

The Effects of Measurement Environment on the Gait Velocity and Balance of Stroke Patients

YOUNG YOUL YOU, MPH, PT¹⁾, JIN GANG HER, PhD, PT²⁾, TAESUNG KO, PhD, PT³⁾,
JOOYEON KO, PhD, PT⁴⁾, HEESOO KIM, MPH, OT¹⁾, Ji-HEA WOO, MPH, PT¹⁾

¹⁾ Department of Rehabilitation Therapy, Graduate School of Hallym University

²⁾ Department of Rehabilitation Therapy, Faculty of Health Science, Hallym University: Okcheon-dong, Chuncheon-si, Gangwon-do 200-702 South Korea. TEL: +82 33-248-1421

³⁾ Department of Physical Therapy, Daewon University College

⁴⁾ Department of Rehabilitation Medicine, CHA University, CHA Bundang Medical Center

Abstract. [Purpose] The purpose of this study was to examine between an hospital environment and a outdoor environment of differences the gait velocity and balance ability of hemiplegia patients, who had received an eight-week rehabilitation treatment for gait and balance [Subjects] A total of 27 hemiplegia patients participated. [Methods] Before and a the rehabilitation treatment, 30 m gait tests and six-minute gait tests were carried out in a hospital environment and a outdoor environment to measure the subjects' gait velocities. To measure their balance, the Berg Balance Scale (BBS) and the Timed Up-and-Go (TUG) test were conducted. The paired t-test was performed to verify the statistical differences between the before and after measurements in the two environments. [Results] The results showed an improvement in the 30 m and six-minute gait tests after the treatment in the hospital environment, but not in the outdoor environment, while the BBS and TUG scores improved after the treatment in both environments. These results suggest the necessity of studies on rehabilitation treatment methods, which can help hemiplegia patients to adapt gait velocity and balance ability to outdoor environments. [Conclusion] In conclusion the results highlight that the measurement environment can affect the outcome of the test and researchers should take this into consideration when testing.

Key words: Hospital environment, Outdoor environment, Hemiplegia patient

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INTRODUCTION

Functional problems in the physical activities of chronic stroke patients universally decrease their quality of life¹⁾. Stroke patients have sensory, motor, cognitive, and emotional disabilities, which limit their activities of daily living (ADL)²⁾. Furthermore, sensory and motor disorders greatly affect their posture control, ADL, and gait³⁾. The goal of rehabilitation for stroke patients is to restore their physical functions, including gait ability, to as near normal as possible, and to return patients to their own homes and communities⁴⁾. A prior study examined 130 patients who had returned to their communities after stroke and reported that about a third of them had difficulties with ADL due to gait disabilities⁵⁾. One of the most important goals of rehabilitation treatment is to encourage patients' independent and safe gait by enhancing their gait function. Problems related to quality of life may arise if gait function is not improved. A gait velocity between 1.1 m/s and 1.5 m/s is generally considered necessary for functional gait in the community⁶⁾, while a gait velocity between 0.8 m/s and 1.2 m/s is generally recorded for hemiplegia patients after stroke⁷⁾.

Patients with hemiplegia following stroke have decreased mobility which leads to social isolation due to decreased

ADL and endurance, indicating that functional disabilities may hamper quality of life⁸⁾. Independent gait is a target of rehabilitation treatment for stroke patients, in order to allow them to live in their own homes and communities because it is very closely related to ADL⁹⁾. Previous studies have revealed that stroke patients have a variety of actual difficulties with postural control and gait in an outdoor environment. This is because they are faced with various tasks due to the unexpected conditions of the outdoor environment, and surrounding situations and factors¹⁰⁾. Despite such difficulties with the outdoor environment, gait training in reality is mostly conducted in a hospital environment¹¹⁾. For example, stroke patients may have trouble walking while shopping at a store, which is one of the instrumental activities of daily living (IADL). A study reported that gait function measurement is mainly carried out in a laboratory or other spaces in a hospital, and stroke patients are not provided with other environments in which they can try to adapt their gait to basic living conditions¹²⁾. Laboratory and hospital environments are different from outdoor environments, and this leads to stroke patients having limited gait ability in their communities and low adaptability to home-dwelling because these environmental factors are not reflected in rehabilitation treatment¹³⁾. Although gait

training, one of the items of rehabilitation for hemiplegia patients, is aimed at patients' return to their communities, evaluations of gait recovery and relevant exercise programs are generally conducted in laboratories.

