternative options, either for injured athletes or just athletes that wish to incorporate the different methods of training to interrupt the monotony during the usual trainings.

1. Deep water running

Deep water running (DWR) is a simulated running in deep water without the ground contact and push-off faze of running. It has been used in physical medicine and rehabilitation and it was introduced to the athletes, mainly runners and game players as a good cross-training mode that minimizes the impact load and stress on the musculoskeletal system and at the same time maintains the cardiorespiratory function. There are two modes of DWR. The first and more commonly used is a classic running mode which is similar to the stair stepping and is characterized with a knee-up position that involves hip-joint flexion (45-70) and shoulder movement in sagittal plane with palms slicing the water or closed without cupping the water (47, 49). The second mode of DWR is a cross-country skiing style (CC) for which the study by Killgore et al. (39) found to be more similar to treadmill running (TR) with respect to the linear ankle displacement. CC style is characterized with a leg and trunk extension and great range of motion in shoulder and hip where knees stay relatively straight throughout the motion (75). When performing DWR, a flotation belt can be worn around the torso to allow vertical head out position, and other equipment could be used such as swimming gloves, paddles, shoes etc.

Table 1. Different physiological responses to DWR and TR
Tablica 1. Različiti fiziološki odgovori na trčanje u dubokoj vodi ili na pokretnoj traci

No.	Study	Participants (n)	Training status	Test mode	VO_{2max} (ml/kg/min)	Hr_{max} (beats/min)	RER_{max}	RPE	BLa (mmol/l)
1	Town and Bradley (1991)	7 M + 2 F	+	TR DWR without vest	67.0 + 49.0 +	183 + 157 +	1.14 + 1.05 +		7.9 + 6.4 +
2	Ritchie and Hopkins (1991)	8 M	+	DWR TR	48.0	159 176	1.05 1.02		
3	Glass et al. (1995)	10 M + 10 F	-	TR DWR	53.1* 47.1	189* 174	0.94 0.98		11.2* 14.9*
4	Mercer and Jensen (1998)	15 M + 13 F	-	TR DWR	54 ± 13* 44 ± 10	190 ± 8* 177 ± 9			
5	Dowzer et al. (1999)	15 M	+	TR DWR	55.39 ± 8.46* 41.27 ± 6.37	176 ± 12* 153 ± 16	1.11 ± 0.1 1.08 ± 0.1		
6	Frangolias et al. (1996)	16 M	+, familiar with DWR	TR DWR	58.8 ± 6.2 53.8 ± 5.4	187.7 ± 12.5 172.6 ± 14.0	1.19 ± 0.07 1.12 ± 0.04	20 20	
7		6 M	+, not familiar DWR	TR DWR	63.8 ± 3.0 53.5 ± 3.5	190.7 ± 8.6 173.8 ± 10.1	1.21 ± 0.06 1.14 ± 0.04	20 20	
8	Nakanishi et al. (1999)	20 M	-	TR DWR	51.8 ± 9.2* 41.0 ± 8.7	190.8 ± 9.1* 171.5 ± 13.6	1.05 ± 0.05 1.05 ± 0.08	9.65 ± 0.67 (10) 9.60 ± 0.82 (10)	12.47 ± 3.49* 10.44 ± 2.73
9	Frangolias and Rhodes (1995)	13 M	+	TR DWR	59.7 ± 6.4* 54.6 ± 5.2	190 ± 11* 175 ± 12	1.20 ± 0.08 1.10 ± 0.06	20 20	10.4 ± 1.9 9.8 ± 2.3
10	Svedenhag and Seger (1992)	10 M	+	TR DWR	4.60 ± 0.14* 4.03 ± 0.13	188 ± 2* 172 ± 3	1.20 ± 0.03 1.12 ± 0.04	17 + 17 +	10.0 ±0.6 12.4 ± 1.3

Abbreviations: VO2max – maximal oxygen uptake, Hrmax – maximal heart rate, RERmax- maximal respiratory exchange ratio, RPE – rate of perceived exertion, BLa – blood lactate concentrations, *statistically significant differences, + approximated values extrapolated from the graph.

