

## Comparison of Underwater and Overground Treadmill Walking Exercise to Improve Gait and Physical Function in People After Stroke

The purpose of this study was to compare the effects of treadmill walking in underwater and overground which affects gait and physical function of people who have had a stroke. Twenty people after a stroke who have become hemiplegic over 6 months were participated. Participants were divided into two groups: underwater treadmill group(UTG) and overground treadmill group(OTG). The intervention was done 4 times per weeks for 6 weeks and 1 session lasted for 30 minutes. Gait and physical function elements were measured at baseline, at the middle(3 weeks) and at the end of the intervention(6 weeks). For the elements of gait, walking velocity, affected stance phase, affected weight bearing were assessed. For the elements of physical function, Short Form 8(SF-8) health survey was used. The result of this study showed that both groups improved similarly in walking velocity. However participants in UTG improved more than those in OTG in affected stance phase( $p < .05$ ), affected weight bearing( $p < .05$ ) and emotional aspect( $p < .001$ ). Based on the results of this study, it can be suggested that treadmill walking both in underwater and on the ground can be effective in improving hemiplegic gait and physical function of people who have had a stroke. The result also suggest that the underwater treadmill exercise can be more effective than overground treadmill in restoration of gait in people after stroke.

Key words: *Underwater Treadmill; Stroke; Gait; Physical Function*

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## INTRODUCTION

Stroke is defined as an obstacle that is accompanied by damage of motor nerve and sensory nerve. It is caused by blocked blood supply or hemorrhage to the brain. About half the stroke patient experience hemiparalysis more than 6 months, and most of them have functional disorders in a long term(1). The ability to perform in fundamental everyday life is difficult for most stroke patients. Thus they need others help which becomes a factor that deteriorates quality of life. The ultimate goal of rehabilitation for stroke patients is to return to the previous lifestyle. To return to the previous lifestyle, the ability to walk is one of the key components in rehabilitation(2). The major causes of gait disturbance is decreased muscle activity, difficulty in weight bearing and reduced

sense of proprioception(3). The gait pattern of people who have had a stroke appear to have slower gait velocity, difference in step length between the affected and the unaffected side and short period of weight bearing in the affected side(4). Gait disturbance in people after stroke can have a significantly effect in their independent performance.

About 50% of people after stroke have a potential to recover their independent walking, consequently most of them become focused on intense rehabilitation training in order to recover the ability to walk(6). In a previous study, Richard and his colleagues reported that the methods of purpose oriented walking such as actual walk was more effective than traditional training(7). Recently, it has been found that treadmill walking is more effective than overground walking to train walking. Therefore, the

efficiency of treadmill walking has been emphasized(8). In addition, treadmill training has positive effects in gait ability, and cardiovascular fitness, as well as activation of cerebellum, midbrain and some cerebral cortex part which may give positive influence in functional improvement of stroke patients(9).

The problem of treadmill training is that it can not be used in case of inability to carry out independent walk due to decline of muscle power. Therefore, study of the underwater exercise which can be achieved without weight bearing has gained great interest, aerobic exercise in water is popularized gradually(10). Exercise in water provides an appropriate environment to patients who are unable to walk independently and can make them exercise sooner(11).

However, walking in the swimming pool is different to walking on the treadmill. Walking in the swimming pool is difficult to control the constant speed, whereas walking on a treadmill can control the speed of walking. In addition, energy consumption is influenced by the swimming form in the swimming pool. So it is, in reality, difficult to make a direct comparison between underwater walking and overground treadmill walking(12). Therefore, underwater treadmill was developed to walk and run in the water. The underwater treadmill provides various environments that can adjust the height and temperature of the water and walking speed.

The purpose of this study was to compare the effects of treadmill walking between underwater and overground which can affect hemiplegic gait and physical function. Therefore, an effective exercise method can be generated.

## MATERIALS AND METHODS

### Participants

Participants were selected from the patients of Rusk rehabilitation hospital(Seongnam, Korea). Twenty patients who have had hemiplegia more than 6 months were included in this study. Participants were randomly allocated into: underwater treadmill group(UTG, n=10) and overground treadmill group(OTG, n=10). The inclusion criteria were 1) the ability to walk 10m independently without any walking aids, 2) a minimum of 22 points in the mini-mental state examination(MMSE), and 3) capability to understand and follow simple instructions. Exclusion criteria were patients with any neurologic disorders other than stroke and patients with orthopedic problems. All subjects were explained sufficiently and they signed consent from before participation to the study. Table 1 shows the general characteristics of participants.

