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Comparison of the Effects of Exercise by Chronic Stroke Patients in Aquatic and Land Environments

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Abstract. [Purpose] The purpose of this study was to compare the effects of land exercise and aquatic exercise on chronic stroke patients. [Subjects and Methods] The subjects were randomly divided into a land exercise group (12 males and 10 females; average age: 56.09 ± 7.22 years) and an aquatic exercise group (15 males and 7 females; average age: 51.55 ± 8.27 years). Subjects from both groups received general conventional treatment during the experimental period. In addition, all subjects engaged in extra treatment sessions. This extra treatment consisted of trunk stability strengthening exercises and balance training exercises in the land exercise group, whereas in the aquatic exercise group subjects participated in balance board exercises and walking exercises using buoyancy equipment in the hospital swimming pool. [Results] The joint position sense test and performance oriented mobility assessment showed significant improvements in both groups. However, the joint position sense test and performance oriented mobility assessment showed there was more improvement in the aquatic exercise group than in the land exercise group. [Conclusion] The results suggest that aquatic exercise is more effective than land exercise at improving the joint position sense and clinical functions of stroke patients.
Key words: Aquatic exercise, Joint position sense, Performance oriented mobility assessment

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INTRODUCTION

The proportion of the elderly in the total population as well as the incidence of adult disease is increasing and the incidence rate of strokes is also increasing. Most stroke survivors suffer after-effects of impairments in motor, sensory, cognitive, perceptive, psychological, social, and physical functions[1)]. Additionally, 65% of stroke patients experience loss of tactile sense, the protection reaction, and proprioceptive sense[2)]. When the proprioceptive sense is lowered, it is highly probable that there will be a reduction in positional control ability, and the protective reaction, motor ability of joints, as well as balance ability for counteracting positional perturbation will be also reduced[3)]. Various rehabilitative programs are carried out to improve these functions and recover the balance of hemiplegic patients. Recently, aquatic exercise therapy has been used to treat various diseases including stroke[4)]. Aquatic exercise programs provide an environment in which patients who are not able to bear a weight load on land can initiate their physical exercise earlier[5)]. Viscosity, which is the mechanical friction of water, stimulates the proprioceptive sensory receptors so that the transmission of noxious stimuli is repressed, and the effect of the water temperature excites the heat receptors so that they can repress the transmission of noxious stimuli[6)]. Exercise in an aquatic environment is considered to be safe because it supports the body and provides a low-risk exercise environment that reduces the fear of falling and the possibility of acute damage[7)]. Therefore, we investigated the effects of aquatic and land exercises on the rehabilitation of chronic stroke patients through the Joint Position Sense (JPS) test and the Performance-Oriented Mobility Assessment (POMA) by conducting physical exercise after dividing the patients into a land exercise group and an aquatic exercise group.

SUBJECTS AND METHODS

The subjects who participated in this study were 44 stroke patients hospitalized in S hospital located in Daejeon, Korea. To minimize the possibility of spontaneous recoveries, the subjects were selected from chronic stroke patients with onset at least six months previously, who had no internal medical disease such as diabetes, had no heart disease and no orthopedic problems, scored 24 or higher in the Mini Mental State Examination-Korea, had no visual problems, and could walk at least 15 m by themselves. These subjects were given explanations until they sufficiently understood this experiment. Then the subjects or their guardians signed consent forms for participation in this experiment. The experiment was conducted with the subjects divided into a land exercise group (12 males and 10 females: 10; average: 56.09 ± 7.22 years; height: 166.05 ± 7.47 cm; weight: 62.91 ± 7.93 kg) and an aquatic exercise group (15 males and 7 females; average age: 51.55 ± 8.27 years; height: 169.55 ± 8.4 cm; weight: 67.05 ± 8.38 kg). The land exercise group included 8 patients with cerebral infarction and 14 patients with cerebral hemorrhages, and the aquatic exercise group also included 8 patients with cerebral infarction and 14 patients with cerebral hemorrhages. The affected side of the subjects in the land exercise group was the right for 9 subjects and the left for 13 subjects, while it was the right for 13 subjects and the left for 9 subjects in the aquatic exercise group. The time since onset of stroke was 7–12 months for 9 subjects and more than 13 months for 13 patients in the land exercise group, whereas it was 7–12 months for 8 subjects and more than 13 months for 14 patients in the aquatic exercise group.