During DWR some of the maximal physiological responses are lower than the ones achieved in the land running, and the others are the same. The decreases in maximal heart rate and VO_{2max} have been reported in many studies (22, 23, 24, 27, 48, 56, 58, 73, 76). It is known that immersion causes an increase in cardiac output that is a result of the elevated stroke volume which is related to the enhanced diastolic filling and it is known as Frank-Starling mechanism (63). O the other hand, the hydrostatic pressure and buoyancy lower the peripheral vascular volume so the heart does not need to pump frequently against the gravity as in land running, which provides 4-18% lower heart rates during WI (42, 81). Still, it is not known in full extents which mechanisms might be responsible for lowered heart rate during the maximal exercise in water (57, 62). One possible explanation is that the immersion induces cardiac adjustments that extend up to the maximal intensity (72) and the second possible explanation is attributed to the reduced sympathetic neural outflow in WI conditions (24). In a study done by Ritchie and Hopkins (61) it was shown that a high level of exercise could be achieved by competitive runners during DWR. However, the heart rates during hard pace in water were similar to those achieved during normal running pace on land. Table 1 shows the results of several studies conducted on trained and untrained individuals who were tested in order to compare the physiological responses between DWR and TR. In these studies, the maximal DWR elicited 85%, 90%, 92%, 93%, 86%, 91%, 91%, 90%, 92% and 91%, maximal heart rate of the one achieved in TR (table 1).

The maximal oxygen uptake ($VO_{2max)}$ is also reduced during DWR and few reasons might be responsible for that. One is a short duration of DWR protocols, so the development of standardized protocols is suggested by several authors (63,76). Another reason could be the different DWR style used in treatment (38, 63). The differences in muscle pattern recruitment could also contribute to lower values (1, 23, 25, 49, 73) and familiarization to DWR can be also one of the factors influencing on VO_{2max}. In the study by Frangolias et al. (23), the competitive runners that were familiar with DWR elicited a similar VO_{2max} values in land and water than the ones unfamiliar with DWR. Table 1 shows achieved VO_{2max} values during test in water and land. Subjects achieved 73%, 90%, 88%, 81%, 75%, 91%, 85%, 80%, 91%, and 87% VO_{2max} values in water of the ones during TR (Table 1).There are some differences in respiration exchange ratio (RER_{max}) between the DWR and TR, mainly not statistically significant ones (22, 24, 27, 56, 63, 73) but there are some studies were RER in water was lower than the one achieved on the land (24, 73). Discrepancies that occur in blood lactate concentrations in these studies could be a result of different experimental designs and protocols, and also a different muscle recruitment during DWR and TR (24, 43, 63, 73, 76). Several studies researched differences between physiological responses to equivalent submaximal levels of VO_{2max} during TR and DWR (26, 38, 48, 60, 73). In the study by Gehring et al. (26) seven female competitive runners and seven female noncompetitive runners were asked to replicate preferred land training intensity with and without the flotation vest. The competitive runners achieved similar intensity in water during both conditions of DWR. However, the recreational noncompetitive runners had lower responses during DWR with flotation vest and significantly lower physiological responses during DWR with flotation vest in comparison to same TR intensity. In the study by Svedenhag and Seger (73) ten trained runners ran in water at four different loads determined with heart rate. The VO_{2max} was significantly lower during DWR, the heart rate showed tendency to less steep slope in water and the blood lactate curves shifted to the left showing higher levels in water and RPE and RER where higher during submaximal DWR. Killgore et al. (39) investigated differences between the shod and barefoot DWR, and compared it to TR. The results of eight male distance runners showed that shod DWR could elicit similar responses as TR, while VO_{2max} was significantly lower during barefoot DWR than on land. Same as for the previous study, both RPE and RER were significantly higher during DWR, shod and barefoot, than in TR. In the study done by Mercer and Jensen (48) fifteen men and thirteen women finished two graded exercise test in water and on land while researchers compared results during each level. Both, VO_2 and heart rate, were significantly lower during 60, 80 and 100% level of intensity in the water than on the land. The main conclusion of this study was that the relative level of intensity during DWR was higher for a given percent of TR because DWR elicited the lower peak responses.