In a prior study, Perry⁷⁾ explained that gait velocity after stroke generally remains at a decreased level, noting that this results in stroke patients having a lack of motivation and confidence in their communities, and difficulties with task performance. The biggest problems that hemiplegia patients experience in communities include temporal factors, postural transitions, physical load, and terrain change¹⁴⁾.

A previous study measured stroke patients' gait ability in various outdoor environments, such as a suburb, a shopping mall, a parking lot, and a supermarket. However, few studies have examined the differences between a laboratory or hospital environment and a community-dwelling environment that patients are familiar with in terms of the measurement of stroke patients' gait ability.

Thus, this study aimed to determine the differences between a hospital environment, a clinical treatment room, and an outdoor environment, which patients feel comfortable with, in terms of their effects on the gait velocity and balance ability of patients, to provide reference data for the IADL of hemiplegia patients for rehabilitation treatment.

SUBJECTS AND METHODS

The subjects of this study were hemiplegia patients who recovered independent gait after receiving rehabilitation treatment focused on gait and balance in a rehabilitation hospital that was located in Hwaseong City, Gyeonggi-do. The study subjects met the following criteria: patients who were scheduled to receive occupational therapy along with balance and gait training based on neurodevelopment treatment two hours a day, five times a week; ability to walking independently without a walking aid; at least six months from onset of stroke; a score of 24 or higher in the mini-mental state examination¹⁵⁾, ability to properly communicate and comprehend instructions; no visual, auditory, or vestibular disabilities; 55 years old or older; no orthopedic problems that might influence balance of the lower extremities; and willingness to participate in the experiment after understanding and consenting to the purposes of this study. Patients with the following conditions were excluded: severe cardiac disorders or uncontrollable hypertensive lesions that might lead to difficulties with gait; complaints of pain in the lower extremity during gait due to orthopedic problems; and neuropsychiatric issues.

We initially recruited 30 stroke patients. They received an eight-week rehabilitation treatment for gait and balance enhancement based on neurodevelopment treatment and occupational therapy. However, the final number of participants was 27 because two patients were discharged and one displayed worsened conditions during the experiment. The subjects' gait and balance ability were measured before and after the rehabilitation treatment in two different environments: a hospital environment and an outdoor environment. Gait and balance measurements in the hospital environment were performed before and after treatment in a treatment

room, which was mostly used for clinical purposes, with a flat and even floor. In contrast, gait and balance measurement in the outdoor environment were carried out before and after treatment in an outdoor environment with uneven concrete ground of the sort that the subjects would actually experience in their daily lives. During the gait tests, the patients were encouraged to walk at a comfortable speed. In both environments, the distance of the 30 m gait test was divided into three parts by a pole every 10 m. For the six-minute gait test, in order to measure the distance, the patients repeatedly walked from the first pole to the last one¹⁶⁾. At the final pole, they were instructed to walk around it keeping their non-affected side closest to the axis. The Berg Balance Scale (BBS) and the Timed Up-and-Go (TUG) test were used to assess balance. Each gait test was carried out at the same time on each measurement day, and a ten-minute break was given to the patients after each measurement in order to minimize physical fatigue. A stopwatch and a 30 m tape measure were used to measure the gait time and distance, respectively. The 30 m gait test is a method employed to measure gait velocity. This is commonly used to evaluate the gait ability of patients with hemiplegia following stroke. The gait time is measured using a stopwatch while subjects walk 30 m at a comfortable speed and the velocity is calculated¹⁷⁾. All measurements were carried out by one examiner to minimize errors. The six-minute gait test was once generally employed for patients with cardiovascular or cardiopulmonary diseases¹⁸⁾. However, it is now mostly used to measure the gait of hemiplegia patients after stroke¹⁹⁾. For the test, the distance patients can walk in 6 min is measured while they walk back and forth along a 30 m course at a comfortable speed. All measurements were carried out by one examiner to minimize errors. The BBS is a tool that is composed of 14 items assessing actions, such as going from sitting to standing, standing with the eyes closed, standing with the eyes open, and standing with the feet together, on a four-point scale²⁰⁾. Scores range from 0 to 56, and a higher score indicates better balance. All assessments were carried out by one examiner to minimize errors. The TUG test is a method of evaluating basic balance, rotation ability, and gait ability. For the test, the time is measured from when a subject stands up from sitting on a chair at the start signal, walks 3 meters, and walks back to the chair, to sitting down again²¹⁾. With an inter-examiner reliability of $r=0.99$ and an intra-examiner reliability of $r=0.98$, this tool shows high levels of reliability and internal validity²²⁾. To minimize errors, the average scores of three repetitive measurements were used, and all measurements were carried out by one examiner. All the subjects gave their written consent to participation in the study.

