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The Effects of Water-Based Exercise on Physiological Cost Index and Balance in Stroke Patients

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Purpose: This study attempts to find the effects of water-based exercise performed on stroke patients in their physiological cost index and static and dynamic balance.

Methods: The subjects were 30 stroke patients, who were randomly divided a water-based exercise group and a land-based exercise group, each with 15 patients. Both exercises ware performed 3 day per week, for 40 minutes a day, for a period of eight weeks.

Results: The Water-based exercise group showed a decreased physiological cost index compared to the land-based exercise group, with the physiological cost index of the water-based exercise group decreasing, while the land-based exercise group, showing a significant decrease. Water-based exercise increased static and dynamic balance capacity better than land-based group, showing a significant difference and better efficiency of water-based exercise when compared to land-based exercise.

Conclusion: From the result of the study, we found that water-based exercise is more effective in improving PCI and static and dynamic balance capacity. Through this study, training in water-based stroke patients could use cardiovascular endurance and buoyancy and the vortex, as an effective treatment that can enhance the growth and voluntary participation in the range of the patient's own movement the thought is, in consideration of the changes in the physiological cost index due to the difference in the ground and water, and should establish a training program that matches the purpose.

Key Words: Water-based exercise, Physiological cost index, Balance, Stroke

I. Introduction

Strokes imposes restriction on independent everyday life in sensation disorder, motor disorder, verbal disorder, and cognitive disorder, which are caused by cellular damage and neurologic functionality loss due to blood ischemia or hemorrhage in the brain.[1,2] Stroke causes difficulty in normal gait and everyday life due to loss of balance and reduced respiratory capability caused by dizziness, loss of vision, and loss of sensation along with damage to the upper limb, lower limb, and face of the affected side.[3] In particular, the deficit of strength in the lower limb reduced motor control, and instability when supporting body weight, which led to the danger of falling down. This results in increased position sway and reduced stability limitation while standing in most stroke patients when compared to normal people of similar age groups.[4]

Balance is classified into two parts, one being static balance and the other being dynamic balance, and has two important aspects in a sitting position. Static balance minimizes the movement of gravity's center, reducing movement or trembling and dynamic balance is the capacity to move weight

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inside the base.[5] Impairment of sense input and weight pressure in stroke patients is due to decreased or lost balance and proprioception. Such unsymmetrical input of sense and processing makes the stroke patient difficult to easily adjust their position,[3] which has been reported to act as a main factor that declines balance capability. The stroke patients used about one and a half to two times the energy when compared to normal people when making normal movements for various activities.[6] Therefore solving complications related to balance adjustment is important as it increases the patient's functionality and independency in rehabilitation.[7,8]

Rehabilitation programs for functionality improvement and balance recovery of stroke patients include objective-focused exercises by Kwakkel et al[9] auditory feedback exercises by Cheng et al[10] and water-based exercises. Recently, the necessity of safe and effective exercises is being proposed.[11] Movements in water can slow down the falling speed and also inhibition and facilitation using property of water helps sustain the balance or express movements freely.[12] Even though water-based exercises possess such pros,[13] balance training is mostly done on land and exercise on land and therefore has a risk of falling down, but water-based training can not only reduce the risk of falling down and fear from it, but can also be used as a training to cope with similar falling sutuations.14 In particular, the water-based exercise program provides patients who can't handle their own weight on land with an environment easier to start exercising early,[15] makes it possible for the patients to exercise with minimal pain as it minimizes the weight load and increases endurance, strength, and stamina without giving stress to joints.[16] Noh et al[17] found that after performing the water-based exercises to 25 chronic stroke patients, their balance capacity increased. Douris et al[18] argued that after the patients were trained in both water-based and on-land for 12 weeks, they showed improvement in strength, flexibility, dynamic and static balance in the water. Through this, it can be said that sufficient time is provided to detect errors in posture independently even with balance disorders.

Measurement of energy consumption according to workout intensity using respiration is expressed in oxygen consumption rate, which measures expiratory air and reflects oxygen consumption in the whole body. Oxygen consumption is used to evaluate energy consumption while walking, but there are some complications in using it clinically due to its difficulties in installing the appropriate equipment. PCI(Physiological Cost Index) devised by Macgregor[19] is a method that evaluates energy consumption when walking by observing the heart rate and is the easiest factor for evaluation. Measurement of energy consumption using PCI is used in researches on healthy adults, children with polio, patients with damaged spine, stroke patients, and etc., and even in healthy children and disabled children, it is considered as a significant criterion that determines adaptability and suitability of exercise programs by showing a linear relation between oxygen consumption and heart rate in walking.[20] According to the studies of Hood et al[21] and Graham et al,[22] in a repetitive experiment, PCI is more repeatable than oxygen consumption index. Also, they state that PCI will be used in different normal gait execution and studies of normal children and patients with spine damage or head injury.

Currently, studies on the effectiveness of water-based exercise on stroke patients are being published in various aspects, but very few studies on the influence of water-based exercise on PCI and balance capability are published. Therefore, this study intends to find what influences water-based exercises have on PCI and balance capability.

