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Correlation among Motor Function and Gait Velocity, and Explanatory Variable of Gait Velocity in Chronic Stroke Survivors

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Objective: The purpose of this study to investigate the correlations among the motor function, balance, and gait velocity and the strength that could explain the variation of gait velocity of chronic stroke survivors.

Design: This was a cross-sectional cohort study.

Methods: Thirty hemiplegic stroke survivors hospitalized in an inpatient rehabilitation center were participated. The muscle tone of ankle plantarflexor and muscle strength of ankle dorsiflexor were measured respectively with modified Ashworth scale (MAS) and hand-held dynamometer. And the motor recovery and function with Fugl-Meyer assessment (FMA), balance with Berg balance scale (BBS) and timed up and go (TUG) test were measured. Gait velocity was measured with GAITRite. The correlation among motor function, muscle tone, muscle strength, balance, and gait were analyzed. In addition, the strength of the relationship between the response (gait velocity) and the explanatory variables was analyzed.

Results: The gait velocity had positive correlations with FMA, muscle strength, and BBS, and negative correlation with MAS and TUG. Regression analysis showed that TUG ($\beta = -0.829$) was a major explanatory variable for gait velocity.

Conclusions: Our results suggest that gait velocity had correlations with muscle strength, MAS, FMA, BBS, and TUG. The tests and measurements affecting the variation of gait velocity the greatest were TUG, followed by FMA, BBS, muscle strength, and MAS. This study shows that TUG would be a possible assessment tool to determine the variation of gait velocity in stroke rehabilitation.

Key Words: Stroke, Gait velocity, Motor function

Introduction

Stroke is a cerebrovascular disease [1], and when the blood flow to the brain is cut off, the nerve cells in the brain area are distributed undergo necrosis, thereby damaging the brain [2]. This brain damage is defined as damage to the central nervous system, and by the type, it is divided into ischemic or hemorrhagic stroke [3]. The major symptoms due to stroke include decreased sensation, muscle weakness, abnormal muscle tone, and the degradation of balance, and the loss of these functional abilities is the main cause for permanent disability [4,5].

The gait velocity of patients with hemiplegia due to stroke is an effective predictive factor that can be used to assess the degree of independent living of such patients in a local community [6,7], in terms of gait activity and activities of daily life [8,9]. Schmid et al [6] and Perry et al [7] classified indoor gait (<40 cm/s), limited community gait (40-80 cm/s), and independent gait (>80 cm/s) as criteria for independent gait in the local community to promote independent

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living with gait training and the use of an appropriate gait device during rehabilitation [6,7].

The level of activity of stroke survivors in which they can participate in daily life differs depending on the body structure and function impairment level and their participation in the community becomes restricted [10]. In other words, to promote independent activity, the functional exercise level of the body should be assessed and correlations should be analyzed accurately to select the appropriate interventions and rehabilitation plans [11], which can be useful also for stroke survivors [12]. In this sense, measuring the impairment levels of stroke survivors' body function and body structure, using objective and accurate measuring tools and analyzing the results of the measurements can be important information as well [13]. Kobayashi et al [14] predicted the gait level of stroke survivors before and after putting on aids and analyzed its correlation with the Berg balance scale (BBS) often used in the clinical setting with gait velocity. Lewek et al [15] also investigated the impacts of balance of chronic stroke survivors on gait and analyze the correlation between the clinical measurement tool, the BBS, and spatiotemporal gait variables. Moreover, in the studies recently reported, the correlations between clinical measurement tools and the measuring equipment with proven reliability and validity have been compared to develop measuring equipment technologies [15-17]. However, the strength that could show the variation of the gait velocity level along with the correlations among the body structure, the results of the measurement of the functional impairment level often used in the clinical setting and gait velocity, one of the most important parameters of the gait abilities, has not been reported.

Thus, the present study examined the correlations among motor function, muscle tone, muscle strength, and balance with gait velocity; and determined the strength in which each parameter could explain the variation of the gait velocity.

Methods

Design

This was prospective cross-sectional cohort study.