This experiment was conducted over 6 weeks from January to February 2010. Exercises were conducted six times a week for six weeks. Each exercise session time was 35 minutes. Three sets were implemented for each type of exercise, counting ten repetitions as one set. The land exercises were carried out in the exercise therapy room at the hospital, and the aquatic exercises were performed in the indoor exercise therapy pool at the hospital. The subjects in both groups also received conventional nervous system exercise therapy six times a week. Different exercise programs were conducted for the land exercise group and the aquatic exercise group. The exercises carried out by the land exercise group followed to the exercise methods of Dean[8] and Evert et al.[9] The following exercise programs were conducted for the land exercise group:. Exercise 1) strengthening the stability of the lower trunk using the upper limbs. In the supine position, a square pillow was placed under the knee joint so that the angles of the hip joint and the knee joint were 90 degrees. The muscles at the back of the neck were lengthened and the epigastric region was pushed to the distal part, elevating the head of the patient. Then, both scapulae were displaced in the anterior direction, and the upper limbs were abducted. At the same time, the head was directed to the knees, and the trunk was held straight;. Exercise 2) walking back and forth, right and left, and standing still;. Exercise 3) anterior tilt and posterior tilt of the pelvis in the sitting position. The therapist moved the pelvis of the patient in front of the patient, holding the outer sides of the pelvis;. Exercise 4) stretching the arms forward, downward, and toward both sides in the sitting position;. Exercise 5) exchanging a ball with a therapist while standing with both feet together;. Exercise 6) repetition of lifting and lowering of the heels within a range in which the patient would not fall down, standing in a comfortable position keeping both feet wide apart.

The exercises carried out in the aquatic exercise group followed the exercise methods of Itshak et al.[10], Peter et al.[11], and Carin et al.[12] We modified the exercises reported in the previous studies so that they were safe for chronic stroke patients, and a physical therapist for extra safety, supervised the exercises. The following exercise programs were implemented for the aquatic exercise group:. Exercise 1) standing on a board while maintaining balance;. Exercise 2) When a stable state was achieved in Exercise 1, the patient bent and spreads the hip and knee joints as slowly as possible;. Exercise 3) walking while wearing a floating cuff;. Exercise 4) moving the hip and knee joints around while wearing a water-noodle between the legs as if riding a bicycle;. Exercise 5) standing on a balance board while keeping the eyes closed and wearing a cuff;. Exercise 6) jumping in a given area of the pool while wearing a cuff and keeping both feet together. For the aquatic exercises, a floating cuff, belt, balance board, and noodle were used. The water depth was fixed at 1.3 m so that the water level would cover the thoracic vertebra No. 11[13]. Since the subjects were patients, the water temperature was kept at 33–35°C for the aquatic exercises.

The JPS test is a method of assessing the position of individual body segments without a visual aid and it can also be applied to the proprioceptive sense of hemiplegic patients[14]. In this study, we employed the Biometrics (Biometrics Ltd, UK) motion analysis system that is composed of a base unit that digitizes the analog joint angles and an electrogoniometer that measures the joint motion angle. The electrogoniometer consists of two electrical potentiometers and a spring that connects them. The two electrical potentiometers were fixed at the top and bottom of the hip joint side of the subjects using tape so that the potential difference during flexion and extension could be transmitted as analog signals. The transmitted analog signals were converted to digital signals and processed with digital signal analysis software (Data LINK PC Software 2.00). The data, expressed in units of volts, are the actual measurements of the joint motion angle. The sampling rate for each signal was 200 Hz. The JPS test was performed as an active setting-active reproduction test. For the active setting-active reproduction test, the subjects were asked to actively move their joints within the full motion range, maintain an arbitrary angle in the middle for three seconds, and remember the joint angle as the reference angle. After 10 seconds of rest, the subjects were asked to press a button when actively reproducing the reference angle within five seconds. In this study, the sensors were attached around the knee joint of the affected side according to the attachment reference while the subjects were standing. The zero point of the motion analysis system operating software was adjusted when the subjects were sitting. After covering the eyes of the subjects with an eye patch and checking the maximum joint motion range of the

Table 1. A comparison of JPS and POMA for the knee joint between pre- and post-intervention in the land exercise and aquatic exercise groups. (M ± SD)

		Pre	Post
JPS	Land Group	4.14 ± 1.99	3.52 ± 1.66*
	Aquatic Group	5.23 ± 1.84	2.53 ± 1.00**
POMA	Land Group	19.82 ± 4.69	21.09 ± 4.70**
	Aquatic Group	21.14 ± 4.48	23.95 ± 4.31**

*p<0.05, **p<0.01, JPS: joint position sense, POMA:performance-oriented mobility assessment.

