Benefits of Walking in Water

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[Received October 8, 2017; Accepted February 6, 2018; Published online February 21, 2018]

The purpose of this article was to review the representative research findings on the effects of walking in water on health-related responses from multiple points of view to elucidate the beneficial effects of walking in water on health for older people. Research findings on positive effects of walking exercises in water were identified and discussed in terms of biomechanics, cardiorespiratory responses, body composition, and cerebral circulation compared with walking exercise on land in young and older adults. Collectively, it was suggested that walking exercise in water would be a recommended form of exercise for older adults, especially with the use of walking poles (i.e. aqua-pole walking).

Keywords: walking, water, brain, circulation, aging

This brief article aims to review the findings on beneficial effects of walking exercise in water in terms of biomechanics, cardiorespiratory responses, body composition, and cerebral circulation by highlighting some of the representative research studies on these topics. Potential benefits of walking exercises in water for brain health as well as a promising exercise of aqua-pole walking are then discussed.

1. Biomechanics: higher force production with less impact force in water

Jumping movement was compared between performances in water and on land for single-leg jumps by Triplett et al. (2009) and two-leg squat jumps by Colado et al. (2010). In each study, the same subjects performed the jumps in water (aquatic jumps) and on land (dry-land jumps), and their ground reaction forces for the jumps were determined using a force platform. Results were similar between the two studies. In both single-leg and two-leg jumps, peak concentric force and rate of force development were higher in aquatic jumps than dry-land jumps, whereas impact force at landing was lower in aquatic jumps.

In considering the application of these findings, the researchers recommended the use of aquatic jumping exercises in therapeutic areas. Aquatic jumping exercises are beneficial for rehabilitating individuals and for aging individuals for the following reason: compared with dry-land jumping exercises, higher force production and higher rate of force development with less impact force in aquatic jumping exercises allow for greater neuromechanical stimulation to the musculoskeletal system with less risks of injury in such vulnerable populations. Therefore, when an aquatic exercise facility is located near one’s home, walking/running exercise in water is a safe and convenient exercise for maintaining and improving their physical health for elderly people as well as for individuals who have problems in their legs in performing whole-body exercise on dry-land.

2. Cardiorespiratory responses

2.1. Linear increase in cardiorespiratory responses with walking speed in water

Yu et al. (1994) compared cardiorespiratory responses to walking in water and to walking on land at various self-selected speeds. The subjects used a swimming flume for walking in water with the water depth adjusted to their chest level. For walking on land, they used a motor-driven treadmill. Nine young, untrained female subjects selected 4 graded walking speeds according to their subjective rating of perceived exertion in Borg’s scale in water and on land, respectively.

Approximately one-half of walking speed was required for achieving a similar rating of perceived exertion in water compared with the speed on land. The range of flume speed in water was from 30 to 60 m/min, whereas that of the treadmill speed was...
from 60 to 120 m/min on land. Oxygen uptake and heart rate during walking increased linearly with flume flow velocity (i.e. walking speed). In other words, physiological intensity of walking in water depends linearly on walking speed. These results indicate that proper exercise intensity for obtaining health benefits can easily be determined by referring to walking speed and/or heart rate in relatively young adults.

2.2. Increased cardiorespiratory responses with upper-extremity engagement during walking in water

Campbell et al. (2003) studied physiological intensity of various modes of walking and jogging in water with different upper-limb engagements in young and older adults. Subjects were 11 older women aged 66.7 years and 11 young women aged 21.3 years. The depth of water was adjusted to the subjects’ chest level ranging from the xiphoid to axillary regions. Participants performed 5 bouts of walking or jogging, each bout in a different mode, in a 25-m pool. Bout 1 was to walk at a normal pace with the arms kept floating on top of the water. Bout 2 was to walk at a normal pace with the arms swinging through the water. Bout 3 was to walk at a slightly faster pace with the arms swinging more forcefully through the water. Bout 4 was to jog at a fairly good pace with arms pumping underwater at the sides. Bout 5 was to jog at a faster pace with arms performing breaststroke-like movements under and toward the surface of the water.

These bouts of shallow-water exercises resulted in physiological intensity ranging from light to vigorous. Oxygen uptake expressed in MET (metabolic equivalent of task) increased from 3.5 METS to 8.6 METS for Bouts 1-5 in young adults. In older adults, it increased from 3.2 to 6.3 METS. Heart rate increased from 95 to 144 bpm for Bouts 1-5 in young adults. In older adults, it increased from 92 to 124 bpm. Thus, Campbell et al. (2003) concluded that shallow-water exercise can elicit cardiorespiratory responses that are substantial enough to maintain and improve physical health. Additionally, there are apparent age-dependent differences in the cardiorespiratory responses to the exercises that were completed at self-selected subjective intensity. These findings must be taken into account in exercise prescription for older adults.