SPSS ver. 17.0 statistical software was used for the statistical analysis of the collected data. To verify the significance of the changes in a single group before and after treatment in each environment, the differences in the changes were examined using the paired t-test. Values of $\alpha \leq 0.05$ were considered statistically significant.

RESULTS

There were 27 subjects in the study, 14 males and 13 females. Their average age was 60.77 ± 4.81 years, and their average time after the onset of stroke was 12 ± 3.25 months. The affected side was the right side for 15 patients and the left side for twelve patients. Twenty-three patients had suffered an infarct, while four had suffered hemorrhage (Table 1).

In the hospital environment, the measured time of the 30 m gait test was 131.64 ± 17.9 seconds before the treatment and 113.70 ± 16.31 seconds after the treatment, indicating a significance difference. In contrast, in the outdoor environment, the measured gait time was 148.25 ± 15.86 seconds before the treatment and 145.34 ± 15.22 seconds after the treatment, showing an insignificant difference (Table 2).

In the hospital environment, the measured six-minute walking distance was 122.41 ± 15.5 m before the treatment and 137.00 ± 17.4 m after the treatment, indicating a significance difference. In contrast, in the outdoor environment, the six-minute walking distance was 109.41 ± 15.6 m before the treatment and 112.91 ± 14.7 m after the treatment, showing an insignificant difference (Table 2).

In the hospital environment, the BBS scores were 45.48 ± 2.73 points before the treatment and 48.00 ± 2.57 points after the treatment, indicating a significant difference. Furthermore, in the outdoor environment, the scores were 40.70 ± 2.2 points before the treatment and 46.55 ± 2.06 points after the treatment, showing a significant difference (Table 2).

In the hospital environment, the TUG times were 28.58 ± 3.51 seconds before the treatment and 25.04 ± 3.58 seconds after the treatment, indicating a significant difference. Furthermore, in the outdoor environment, the scores were 29.69 ± 3.64 seconds before the treatment and 27.43 ± 0.77 seconds after the treatment, showing a significant difference (Table 2).

DISCUSSION

This study was conducted to examine the influence of a hospital environment and an outdoor environment on the measurement of the gait ability of hemiplegia patients who had received an eight-week rehabilitation treatment program for gait and balance enhancement. During both the 30 m walking speed and six-minute walking distance, the patients were encouraged to walk at the speed which was most comfortable for them. Their gait ability and balance were tested before and after eight weeks of rehabilitation treatment, and the results reveal that 30 m walking speed, six-minute walking distance, and balance ability were significantly enhanced in the hospital environment. In contrast, in the outdoor environment, the subjects did not show significant differences in gait ability, though they did show significant improvements in balance ability. In other words, in both hospital and outdoor environments, the subjects' balance ability improved in short-term tests, whereas the results of the 30 m walking speed and

Table 1. General characteristics of the subjects (n=27)

Age	60.77 \pm 4.81 years
Onset	12.00 \pm 3.25 months
Gender	
male	14
female	13
Affected side	
Right	15
Left	12
Infarct/Hemorrhage	
Infarct	23
Hemorrhage	4

Table 2. Differences in the measurements made before and after rehabilitation treatment (n=27)

	Hospital environment	Outdoor environment	
30m walking time (sec)	17.94 \pm 5.70	2.27 \pm 2.26	*
Six-minute walking distance (m)	14.54 \pm 4.43	3.51 \pm 2.65	*
BBS (points)	2.51 \pm 0.93	2.85 \pm 0.94	
TUG (sec)	3.54 \pm 1.15	2.91 \pm 2.73	

