The Role of Aquatic Exercise on Strength of Quadriceps Muscle and Falling Risk in Elderly People

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ABSTRACT The present study aims at comparing the effects of aquatic exercise in shallow and deep water on the Quadriceps muscle strength and the risk of falls in elderly women with chronic knee Osteoarthritis. 43 elderly women suffering from knee OA aged over 55 years old participated in the present study. Based on the preliminary examination and pretest, the subjects were divided by random matching into 3 homogeneous groups: shallow-water exercise program (N=14); deep-water exercise program (N=14); control group (N=15) without intervention. Using Dynamometer and Berg questionnaire, the strength of the quadriceps muscle and falling risk were evaluated respectively. Their exercise intensity and perceived exertion were evaluated by measurement of the percentage of the maximum heart rate and Borg questionnaire respectively. Data were analyzed using two-factor repeated measure ANOVAs and post hoc LSD and paired t-tests at p<0.05 significance level. After the intervention, the quadriceps strength and falling risk in the shallow water were significantly improved compared with the deep water (respectively: p=0.008, p<0.001), and with the control group (p<0.001) and (p<0.001) respectively. Furthermore, the quadriceps strength and falling risk in the deep water were significantly improved compared with the control group (p=0.004) and (p<0.001) respectively. Findings support the effectiveness of physical exercise in water. It seems that training exercises in shallow water more significantly affects the quadriceps strength and the falling risk compared to such exercises in deep water.

KEYWORDS Aquatic Exercise, Shallow Water, Deep Water, Muscle Strength, Falling Risk, Knee Osteoarthritis.

INTRODUCTION Osteoarthritis is the most common type of arthritis (Bruce & Peck, 2005). This progressive contagious disease is usually associated with aging and does not have an effective cure (Brady, Kruger, Helmick, and Callahan & Boutaugh. 2003). Suomi and Collier, 2003 predicted that as life expectancy increases, the number of arthritis patients is also rising. Also, more women than men are susceptible to arthritis particularly knee osteoarthritis (Brosseau, Pelland, Wells & et al., 2004; Dias, Dias & Ramos, 2003). Ligament Osteoarthritis, affect the joint capsule, muscles and tendons (Barrett, Cobb & Bentley, 1991; Dias, Dias & Ramos, 1993). This in turn causes swelling, joint deformity, decreased range of motion, decreased muscle strength, damage to th Proprioseptive system and ultimately increases the level of knee pain. On the other hand, rest and the prohibition of any heavy activity and limited activity due to knee pain lead to atrophy in
lower extremity muscles, also decrease the muscle strength especially in the quadriceps and finally cause increased fall risk (Sturnieks, Tiedemann, Chapman, Munro, Murray & Lord, 2004; Slemenda et al., 1998; Jones, Nguyen, Sambrook, Lord, Kelly & Eisman, 1995). This problem in elderly people suffering from knee Osteoarthritis more severely causes the reduced quadriceps muscle strength (Tsourlar, 2006) and increases their postal sway that in turn increases the risk of falling for such patients (Hassan, Doherty, Mockett & Doherty, 2002; Masui, Hasegawa, Yamaguchi, Kanoh, Ishiguro & Suzuki, 2006). So femoral quadriceps strengthening is an effective way to reduce the risk of falls (Cayley, Bcom& Grad, 2008; Rebecca, Miriam & Nelson, 2003). However, because of the arthritis pain we cannot achieve the training goals, that is, strengthening the muscles.

A Kind of exercises that helps those who suffer from arthritis, manages their condition, and improves their daily performance is exercising in water. Several studies have shown that exercise can play an important role in the improvement of knee osteoarthritis. Exercise reduces the pain, improves postural control ans muscle strength, improves daily activities and fall risk (Messier, Royer, Craven, O’Toole, Burns & Ettinger, 2000; Wang, Belza, Thompson, Whitney & Bennet, 2007). Exercise in water in particular is the most effective method for the patients who suffer from knee osteoarthritis. Exercise in water is a non-weight bearing exercise that reduces stress on the joints and protects joints submerged in the water from damage due to overload (Silva, Valium, Pessanha, Oliveira, Myamoto, Jones et al., 2008; Hinman, Heywood & Day, 2007). Although there are various studies on patients with osteoarthritis and exercise in the water, most of them are in low-deep water (Roper, 2010; Boothe, 2006; Cochrane, Davey & Edwards, 2005).