Sample

This study recruited participants through a post in a public bulletin board at H. Rehabilitation Hospital, and 35 inpatients with hemiplegia due to stroke were recruited. The participants were screened according to the following criteria: 1) interval from stroke onset of ≥6 months; 2) a patient who has a hemiplegic disability due to stroke; 3) a patient with >24 points in a mini-mental state examination (MMSE); 4) a

Table 1. Characteristics of the participants

Characteristics	
Sex (male / female)	21 (70) / 9 (30)
Age (year)	50.47 (7.74)
Height (cm)	167.87 (6.66)
Weight (kg)	66.80 (10.37)
Disease duration (month)	43.10 (30.49)
Etiologic type (infarction/hemorrhage)	10 (33.3) / 20 (66.7)
Mini-mental state examination (score)	27.43 (2.11)
Fugl-Meyer assessment-lower extremity (score)	22.57 (5.16)
modified Ashworth scale (grade)	1.35 (0.82)
Muscle strength (lb)	5.65 (2.82)
Berg balance scale (score)	47.07 (5.61)
Timed up & go test (sec)	19.14 (8.69)
Gait velocity (cm/sec)	57.41 (28.00)

patient who can walk >10 m without a walking aid; 5) a patient who does not have a problem or disease in the nervous system or musculoskeletal system due to other cerebrovascular injuries other than stroke. In addition, patients with psychological problems or congenital joint deformities were excluded. Of the 35 volunteers recruited, three fell short of the MMSE score, and two could not walk more than 10 m, so they were excluded. A total of 30 volunteers finally participated in this study. The general characteristics of the participants in this study are in Table 1.

Sample size calculation

Using the G Power 3.1 statistical tool to achieve a statistical power of 80% with statistical significance at $p < 0.05$ (two-tailed test) and an effect size of $r = 0.5$, a total sample size of 26 participants was required for present trial.

Procedure

General characteristics such as sex, age, height, weight, disease duration, and etiologic type were collected from the medical charts or brief interviews with the patients. The test or measures for motor function, muscle tone, muscle strength, balance, and gait were conducted. First of all, the participants are informed of the test and measurement tools. The order of the test and measurement tools used was as follows: Fugl-Meyer assessment (FMA) for motor function, modified Ashworth scale (MAS) for muscle tone, hand-held dynamometer for muscle strength; BBS and timed up and go test (TUG) for balance; and GAITRite for gait velocity. After data acquisition, the correlation among motor function, muscle tone, muscle strength, balance, and gait were analyzed. In addition, the strength of the relationship between the response (gait velocity) and the explanatory variables was analyzed.

Measurements

Motor recovery and function

To assess motor function on the lower extremity, FMA was employed. FMA is a testing tool to quantitatively assess the degree of stroke survivors' recovery, including motor function, balance, sense (sensation), joint range of motion, and pain. This study conducted testing, only using motor function on the lower extremity, up to 34 points. Inter-tester reliability is 0.995; intra-tester reliability, 0.992; and test-retest reliability, 0.94－0.99 [18].

Muscle tone

To assess the ankle dorsiflexor tone, MAS was employed. MAS is a tool often used in muscle tone testing, and as for its intra-tester reliability of stroke survivors' muscle tone, $K = 0.84$ [19]. To test the muscle tone of the ankle dorsiflexor, the participants were asked to lie down comfortably, keep the knees flexion at 90°. Then, the resistance felt using the fast stretching to the dorsiflexion direction of the ankle was tested. Muscle tone is graded into five degrees which increase from 0 to 4 [19].

Muscle strength

Hand-held dynamometer (Power Track II, Jtech Medical Inc., Utah, USA) was used to test muscle strength in numerical value (pound). The present study tested the muscle strength of the ankle dorsiflexor. To test in the same condition, the participants were asked to keep the angles of the hip, knees and ankle joints at 90° in the position of sitting on the chair, and the degree of resistance of the opposing measuring point at the maximum dorsiflexion of the participant's ankle. For the muscle strength of the dorsiflexor, the mean of the values measured for three seconds was used in the maximum muscle contraction. Intra-class Correlation Coefficients (ICC)＝0.88－0.98, and test-retest reliability, ICC＝0.79－0.97 [20].