II. Methods

1. Subjects

This study is based on 30 stroke patients who were admitted to hospital in J rehabilitation clinic located in Mokpo, Jeollanam-do after providing sufficient explanation to the patient or legal guardian and receiving informed consent from themselves. The criteria for the selection of subjects are as follows; those who can walk for over 10 meters by themselves, those who have no loss of vision and hearing, and those who have limited vocabulary but can have a conversation with test scores of at least 26 points in the K-MMSE (K-Mini Mental State Examination), and those who can follow instructions when in evaluation. 15 subjects in the experimental group and 15 subjects in the control group were randomly selected and

Table 1. General characteristics of the subjects

	WBE group (n=15) Mean ± SD	LBE group (n=15) Mean ± SD	F	p'
Age (year)	55.06 ± 1.71	52.60 ± 1.90	0.286	0.597
Height (㎝)	164.86 ± 3.28	167.60 ± 2.30	0.082	0.777
Weight (㎏)	63.74 ± 2.41	66.33 ± 1.75	0.822	0.372
Onset (month)	16.06 ± 1.80	15.80 ± 1.84	2.604	0.118

p' = independent t-test
WBE : Water based exercise
LBE : Land based exercise

general characteristics of subjects are shown in Table 1.

2. Experimental methods

After the test subjects were mediated with general neurological physical therapy for 30 minutes, the experimental group carried out water-based exercises based on works of Itshak Melzer et al[14] while the control group carried out land-based exercises. This training program is based on the Functional and Specific Balance Training Program. The training program adheres to the principles of exercise prescription-specificity, progressive overload, individualization.[14] The program is performed on five levels, where each level reflects different demands on the postural control system. Intervention lasted for 8 weeks, 3 times a week, 40 minutes each time. Before mediating the water-based exercise, the group received a sufficient education and intensity of the exercise was done in scale of 11 (light) to 13 (a little hard) in Borg' s scale which is a subjective rating of perceived exertion used by Didier pardon et al.[23]

1) Measurement

(1) Physiological cost index

PCI the measurement is to measure the heart rate and the walking speed is easily variable, resting heart rate which was measured using a heart rate meter in a way of evaluating the energy consumption during walking, walking when use the heart rate and walking speed.

Heart rate was measured by a pacer heart rate monitor. A pacer heart rate monitor consists of a signal transferor, elastic band, and wrist receiver. It was strapped around the lower chest with the product name facing front and the wrist receiver was strapped just like a normal wristwatch. The first step of the experiment was to measure the heart rate and instruct the subject to walk in a pace the subject had chosen. The heart rate of their steady state was obtained after 5 minutes of stable rest in a sitting position.[24] Walking speed was measured by the 10 m walking test.

(2) Balance

The Biorescue (RM Ingenierie, France) for analyzing weight distribution rates consists of a movable rectangular force plate for standing with both feet and a graduated ruler is marked on the force plate for appropriate foot positions. Static balance ability was measured in the whole path length. It was simple to measured, evaluates the variation in the ability to movement distance before and after treatment, and serves as standards that are useful for studying normal and abnormal posture. Whole path length was measured when the subject was standing on both feet in a natural posture looking at the monitor in front of him/her. Dynamic balance ability was measured in the limited of stability. Limited of stability was measured distance to the center of gravity of the weight transfer during the eight directions indicated by the display of the front in order to measure. In the evaluation, the resultant mean values were obtained rates three times.[25-27]

2) Statistical methods

The data obtained in the present study were statistically processed using SPSS Windows 19. Analyses of covariance (ANCOVA) were conducted to compare PCI and balance between different intervention methods. All the statistical significance levels used were 0.05.

III. Results

1. Comparison of physiological cost index between groups

In the comparison between PCI before and after intervention of each group, the water-based exercise group showed 0.76±0.11 beat/m from what was originally 0.93±0.15 beat/m, which was a statistically significant difference when compared to control group($p<0.001$)(Table 2).

2. Comparison of static and dynamic balance between groups

In the comparison between static balance capability before/after intervention of each group, the whole path length of the water-based exercise group changed from 8.96±1.49 ㎝ to 8.38±2.95 ㎝, which was a statistically significant difference when compared to control group($p<0.005$). In the comparison of dynamic balance capability, the stability limit of water-based exercise group limited of stability from 137.36±10.83 ㎠ to 152.06±7.17 ㎠, which was a statistically significant difference when compared to control group($p<0.01$)(Table 3).

IV. Discussion

This study was conducted to understand the influence of water-based exercises of 8 weeks has on PCI and static and dynamic balance capability.

