A Perspective on Water Properties and Aquatic Exercise for Older Adults

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Abstract

Aging causes the undesirable physiological changes and incline physical function. Older adults have more limited ability for exercising while they are greatly eager to do exercise and sustain their physical health and fitness. The knowledge about unique properties of water will assist to provide proper exercise media and as well designing rehabilitation programs for older adults or people who has limitation to exercise in land. In that, the purpose of this study is to understand the assistance of temperature, buoyancy, hydrostatic pressure and viscosity of water which made the aquatic exercise more effective than land-based exercise for this population. The physical properties of water can significantly reflect static weight-bearing, which resulted in upgrading the speed of movement like walking/running inside water. Meanwhile, a perspective of the effect of aquatic exercise on pain level, flexibility, cardiovascular fitness and balance are reviewed. The synthesis of relevant literature revealed that an appropriate aquatic exercise program can effortlessly improve quality of life and support physical health outcomes in older adults particularly in the fifth and sixth decades of life. At that point, although the limitation and physical and mental difficulty among this population should be cautionary considered, they are typically able to do exercise in the water with less joint stress and minimal difficulty.

Keywords: Water Properties, Aquatic Exercise, Fitness, Physical Health, Quality of Life, Older Adults
1. Introduction

Individuals of all ages commonly enjoy participating in physical activity and exercise. However, an apparent restriction can limit people’s ability to partake in the exercise programs, particularly obesity, low levels of physical fitness, locomotion difficulties caused by aging, some disabilities, or diseases [1, 2]. Considering these limitation, water-based exercises can be an alternative to land-based exercise to increase performing physical exercise in an aqua environment. Exercise in the water or aquatic program developed by National Arthritis Foundation YMCA in 1980, as a therapeutic medium in health care [3]. In the past two decades, water-based exercise become as an alternative exercise program to achieve fitness and rehabilitation purposes for individuals who physically had difficulty in exercising on land [4]. Meanwhile, the physical properties of water not only can reduce the effect of body weight on the joints stress and risk of injury or fall [5], it also can be combined with the resistance of the water during all movements to provide the beneficial for overall body exercise for people with physical limitation and as well for older adults [6].

In addition, water exercise is either safer than land-based exercise to reduce risk of injuries and difficulty of exercise [7] or this type of recreational exercise is an enthusiast for older sportive people [8]. All these exercises are typically performed as an aerobic exercise with generally more low-impact than land-based exercises. Even though, it also is carried out in shallow and deep water, it is particularly performed in shallow water for older adults who probably are not skilled to swim. In fact, the water's unique properties can create a great foundation movement in water media for older adults the fifth and sixth decades of life.

Meanwhile, previous studies proved aquatic exercise able to improve fitness components such as muscle strength, cardiovascular endurance, flexibility, balance and body composition of patients with arthritis, disabled population and elder people [9, 10]. It has also a significant multiple health outcomes and positive physical and psychological effects [11]. In that, aquatic exercises can bring some advantages due to the impact of the biophysical properties of immersion such as buoyancy, hydrostatic pressure gradient, water viscosity, the specific heat of water and controlled temperature [12]. Therefore, the purpose of this study was to brief aquatic exercise for older adults. Moreover, a summary of the physical properties of water is reviewed, and the recommendation regarding to current research in the benefit of aquatic exercise on pain level, flexibility, cardiovascular fitness and balance abilities will be proposed. Lastly, the summary of an aquatic exercise program to improve the quality of life will be recommended for older adults.

2. Physical Properties of Water and Exercising

2.1 Effect of Water Temperature

While exercising, the slowed enzymatic processes and slowed nerve conduction that impairs the rate of force development reduce local muscular endurance during dynamic contraction and impair manual dexterity until 35°C [13]. The warmth of the water may decrease muscle tension, muscle spasticity, co-contraction, and spasm, which allow an increased blood flow and oxygen to effect healing in body tissues by improving range of motion which is a benefit for some physical conditions and pathologies as well [14, 15]. Water temperature can have a profound effect on the cardiovascular response to exercise. A previous study which conducted at the similar exercise intensity level in the land, and 32 and 20°C water temperature, revealed exercising in the cold water enhanced stroke volume and decreased heart rate, increasing exercise efficiency [13].
In contrast with warm water, exercising in cold water, or lower water temperature can cause vasoconstriction in the periphery to decrease heat loss, forcing blood centrally, enhancing venous return and increasing stroke volume. However, considering the centralization of peripheral blood flow which overcome by the thermal stimulus to increase heart rate at 36°C. Regarding to the potential for heat illness, in general, temperature recommendations for low impact intensity training should be between 28 -31°C to prevent any heat-related complications [8, 16].