Balance

BBS is used to measure the balance ability of the patient with neurological damage in moving and standing postures, consisting of 14 tasks [21]. This test is conducted on a 4-point scale from 0 to 4 for each item, 56 points in total. In this tool, as for intra-tester and inter-tester reliability respectively, $r = 0.98$ and $r = 0.97$, which has high reliability [21]. TUG is a test that can measure functional motility and dynamic balance fast and tests the time at which the participant sits on a chair with armrests, 46cm in height, rises from the chair at the tester's start signal, walks 3m, returns and sits on the chair. It is a reliable tool with intra-tester reliability, r=0.99, and inter-tester reliability, r=0.98 [22].

Gait

GAITRite was employed to measure gait velocity. GAITRite (GAITRite, CIR system Inc., New Jersey, USA) used in the present study is the equipment mainly testing temporal and spatial gait. The participants were asked to stand in front of GAITRite, to walk out of the device, 461cm in length and 88cm in width, keeping eyes forward with the most comfortable gait velocity by the tester's oral signal. The test-retest reliability of this testing equipment, ICC =0.91 has a very high reliability [23].

Statistical analysis

For statistical analysis of this study, SPSS 18.0 (IBM Corporation, NY, USA) was employed. For a test of normality, a test was conducted using the Kolmogorov-Smirnov test. To examine the correlations among the variables, Pearson's correlation and Spearman's correlation analysis was employed. To examine the strength that could explain the variation of gait velocity level using motor function, muscle tone, muscle strength, and balance, regression analysis was employed. The significance level was set to 0.05.

Results

Correlations among motor function, muscle tone, muscle strength, balance, and gait velocity

The result of the analysis of the correlations among motor function, muscle tone, muscle strength, balance, and gait velocity are in Table 2. Gait velocity had positive correlations with FMA (r=0.652), muscle strength (r=0.495), and BBS (r=0.596) while it had negative correlations with MAS (r=−0.423) and TUG (r=−0.829) (P<0.05) (Table 2).

Regression analysis of the impact on the variation of gait velocity level

As a result of regression analysis with FMA, MAS, muscle strength, BBS, TUG as explanatory variables, there were significant impacts in all variables (P <0.05), and TUG (β=−0.829) had the greatest impact on the dependent variable, gait velocity, followed by FMA (β=0.652), BBS (β=0.596), muscle strength (β=0.495), and MAS (β=−0.423) (Table 3).

Table 2. Correlation among motor function, balance, gait velocity in the participants

	FMA	MAS	Muscle Strength	BBS	TUG
Gait velocity	0.652*	−0.423*	0.495*	0.596*	−0.829*

*P<0.05, Pvalues are quoted for correlation between gait velocity and other variables.
Abbreviations: FMA; Fugl-Meyer assessment-lower extremity. MAS; modified Ashworth scale. BBS; Berg balance scale. TUG; Timed up & go test.

Table 3. Multivariate regression to identify factors related to FMA, MAS, Muscle strength, BBS, and TUG in the participants

Explanatory variable	Dependent variable	Standardized coefficient(β)	F	R2	t	p
FMA	Gait Velocity	0.652	20.750	0.426	4.555	0.000*
MAS	Gait Velocity	−0.423	6.100	0.179	−2.470	0.020*
Muscle strength	Gait Velocity	0.495	9.096	0.245	3.016	0.005*
BBS	Gait Velocity	0.596	15.417	0.355	3.927	0.001*
TUG	Gait Velocity	−0.829	61.742	0.688	−7.858	0.000*

*P<0.05, P values are quoted for regression between variables.
Abbreviations: FMA; Fugl-Meyer assessment-lower extremity. MAS; modified Ashworth scale. BBS; Berg balance scale. TUG; Timed up & go test.

Discussion

The present study was conducted to examine correlations among motor function tested with FMA, the tone of ankle plantarflexor tested with MAS, muscle strength of ankle dorsiflexor tested with a hand-held dynamometer, and balance tested with BBS and TUG, gait velocity and to determine the strength that could explain the variation of gait velocity levels in chronic survivors. As a result, gait velocity had positive correlations higher than a moderate level with FMA, muscle strength, and BBS while it had a negative correlation higher than a moderate level with muscle tone. Also, there was a strong negative correlation with TUG. In addition, it turned out that FMA showing a positive correlation, and TUG showing a negative correlation had the greatest impacts on the dependent variable, gait velocity.