3. Body composition: similar or greater improvement in body composition after walking training in water

Greene et al. (2009) performed experiments to compare adaptations in aerobic fitness and body composition in overweight and obese adults after they trained with two different modes of walking exercise: walking in water and walking on land. Fifty-seven male and female inactive, overweight and obese subjects aged 44 years participated in 12-week training of walking exercise in water or on land. One group of subjects walked on a variable-speed underwater treadmill with adjustable frontal resistance to the umbilicus level by means of a pump-driven waterjet. Another group walked on a motor-driven treadmill on land. Three training sessions were performed every week in both groups. Exercise intensity was increased by 5% every week from 60% to 85% of maximal oxygen uptake. Caloric expenditure during exercise was increased progressively from 250 to 500 Kcal per session by week 6 and remained 500 Kcal per session thereafter through week 12.

Adaptations to the training were not different between sexes. After the training, maximal oxygen uptake was increased in both groups. Body weight, body mass index (BMI), body fat percentage and fat mass were reduced in both groups. In contrast, lean body mass (LBM) was increased in the group that trained while walking in water more than the group that trained while walking on land. Greene et al. (2009) concluded that walking exercise training in water and on land are equally capable of improving aerobic fitness and body composition in physically inactive overweight individuals. It is of note that greater improvement in LBM can be achieved through training while walking in water compared with training while walking on land.

4. Cerebral circulation: greater cerebral blood flow during walking in water

The response to exercise in the cerebral vasculature is different from other peripheral vasculatures (e.g. muscle). The cerebral vasculature has small vascular beds and is strongly regulated by cerebral autoregulation and by the partial pressure of arterial carbon dioxide (Ogoh and Ainslie, 2009). Ogoh and Ainslie (2009) further described that the change
in cerebral blood flow depends on exercise intensity. Increases in exercise intensity elevates cerebral blood flow up to approximately 60% of maximal oxygen uptake, after which cerebral blood flow decreases toward baseline values, despite further increases in exercise intensity and brain metabolism. They speculate that hyperventilation-induced hypercapnia during heavy exercise seems to be a stronger regulator of cerebral blood flow compared with elevation in cerebral metabolism.

Pugh et al. (2015) examined the hypothesis that water-based exercise would augment cerebral blood flow velocity more than land-based exercise would. Fifteen healthy subjects aged 26 years performed two 20-min bouts of low-intensity exercise. The exercise consisted of a repetitive stepping protocol at approximately 100 bpm in water, with the depth of water adjusted to the chest level. The subjects also performed similar stepping exercise of matched intensity on land. Compared with land-based exercise, water-based exercise resulted in higher middle cerebral artery blood velocity (74 cm/s in water vs. 67 cm/s on land), posterior cerebral artery blood flow velocity (47 cm/s vs. 43 cm/s), mean arterial blood pressure (106 mmHg vs. 101 mmHg), and partial pressure of expired carbon dioxide (28 mmHg vs. 26 mmHg). Pugh et al. (2015) concluded that, in healthy individuals, water-based exercise augments cerebral blood flow more than land-based exercise of comparable intensities.

Parätt et al. (2017) tested the hypothesis that aquatic treadmill exercise would augment responses of cerebral blood flow and lower heart rate compared with land-based treadmill exercise. Eleven subjects aged 27 years performed incremental walking exercises for 10 minutes in water and on land. The walking speed was increased every 2 minutes from 4 km/h up to 6 km/h in water, while it was increased from 6 km/h up to 10 km/h on land. The depth of water was adjusted to the iliac crest level. After completing the incremental exercises, the subjects performed two 2-min bouts of constant-speed walking: one while immersed to the mid-thigh level and another to the mid-chest level. Combined mean value of right and left middle cerebral artery blood flow velocity during walking increased from the baseline in a greater amount in water than on land. In contrast, heart rate during walking was lower in water than on land. Greater water immersion resulted in lower heart rate (139 bpm at mid-chest level vs. 178 bpm at mid-thigh level), whereas cerebral artery flow velocity was not influenced by the level of immersion. Parfitt et al. (2017) concluded that aquatic treadmill exercise could enhance exercise-induced elevation in cerebral blood flow and optimize shear stress-mediated adaptation of the cerebral vasculature.

5. Brain health

5.1. Possibility for reducing the risks of cognitive dysfunction by walking training in water

Most longitudinal studies have found that high levels of physical activity are associated with 30~50% reductions in the risks of cognitive decline and dementia (Barnes et al. 2007). Yuki et al. (2012) examined whether daily physical activity prevents age-related progress in brain atrophy. Their results of 8-year longitudinal observation on 774 men and women aged 60 years indicated that physical activity is beneficial for attenuating age-related frontal lobe atrophy and for preventing dementia.

This review explained that walking training increases aerobic fitness and cerebral blood flow both in water and on land. Physical exercise enhances cardiac output, heart rate, partial pressure of arterial carbon dioxide, and additionally metabolic expenditure in nerve cells in the brain. These known responses to exercise may result in the elevation of cerebral blood flow. Interestingly, two studies that compared water-based and land-based exercises showed that the water-based exercise increased cerebral blood flow velocity more than the land-based exercise did (Parfitt et al. 2017, Pugh et al. 2015). These reports might be explained by the effect of increased hydrostatic pressure to the human body when immersed in water. Increased hydrostatic pressure leads to centralizing blood distribution within the body, which enhances cardiac performance and tissue perfusion (Parfitt et al. 2017).