Table 1. General characteristics of participants

	UTG	OTG	p
Sex(male/female)	5/5	4/6	.548
Age	51.80±14.46	58.70±8.34	.085
Weight(kg)	61.80±9.33	60.90±5.25	.073
Height(cm)	161.30±8.32	159.30±10.15	.661
Affected side(left/right)	7/3	5/5	.207
Time after stroke(month)	13.10±8.43	12.50±8.44	.736
Type of stroke (infarction/hemorrhage)	6/4	6/4	1

UTG: underwater treadmill group; OTG: overground treadmill group

### Measurement

Participants were assessed for gait analysis and physical function. The Smartstep(Andante Medical, America) was used to analyse the gait which measured the velocity, stance phase and body weight on the

affected side during walking. Physical function was assessed by using the Short Form 8(SF-8) health survey. The SF-8 is the summary of Short Form 36 which comprised of 8 questions to evaluate mental state as well as physical health. Lower scores reflect a better level. All participants in both groups were

both groups were evaluated at prior to, 3 weeks and 6 weeks after the starting of intervention.

### Procedure

The program was consisted of 30 minutes a day, four times per week for 6 weeks. The treadmill had a installed emergency device to ensure their safety.

#### Underwater treadmill group(UTG)

Underwater treadmill program was consisted of 30 minutes. The treadmill inclination was setting horizontally. The level of water was setting thoracic vertebrae 11. The range of water temperature was between 28°C and 30°C. The treadmill speed was carried out maximum velocity within the limit of 2–4m/s. If participants were experiencing shortness of breath, light headed, or over exerted, they were allowed to take a break.

#### Overground treadmill group(OTG)

Overground treadmill program was consisted of 30 minutes. The treadmill inclination was setting horizontally. The temperature in laboratory was between 24°C and 26°C. The treadmill speed was carried out maximum velocity within the limit of 2–4m/s. If participants were experiencing shortness of breath, light headed, or over exerted, they were allowed to take a break.

### Data Analysis

Data were analyzed using SPSS statistical software for Windows version 12.0. A repeated analysis of variance(ANOVA) was used to evaluate the change by application period of group exercise program in group. An analysis of covariance(ANCOVA) was used to evaluate the change by application period of group exercise program between group. In all analysis,  $p < .05$  was considered significant.

## RESULTS

A total of 20 subjects completed the study, 10 UTG and 10 OTG subjects. Table 2 was shown difference in baseline between group.

**Table 2.** Difference in baseline between groups

	UTG	OTG
Gait velocity(m/min)	18.13±7.66	21.56±9.78
Stance phase(%)	55.08±6.84	54.05±8.36
Weight bearing(kg)	52.56±10.73	53.67±13.19
Short Form 8		
• physical component	14.00±2.00	13.80±2.65
• mental component	11.40±2.91	11.90±3.07

UTG: underwater treadmill group; OTG: overground treadmill group

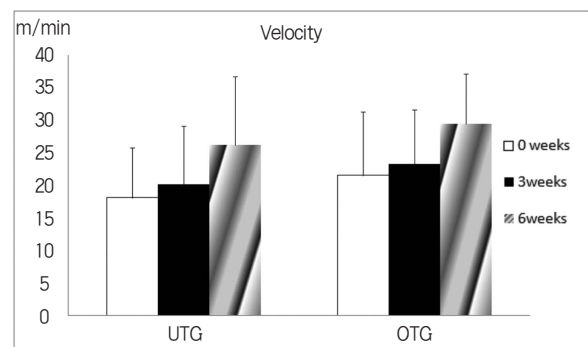
### Comparison of Within Groups

#### Gait analysis

Within group effects on gait parameters were provided in Figure 1. Both groups revealed a significant increase by time interaction for gait velocity. In the UTG, gait velocity was increased from 18.13±7.66m/min to 26.23±10.48m/min( $p < .05$ ). OTG results were shown similarly. In the OTG, gait velocity was increased from 21.56±9.78m/min to 29.48±7.72m/min( $p < .05$ ).

