Arch AHS

ORIGINAL ARTICLE

Archives of Allied Health Sciences 2025; 37(3): 130-137.

Tactile sensation is needed for challenging walking ability among ambulatory individuals with stroke

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KEYWORDS
Cerebrovascular accident; Gait, Neurology; Proprioception; Rehabilitation.

ABSTRACT
The improvement of walking ability is a key goal of stroke rehabilitation. The exploration of the contribution of sensorimotor functions to walking ability specifically among ambulatory individuals with stroke may provide data to enhance patient-centered care planning for this population. This study investigated the relationship between the lower extremity (LE) sensorimotor functions and walking ability as measured using the 10-meter walk test (10MWT) among 75 ambulatory individuals with stroke. Participants with stroke who could walk independently with or without a walking device were assessed for their LE sensorimotor functions, and 10MWT while walking at their preferred and fastest speeds. The correlations were analyzed using the Spearman's rank correlation coefficient (r_s). The findings indicated that walking ability of the participants correlated predominantly with LE motor scores (r_s = 0.628–0.660; *p*-value < 0.01), followed by LE proprioception scores (r_s = 0.449–0.473, *p*-value < 0.01), while the LE tactile scores significantly correlated only with the fastest walking speed, and the differences between preferred and fastest speed) (r_s = 0.254–0.279, *p*-value < 0.01). The fastest walking speed is important for community participation, and the ability to voluntarily increase walking speed could indicate the remaining capacity for a community challenge as well as indicate and quantify how well the individuals could modify their walking pattern to varying demands during daily life. The present findings suggest contribution of sensorimotor scores on walking ability of the participants, whereby the tactile sensation is needed for challenging ability. Therefore, apart from motor functions and proprioception, tactile sensation is also required to thoroughly promote walking ability of ambulatory individuals with stroke.

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Received: 8 April 2025/ Revised: 7 May 2025/ Accepted: 13 May 2025

Introduction

Gait restoration is accounted as a key goal in stroke rehabilitation[1]. However, current rehabilitation therapy likely emphasizes on motor functions, while sensory deterioration is frequently overlooked[2,3]. Previous studies reported that sensory impairments can be commonly found in up to 64% of all individuals with stroke, especially the tactile and proprioception senses of the lower extremity (LE), and are closely related to their functional recovery and mobility[2-4]. The LE somatosensory impairment also attributes significant impacts on independence in daily activities[5], as well as prolongs hospital stays, and decreases the possibility of discharge after stroke[4]. As a key goal of rehabilitation treatments, the exploration on the contribution of sensorimotor functions to walking ability specifically among ambulatory individuals with stroke may provide data to enhance patient-centered care planning for this population.

Previous studies reported that the 10-meter walk test (10MWT) is a vital outcome that is widely used to indicate overall quality of gait, independence in daily living, and community participation[6,7]. However, existing evidence likely involves the data of preferred walking speed[8,9]. In fact, obtaining sufficient information on adequate walking ability requires measurements of both preferred and maximum walking speed, as the latter may be important for community involvement, such as crossing a street, walking with others, and catching a bus. In addition, the ability to voluntarily increase walking speed could reflect the remaining capacity for a community challenge as well as indicate and quantify how well the individuals could modify their walking pattern to varying demands during daily life[10]. Therefore, this study explored the correlation between LE sensorimotor functions and outcomes of the 10MWT (preferred, fastest, and the differences between preferred and fastest speed) in ambulatory individuals with stroke. The researchers hypothesized that both proprioception and tactile sensations significantly correlated to walking ability, especially the challenging ability, i.e., fastest walking speed and their ability to modify their walking pattern. The findings would thoroughly suggest clinical contribution of LE somatosensory functions on walking ability of ambulatory individuals with stroke.

Materials and Methods

Study design and participants

This cross-sectional study was conducted among ambulatory individuals with the first stroke episode from hospitals and rural communities of the northeast areas of a developing country. The eligible participants required the ability of independent walking with or without a walking device for at least 10m, aged between 30 to 75 years old, had stable medical conditions, and were able to understand and follow the instructions of this study[11,12]. The individuals with a condition that might affect participation or the outcomes of the study were excluded from the study, such as aphasia, neurogenic or musculoskeletal pain with a score of at least 5 out of 10 on a visual analog scale, severe spasticity (modified Ashworth scale score of > 2)[13], joint limitation and/or deformity affecting mobility, and LE discrepancy (>1.4 cm)[14].

The sample size calculation for a correlation coefficient (r) using data from 14 pilot cases indicated that the study required at least 75 participants. The study protocol was approved by the Khon Kaen University Ethics Committees for Human Research (HE671050). All eligible participants signed a written informed consent form prior to participation in the study.

