A Comparison of the Effects of Different Water Exercise Programs on Balance Ability in Elderly People

Koichi Kaneda, Daisuke Sato, Hitoshi Wakabayashi, Atsuko Hanai, and Takeo Nomura

This study compared the effects of 2 types of water exercise programs on balance ability in the elderly. Thirty healthy elderly persons (60.7 ± 4.1 yr) were randomly assigned to a deep-water-running exercise (DWRE, n = 15) group or a normal water exercise (NWE, n = 15) group. The participants completed a twice-weekly water exercise intervention for 12 wk. Exercise sessions comprised a 10-min warm-up on land, 20 min of water-walking exercise, 30 min of water exercise while separated into NWE and DWRE, a 10-min rest on land, and 10 min of recreation and relaxation in water. Postural-sway distance and tandem-walking time were decreased significantly in DWRE. Postural-sway area was decreased significantly in NWE. In both groups, simple reaction times were significantly decreased. The findings of this study show that a water exercise program including deep-water running is much better than normal water exercise for improving dynamic balance ability in the elderly.

Keywords: water exercise intervention, deep-water running, dynamic balance, static balance, older adults

Falls involving elderly people pose a serious problem in an aging society because they cause bone fractures and reduce physical activities in daily life because of the attendant fear of further falls (Vellas, Cayla, Bocquet, de Pemille, & Aalbarede, 1987). The main factor in falls among elderly people is the decline of physical function with age: muscle strength, aerobic capacity, joint flexibility, and balance ability (Edelberg, 2001). The fear of falling limits daily activities, which in turn further decreases physical function. Balance ability is an important function that prevents falls because it is associated with postural control (Woollacott, 1993). Nelson et al. (2004) showed that balance improvement and balance training are crucial in fall prevention. Balance ability is widely acknowledged to decline with age; it is markedly lower in those who are 60 years old or older (American Geriatrics Society, British Geriatrics Society, & American Academy of Orthopaedic Surgeons Panel on Falls Prevention, 2001). Therefore, exercises to

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improve balance ability are important to prevent, or at least forestall, the decline in physical function and consequential falls.

Many exercises are conducted to prevent the decline of balance ability among elderly people (Gauchard, Jeandel, Tessier, & Perrin, 1999; Wong et al., 2001). Water exercises such as water walking and water aerobic exercises are effective exercises used in fitness programs for health improvement in elderly people or in rehabilitation programs for people with disabilities (Foley, Halbert, Hewitt, & Crotty, 2003; Ruoti, Troup, & Berger, 1994). In water, buoyancy acts against the body to reduce the vertical load at the joints; furthermore, water resistance necessitates that individuals in water exert greater force than when on land (Miyoshi, Shirota, Yamamoto, Nakazawa, & Aakai, 2004). With regard to influences on cardiovascular responses, the central shift in blood volume from lower limbs to the thoracic region during water immersion is caused by hydrostatic pressure, which subsequently increases cardiac output and stroke volume (Arborelius, Ballidin, Lilja, & Lundgren, 1972). Other advantages include a low risk of falling and the consequent lack of fear of falling during water exercise (Debeveux, Robertson, & Briffa, 2005).

Suomi and Koceja (2000) described the positive effects of the Arthritis Foundation Aquatic Program on balance ability in people with rheumatoid arthritis. Simmons and Hansen (1996) conducted water exercises such as walking, marching, sidestepping, kicking, and twisting in healthy elderly participants that thereby improved their balance ability. Few studies, however, have investigated the effects of different types of water exercise on balance ability. Clarification on the effects of water exercise type and of these interventions in elderly persons is important to assess water exercise programs intended to improve balance in elderly people. Although previous reports have shown the benefits of water exercise, deep-water running with feet separated from the swimming pool bottom is a specific form of exercise in water. The advantages of this type of exercise include a reduction in impact stress on lower limb joints and positive effects on aerobic fitness (Reilly, Dowzer, & Cable, 2003). Deep-water running is widely used by athletes in endurance training and by elderly people in fitness training (Broman et al., 2006; Svedenhag & Seger, 1992). Moening, Scheidt, Shepardson, and Davies (1993) described deep-water running as an open kinetic chain, in contrast to a closed kinetic chain such as water walking. For that reason, deep-water running might be more unstable than water walking. We hypothesized that deep-water running is more beneficial for maintaining balance ability than water walking.

This study was designed to compare the effects of a water exercise program that included deep-water running with those of normal water exercise that mainly consisted of water walking. The program was especially designed to improve balance ability in elderly adults. We evaluated participants’ static and dynamic balance ability after the 12-week water exercise intervention.