These criteria show muscle weakness, balance disability, fatigue, and reduced cardiovascular endurance which are significantly common in stroke patients significantly. Such muscle weakness and fatigue brings forth the limitation to functional execution of everyday tasks.[28]

Water-based exercises reduce gravity, making movement easier than when on land. It also brings the patient's participation with easier and more entertaining factors and provides a sense of physical stability due to the influence of buoyancy, which makes the patients perform more challenging tasks better than when on land, increasing oxygen consumption and heart rate and while improving physical abilities with a reduced fear of falling down.[29]

Measurement of energy consumption in relation to intensity

Table 2. Comparison of physiological cost index between groups

Item	Groups	Pre-test Mean ± SD	Post-test Mean ± SD	F	p'
PCI (beat/m)	WBE	0.93 ± 0.15	0.76 ± 0.11	75.22	0.000*
	LBE	1.06 ± 0.23	0.99 ± 0.18		

p' = ANCOVA
*p<0.001
WBE : Water-based exercise
LBE : Land-based exercise
PCI : Physiological cost index

Table 3. Comparison of balance between groups

Item	Groups	Pre-test Mean ± SD	Post-test Mean ± SD	F	p'
PCI (beat/m)	WBE	8.96 ± 1.49	8.38 ± 2.95	41.75	0.001*
	LBE	9.08 ± 3.74	8.82 ± 1.68		
LOS (㎠)	WBE	137.36 ± 10.83	152.06 ± 7.17	11.38	0.008 †
	LBE	136.17 ± 4.11	146.87 ± 5.61		

p' = ANCOVA
*p<0.005
† p<0.01
WBE : Water-based exercise
LBE : Land-based exercise
WPL : Whole path length
LOS : Limited of stability

of workout shows the whole body oxygen consumption through oxygen consumption rate, which is used in evaluating energy consumption when walking. But difficulty in installing the equipment, breathing limitation when collecting expiration, and a comparatively higher price makes it difficult to be used in clinics.[30] The PCI has been used as an easy and simple way to measure oxygen consumption when working out using heart rate.

The result of the exercise in this study based on Melzner et al14 study showed a significant difference between before/after in both control group and experimental group, but it was more effective in the experimental group. Also in static and dynamic balance, both control group and experimental group showed significant differences before/after, but it was more effective in the experimental group.

Chu et al[28] study showed a 22% increase in maximum oxygen consumption after treating water-based circulatory exercises to 7 chronic stroke patients, 3 times a week for 8 weeks and this study showed a significant reduction in PCI with the water-based exercise of 40 minutes, 3 times a week for 8 weeks. In the study of Ijzerman et al31 resting and walking of normal people showed linear correlation between oxygen consumption and heart rate, and Chin et al[32] showed linear correlation between oxygen consumption and heart rate in maximum level of treadmill exercise performed on patients with orthosis. Though the measuring method of this study differed from Chu et al[28] study, the results were the same, showing linear correlation between measuring the method, which is considered to explain the necessity of water-based exercise for patients showing a reduction of cardiovascular endurance. Bocalini et al[33] performed 60-minute exercise 3 times a week for 12 weeks on general females and 25 water-based exercise participants showed a 10% reduced heart rate in rest and 42% increased maximum oxygen consumption compared to 15 land exercise participants. Also, Takeshima et al[34] found an increase of maximum oxygen consumption by performing circulatory exercises in the water 3 times a week for 12 weeks. Also in this study, water-based exercise group that underwent 40 minute exercises 3 times a week for 8 weeks showed more significant PCI than the land-based exercise group, which is consistent with previous works of Bocalini et al33 and Takeshima et al,[34] supporting the contents of this study. To improve cardiovascular endurance with the water-based exercise, intervention duration of at least 8 weeks and dynamic exercises that use resistance of inside/outside such as gait exercise are considered necessary.[35] It is thought that gave a positive effect on the cardiovascular endurance increasing the voluntary participation by an increase in the moving range through a water-based exercise.

Saavdra et al[36] found no significant difference in balance capability after performing circuit training to 20 normal individuals in shallow water for 60 minutes, twice a week, for 8 months. But Devereux et al[37] found significant difference in dynamic balance capability after performing water-based exercises to 50 elderly females whose age were 65 & over for 10 weeks. Also, Suomi et al[38] found a significant difference in decrease of lateral and total sway distance after performing water-based exercises to 24 females with arthritis in lower limbs 3 times a week for 6 weeks. Also in this study, the water-based exercise group that underwent 40-minute exercises 3 times a week for 8 weeks showed a more significant difference in balance capability, which is consistent with previous works of Devereux et al[37] and Suomi et al[38] supporting the contents of this study and it is considered that water-based exercise should be done at least at the depth of xiphoid process along with obstacle exercises and objective-focused exercises. The result is improved due to the ability to balance reason is considered to be a greater motivation and posture control ability through action in the event of a modification of movement when training on interventions tasks underwater.

From the result of the study, we found that water-based exercise is more effective in improving PCI and static and dynamic balance capacity. Through this study, training in water-based stroke patients could use cardiovascular endurance and buoyancy and the vortex, as an effective treatment that can enhance the growth and voluntary participation in the range of the patient's own movement the thought is, in consideration of the changes in the physiological cost index due to the difference in the ground and water, and should establish a training program that matches the purpose.

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