Research protocol

The eligible participants were interviewed and assessed for their demographics (i.e., age, sex, body mass index), stroke characteristics (i.e., post-stroke onset, type of stroke, and hemiplegic side), and walking ability (i.e., the ability of walking with or without a walking device). Subsequently, participants were assessed for the outcomes of the study, including LE somatosensory

functions using the sensory section of the Fugl-Meyer assessment (FMA), and the motor functions using the Motricity Index (MI). Then, the participants were assessed for their walking ability using the 10MWT. Details of the assessments are described below.

Fugl-Meyer Assessment

The sensory section of the FMA is one of the most widely used as a standard reliable scale to quantify somatosensory functions of individuals with stroke (Kappa = 0.3–0.55 for tactile and 0.71–0.99 for proprioception)[15]. The outcomes were assessed with the eye-closed and compared with the non-affected side. The LE tactile sensation was assessed in the areas of thigh, and sole of the affected foot. The outcomes of each area were scored as 0 for absent, 1 for impaired, and 2 for intact, and the total score ranging from 0 to 4. The proprioception was tested in the joints of the LE, including the hip, knee, ankle, and great toe. The score of each joint was given as 0 for absent, 1 for impaired, and 2 for intact. Hence, the total LE proprioception score ranged from 0 to 8, and the maximum FMA sensory score of LE is 12[16,17].

Motricity Index

The MI is a feasible, brief, and reliable (intraclass correlation coefficient [ICC] = 0.93) measure of the general motor strength among individuals with stroke, with the outcomes predicting post-stroke mobility. Participants were assessed in a sitting position for the three movements for the LE, including the hip flexion, knee extension, and ankle dorsiflexion. The scores were assigned as 0 for no movement, 9 for palpable contraction in muscle but no movement, 14 for visible movement but not full range against gravity, 19 for full range of movement against gravity but not against resistance, 25 for full movement against gravity but weaker than the other side, and 33 for normal strength. The total LE-MI score is 99[18,19].

10-Meter Walk Test

The 10MWT is a standard and excellent reliability measure (ICC = 0.99)[7,9] with the outcomes reflecting overall walking ability, the ability to perform daily activities, and community participation[6,7]. Participants walked at a preferred and fastest speed, with or without a walking device according to their daily walking, along a 10m walkway with the time recording during the middle 4m of the walkway, and the average value of the two trials was converted to their walking speed (in m/s)[7,21].

The aforementioned tests were executed by two excellent rater reliability examiners (ICC = 0.96–0.98). During the tests, participants wore proper-sized sandal sport shoes that were prepared by the researchers, and were given a practice session in order for them to familiarize with the shoes. An examiner walked alongside or was beside the participant without interruption to ensure their safety and accuracy of the outcomes. Participants were able to rest between the trials and the tests as required.

Statistical analysis

The Kolmogorov-Smirnov test was used to assess the normality of the data distribution. As the data were non-normally distributed, the descriptive statistics (number [percent], and median with interquartile range [Q1:Q3]) were applied to explain demographics and stroke characteristics of the participants, as well as the findings of the study. Then the correlations between the sensorimotor outcomes and the 10MWT data were analyzed using the Spearman's rank correlation coefficient (r_s). The correlation strength was designated as weak (< 0.3), moderate (0.3-0.6), strong (> 0.6)[22]. A level of statistical significance was set at *p*-value < 0.05.

Results

Seventy-five ambulatory individuals with stroke (average age of approximately 59 years and normal body mass index) completed the study (Table 1). More than half of the participants were male with equal number of those with right and left hemiplegia. Most participants had ischemic stroke and were at a chronic stage (72%). About one-fourth of the participants walked with a walking device (28%), primarily using a tripod cane.

Table 1 Demographics and stroke characteristics of the participants, and outcomes of the study

Variable	n = 75
Sex; male[a]	43 (57.3)
Types of stroke; ischemic[a]	65 (86.7)
Hemiplegia side; left[a]	38 (50.7)
Use of walking aid; yes[a]	21 (28.0)
Age (years)[b]	59.0 (51.0:68.0)
Body mass index (kg/m^2)[b]	23.0 (21.3:25.3)
Post-stroke onset (months)[b]	12.0 (6.0:26.5)
Fugl-Meyer Assessment of the lower extremity[b]	
Total (12 score)	11.0 (9.0:12.0)
Tactile (4 scores)	4.0 (2.5:4.0)
Proprioception (8 scores)	7.0 (6.0:8.0)
Motricity index of the lower extremity (99 scores)[b]	72.0 (53.0:85.0)
10-Meter walk test[b] (m/s)	
Preferred speed	0.63 (0.39:0.81)
Fastest speed	0.85 (0.49:1.13)
Difference between preferred and fastest speed	0.18 (0.08:0.3)

Note: [a]The data are presented using the number of participants (%).
[b]The data are presented using median (interquartile range, Q1:Q3).