**Methods**

**Participants**

For this single-blind, interventional study, 49 community-dwelling elderly volunteers were recruited. All participants completed author-administered medical
examinations and questionnaires related to their physical activity. Volunteers were excluded from the study if they reported any problems such as orthopedic diseases of the lower extremities. Participants with circulatory diseases obtained their physician’s permission to participate in the study; the results from these participants were included in the experimental data. Low-attendance participants in the water exercise sessions (attendance rate <50%) were excluded from the experimental data. We could not assess postperformance test results for some participants because illness or work commitments. Results from a total of 30 elderly participants (4 men, 26 women) are included in this report. A flowchart of the participants is shown in Figure 1. The participants were instructed not to change their usual lifestyle during the study. All participants were informed of the purposes, experimental procedures, and risks of the study and subsequently gave their informed written consent to participate. The ethics committee of the Institute of Health and Sports Sciences at the University of Tsukuba approved this study.

![Flowchart of the study participants.](image-url)
Exercise Protocol

The water exercise intervention was conducted twice weekly for 12 weeks. The participants were assigned to a normal water exercise (NWE) group or a deep-water-running exercise (DWRE) group based on pre-performance-test data to ensure that there were no differences between the two groups before the intervention. Exercise sessions were divided into a 10-min warm-up on land; 20 min of water-walking exercise; 30 min of water exercise, either NWE or DWRE; a 10-min rest on land; and 10 min of recreation and relaxation in the water. Figure 2 shows the schedule of a water exercise session. NWE participants performed forward walking, backward walking, side walking, kicking, knee up, twisting, and other water-walking exercises similar to the 20-min water-walking exercise protocol. DWRE participants performed running exercises without their feet touching the bottom of the pool using a flotation device (Reilly et al., 2003). The water exercise program was conducted at a public indoor swimming pool that had a water depth of 1.1–1.3 m and a water temperature of 30 °C throughout the 12-week period.

As a health check before each session, blood pressure was measured in the pool lounge using a wrist sphygmomanometer (EW284, Matsushita Electric Industrial Co., Ltd.). Using Borg’s scale (Borg, 1973), the ratings of perceived exertion (RPE) were recorded to investigate exercise intensity after each session.

![Figure 2](image)

**Figure 2** — Contents of the water exercise programs used in this study. A normal water exercise (NWE) group and a deep-water-running exercise (DWRE) group were assessed. NWE participants performed water walking, water-resistance training using a kickboard, and other water-walking exercises. DWRE participants performed locomotive motions, mainly running motions, using a flotation device.
Outcome Measurements

Performance tests were conducted before and after the 12-week intervention. Individual characteristics (height, weight, and body-mass index) were also measured preintervention. The participants practiced each measurement before the experimental trials.

The postural-sway test was conducted using a posturographic meter (Gravicoda GS-10, Type C, Anima Co., Tokyo, Japan). Participants stood silently on the meter staring at a point marked on the wall (distance was 3 m forward, height was 1.5 m) with their bare feet together. Tests were conducted for 30 s with eyes open. Postural-sway distance and postural-sway area were analyzed. Postural-sway tests are often used to measure static-balance ability (Colledge et al., 1994).

Tandem-walking tests were conducted. Participants were required to walk heel to toe along a 10-step line as quickly as possible without misstepping. A misstep was defined as the participant’s completely stepping off the line or failing to follow a heel-to-toe pattern. The times of the two trials without misstepping were then averaged. Tandem walking is defined as walking with the feet in the position of a tandem stance during the double-support phase and then moving the rear foot to the front. These tasks were performed to assess the postural-control system with a reduced base of support compared with normal standing and walking (Speers, Ashton-Miller, Schultz, & Alexander, 1998). The tandem-walking test is often used as a measure of dynamic-balance ability (Medell & Alexander, 2000).

Reaction times were assessed using a simple paradigm, with a light as the stimulus and depression of a switch by the foot as the response in milliseconds. Participants underwent three experimental trials, and the results of these trials were averaged. This method is often used in central nervous system assessment (Lajoie & Gallagher, 2004).

For normal and maximal walking tests, participants walked along an 11-m walkway without walking aids. Participants completed this walking test four times. During the first and second trials, the participants were asked to walk at a self-selected comfortable speed for the normal trial. During the third and fourth trials, they were asked to walk as fast as possible without running for the maximal trial. The time from 3 m to 8 m was measured at the participant’s waist, and the walking speeds were calculated. The calculated speeds of the two trials were then averaged. Walking speed is often used to assess the total fitness level of elderly people (Himann, Cunningham, Rechnitzer, & Paterson, 1988).