* p<0.05

six-minute walking distance tests, which evaluate medium to long distance walking, showed significant changes in the hospital environment, but not in the outdoor environment. These results are in agreement with the results of Cristiane²³⁾ who determined the differences between two different environments, hospital and community, and their influence on the gait ability of chronic stroke patients. Our two studies both share the same conclusion that gait velocity is greatly influenced by environmental factors. Moreover, Kimberly¹¹⁾ also noted that environmental changes significantly affected the gait velocity of chronic stroke patients, and that differences in gait velocity can be detected even between walking on regular sidewalks and in shopping malls. Kimberly's study focused on the differences between a quiet outdoor environment and a crowded outdoor environment, unlike this study, which focused on hospital and community environments. Nevertheless, both our studies conclude that gait velocity and ability are influenced by environment.

The evaluation of stroke patients' gait velocities in the community and outdoor environments is crucial because gait velocity is an important factor of IADL. Moreover, a prior study argued that the proper gait velocity for an outdoor environment in the community is 0.8 m/s to 1.2 m/s⁷⁾. The average gait velocities of the subjects of this study were 0.32 m/s in the hospital environment and 0.25 m/s in the outdoor environment, which fall short of the proper velocity for adapting to IADL in the community. Our present results were probably influenced by the subjects being mostly inpatients. Furthermore, the differences in their gait abilities in the two environments were presumably the result of the

hemiplegia patients being accustomed to walking in the hospital environment, since most rehabilitation treatment and gait ability tests was conducted in hospital treatment rooms. In addition, Lord et al.⁵⁾ examined patients who had returned to their communities after stroke and reported that the mobility of the majority was enhanced, while about a third of them showed decreased gait ability in their communities as compared to in the hospital.

Balance ability, which is closely related to gait ability, can be enhanced through changes in muscle strength and postural strategy. However, exercise methods for improving gait endurance should be introduced because the purpose of gait depends on the interrelationship between long-term task performance and environment, which is also closely associated with gait velocity²⁴⁾. Although the results of this study showed significant improvements in balance measurements, which are conducted in a short period of time in both environments, the patients showed differences in actual gait ability, which were probably due to difficulties in adapting to the walking environment. This is in agreement with the remarks of Shumway-Cook et al.¹⁴⁾ who noted that postural control and balance ability are crucial for physical mobility and vertical orientation, and are related to gait, and that various environments should be provided to enhance patients' abilities to perform independent gait in their communities.

Physical fatigue generally adds to the difficulties of stroke patients' gait ability²⁵⁾. Furthermore, patients' mood and motivation at the time of gait tests also have strong correlations with their gait ability²⁶⁾. A limitation of this study was that it did not present the subjects' levels of fatigue, mood, motivation and heart rate, which may have influenced their gait abilities. Therefore, future studies should consider the influence of these factors on gait ability.

The focus of rehabilitation treatment for hemiplegia patients after stroke is on helping them to return to their communities and recover their gait ability, so that they will have no problems with walking in terms of IADL in their homes after discharge. Patients' activities, social independence, and quality of life in communities would be enhanced not only by therapy in a hospital environment but also by providing community-dwelling environments where proper gait velocity and safe gait could be promoted for improvement of gait ability.

In conclusion, we suggest the necessity of future studies of rehabilitation treatment methods that can enhance patients' gait ability in hospital environments, as well as improving their adaptability to outdoor environments.