While observing the effects of DWR program it might be concluded that such programs could maintain the land-based running performance level (9, 23, 24, 80) and cardiorespiratory function (9, 33, 80), but could also provide an improvement in untrained individuals (49).

In summary, it could be said that while running on land more energy is needed to “fight” the gravity, whilst running in deep water has its “opponent” in frictional resistance and turbulence of the water (23). The differences in length of the lever, girth of the legs, and speed of the displacement will influence the resistance and turbulence experienced in water and these are all parameters that need to be considered in further studies of DWR. Although DWR is affirmed as a training mode that might help in maintaining performance level and cardiorespiratory function, there is still a need for other confirmative studies of DWR to recognize it as a tool for a fitness improvement in trained athletes because of its nonimpact influence on musculoskeletal system.

2. Shallow water running

Shallow water running (SWR) is an imitation of running in an ankle to shoulder level water depth immersion (11). With a greater immersion, the weight bearing is lowered, but the hydrostatic pressure is greater as is the resistance of water caused by viscosity.

Because of the absence of ground support in DWR, the lower extremities muscle recruitment is different from land based running (39, 69). Therefore SWR presents a better option for more specific running training, especially considering the neuromuscular recruitment patterns activation (29, 30). Several studies compared SWI to land running and also to DWR (22, 32, 60, 76).

In a research done by Dowzer et al. (22) the maximal physiological responses were compared between treadmill running (TR), SWR and DWR. TR elicited significantly higher VO_{2max} and HR_{max} than both SWR and DWR. The peak HR and VO_2 for SWR were 94.1% and 83.7% of the maximal values reached in TR, respectively, and also higher than the values reached with DWR. Similar research was done by Town and Bradley (76) in which they compared the maximal metabolic responses between SWR and TWR, and their relation to TR in competitive runners. The peak HR and VO_2 for SWR were 88.6% and 90.3% of the maximal values reached in TR, respectively, and SWR elicited higher values than DWR. There was no significant difference between the blood lactates concentration (81% of TR for both water tests) and respiratory exchange ratio. These two studies concluded that SWR was adequate enough to elicit similar responses to TR and could be an efficient method for maintaining the cardiovascular fitness. It might be expected that the depth of immersion will also affect physiological responses to SWR, but investigation done by Haupenthal et al. (32) showed that there were no difference in forces value in chest- and hip-deep water, probably due to the variability of speed in SWR that was self-determined. Therefore, not only the level of immersion but also the speed of displacement should be considered while designing programs in shallow water. When comparing the water and the land parameters it is necessary to know that water parameters need to be changed to attain equivalent intensities from 50% to 80% of VO_{2max} achieved in land treadmill running. The subjects in a study researched by Rife et al. (60) were able to run in water at intensities equivalent to 55% to 94% of their maximum heart rate in land treadmill running. The given study concluded that the SWR on treadmill is an effective alternative to the land based treadmill running. In research done by Hamer & Morton (31) the VO_{2max} in untrained subjects during submaximal water running increased for 9% (pre = 49.32 ± 5.42, post = 53.98 ± 4.83 ml/kg/min) after 8 weeks of running in depth of 1 meter, and the heart rate was 10-12 bpm lower compared to treadmill running.

In conclusion, the benefits of training in shallow water would be; less stress on the body than in land based training (32), the ground contact, ground reaction forces, the movements are similar to the ones than in land (76), the cardiovascular benefits for untrained subjects (58). Still, there are only a few studies done researching the cardiovascular benefits in SWR in elite trained athletes (75). In opinion of several experts (29, 30) it is expected that SWR could induce many beneficial responses if enough stimulus is provided, so that adaptation can occur. RPE proved to be a good tool as indicator for untrained women for monitoring the intensity, if nothing better is provided (1).