2.2 Effect of Buoyancy
According to Archimedes' principle, buoyancy is defined as the upward thrust acting in the opposite direction of gravity which is related to the specific gravity of the immersed object. Specific gravity or relative density is related to buoyancy. A substance with a specific gravity greater than water will sink, whereas a sense with a specific gravity of less than water will float [16, 17]. The variations in buoyancy (mid-chest) and of gravity (umbilicus) during immersion in the water show in Figure 1.

Figure 1. Variation in the buoyancy center and immersion in the water (adapted from Weller et al., 2016).

The force of buoyancy will support, assist and helps to overcome the resistance of weight-bearing. Resistive buoyant forces are most significant when the lever arm is perpendicular to the buoyant force [16, 17]. In addition, buoyancy can be affected by three methods of exercise; as assistance, supportive, and resistance. Buoyancy-assisted exercise occurs when movements are toward the surface of the water. These assistance exercises are mostly used to increase mobility during the movements are toward the surface of the water like passive abduction of the arm toward the water surface. In addition, buoyancy can easily support the movements that are perpendicular to the upward thrust of buoyancy and parallel to the bottom of the pool such as horizontal abduction and adduction of the shoulder in standing position [3, 8]. Finally, buoyancy as resisted exercise can directly oppose the upward thrust of buoyancy. For example, the hip extensor muscle the hip extensor would become buoyancy-assisted if the hip extends from standing in 90' (degree) to flex and then extend to neutral position [8, 16]. The ways to change buoyancy depends on the depth of immersion.
2.3 Effect of Depth of Immersion on Weight Bearing

There are several investigations about the influence of body immersion level during aquatic exercises. Firstly, the rate of perceived exertion (RPE) scale is used to measure the intensity of the exercise. Rate of perceived exertion (RPE scale; 0-10) is higher when the activity immersed by the hip level, comparatively with immersion up to the chest [15]. The increased scale rate of perceived exertion may be due to the higher intensity of drag forces acting in the lower limbs, as compared to those acting in the trunk and upper limbs, when partially immersed [18]. Secondly, the shallow water reduces the buoyancy and increase ground reaction force and then changes in the neuromuscular pattern of active muscles at different levels of the body in the water. When comparing shallow-water versus deep-water exercises, the physiological demand seems to be lower for deep-water exercises which are helpful for individuals [15]. Weight-bearing is affected by the depth of water owing to buoyancy as well. As Figure 2. shows, in general, weight-bearing is depending on water immersion level which determined at the seventh cervical vertebral level (C7), the xiphoid, and the anterior superior iliac (ASIS) approximately 10, 25, and 50% of their body weight, respectively [16, 17].

![Figure 2. Depth of water immersion and weight-bearing](image)

Then, decreasing depth of water is one way to progress lower extremity weight-bearing. Depth of immersion becomes an essential issue in aquatic exercise, especially for rehabilitation purpose with lower extremity limitation. However, the depth of immersion can reflect static weight-bearing, and effect on the speed of movement like fast or slow walking/running inside water [8]. In that, exercising in water makes feel about 90% lighter. This makes water exercise, with low impact, an ideal activity for the older adult and also those who physically had difficulty in exercising on land [7].

2.4 Effect of Hydrostatic Pressure and Immersion

According to Pascal’s law states that, at any given depth, the pressure from the liquid is exerted equally on all surfaces of the immersed object. It is a pressure exerted on immersed an object equally. Hydrostatic pressure is responsible for the cardiovascular changes seen with immersion and has a significant impact on exercise training parameters [16].

Hydrostatic pressure is derived from hydro-to do with water, and static-not moving. The objective movements depend on water movement and action. While individual horizontally floating (prone or supine position), hydrostatic pressure aids in returning fluid and blood to the heart & lymph return. It also makes lower working heart rate and affect respiration (HR is 13-17 bpm on average lower in the water) which consequence to increased vital capacity [8].
Immersion in the water offers many practical consequences during exercise. The participants possibly will experience less stress on the heart and vessels during exercise, reduced joint pain, or reduced blood pressure. Furthermore, during water therapy exercise, individual possibly can recover more rapid due to the influx of blood flow to the muscles and tissues, which resulted in the respiratory muscles probably, become more robust and more efficient. Immersion will affect people differently depending on their age, gender, physical condition, and body composition [5, 19].

