The effect of a water exercise on gait characteristics in the elderly post stroke patients

Hee-Sung Lim*, Suk-Min Lee*

*Department of Physical Therapy, The Graduate School, Sahmyook University, Seoul, Republic of Korea

Objective: To investigate the effect of long-term water exercise on gait parameters in the elderly post stroke patients.

Design: One group pretest-posttest design.

Methods: Twenty elderly post stroke patients (age: 56.5±10.1 years, height: 168.6±5.8 cm, body mass: 69.3±6.9 kg, handicapped level: 2.5±0.8) participated in this study. Participants took part in gait training of 1 hour per day, three days per week, for three months. Participants’ gaits were analyzed to find the effect of 3 months water exercise by a 3-D motion analysis with 8 infrared camera and 1 force plate (sampling frequency: 100 and 1,000 Hz, respectively). A paired t-test was used to find the significance with significant level as 0.05.

Results: Gait velocity, step length & step width significantly increased, and asymmetric index for gait parameters significantly decreased after the water exercise (p < 0.05).

Conclusions: The water exercise effectively affect on patients’ gait ability and electromyography analysis will be needed further study.

Key Words: Gait, Stroke, Water

Introduction

Stroke is known to be one of the biggest causes of adult disability today. According to the statistics of World Health Organization, there are about 15 million new stroke patients each year and one third of them suffer permanent impairment [1,2]. In South Korea, stroke is one of the top three disease-inflicted causes of death and shows the highest death rate among circulatory system diseases [3].

After the injury, most stroke patients experience hemiplegia, which refers to paralysis of one side of the body caused by cerebrovascular disorders. As hemiplegia patients mainly use the healthier side of the body during physical activities, they show more asymmetrical movement in comparison to healthy people by, for instance, standing with 61-81% of their weight inclined on the healthier side of their body [4]. Also, they show more obvious difference from normal people while gaiting, which is the most important physical activity in everyday life, which serves as a measure of the conditions of hemiplegia patients. In other words, because stroke patients - when gaiting - try to move the center of gravity quickly to the healthier side of their body due to unstableness of the impaired side, the stance and swing periods of the impaired side become shorter, which leads to slower gait speed, increased pattern of asymmetrical gait, and deteriorated balance [5,6]. Such decline results in limitation to patients’ independence in everyday life and secondary damages such as falling, which acts as a substantial obstacle for them in returning to the society [7,8]. Therefore, reports have been made that the most important goal in rehabilitation of stroke patients is to maximize the independence of motor skills like gaiting [9-12].
Many researchers believe that the decline of motor skills and balance in stroke patients is due to weakened muscular strength on the impaired part of their body, and conducted studies through various mediations to improve the independence of the patients’ motor skills, that is gaiting and balance. In other words, the researchers report that the muscular strength, balance, and stability of the impaired side of patients’ body improved with resistance muscular training [13,14], gaiting on a treadmill [15-17], proprioceptive neuromuscular facilitation [18,19], and treadmill gait training based on task-oriented approach [12,20-22].

However, the exercise programs in previous studies, despite having many advantages for improving motor skills of stroke patients, can have potential limitations in carrying out the exercises. In other words, for physically weakened patients, aerobic exercise like treadmill on the ground or muscular training can cause excessive stress or pain on joints and muscle, and these concerns have been reported to reduce the amount of exercise for patients who need exercise. Therefore, there should be a way to improve patients’ muscular strength without the risk of injury.

Unlike exercising on the ground, exercising in the water has the advantage of reducing the burden on the joints because the weight is reduced by buoyancy, and the high density helps patients exercise without the risk of injury. These advantages have been reported to enable patients to have time to control their motion in the water and experience various movement errors without injury [23]. Also, water exercise causes resistance to the entire body and, therefore, isokinetic muscular contraction as well as balanced development of agonistic and antagonistic muscles, according to a report [23], and therefore, it is thought to be more suitable than exercise on the ground for patients who are at a physical disadvantage.

While aquatic rehabilitation exercise is thought to be effective for rehabilitation of stroke patients, there are few studies that demonstrated this. Therefore, the purpose of this study is to prove the change in characteristics in gaiting of stroke hemiplegia patients after applying regular water exercise to them for three months, and examine whether it reduces asymmetry that is often found in these patients.

### Methods

**Subjects**

To achieve the purpose of this study, total 20 male patients diagnosed with stroke participated. Patients who experienced other orthopaedic or neurological diseases were excluded and participants were selected among patients diagnosed with class 1-4 brain lesion who are capable of water exercise three times per week (Table 1). Research participants took part in gaiting exercise of 1 hour per day, three days per week, for three months, and no one withdrew in the middle of the program.