The studies that examine the impact of deep water or compare and contrast the impacts of the deep water and shallow water, have mostly been on healthy athletic people, or the studies have been on other types of diseases. No study was found on comparing the effect of deep or shallow water on elderly people suffering from osteoarthritis. For example, Chu & Rhodes (2001) studied the effect of running in deep water on the functional capacity of healthy adults. Other studies conducted in deep water investigated the physiological responses of athletes (DeMaere et al., 1997) or compared the results with those related to running on treadmills (Butts, Tucker & Greening 1991; Butts, Tucker & Smith, 1991; Frangolias, Rhodes & Taunton, 1996; Michaud et al., 1995; Brown & et al., 1997). Kaneda, Sato, Wakabayashi, Hanai and Nomura (2008) compared the effect of exercise in deep and normal-depth water on the healthy elderly’s ability to balance. Lund et al (2008), compared the effect of exercise on land and in the water on the muscle strength in healthy elderly. Another study compared the effect of running in deep and shallow water on patients with spinal problems Dowzer, Reilly and Cable (1998). Considering the fact that the hydrostatic pressure and buoyancy vary in deep and shallow water and this affects the level of the irritability and strength of the muscles and the joints, this study aims at comparing the effect of 12 weeks exercise in deep and shallow water on the muscular strength and risk of fall in elderly women suffering from knee Osteoarthritis.

**MATERIALS AND METHODS**

Originally, 43 female elderly patients who had knee OA in present study. They were selected from among elderly patient over 55 years old who had been diagnosed with chronic degenerative OA that suffered over 8 months. Based on the preliminary examination and pretest (on dependent variables and BMI and BFP), the subjects were divided by random matching into 3 homogeneous groups that there was no significant mean difference between 3 groups: 1) shallow-water exercise program (N=14, age: 62.41±5.16 year, height: 154.92±4.63 Cm, weight: 59.84±10.45 kg, Body Mass Index (BMI): 25.71±3.96 kg/m2, Body Fat Percentage (BFP): 30.69±7.24), 2) deep-water exercise program (N=14, age: 63.11±5.37 year; height: 155.22±4.03 cm. weight: 61.03±11.20 kg; BMI: 26.11 ± 4.09 kg/m2, BFP: 31.83 ± 6.88), and 3) control group (N=15, age: 63.41±5.16 year; height: 154.85±3.99 cm; weight: 60.13±10.86 kg; BMI:
25.83± 4.21 kg/m², BFP: 31.17±7.55) without intervention. The water exercise program was performed three sessions per week on shallow water group (water until chest and feet touch the floor) and deep water group (patient do exercise while the body is immersed in the water and feet do not touch the floor) underwent a 12 weeks period as was prescribed by Zamanian et al., 2013.

Using Dynamometer and Berg questionnaire, the strength of the quadriceps muscle and falling risk were evaluated respectively. The Berg questionnaire includes 14 items that questionnaire replies in all sections in related using likert 5-point to degree from zero to 4 (Miyamoto, Lombardi, Berg, Ramos & Natour, 2004). The Isometric contraction of quadriceps muscle was measured by dynamometer as muscle strength of lower extremity (Bohannon, 1997). In the present research, to control the rate of participants' engagement in the exercises, their heart rate and that of the Rating of the Perceived Exertion (RPE) (Borg 10 score modified version) were measured (Borg, 1973).

The maximum heart rate percentage and that of the RPE in each week have been measured via the mean for measured values during weekly meetings. Based on the data on experimental groups, the participants' heart rate range has been, while doing the exercise, between 55% to 65% of the maximum heart rate. Also, the RPE reported has been in the range of 4 to 6, which is indicative of the rate of the perceived exertion from moderate to intense. Data were analyzed using two factor repeated measure ANOVAs and follow up tests included LSD and paired samples t test at p<0.05 significance level.

RESULTS

The results obtained from multi-variable analysis of variance showed that the main effect of group type on the two important variables of body mass and the fat percentage did not display any significant mean difference between groups (p=0.428, F (4,78)=1.08, Wilks's Lambda=0.897), showing that the whole groups join a similar level from the viewpoint of the mentioned variables.

Table 1 shows the descriptive statistics related to the muscle strength and risk of fall among the groups in the pretest and the post-test.

Table 1. The data of descriptive statistics related to the muscle strength and risk of fall among the groups in the pretest and the post-test.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Variables</th>
<th>Measures</th>
<th>% Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td>Shallow-Water</td>
<td>Strength</td>
<td>193.58±23.42</td>
<td>215.31±16.10</td>
</tr>
<tr>
<td></td>
<td>Risk of Fall</td>
<td>32.15±10.48</td>
<td>46.33±6.72</td>
</tr>
<tr>
<td>Deep-Water</td>
<td>Strength</td>
<td>195.45±27.18</td>
<td>208.84±21.55</td>
</tr>
<tr>
<td></td>
<td>Risk of Fall</td>
<td>30.97±8.99</td>
<td>39.64±7.28</td>
</tr>
<tr>
<td>Control</td>
<td>Strength</td>
<td>197.12±25.06</td>
<td>195.39±25.62</td>
</tr>
<tr>
<td></td>
<td>Risk of Fall</td>
<td>33.50±9.81</td>
<td>30.32±9.01</td>
</tr>
</tbody>
</table>

Mean difference at level of p≤0.05

The results obtained from two factor repeated measure ANOVAs for analysis of main effects for independent variables (within group factor: exercise in the water; between group factor: water depth) on the risk of fall and muscle strength has been stated in table 2.
Table 2. Data of analysis of main effects for strength muscle and risk of fall.