Aquatic plyometric training

The plyometric training (PT) is a technique and method used by many athletes for improving jumping technique and leg muscle power, especially the vertical jump height (44). The plyometric drills can be divided in several groups: a) jumps; b) hops; c) bounds and d) shock drills that can be divided in box jumps and depth jumps. These activities incorporate stretch-shortening cycle that involves a rapid and intensive eccentric contraction, storing elastic energy, which is immediately followed by rapid concentric contraction producing explosive movement (44, 50, 51). High forces during the eccentric contraction followed by a landing phase put extremely high loads on musculoskeletal system and result with muscle soreness and increase the risk of lower limb injuries (18, 51, 72). Therefore, an aquatic-based plyometric training (APT) is used for reducing ground reaction forces and to reduce the risk of lower extremities injuries but without compromising the plyometric training effect.

In past few years various studies included APT as a supplemental method to the normal training regime with an aim to investigate the effects of such training. In study done by Miller et al. (50) twenty-nine male and female participated in six week plyometric program two times per week. They were randomly assigned to one of three groups (control, waist deep aquatic and chest deep aquatic group). Training program was identical in drills, sets, repetitions and volume that ranged from 90 to 140 foot contacts. There was no significant difference in force production for squat jump, countermovement jump and drop jump, neither in vertical jump height for all groups. Although, waist deep group had slightly better vertical jump and chest deep group had increase in force and power for two of three plyometric jumps. Main reason for these results could be a fact that less experienced individuals benefit less from plyometric training (67). Despite the lack of significant results it is appropriate to use plyometric programs in water, perhaps with higher loads. Robinson et al. (64) compared changes in performance indicators and muscle soreness between aquatic and land plyometric programs. Thirty-two women were randomly assigned to groups with identical plyometric program for eight weeks. Results of this study showed that APT can be effective in enhancing power, torque and velocity in physically active women with less reported muscle soreness.

In research done by Martel et al. (245) nineteen female volleyball players performed 6 weeks of APT twice a week. Control group performed whole-body flexibility program that consisted of 8-10 static stretching drills. The result of APT showed significant improvement for vertical jump height in APT group (11%), and thus it is proposed that APT could provide similar benefits as land-based plyometrics with less risk of muscle soreness and/or overtraining. Stemm and Jacobsen (72) compared APT and land based plyometric training in a study of 21 active men who were randomly assigned to one of the three groups (aquatic, land and control group). The land and the aquatic group performed the identical plyometric program, twice a week for six weeks, which resulted in a significantly better vertical jump performance in aquatic and land group than in a control group, and no differences were found in the same jump performance between the aquatic and the land group. It was concluded that APT resulted in similar training effects as the ones obtained with land plyometric training but with a benefit of possible reduction in stress.

In more recent study done by Triplett et al. (77) twelve junior handball female players performed the single-leg jumps in water an on the land. Aquatic jump resulted with statistically greater force production and rate of force production with less statistically significant impact forces and therefore can be offered as an alternative to land jump exercises. In the study done by Arazi and Asadi (2) eighteen young basketball players, divided in three groups, went through eight week long plyometric training program. The results showed no significant differences between APT and land plyometric training group in any tested variable (leg muscle strength, 36.5 and 60 m sprint time and dynamic balance test), but there was significant improvement in sprint times in both aquatic and land group. So, it was suggested that APT can provide a better environment for improving performance.

Coleman (18) investigated the effects of plyometric program on sprint performance on high school sprinters. After six weeks of plyometric training both aquatic and land group had similar scores in vertical jump height, 20 meters sprint and muscle soreness, while land group performed significantly better in 10 meter block sprint. Both groups improved their scores with plyometric training indicating that both types of training were effective. It proved that APT could be just as effective as the traditional land-based plyometric training.