Clinical assessment tools should be able to assess patients' conditions accurately and become the baseline data in planning therapeutic interventions to predict their prognosis accurately. Thus, in a rehabilitation protocol, assessment is the task that must be performed first [24]. Clinicians should select easy and efficient clinical tools in assessing patients and be able to explain the correlations with other variables through the results of the selected clinical tools as well [24]. The utilization of these clinical assessment tools helps manage patients by providing information about functional limitations and sensorimotor recovery [25]. Thus, like the preceding studies, studies of the correlations among clinical tools aim to resolve the difficulty in conducting all assessments, taking much time and cost in the actual clinical setting [26]. These studies allow the planning of the proper rehabilitation protocol because of the acquisition of the basic information through the description and predictive analysis of other variables not measured using the results of a small number of clinical tools in the clinical setting [26]. The tools measuring gait are important clinical tools for the goal of stroke survivors' rehabilitation, and gait velocity, the most basic measurement in gait assessment is measured in any stroke survivors who can walk, and it was reported that this gait velocity could be an important criterion for the easy differentiation of the level of independent daily life in the community [7]. Also, for stroke survivors, along with gait velocity, the assessments of the recovery of motor function after the initial event of a stroke, muscle tone, muscle strength, and balance are very important elements. However, there are many limitations in executing all assessments in the early phase of the stroke, and it may be said to be inappropriate to measure motor function and muscle strength immediately after a stroke has occurred [27]. As a typical reason in the process of assessing stroke survivors, the synkinesis phenomenon might often occur, so it was reported that it is very restrictive to get accurate information [27]. Also, it may be hard to assess gait abilities, including gait velocity in patients with insecure gait since patients may encounter a very dangerous situation. Thus, it is necessary to understand the level of individuals' functional conditions by using the minimum clinical tools and to use them for setting the goals of assessments and interventions [26].

In the results of this study, gait velocity had correlations higher than a moderate level with FMA, muscle strength, BBS, and muscle tone, and there was a strong correlation with TUG. The FMA is used as an important clinical tool to assess motor function, considering the synkinesis based on stroke survivors' recovery stage [27], and the higher the FMA score, the less the synkinesis phenomenon becomes in gait, which may have positive impacts on gait velocity and balance. A preceding study also reported that the recovery of the coordination ability of the lower limbs and motor function has correlations higher than a moderate level with gait velocity and dynamic balance [28]. Therefore, gait velocity can be utilized as measuring data usable for explaining the variation of the gait velocity levels as well as having moderate correlations in the FMA and dynamic balance as in the results of this study. In addition, in the FMA for scoring the coordination ability of the lower limbs for the recovery of motor function, stroke survivors can get a high score when their ankle and knee joint on the paretic side move as they want to [18]. In other words, to get a high score, it is necessary for the test of the coordination of the lower limbs to decrease the muscle tone of the ankles and support with sufficient muscle strength. To sum up the results in this study, there were negative correlations higher than a moderate level in gait velocity, the FMA score, and muscle tone, while there was a positive correlation higher than a moderate level in muscle strength. Thus, with the decrease of muscle tone and the increase of muscle strength, the result of the FMA will increase, and the increase of the FMA would lead to the decrease of the synkinesis phenomenon with the recovery of motor function and have positive impacts on dynamic balance (TUG) and gait velocity.