<table>
<thead>
<tr>
<th>Source of Changes</th>
<th>Variables</th>
<th>(df_1)</th>
<th>(df_2)</th>
<th>(F)</th>
<th>(p)</th>
<th>(\eta^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise in the Water</td>
<td>Strength</td>
<td>1</td>
<td>40</td>
<td>2.901</td>
<td>0.024*</td>
<td>0.079</td>
</tr>
<tr>
<td></td>
<td>Risk of fall</td>
<td></td>
<td></td>
<td>8.725</td>
<td>&lt;0.001***</td>
<td>0.207</td>
</tr>
<tr>
<td>Depth of Water (shallow-water/ deep-water/ control)</td>
<td>Strength</td>
<td>2</td>
<td>40</td>
<td>3.147</td>
<td>0.011*</td>
<td>0.093</td>
</tr>
<tr>
<td></td>
<td>Risk of fall</td>
<td></td>
<td></td>
<td>8.725</td>
<td>&lt;0.001***</td>
<td>0.234</td>
</tr>
<tr>
<td>Exercise in the water × Depth of Water</td>
<td>Strength</td>
<td>2</td>
<td>40</td>
<td>4.912</td>
<td>0.004**</td>
<td>0.181</td>
</tr>
<tr>
<td></td>
<td>Risk of fall</td>
<td></td>
<td></td>
<td>12.406</td>
<td>&lt;0.001***</td>
<td>0.351</td>
</tr>
</tbody>
</table>

*Mean difference at level of \(p \leq 0.05\), **Mean difference at level of \(p \leq 0.01\), ***Mean difference at level of \(p \leq 0.001\)

Considering the significant difference of the interaction effect for the two independent variables, the paired-t test for performing within group post hoc comparisons and considering the significant difference of the main effect for water depth LSD test for performing multiple comparisons were used the result of which have been shown in tables 3, 4, respectively.

Table 3. The data of paired-t test for performing within group comparisons for Strength and risk of fall.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Variables</th>
<th>Mean Difference</th>
<th>(t)</th>
<th>(df)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow-water</td>
<td>Strength</td>
<td>-21.73</td>
<td>-11.28</td>
<td>13</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td></td>
<td>Risk of Fall</td>
<td>-14.18</td>
<td>-12.79</td>
<td>13</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>Deep-water</td>
<td>Strength</td>
<td>-13.39</td>
<td>-8.73</td>
<td>13</td>
<td>0.001***</td>
</tr>
<tr>
<td></td>
<td>Risk of Fall</td>
<td>-8.67</td>
<td>-10.25</td>
<td>13</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>Control</td>
<td>Strength</td>
<td>1.73</td>
<td>0.193</td>
<td>14</td>
<td>0.862</td>
</tr>
<tr>
<td></td>
<td>Risk of Fall</td>
<td>3.18</td>
<td>0.827</td>
<td>14</td>
<td>0.594</td>
</tr>
</tbody>
</table>

***Mean difference at level of \(p \leq 0.001\)

Table 4. The data of LSD test for performing between groups post hoc comparison for strength and risk of fall.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Groups</th>
<th>Mean Difference</th>
<th>Standard Error</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength</td>
<td>Shallow-water</td>
<td>6.47</td>
<td>1.08</td>
<td>0.008**</td>
</tr>
<tr>
<td></td>
<td>Deep-water</td>
<td>19.92</td>
<td>1.65</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>13.45</td>
<td>1.98</td>
<td>0.004**</td>
</tr>
<tr>
<td>Risk of Fall</td>
<td>Shallow-water</td>
<td>6.69</td>
<td>0.96</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td></td>
<td>Deep-water</td>
<td>16.01</td>
<td>0.74</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>9.32</td>
<td>1.08</td>
<td>&lt;0.001***</td>
</tr>
</tbody>
</table>

**Mean difference at level of \(p \leq 0.01\), ***Mean difference at level of \(p \leq 0.001\)

Table 3 shows that the score for strength of quadriceps muscle in the shallow-water group \((t(13)=-11.28, p<0.001)\) and deep-water \((t(13)=-8.73, p=0.001)\) has had a significant increase compared to the pre-test, but the muscle strength of quadriceps' changes among the control group did not show statistically significant difference \((t(14)=0.193, p=0.862)\). Based on the given results in table 4, the strength of quadriceps muscle in the shallow water group compared to deep-water group \((p=0.008)\) and control group \((p<0.001)\) is located in a higher level. In addition to, the deep water group compared to control group is located in a higher level \((p=0.004)\).