The stance phase rate on affected side were increased significantly from 55.08±6.84% to 58.60±4.34% in UTG( $p = .007$ ). In contrast, OTG showed no change in stance phase rate on affected side.

The weight bearing on the affected side were increased significantly from 52.56±10.73kg to 55.15±11.26kg in UTG( $p = .002$ ). In contrast, OTG showed no change in weight bearing on the affected side.



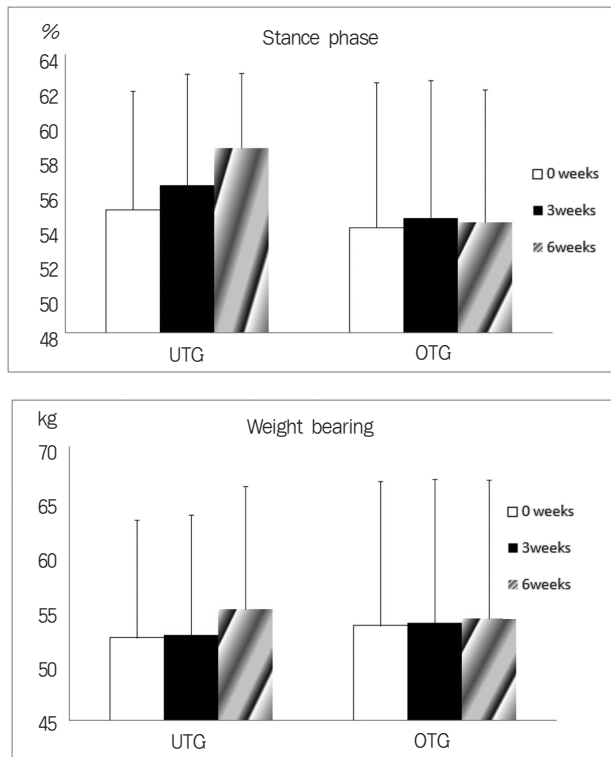


Fig. 1. Effects of gait ability in UTG versus OTG

### Physical function

Within group effects on physical function were provided in Figure 2. Physical function was assessed by using the SF-8 health survey. In the physical component, the score of UTG was improved from  $14.00 \pm 2.00$  to  $13.40 \pm 2.01$ . UTG did not shown significant difference. In contrast, the score of OTG was improved from  $13.80 \pm 2.65$  to  $12.50 \pm 2.63$ . OTG did shown significant difference ( $p < .05$ ).

In the mental component, the score of UTG was improved from  $11.40 \pm 2.91$  to  $9.10 \pm 2.80$ . UTG did

shown significant difference. In contrast, the score of OTG was improved from  $11.90 \pm 3.07$  to  $11.20 \pm 3.01$ . OTG did not shown significant difference.

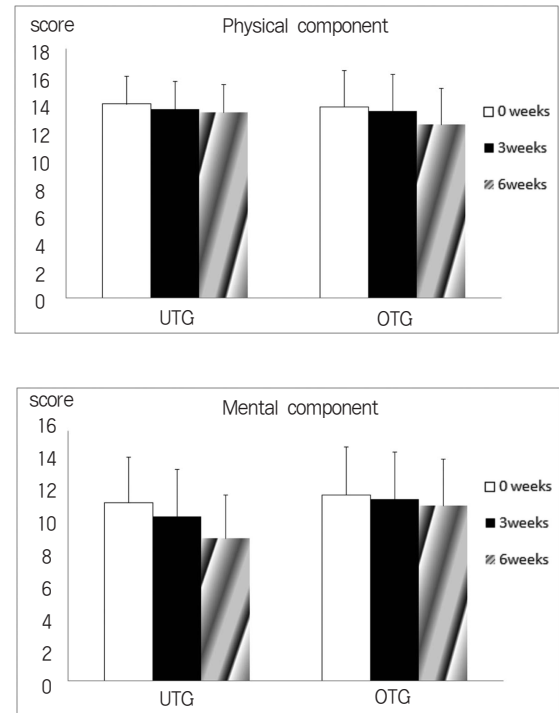


Fig. 2. Effects of SF-8 in UTG versus OTG

### Comparison of Between Groups

#### Gait analysis

Table 3 was shown comparison of gait ability in between groups. Comparing UTG with OTG, there was a significant different in gait stance phase and weight bearing on the affected side. However, there were no significantly difference between groups in gait velocity.