Test–Retest Reliability

In a pilot study of test–retest reliability for the six outcome measurements, 28 healthy elderly volunteers (61.8 ± 5.9 years) participated. The participants attended two test sessions 1 week apart. Intraclass correlation coefficients (ICC’s) revealed high test–retest reliability for postural-sway distance (ICC = .89), tandem walking (ICC = .87), reaction time (ICC = .81), and 11-m maximal walking speed (ICC = .86). Postural-sway area (ICC = .54) and 11-m normal walking speed (ICC = .68) showed moderate reliability. The measured values are presented in Table 1.
Statistical Analyses

Measured values are presented as $M \pm SD$. The data were analyzed using computer software (SPSS v.14; SPSS Inc.). All group comparisons were evaluated using two-way analysis of variance (ANOVA) with Tukey’s post hoc test for parametric data. A paired Student’s $t$ test was used to evaluate differences between pre- and posttest for each group if no significant interaction was shown using two-way ANOVA. An unpaired Student’s $t$ test was used to assess differences between the two groups. Wilcoxon’s signed-rank test was used to assess differences between pre- and posttest with nonparametric data, and a Mann Whitney’s U test was used to compare differences between the two groups. Results were considered statistically significant when $p < .05$.

Results

Participant Characteristics

There were 15 participants in the NWE group (13 women, 2 men) and 15 in the DWRE group (13 women, 2 men). The participants’ characteristics are listed in Table 2. No significant differences were found between the groups.

Table 1 Values of Test–Retest Reliability Measurements, $M \pm SD$

<table>
<thead>
<tr>
<th></th>
<th>Test ($n = 28$)</th>
<th>Retest ($n = 28$)</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postural-sway distance (cm)</td>
<td>47.42 ± 16.51</td>
<td>45.02 ± 12.39</td>
<td>.89</td>
</tr>
<tr>
<td>Postural-sway area (cm²)</td>
<td>2.24 ± 1.19</td>
<td>1.75 ± 0.80</td>
<td>.54</td>
</tr>
<tr>
<td>Tandem-walking time (s)</td>
<td>7.8 ± 1.3</td>
<td>7.8 ± 2.1</td>
<td>.87</td>
</tr>
<tr>
<td>Reaction time (ms)</td>
<td>486.8 ± 88.3</td>
<td>461.6 ± 48.6</td>
<td>.81</td>
</tr>
<tr>
<td>11-m normal walking speed (m/s)</td>
<td>1.44 ± 0.15</td>
<td>1.31 ± 0.18</td>
<td>.68</td>
</tr>
<tr>
<td>11-m maximal walking speed (m/s)</td>
<td>1.93 ± 0.15</td>
<td>2.00 ± 0.19</td>
<td>.86</td>
</tr>
</tbody>
</table>

Table 2 Physical Characteristics, Attendance Rate, and Averaged Rating of Perceived Exertion of 12 Weeks, $M \pm SD$

<table>
<thead>
<tr>
<th></th>
<th>Normal water exercise group ($n = 15$)</th>
<th>Deep-water-running exercise group ($n = 15$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>60.5 ± 4.1</td>
<td>60.9 ± 4.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>152.5 ± 6.6</td>
<td>153.2 ± 6.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>56.4 ± 8.7</td>
<td>61.2 ± 10.9</td>
</tr>
<tr>
<td>Body-mass index (kg/m²)</td>
<td>24.2 ± 2.4</td>
<td>25.9 ± 3.5</td>
</tr>
<tr>
<td>Attendance (%)</td>
<td>82.2 ± 15.0</td>
<td>76.7 ± 13.4</td>
</tr>
<tr>
<td>Rating of perceived exertion</td>
<td>11.5 ± 1.4</td>
<td>11.5 ± 1.0</td>
</tr>
</tbody>
</table>

Note. There was no significant difference between the two groups.
Attendance and RPE

The attendance rate and averaged RPE scores during the 12-week intervention are shown in Table 2. Attendance rates were 82.2% ± 15.0% and 76.7% ± 13.4% over 24 sessions in the NWE and DWRE groups, respectively. The attendance rates were not found to be significantly different between groups. The average RPE scores for all the exercise sessions over the 12-week period were 11.5 ± 1.4 and 11.5 ± 1.0 in the NWE and DWRE groups, respectively. The RPE scores were not found to be significantly different between groups.

Performance Tests

Performance-test data of the respective groups are presented in Table 3. No significant differences between the two groups were found in any of the characteristics studied before the start of the intervention.