Table 3 shows that the score for risk of fall in the shallow-water group \((t(13)=-12.79, p<0.001)\) and deep-water \((t(13)=-10.25, p<0.001)\) has had a significant increase compared to the pre-test, but the risk of fall changes among the control group did not show statistically significant difference \((t(14)=0.827, p=0.594)\). Based on the given
results in table 4, the risk of fall in the shallow water group compared to deep-water group (p<0.001) and control group (p<0.001) is located in a higher level. In addition to, the deep water group compared to control group is located in a higher level (p<0.001). The effect of independent variables on the strength and risk of fall has been shown in figure 1 and 2 respectively.

![Figure 1](image1.png)

**Figure 1.** The effect of exercise in the water and the water depth on the muscle strength.

1^Significant increase to the pre-test (p<0.05). †Significant mean difference to control group (p<0.05). ‡Significant mean difference to deep water group (p<0.05).

![Figure 2](image2.png)

**Figure 2.** The effect of exercise in the water and the water depth on the risk of fall.

1^Significant increase to the pre-test (p<0.05). †Significant mean difference to control group (p<0.05). ‡Significant mean difference to deep water group (p<0.05).
DISCUSSION AND CONCLUSION

In relation to the muscle strength, the results of the present study revealed that physical exercise in deep and shallow water significantly increases the muscle strength in elderly women suffering from chronic knee Osteoarthritis. The effect of physical exercise in shallow water on muscle strength is significantly more than the effect of such exercises in deep water. The findings suggest that deep water and shallow water environments provide varied resistance for increasing the muscle strength, so that the shallow water environment leads to higher muscle strength. In water buoyancy keeps the body up against gravity and it can serve as an auxiliary, supporting force that is associated with weight loss (Genuario & Vegaso, 1990; Thein & Brody, 1998). Previous research has shown that compared to the shallow water, dry environment has a greater role in increasing muscle strength (Foley, Halbert, Hewitt & et al., 2003; Yennan et al., 2010).

As a result it seems that as the training environment further provides the condition for the influence of gravity, muscles are involved with more resistance and ultimately they experience higher strength. So in the present study not fully submerging in shallow water—so that the feet remain in contact with the ground—may impose more resistance on the muscles. It has caused higher strength in muscles. Yet Some studies of elderly patients with osteoarthritis of the knee and hip have not reported the water environment as a suitable environment for the increase of the femoral quadriceps muscle strength (Davey & Cochrane, 2003) that is not in line with the findings of the present study. The reason for this inconsistency might be due to the age of the subjects, type and the duration of the training program in the present study. Considering the fact that the collapse of the elderly is interconnected to the lower body muscle strength (Michael & et al., 2003), by increasing quadriceps muscle strength, it is expected to see a decrease in the risk of fall in the subjects of the study. In this relation the findings of the present study showed that physical exercise in deep and shallow water has significantly reduced the risk of fall in elderly women with chronic knee osteoarthritis.

The effect of physical exercise in shallow water on fall risk was significantly more than effect of physical exercise in deep water. Research evidence also suggests that exercise on land and in shallow water, both reduce the risk of falls (Douris et al., 2003) that is in line with the findings of the present study. Knee osteoarthritis causes the knee movement problems, muscle loss or atrophy of the lower body (especially the quadriceps muscle) and increases the risk of falls (Sturnieks, Tiedemann & Chapman, 2004; Jones, Nguyen & Sambrook, 1995). Moreover, physiologically, the strength and muscle mass decreases with age (Cayley, Com & Grad, 2008). Therefore since all the body movement is due to the skeletal muscle strength and contraction. Sarcopenia causes muscle weakness (Rebecca, Miriam & Nelson, 2003) and impaired balance in older people, especially older people with osteoarthritis of the knee and increases the likelihood to fall (Masui, Hasegawa & Yamaguchi, 2006).

As a result, improving lower body muscle strength, especially quadriceps muscle of the thigh, as we already referred to, will have a considerable contribution in reducing the risk of falls. On the other hand, due to the higher efficacy of exercise in shallow water in improving quadriceps muscle strength, this factor may result in greater efficacy of shallow water condition in reducing the risk of falls. According to the findings of research that supports the effectiveness of physical exercise in the water, it seems that training exercises in shallow water compared to exercise in deep water, has better impact on quadriceps muscle strength and the risk of falls.
REFERENCES