Table 3. Comparison of gait ability in UTG and OTG

	UTG		OTG		p
	Before	After	Before	After	
Velocity(m/min)	18.13±7.66	26.23±10.48	21.56±9.78	29.48±7.72	.979
Stance phase(%)	55.08±6.84	58.60±4.34	54.05±8.36	54.33±7.67	.006 **
Weight bearing(kg)	52.56±10.73	55.54±11.26	53.67±13.19	54.15±12.65	.033 *

UTG: underwater treadmill group; OTG: overground treadmill group  
\*  $p < .05$ , \*\*  $p < .01$

### Physical function

Physical function was assessed by using the SF-8 health survey. Table 4 was shown comparison of SF-8 in between groups. Comparing UTG with OTG, there was a significant different in mental compo-

nent(emotional aspect). However, there were no significantly difference between groups in physical component.

**Table 4.** Between-groups comparison of SF-8

	UTG		OTG		p
	Before	After	Before	After	
Short Form 8					
• physical component	14.00±2.00	13.40±2.01	13.80±2.65	12.50±2.63	.076
• mental component	11.40±2.91	9.10±2.80	11.90±3.07	11.20±3.01	.00**

UTG: underwater treadmill group; OTG: overground treadmill group  
\*p<.05, \*\*p<.01

## DISCUSSION

This is the first study to investigate the difference of treadmill walking program in underwater and over ground. The results of this study showed that both exercise programs can significantly improved walking in patients who have had a stroke. However, UTG was taken more positive effect of affected stance phase, affected weight bearing and emotional aspect than OTG.

Gait velocity did not show significant difference between groups. Our results revealed that both groups have a positive effect on gait velocity in people with stroke. In a previous study, when the treadmill training was applied for 8 weeks on stroke patients, gait velocity improved from .15m/s to .22m/s(13). This result was consistent with the present study. In another study, underwater exercise group was more effective in improving gait velocity than conventional physical therapy group(14). This is different to our current study which showed no difference between groups. The reason for this would be the difference in tasks of the two study as the previous study underwater exercise whereas current study used a walking exercise.

The stance phase rate on affected side were increased significantly in UTG. In contrast, OTG did not shown significant difference. In between groups, stance phase rate on affected side did show significant difference. This means that underwater treadmill training have a positive effect on stance phase rate on affected side than overground treadmill training. On the improvement of stance phase rate means advancement of gait cycle. In a previous

study, when people with stroke were training for a long time on overground, weight shifting to affected side had become difficult(15). It means that center of gravity shifted to the unaffected side in people with stroke. In contrast, underwater training could maintain center of gravity.

The weight bearing on the affected side were increased significantly in UTG. In contrast, OTG did not shown significant difference. In between groups, weight bearing on the affected side did show significant difference. That means underwater training have a positive effect than overground training, because underwater training could maintain center of gravity(15).

In this study, SF-8 was used to investigate the physical function of stroke participants. The SF-8 was comprised of physical component and mental component. In the physical component, OTG did show significant difference. However, UTG did not show significant difference. In addition, between two groups did not show significant difference. It means that underwater treadmill training has not influenced largely on physical satisfaction in people with stroke.

In the mental component, OTG did not show significant difference. In contrast, UTG did show significant difference. In addition, between two groups did show significant difference. The change of psychology in people with stroke is caused sadness, fury, psychological fear according to the limited body function. The exercise in warm water provide mental relaxation for people with stroke(16). It means that underwater treadmill training has a positive effect on emotional aspect.

## CONCLUSION

In conclusion, both groups (UTG and OTG) were positive effect in gait velocity and physical function on people with stroke. However, UTG was superior to improving affected weight bearing, stance phase and emotional aspect than OTG. Further studies are needed to determine whether underwater treadmill exercise can improve long-term functional independence and quality of life in neurological patients.

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