After the intervention, a significant decrease in postural-sway distance was found in the DWRE group (p < .05). With regard to the postural-sway area, a significant decrease was found in the NWE group (p < .05). A significant decrease was found in the tandem-walking time in the DWRE group (p < .05). Reaction time was significantly decreased in both groups (p < .05). The 11-m normal and maximal walking speeds showed no significant differences between the groups. No significant differences were observed in any of the measurements between the NWE and DWRE groups after the 12-week intervention.

Table 3  Results of Each Performance Test Preintervention and 12 Weeks After, M ± SD

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NWE (n = 15)</td>
<td>DWRE (n = 15)</td>
<td>NWE (n = 15)</td>
<td>DWRE (n = 15)</td>
</tr>
<tr>
<td>Postural-sway distance (cm)</td>
<td>47.42 ± 16.51</td>
<td>45.02 ± 12.39</td>
<td>45.84 ± 15.38</td>
<td>41.24 ± 10.81*</td>
</tr>
<tr>
<td>Postural-sway area (cm²)</td>
<td>2.24 ± 1.19</td>
<td>1.75 ± 0.80</td>
<td>1.70 ± 0.64*</td>
<td>1.84 ± 0.83</td>
</tr>
<tr>
<td>Tandem-walking time (s)</td>
<td>7.8 ± 1.3</td>
<td>7.8 ± 2.1</td>
<td>7.3 ± 1.4</td>
<td>6.7 ± 1.2*</td>
</tr>
<tr>
<td>Reaction time (ms)</td>
<td>486.8 ± 88.3</td>
<td>461.6 ± 48.6</td>
<td>450.1 ± 69.3*</td>
<td>417.0 ± 36.9*</td>
</tr>
<tr>
<td>11-m normal walking speed (m/s)</td>
<td>1.43 ± 0.14</td>
<td>1.38 ± 0.16</td>
<td>1.44 ± 0.18</td>
<td>1.40 ± 0.17</td>
</tr>
<tr>
<td>11-m maximal walking speed (m/s)</td>
<td>1.93 ± 0.15</td>
<td>2.00 ± 0.19</td>
<td>1.99 ± 0.20</td>
<td>2.07 ± 0.30</td>
</tr>
</tbody>
</table>

Note. NWE = normal water exercise group; DWRE = deep-water-running exercise group.

*Significant difference between pre- and posttest, p = .05.
Discussion

To our knowledge, this is the first direct study of the effects of different water exercise programs on balance ability in elderly adults. We established a normal water exercise (NWE) group and a deep-water running exercise (DWRE) group who performed this type of exercise for a 30-min period in a 60-min water exercise program twice weekly for 12 weeks.

Postural-sway area and reaction time were improved in the NWE group. In the DWRE group, postural-sway distance, tandem-walking time, and reaction time were improved. Although no differences were found between the two groups pre- and postintervention, each of the two types of water exercise improved different aspects of balance ability assessed by the performance tests, even though the water environment was identical.

Postural-sway distance, which reflects the distance of postural disturbance, and postural-sway area, which reflects the extent of postural disturbance, are, respectively, longer and larger in older adults (Fujita et al., 2005). These two measurements are often used to assess static-balance ability (Colledge et al., 1994; Hageman, Leibowitz, & Blanke, 1995). No assessments have been carried out on healthy elderly adults to measure postural sway during a water exercise intervention. The current study of healthy elderly participants showed that postural-sway distance was decreased in the DWRE group. This means that postural disturbance was slower and better during static balance. Although postural-sway area was increased in the DWRE group, however, indicating that postural disturbance was larger, no significant differences between the groups were observed. These results suggest that DWRE might not improve static-balance ability. In the NWE group, postural-sway area was decreased, but the postintervention value was similar to that of the DWRE group. Rogers, Fernandez, and Bohlken (2001) reported reductions in lateral-sway amplitude, speed of sway, and postural-sway area in elderly adults during land exercise. Improvements in lateral- and sagittal-sway standard deviation and postural-sway area in women with lower extremity arthritis were demonstrated during a water exercise intervention with the Arthritis Foundation Aquatic Program, which consisted of 68 aquatic exercises designed to promote strength, range of motion, and mobility for people with arthritis (Suomi & Koceja, 2000). Results from the current study and from previous studies suggest that water exercise has the potential to improve postural sway. Moderate test–retest reliability in postural-sway area was observed in this study, however. This might indicate that these measurements are affected by physical conditions at the time of the tests. Therefore, more varied and detailed evaluation is needed to clarify the effects of a water exercise intervention on static-balance ability in healthy elderly adults.