2.5 Effect of Viscosity or Resistance
Viscosity is defined as the friction occurring between individual molecules in a liquid, causing resistance to flow. Since water is denser than air, there is resistance to most movement in the water regardless of buoyancy, and it can provide more resistance to motion than air. A combination of the surface area of an object and its speed determines the resistance to the motion caused by the fluid viscosity (drag). In other words, the size, shape, and speed of the object determine how much drag resistance will be experienced [16, 17, 20]. During exercise, additional resistance increases the intensity of the movement and thus requires greater muscular effort. Greater energy expenditure causes higher caloric expenditure. At the same time, water offers more resistance to movement than air due to its intensity 700-800 times more, exercising in the water media provides high levels of energy usage with relatively little effort to the body, which is essential to expend calories and weight loss [11]. In that, since the viscosity of water creates resistance with all active movements, it may result to increase flexibility, range of motion and strengthening [6].

In addition, these properties will provide adequate resistance to support trunk strength acquisition which gives benefit in lumbar stabilization program. The resistance of the water offers undue axial stress on weight-bearing joints which easily managed by the participants and accommodates most normal daily movements into an exercise format [21]. Weight-bearing, tactile, and thermal stimulation, as well as the inertial effect of the movement, can lead to relaxation, joint overload and eccentric effort reduction, vasodilatation by warming, and analgesia. When the immersed limbs move faster, reaching a critical level of speed, water turbulence occurs. This situation creates a hydrodynamic force that offers resistance [7, 12, 17].

3. Aquatic Exercise and Physical Health Outcomes

Many studies proved aquatic exercises can improve significantly fitness components such as muscle strength, cardiovascular endurance, flexibility, balance and reduction of the body fat percentage for people who physically had difficulty exercising on land and older adults. It has significant multiple health outcomes and positive physical and psychological effects [11]. Several studies have been conducted to determine the effectiveness of water-based exercise on rehabilitation purpose and fitness components which briefing in this paper.

3.1 Effect on Pain Level
The aquatic exercise is one of the effective forms of exercise according to the gait control theory, due to the low-impact property of underwater fitness. The movement of a limb results in feedback from neurons which provide information to the central nervous system regarding limb position, muscle tension and rate of muscle stretch. As with the pressure and touch receptors, these fibers have a large diameter and are myelinated, and their signals may also reduce the pain level [22, 23].
Performing the strength exercises in water is eligible in any direction and limited only by the restriction of the joints being used. Hydrotherapy provides buoyancy, which unloads the operated joint and other painful joints and may allow patients to exercise more effectively with less pain and swelling [24]. The aquatic exercise program can facilitate the level of challenge in workouts by increasing the speed of movements without complex equipment is needed. Then, all aquatic exercises can enhance upright position with appropriate posture as well [21].

Moreover, another study by Dundar et al. (2009) compared the effectiveness of aquatic exercise interventions with land-based exercises in the treatment of chronic low back pain. The result concluded that both groups showed the improvement, but the water-based exercises produced better improvement in disability and quality of life of the patients with chronic low back pain than land-based exercise [25].

3.2 Effect on Joint Flexibility
As the connective tissue around the joint tends to get hardened during aging process, the prolong fascia adhesion causing it loses its flexibility [2, 24]. Stretching exercise in the water claims to quickly dissolve fascia adhesions, realign the soft connective tissue dislocation and the increase the range of motion. The fundamental principle underlying the treatment is to accentuate the body’s natural movement that occurs when all the joints are subjected to stretch pressure. The influence of low gravity environment of water eases the body to stretch in the position, which restricted to do on land with the influence of normal gravity and much longer periods of time [24]. Moreover, Cochrane et al. (2005) believed that aquatic exercise is a significant therapy increase joint flexibility and functional ability while reducing pain and difficulty with daily tasks [26]. Similarly, Colado et al. (2009) and Neiva et al. (2017) reported a significant improvement of water-based exercise in the flexibility on non-active healthy women by comparing the land-based exercise [27, 28]. Furthermore, the other studies focused on the effects of aquatic exercise on the physical function that displayed aquatic exercise significantly enhanced ankle, knee and hip flexibility, as well as strength and cardiovascular fitness [6, 29].

3.3 Effect on Cardiovascular Fitness
The mechanisms in the adaptations to aerobic fitness have been found primarily in peripheral skeletal muscles with an increased arterial-venous difference, increased capitalization, and higher mitochondrial enzyme activities [19]. The exercise programs that combine resistance and aerobic exercise performed either on land or in water will improve the exercise tolerance, muscular strength and induce similar favourable adaptations on total cholesterol, triglycerides and body composition in patients with coronary artery disease [27]. The cardiovascular, metabolic and body composition adaptations are strongly related to the patient’s cardiovascular health and their rehabilitation intervention program. However, termination of the exercising can reverse these adaptations [19]. Similarly, numerous researchers have investigated the effects of water-based exercise or aqua aerobic exercise on cardiovascular risk factors and obesity, which revealed the significant improvement in health benefit among older adults. In Addition, aqua aerobic exercise can increase energy expenditure while immersing the body in water and weigh up to 90% less than on land and it is non-weight bearing nature [11, 17, 30].
### Table 1. A summary of 12-week aquatic exercise program to improve quality of life among older adults; 2 sessions weekly and in shallow water