However, since this study took the participants who could walk as a criterion for selection, all of them could walk and tended to have a high balance score. Lee et al [26] measured clinical tools for balance, including BBS and TUG and investigated the correlations of the results with 20 chronic stroke survivors. As a result, BBS had a negative correlation higher than a moderate level with TUG. As for this relationship, the more the balance ability, the more the gait velocity became. As a result, the time for clinical tools like TUG decreased, and the daily life ability like modified Barthel index improved [26]. In addition, Steffen et al [29] investigated the correlation between BBS and TUG with 96 elderly persons, and as a result, there were very strong negative correlations among the measuring tools. Podsiadlo and Richardson [30] reported that there was a very strong negative correlation between BBS and TUG with 60 elderly persons. This result is consistent with the result of this study in that there was a moderate negative correlation. However, in the comparison among stroke survivors, there were negative correlations higher than a moderate level like this study, but there were strong negative correlations in a study with the elderly. Thus, the reason why there were no strong negative correlations in this study might be the difference in the results of correlations due to the difference between the groups of participants. Kobayashi et al [14] reported that in the comparisons of the BBS score with gait velocity, step, and stride length measured with a motion analysis device with stroke survivors, there were positive correlations higher than a moderate level in all of them. In this study too, in a comparison between BBS and gait velocity, there was a significant correlation. In this study, the higher the BBS score, the more improved the gait ability might become [14]. Also, Lewek et al [15] investigated BBS and the asymmetry between the non-paretic side and the paretic side in walking with stroke survivors. As a result, in gait velocity, the asymmetry between the paretic side and the non-paretic side had a negative correlation in which the higher the balance score of BBS, the less the asymmetric ratio became. In other words, it was reported that the increase of balance ability reduces the asymmetric ratio on both sides, which could further increase gait velocity [15]. From the results of the preceding studies, the lower asymmetric ratio on the paretic side of the subjects with high BBS scores could have a positive impact on gait velocity, and clinical tools like TUG having gait elements too had strong correlations in comparison with gait velocity.

However, in BBS, for the participants with less limit in balance, there may be a learning effect and ceiling effect according to the repeated measurement. Also, for patients with very poor balance ability, there may be a floor effect [31]. Orr et al [32] reported as a result of systematic analysis of clinical tools for the balance of the elderly that BBS is suitable for examining the enhancement of balance ability for stroke survivors with a score lower than 35 points; however, it would be difficult to detect changes in the participants with a score higher than that. In this study, the BBS score was 47.7 points. This shows that in explaining the variation of gait velocity accurately, the actual stroke survivors' balance ability may not be reflected well. In addition, TUG used to assess dynamic balance is a clinical tool measuring the time to start to walk after standing up in a sitting position [30]. It is problematic for patients with poor muscle strength of the lower limbs to do the motion of the posture of sitting and standing up. The measuring time therefore relatively increases. Kligyt et al [33] too reported in a study on the correlation between the muscle strength of the lower limbs and dynamic balance (TUG) that there is a negative correlation higher than a moderate level between muscle strength and dynamic balance. In other words, the stronger the muscles related to the standing motion, the less the time of measuring dynamic balance TUG may become. Thus, gait velocity has a strong correlation with TUG, but moderate correlation with muscle strength,

Van Peppen et al [34] reported that a clinical tool that understands patients' conditions well is an essential component in increasing therapeutic effects and that it is very important to treat and control based on evidence. Currently, many clinical tools testing reliability and validity are presented [35]. Analysis of correlations using many clinical assessment tools that can make measurements simply according to the development of equipment and the measuring equipment developed together is currently in progress. However, a lot of assessment tools are not available use by therapists in the clinical settings. Thus, the results of this study can be used as baseline data in predicting the relationships with other variables. In particular, in the clinical settings, when therapists use TUG to test the dynamic balance and mobility of chronic stroke survivors, this test may also be used to predict the gait velocity.

However, this study has a few limitations. This study included patients who could walk after chronic stroke, which means they have a high balance ability. In addition, the number of participants is small, so the results of the study could not be generalized. It would therefore be necessary to conduct a more qualitative study addressing the limitations of this study in the future.

Conclusion

This is a study conducted with 30 chronic stroke survivors hospitalized in a community setting in South Korea. Our results suggest that gait velocity had correlations with muscle strength, MAS, FMA, BBS, and TUG. The tests and measurements affecting the variation of gait velocity the greatest were TUG, followed by FMA, BBS, muscle strength, and MAS. It would be possible to present the test and measurement tools to determine the variation of chronic stroke survivors' gait velocity and the tools that could predict gait velocity through a study in the future. Especially, When TUG is used to test the dynamic balance and mobility of chronic stroke survivors, this test may be used to predict the gait velocity.

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Conflict of interest

The authors declare that they have no competing interests.

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