REFERENCES

- Corriveau H, Hebert R, Raiche M, et al.: Evaluation of postural stability in the elderly with stroke. *Arch Phys Med Rehabil*, 2004, 85: 1095–1101. [Medline] [CrossRef]
- Hochstenbach J, Donders R, Mulder T, et al.: Long-term outcome after stroke: a disability-orientated approach. *Int J Rehabil Res*, 1996, 19: 189–200. [Medline] [CrossRef]
- Fong KN, Chan CC, Au DK: Relationship of motor and cognitive abilities to functional performance in stroke rehabilitation. *Brain Inj*, 2001, 15: 443–453. [Medline] [CrossRef]
- Goldie PA, Matyas TA, Evans OM: Deficit and change in gait velocity during rehabilitation after stroke. *Arch Phys Med Rehabil*, 1996, 77: 1074–1082. [Medline] [CrossRef]
- Lord SE, McPherson K, McNaughton HK, et al.: Community ambulation after stroke: how important and obtainable is it and what measures appear predictive? *Arch Phys Med Rehabil*, 2004, 85: 234–239. [Medline] [CrossRef]
- Carr J, Shepherd R: *Stroke rehabilitation: Guidelines for exercise and training to optimize motor skill*. London: Butterworth-Heinemann, 2003, pp 100–106.
- Perry J, Garrett M, Gronley JK, et al.: Classification of walking handicap in the stroke population. *Stroke*, 1995, 26: 982–989. [Medline] [CrossRef]
- Kwakkel G, Kollen BJ, Wagenaar RC: Long term effects of intensity of upper and lower limb training after stroke: a randomised trial. *J Neurol Neurosurg Psychiatry*, 2002, 72: 473–479. [Medline]
- Dobkin BH: Clinical practice: rehabilitation after stroke. *N Engl J Med*, 2002, 352: 1677–1684. [Medline] [CrossRef]
- Patla AE: Mobility in complex environments: implications for clinical assessment and rehabilitation. *Neurol Rep*, 2001, 25: 82–90.
- Donovan K, Lord SE, Weatherall M, et al.: Mobility beyond the clinic: the effect of environment on gait and its measurement in community-ambulant stroke survivors. *Clin Rehabil*, 2008, 22: 556–563. [Medline] [CrossRef]
- Eng JJ, Chu KS, Dawson AS, et al.: Functional walk tests in individuals with stroke: relation to perceived exertion and myocardial exertion. *Stroke*, 2002, 33: 756–761. [Medline] [CrossRef]
- Logan PA, Gladman JR, Dyas J: An interview study of the use of transport by people who have had a stroke. *Clin Rehabil*, 2004, 18: 703–708. [Medline] [CrossRef]
- Shumway-Cook A, Patla AE, Stewart A, et al.: Environmental demands associated with community mobility in older adults with and without mobility disabilities. *Phys Ther*, 2002, 82: 670–681. [Medline]
- Folstein MF, Folstein SE, McHugh PR: Mini-mental state: a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*, 1975, 12: 189–198. [Medline] [CrossRef]
- Harada ND, Chiu V, Stewart AL: Mobility-related function in older adults: assessment with a 6-minute walk test. *Arch Phys Med Rehabil*, 1999, 80: 837–841. [Medline] [CrossRef]
- Witte US, Carlsson JY: Self-selected walking speed in patients with hemiparesis after stroke. *Scand J Rehabil Med*, 1997, 29: 161–165. [Medline]
- Guyatt GH, Sullivan MJ, Thompson PJ, et al.: The 6-minute walk: a new measure of exercise capacity in patients with chronic heart failure. *Can Med Assoc J*, 1985, 132: 919–923. [Medline]
- Carvalho C, Willen C, Sunnerhagen KS: Relationship between walking function and 1-legged bicycling test in subjects in the later stage post-stroke. *J Rehabil Med*, 2008, 40: 721–726. [Medline]
- Berg KO, Maki BE, Williams JJ, et al.: Clinical and laboratory measures of postural balance in an elderly population. *Arch Phys Med Rehabil*, 1992, 73: 1073–1080. [Medline]
- Deathe AB, Miller WC: The test of functional mobility: measurement properties of a modified version of the timed 'up and go' test designed for people with lower-limb amputations. *Phys Ther*, 2005, 85: 626–635.
- Podsiadlo D, Richardson S: The timed 'up and go': a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*, 1991, 39: 142–148. [Medline]
- Carvalho C, Sunnerhagen KS, Willen C: Walking speed and distance in different environments of subjects in the later stage post-stroke. *Physiother Theory Pract*, 2010, 26: 519–527. [Medline] [CrossRef]
- Hill K, Ellis P, Bernhardt J, et al.: Balance and mobility outcomes for stroke patients: a comprehensive audit. *Aust J Physiother*, 1997, 43: 173–180. [Medline]
- Staub F, Bogousslavsky J: Fatigue after stroke: a major but neglected issue. *Cerebrovasc Dis*, 2001, 12: 75–81. [Medline] [CrossRef]
- Bogousslavsky J: Emotions, mood, and behaviour after stroke. *Stroke*, 2003, 34: 1046–1050. [Medline] [CrossRef]