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Intensity &amp; Frequency (week 1→ week 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Exercise (40 min)</strong></td>
<td></td>
</tr>
<tr>
<td>Walking: forward/backward/side walk (with or without music)</td>
<td>Self-chosen speed 10m×4 → 25m×8</td>
</tr>
<tr>
<td>Forward lunges</td>
<td>Self-chosen rpm ×3 → 10</td>
</tr>
<tr>
<td>Side lunges</td>
<td>Self-chosen rpm ×3 → 10</td>
</tr>
<tr>
<td>Supine position with hip and knee bent</td>
<td>Self-chosen rpm ×3 → 20 ×6</td>
</tr>
<tr>
<td>Supine position + leg pedaling</td>
<td>Self-chosen rpm×3 → 20×6</td>
</tr>
<tr>
<td>Supine position + cycling</td>
<td>Self-chosen rpm ×3 5 → 20</td>
</tr>
<tr>
<td>Shoulder transvers (abduction, adduction, flexion and extension)</td>
<td>Repeated slowly ×3 6 → 15</td>
</tr>
<tr>
<td>Upper body mobilization (with kickboard)</td>
<td>Self-chosen rpm ×3 → 10</td>
</tr>
<tr>
<td>Arm pendulum (in different intense)</td>
<td>Repeated slowly ×3 6 → 15</td>
</tr>
<tr>
<td>Deep water cycling (with woggle)</td>
<td>30sec → 1 minute ×3</td>
</tr>
<tr>
<td>Pool plank (with woggle)</td>
<td>Self-chosen rpm ×3 3 → 10</td>
</tr>
<tr>
<td>Wall push-up</td>
<td>Self-chosen intense ×3 5 → 10</td>
</tr>
<tr>
<td><strong>Warm-up (10 min)</strong></td>
<td></td>
</tr>
<tr>
<td>Static walk, combination of stretching exercise, water walking for range of motion and relaxation)</td>
<td></td>
</tr>
<tr>
<td><strong>Cool-down (10 min)</strong></td>
<td>Stretching, deep breathing technique, relaxation and self-care free water-activity</td>
</tr>
</tbody>
</table>

### 3.4 Effect on Balance

Balance is controlled by sensory input, central processing, and neuromuscular responses. Balance is musically associated to proprioception sense which defined as position sense that
orients the body or specific body parts to space or other objects [31]. Balance and proprioception may be trained in a water-based program; hip flexion/extension and circumduction in waist-deep water while standing on the leg, progressing to shallower water [8]. Possibly buoyancy of water and non-weight bearing provide a minimizing dynamic postural stability effected on the speed and direction of movements during exercise. Therefore, while the buoyancy acts in the opposite direction to the gravity, it gives the muscles, tendons and joint sense of feeling lighter in water media comparing to land [32]. Another available evidence to support improvement of balance could be related to viscosity and resistance of water that resulted in the slower motion, response and reaction time [6].

In spite of aquatic exercise program can improve physical fitness and quality of life among older adults, many adults still have limitation and difficulty to join the aquatic exercise. Therefore, while the advantages of aquatic exercise are considerable, the potential risks also should be determined to create appropriateness of aquatic exercise program. In that, the policies and procedures should be specified basis of the precautions and contraindications. Some of the special precautions and contraindications are water phobia, neurologic disorders, uncontrolled seizures, cardiac/respiratory dysfunction, open wounds, chlorine allergy, epilepsy and aspiration. Consequently, during aquatic exercise, it is essential to consider the warning signs like light-headedness, nausea, headache, dizziness, increased pain, agitation, high fever particularly for older adults and older people [16]. In that, while the limitation and difficulty (physically or mentally) should be considered, it is notable for monitoring individual while exercising or relaxing in the water and the program should start with their 55-60% of intensity (reserve heart rate). A summary of 12 week aquatic exercise program to improve quality of life among older adults recommended in Table 1 [7].

4. Conclusion
The aspects of physical properties of water (temperature, buoyancy, hydrostatic pressure and viscosity) can provide safe, effective and comfortable media to do exercise for people who had difficulty in land-based exercise. As the effect of water-based exercise on pain level, flexibility, cardiovascular fitness and balance were discussed, the benefit of aquatic exercise program is considerable, and it can be probably suggested to improve quality of life and physical fitness in older adults.

References