**Table 1. General characteristics of participants (N=20)**

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Height (cm)</th>
<th>Body mass (kg)</th>
<th>Handicapped level</th>
</tr>
</thead>
<tbody>
<tr>
<td>56.5 (10.1)</td>
<td>168.6 (5.8)</td>
<td>69.3 (6.9)</td>
<td>2.5 (0.8)</td>
</tr>
</tbody>
</table>

Values are presented as mean (SD).

**Asymmetry index**

The asymmetry index (AI) used in this study for understanding how much asymmetry in patients’ gait has improved after regular water exercise was the Robinson formula [24], and AI= 0 represents perfect symmetry and higher AI means bigger asymmetry.

**Data collection**

The test for this study was conducted before the beginning and after completion of the 3-month water exercise program. To examine the asymmetry in gait, 3-dimensional motion analysis was performed using eight infrared ray cameras and one force platform, and the sampling frequency was set at 100 Hz and 1,000 Hz. First, selected research subjects who agreed to the test were explained about the procedure, and asked to wear the top and bottom tights and put on markers. After sufficient warm-up, they performed the walking motion on a 10-m track installed in this laboratory. In order to induce natural gait of participants, the walking pace was chosen by their preference and the test was repeated total 10 times.

In order to produce kinematic variables of participants’ lower limb, a rigid-link human body model composed of eight segments (trunk, pelvis, left and right feet, legs, and thighs) was used. Each participant was attached with 73 reflective markers on each joint and reference points, to define joint center and body segments, and the 3-dimensional coordinates were obtained by using QTM program. Standing trial was obtained before the test, and was used as a reference data in analyzing the data obtained from this test.

For quantitative analysis, all cameras set the space coor-
Table 2. Gait parameters between pre- and post-water exercise (N=20)

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SL (cm)</td>
<td>65.4 (6.29)</td>
<td>79.6 (4.7)</td>
<td>3.9</td>
<td>0.001</td>
</tr>
<tr>
<td>SV (cm/s)</td>
<td>60.5 (5.2)</td>
<td>95.8 (3.4)</td>
<td>5.2</td>
<td>0.001</td>
</tr>
<tr>
<td>SW (cm)</td>
<td>9.9 (0.9)</td>
<td>11.9 (0.9)</td>
<td>3.0</td>
<td>0.008</td>
</tr>
</tbody>
</table>

Values are presented as mean (SD).

Table 3. Asymmetric index for kinematic and kinetic variables between pre- and post-water exercise (N=20)

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MHA</td>
<td>11.7 (7.3)</td>
<td>3.5 (2.3)</td>
<td>7.2</td>
<td>0.000</td>
</tr>
<tr>
<td>MKA</td>
<td>11.0 (7.8)</td>
<td>4.0 (3.8)</td>
<td>2.9</td>
<td>0.008</td>
</tr>
<tr>
<td>MiHA</td>
<td>17.5 (7.1)</td>
<td>10.9 (5.4)</td>
<td>2.8</td>
<td>0.012</td>
</tr>
<tr>
<td>MiKA</td>
<td>39.0 (31.2)</td>
<td>31.6 (15.4)</td>
<td>0.9</td>
<td>0.343</td>
</tr>
<tr>
<td>VGRF</td>
<td>14.4 (13.5)</td>
<td>9.2 (5.3)</td>
<td>2.4</td>
<td>0.027</td>
</tr>
</tbody>
</table>

Values are presented as mean (SD).
MHA: peak hip angle, MKA: peak knee angle, MiHA: lowest hip angle, MiKA: lowest knee angle, VGRF: peak vertical ground reaction forces.
the water strengthened iliopsoas muscle and extensor and improved the walk stability.

Walking is one of the most characteristic human motion that repeat segments of the left and right. As the left and right segments normally show symmetrical movement, it is used as a barometer in evaluating injury or rehabilitation of the lower limb [32]. In this study, symmetry was checked by obtaining the biggest and smallest angles of the left and right buttocks and knee joints of the patients and the maximum vertical ground reaction force. The result showed that the water exercise improved patients’ gait symmetry by 18-70% except for the smallest knee angle (Table 3, p < 0.05). In order to increase symmetry of gait variables of stroke patients, the movement of the healthier side of the body should decrease or the impaired side movement should increase. It seems that the main cause of this study result was that the muscular strength of the impaired side was strengthened by exercising in the water and, therefore, showed similar movement to that of the healthier side.

In this study, gait characteristics were analyzed to demonstrate the effect of exercising in the water. However, for this result to be more reliable, it is necessary to examine the change in muscular strength of the lower limb, which is the cause of actual movement. Therefore, future studies will need to check the activity of muscles during walking by using EMG.

This study proved that three months of water exercise was very effective for improving patients’ stroke hemiplegia, and future studies will need to examine the change in muscular strength of the lower limb, which is the actual cause that improved the gait.

References