In summary, APT can provide a good stimulus for performance improvement, which is slightly different from the land-based plyometric programs. In in water, the athletes encounter greater resistance during concentric movement due to the viscosity of the water and smaller eccentric load due to the buoyancy of water. It can be a good time-out from monotonous drills on land; it provides less stress on the musculoskeletal system and might be a good introduction for heavy and serious plyometric training program. That is why APT might be a good alternative for land-based plyometric programs.

Aquatic resistance training

The water provides resistance in multiple planes of the movement so athletes can overload almost all phases of movement (29, 30). Even without using special water-based devices like ankle cuffs, kickboards, water dumbbells, paddles, noodles and etc., the density of the water adds more resistance which increases with an increased speed of the movement. The buoyancy is one of the physical properties of the water that can be used as assistance while doing upward motion; the resistance while doing downward motion; and as a support while flotation (74, 75). Using the drag force increases the intensity of resistance exercise. It is affected by a surface area, velocity and shape of the object (19).

The published studies mainly reported an increase in muscle strength after a head-out water exercises program (10, 11, 12, 15, 17, 58, 62). These significant improvements may be due to the low fitness levels of subjects as there are no studies that investigated the effects of a resistance program in elite athletes. These athletes mainly use the aquatic environment as an alternative training site to rehabilitate the specific injuries and to restore the functional movement pattern (59, 75). One factor could also be the lack of the eccentric muscle contraction component in water and the second important factor is the difficulty in maintaining the postural control (15, 46). While controlling the intensity, one needs to quantify the pace of the movement with a perception of movement effort and adjust it to targeted number of repetitions and sets (16). Because of the previously mentioned factors and difficulties in monitoring intensity, the aquatic resistance training has limited usein trained athletes.

Aquatic flexibility and balance training

Performing the stretching exercises in water is not often used for improving flexibility in athletes. Only one study investigated the effects of an aquatic training program on flexibility showing that there might be an improvement in flexibility but depending on water temperature. Still there was no difference between the effects of water and land based training programs for improving flexibility (8). Other studies observed the effects of different water exercise programs on flexibility with both significant and non-significant improvements in untrained individuals such as collegiate women or older people (34, 77, 78, 79). Thermoneutral and warm water properties might induce an increase in joint flexibility and also reduce the muscle spasticity (4) that can improve range of motion and therefore could be used as one method for improving flexibility (29, 30, 41, 58).

Same as for flexibility, the balance training water programs are mainly studied in older people. Those studies concluded that both water and land based balance training might be efficient as no significant differences between them were confirmed (21, 65, 70). The balance control and proprioception are very important for almost every athlete (74) and changing the environment and conducting the same land based training in water can be motivating and also a good type of rehabilitation.

CONCLUSIONS

The water immersion induces a displacement of body fluids to the central parts of body, a decrease in heart rate and increase of stroke volume and cardiac output. The physical properties of the water stimulate the clearance of accumulated products produced during the vigorous exercise, and also help in lowering the symptoms of the delayed onset of muscle soreness (DOMS) and muscle inflammation processes. This review offered many positive effects of different exercise modes in water. With an opportunity of graded loading and without high impact forces on skeletal system, the athletes might achieve large benefits from aquatic plyometric training. It might be used in learning processes of junior athletes but also for improving the strength and jumping abilities in elite athletes. The deep and shallow water running offers a good cardiorespiratory training that might be an alternative to the land based training, but the intensity needs to be slightly higher in order to achieve the effects which occur during the land based training. The resistance aquatic training at this moment provides many different modes of exercises, with or without devices, although th eccentric contractions are minimized, while the posture muscles and concentric contractions can be overloaded in multi planes of the movement. The various methodologies, especially in studies regarding the resistance, flexibility and balance training, is responsible for an unclear picture of possible beneficial effects of water training in land based athletes. Therefore, more research on aquatic training is needed, especially studies involving the elite athletes, to determine with certainty whether and which modes of exercise in water cause specific performance benefits.

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