Table 2. A comparison of JPS and POMA for the knee joint between the land exercise group and the aquatic exercise group (M ± SD)

		Land Group	Aquatic Group
JPS	pre	4.14 ± 1.99^{a}	5.23 ± 1.84
	post	3.52 ± 1.66	2.53 ± 1.00*
POMA	pre	19.82 ± 4.69^{a}	21.14 ± 4.48
	post	21.09 ± 4.70	23.95 ± 4.31*

*p<0.05, JPS: joint position sense, POMA:performance-oriented mobility assessment.

knee joint, a reference angle was set in the middle of the joint motion range. Measurement was started after allowing the patients to practice sufficiently with the decided reference angle. The duration for one measurement was seven seconds: two seconds each at the beginning and the end were discarded, and the three seconds in the middle were recorded as the measurement value. The measurement was repeated three times and the mean value was calculated. POMA is a tool that has been used to assess the mobility and the falling risk of the elderly[15]. The measurement items are divided into the balance score (16 points) and the gait score (12 points), and the total maximum score is 28 points. A score of 25–28 points indicates a low falling risk, 19–24 a mild falling risk, and less than 19 a high falling risk. For the JSP test and the POMA, the environment was kept warm, calm and bright, and the subjects wore simple clothes.

For the data processing in this study, the paired sample t-test was performed to test the difference before and after the exercise in each group, and the independent sample t-test was performed to test the difference between the groups. SPSS 12.0 software for Windows was used for the analysis and a significance level, α, of 0.05 was chosen.

RESULTS

The land exercise group ($p<0.05$) and the aquatic exercise group ($p<0.01$) showed a significant difference in the knee joint position sense variation before and after the exercise (Table 1). The joint position sense was improved in both the land exercise group and the aquatic exercise group, and the error in the joint position sense variation decreased in the aquatic exercise group. The POMA score was also significantly different before and after exercise in both the land exercise group and the aquatic exercise group ($p<0.05$) (Table 1). The POMA score increased in both the land exercise group and the aquatic exercise group.

The JPS and POMA results were compared between the land exercise group and the aquatic exercise group. There was no difference between the two groups before the initiation of the exercises, indicating the homogeneity of the groups. The JPS and POMA results improved more in the aquatic group ($p<0.05$) (Table 2).

DISCUSSION

The factors involved in post-stroke gait ability include the ability to follow directions, balance in the standing position, existence of joint contracture, ability to voluntarily control the lower limb of the affected side, and the joint position sense[16]. The error in the joint position sense was decreased in both the land exercise group and the aquatic exercise group in this study, but the decrement of the error in the joint position sense was greater in the aquatic exercise group. Thus, the mechanical properties of water are better at stimulating the physical proprioceptive senses. It was reported that greater somatosensory input is generated when moving an object in a viscous fluid than in a gas which is less viscous[17]. Moreover, the resistance to motion causes skin expansion or elongation, which induces a faster adjustment of mechanoreceptors and contributes to proprioception, leading to an improvement in the lowered proprioceptor functions through the buoyancy and resistance of water[18]. The present finding is similar to the results of previous studies which also showed that the mechanical properties of water are better at stimulating the proprioceptive sense.

Lee investigated the effect of aquatic exercise on the balance and gait of stroke patients and reported that the balance and gait ability were improved more in an aquatic exercise group than in a land exercise group[19]. Kelly et al. reported that gait speed, muscle strength of the lower limbs, and cardiovascular health were improved in chronic stroke patients when aquatic exercise was conducted [20].

Additionally, it was reported that lower limb muscle strength exercises in water improved the gait speed of hemiplegic patients. In our study, although POMA showed that both balance and gait ability were improved in both the land exercise group and the aquatic exercise group, the error decreased more in the aquatic exercise group than in the land exercise group. Therefore, we assume that the aquatic exercise is more effective than land exercise therapy, even though land exercise therapy is also effective. We anticipate that the parallel implementation of aquatic exercise, in addition to land exercise therapy for chronic stroke patients, will be effective at improving the joint position sense and physical exercise ability of stroke patients.

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