5.2. Potential uniqueness in the excitation of brain during walking in water

Another interesting finding by Parfitt et al. (2017) is that the peak value in cerebral blood velocity in reference to the baseline was achieved at the 4th-min stage of incremental walking exercise and was
then maintained until the 10th-min stage in water despite further increases in exercise intensity. In walking on land, in contrast, cerebral blood velocity kept increasing successively with exercise intensity in reference to baseline. Their experimental results indicate that a factor other than exercise intensity may enhance cerebral blood flow velocity. Exercise is initiated by neural excitation of mainly the motor area of the brain, which elevates metabolic expenditure more than the resting condition. Metabolic expenditure is increased as exercise intensity becomes higher in walking both in water and on land, resulting in increased cerebral blood flow velocity. Notably, cerebral blood flow velocity is greater while walking in water than while walking on land at a comparable exercise intensity.

Although physical motions in walking are similar in water and on land, the excitation of higher motor center, such as the primary motor area may be higher during in water walking as compared to that on land. Walking in water is considered to need further involvement of the higher motor centers compared to normal walking on land, since the higher buoyancy and resistance of water should make the walking in water be more non-automatic and more voluntarily controlled movement. In addition to the increased excitation of the primary motor area, peripheral sensory organs receive more stimuli during walking in water because water pressure to the skin stimulates the cutaneous sensory system, and wave sounds caused by each step stimulate the auditory organs, for example. Thus, higher excitation of sensory area may lead to greater metabolic expenditure in the nerve cells of central sensory area during walking in water than on land. Therefore it may be speculated that nervous activity in the brain is more enhanced during walking in water not only by the excitation of motor area, but also by sensory area simultaneously. This may lead to greater cerebral blood flow velocity in water compared with walking on land.

Cerebrovascular reserve is the capability of cerebral blood vessels to respond to increases in metabolic demand and chemical, mechanical, or neural stimuli (Davenport et al. 2012). Therefore, glucose and oxygen in the brain are supplied 2-3 times more than the amount of demand via blood even in the resting condition. As the most important organ of the human being, the brain would be protected against the shortage of glucose and oxygen by sufficient supply because the cells in the brain can store a limited amount of glucose and oxygen. The energy consumed by the nerve cells is so small that the increase of cerebral blood flow velocity from the baseline remains almost the same while performing exercise across moderate intensities. Namely, a slight increase of cerebral blood flow would be enough to supply glucose and oxygen to the nerve cells. These speculations are in line with the experimental results by Parfitt et al. (2017); mean cerebral blood velocity was increased at moderate exercise intensity and remained constant even at higher intensities and was constant across different depths of water immersion during walking at constant speed.

6. Aqua-pole walking: promising walking exercise in water for physical and brain health

Walking with a pair of poles reduces reaction force, so pole-walking is recommended for elderly people and for individuals having problems in lower extremities. Based on their experiments, Figard-Fabre et al. (2011) concluded that, in addition to being safe and effective from the physiological standpoint, pole-walking appeared to represent a suitable type of exercise for obese people in terms of ensuring long-term adherence. Furthermore, aqua-pole walking (i.e. pole walking in water) is a good exercise for individuals having serious problems in their legs because gravity force is reduced by buoyance.

In order to promote the popularity of aqua-pole walking in shallow water with 1.0-1.2 m depth, walking poles specially designed for in-water use have been developed using stainless steel. The specially-designed pole floats vertically in water with the grip part above the water surface so that the users can easily grasp the poles and keep their body in the upright and stable position (Figure 1). Our measurements of heart rate responses to aqua-pole walking show that heart rate increased with speed increase to a greater amount in walking with poles than without poles (unpublished data). As described above in this review, aqua-pole walking can be recommended not only for improving cardiorespiratory function and body composition, but also for increasing cerebral blood flow that may contribute to reducing progressive declines of cognitive function with aging.
Figure 1 Poles specifically designed for aqua-pole walking. The poles are designed to float vertically with the grip part above the water surface.

7. Conclusions

The amount of people aged 65 years and older has rapidly increased in this century, which brings serious burdens in socio-economic aspects of our living. The organization of the central nervous system promotes certain muscle activations of both upper and lower extremities during aqua-pole walking, and the associated sensory organs provide additional excitations to the central nervous system in parallel. The collections of current knowledge and speculations based on the research findings cited in this article lead to indicate that aqua-pole walking may prevent or ameliorate at least 3 of 5 criteria of frailty such as slow walking speed, weak grip strength, and low physical activity level (Fried et al., 2001). In conclusion, the author would like to emphasize the beneficial effects of aqua-pole walking on aerobic fitness and cognitive function for older people.

Acknowledgement

The author thanks Dr. Minoru Shinohara (Georgia Institute of Technology) for his editorial assistance with the development of this paper.

The author has no conflict of interest to declare.

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