In addition to the improvement in postural-sway distance, tandem-walking time improved only in the DWRE group in this study. Several studies have assessed dynamic-balance ability using tandem-walking tests against static-balance ability using the postural-sway test (Medell & Alexander, 2000; Nelson et al., 2004). Nelson et al. investigated the effects of a 6-month, home-based exercise program that included strength and balance training. They reported improvement in 20-step tandem-walking time, reflecting dynamic balance ability. Medell and Alexander also investigated dynamic-balance ability using 10-step tandem-walking time.
among different groups of women: young (21 ± 2 years), unimpaired older (69 ± 3 years), and balance-impaired (more than one fall in the preceding year) older women (77 ± 6 years). They reported faster tandem-walking times in young (7.5 ± 1.1 s) and unimpaired older (8.5 ± 1.6 s) women than in impaired older (17.0 ± 3.5 s) women. The values for tandem-walking times measured in young and unimpaired older women were similar to those in our study. The results of the current study suggest that water exercise including deep-water running is effective in improving dynamic-balance ability in elderly adults.

Reaction time is reportedly a sensitive marker of central nervous system function (Lajoie & Gallagher, 2004). Some studies have demonstrated an improvement in reaction time with an exercise intervention in older adults (Lajoie & Gallagher; Lord & Castell, 1994). Results of the current study indicate that central nervous system function can be improved by water exercise. Lord, Rogers, Howland, and Fitzpatrick (1999) found that reaction time was an excellent predictor of postural sway among elderly people. The improvements in postural-sway test results in the current study might reflect improvements in central nervous system function.

No improvements in the 11-m normal and maximal walking trials were found in this study. Chu et al. (2004) and Chandler, Duncan, Koehsersberger, and Studen- (1998) reported an association between normal walking and lower extremity muscle strength. Maximal walking speed is often used to assess total fitness level of elderly adults (Himann, Cunningham, Rechnitzer, & Paterson, 1988; Nelson et al., 2004). Some studies have demonstrated that lower extremity muscle activity is significantly higher during water walking than during land walking because of water resistance (Kaneda, Kimura, Akimoto, & Kono, 2004; Miyoshi et al., 2004). In addition, the biceps femoris muscle is more highly activated by deep-water running than by water walking (Kaneda, Sato, Wakabayashi, & Nomura, in press). The exercise intensity achieved in the current study was approximately 11 (light) on Borg’s scale (Borg, 1973). With this level of exercise intensity the participants did not gain adequate stimulus for muscle strengthening (Nelson et al.; van Vilsteren, de Greef, & Huisman, 2005).

The most important difference between the two water exercise programs used in this study was that the feet of participants in the DWRE group did not touch the pool floor. Moening et al. (1993) described deep-water running as an open kinetic chain in contrast to a closed kinetic chain such as water walking. For that reason, deep-water running might be more unstable than water walking. Kaneda et al. (in press) reported higher muscle activity in the biceps femoris during deep-water running than during water walking. Older people activate the hamstrings more than younger people when attempting to enhance hip-joint stabilization (Benjuya, Melzer, & Kaplanski, 2004; Laughton et al., 2003). Deep-water running would improve hip-joint stability, which affected static- and dynamic-balance tests in the current study. Wong et al. (2001) reported that sensorimotor information is more important in dynamic-balance tasks than in static-balance tasks. For deep-water running, sensorimotor information might be more important than for water walking. This is because of the unstable position of the former exercise, which resembles that of using a foam floor to reduce somatosensory input (Colledge et al., 1994; Woollacott, 1993). It is likely that this affected improvement in the tandem-walking test in the DWRE group.
Gauchard, Jeandel, Tessier, and Perrin (1999) reported that balance exercise (yoga or soft gymnastics) can improve dynamic balance ability and that aerobic exercise (swimming or cycling) can improve muscle strength. Wolfson et al. (1996) also reported improvements in balance ability in balance-exercise groups and of muscle strength in muscle-training groups. In the current study outcomes differed according to type of water exercise. In the main, dynamic-balance ability particularly improved as a result of DWRE.

This study had some limitations. First, more varied and detailed evaluations in postural-sway tests are needed. Data on postural-sway distance or area are insufficient to clearly interpret the effects of water exercise on static-balance ability. Second, the test–retest reliability was poor in postural-sway area (ICC = .54) and in the 11-m normal walking test (ICC = .68). This might indicate that these measurements are affected by physical conditions at the time of the tests. Finally, there are many measurements that were not conducted in this study (muscle strength, flexibility, aerobic capacity, etc.) that might affect postural sway, tandem walking, and reaction time. Nevertheless, it is considered that a water exercise program that includes deep-water running is effective in improving not only aerobic capacity but also balance ability, particularly for dynamic balance, in elderly people.

Acknowledgments

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References