Most participants had intact tactile sensation (n = 52), but impaired proprioception with the median FMA scores of 11.0 (Table 1). Their walking speed data, including preferred, fastest, and the difference between preferred and fastest walking speed are presented in table 1.

The findings further indicate a significant correlation between the LE sensorimotor scores and data of the 10MWT, especially the motor scores (r_s = 0.628–0.660, *p*-value < 0.01; Table 2). In addition, the proprioception scores showed moderate correlation with the 10MWT data (r_s = 0.449–0.473, *p*-value < 0.01), while the tactile scores had weak but significant correlation with the fastest, and the difference between preferred and fastest walking speed of the participants (r_s = 0.254–0.279, *p*-value < 0.05, Table 2).

Table 2 Correlation between the data of the 10-meter walk test and lower extremity sensorimotor scores

10-Meter walk test	Motor	Proprioception	Tactile
Comfortable speed	0.628**	0.449**	0.226
Fastest speed	0.660**	0.473**	0.254*
Difference between preferred and fastest speed	0.649**	0.461**	0.279*

Note: Motor scores were derived from the Motricity index. Sensory scores were gathered using the Fugl Meyer (sensory) assessment. The data were analyzed using the Spearman's rank correlation coefficients. *, **indicate significant correlation with a *p*-value of < 0.05 and < 0.01, respectively.

Discussion

The efficient and functional walking is a prerequisite for independent living. This study explored the correlation between walking ability as measured using the 10MWT and the LE sensorimotor scores. The findings indicated that the 10MWT data correlated predominantly with the motor scores, followed by the proprioception scores, while the tactile scores had weak correlation with the fastest, and the difference between the preferred and fastest speed (*p*-value < 0.05, Table 2).

Several studies have reported the vital role of motor ability on walking activity of many individuals[23,24]. After stroke, a large proportion of the patients reduced their motor strength. In this study, the motor scores were measured using the MI for the three LE muscles, including hip flexor, knee extensor, and ankle dorsiflexor muscles, that are the key components for both stance and swing phases of walking[18]. The present findings support the close relation between motor strength and gait performance of the participants (Table 2). Thus, the improvement in motor strength is crucially needed in stroke rehabilitation that subsequently improves walking ability and facilitates participation in everyday activities of individuals with stroke[24,25].

However, the ability to perceive information is needed for the adequate utilization and control of motor functions. Thus, the findings additionally indicated the significant correlation between walking ability and proprioception scores (r_s = 0.473, Table 2). Wirz et al[23] reported that an increase in motor scores is the factor associating with functional improvement. Proprioceptive feedback plays vital roles for an extra-activation of LE muscles[26]. The proprioception allows the body to sense its position and movement in space; thus it is crucial for enabling smooth, coordinated, and automatic walking and balance adjustments without consciously thought[27,28]. Lee et al[29] reported that intact proprioception from the affected ankle enabled individuals to position and load the foot during movements. Proprioceptive feedback is also needed for weight-bearing information, underscoring their roles in movement stability while walking[29,30].

Interestingly, a weak but significant correlation also suggested the contribution of tactile sensation on challenging walking ability, fastest speed, and the differences between preferred and fastest speed (r_s = 0.254-0.279, Table 2). Although it has low attention in stroke rehabilitation, tactile sensation is important for individuals to perceive their feet placement and weight-bearing during locomotion. Cutaneous afferent information from the foot contributes to the adequate upright mobility and postural sway. Thus, the decreased tactile sensation is frequently associated with stability and mobility of the individuals[31]. Previously, post-stroke tactile deficits have also been reported to relate to the reduction in balance ability and increased postural sway. Furthermore, tactile sensation in combination with proprioception provide accurate

intrinsic feedback essential for movement adjustments, weight-bearing information and stability, underscoring their roles for demanding tasks[29,30]. However, the small proportion of participants with impaired tactile sensation (31%) with high tactile scores may reflect natural characteristics of those who could walk independently. These particular characteristics of the participants may result in a low correlation of the tactile scores, and the significant correlation with the tactile scores was found only for challenged walking ability (Table 2).

Without clear evidence on the sensorimotor contributions on walking ability, the present findings confirm the need of not only motor functions but also proprioception and tactile sensations on walking ability of ambulatory individuals with stroke. However, the findings contain some limitations. This study assessed sensorimotor functions of only the lower extremity as they are directly linked to walking ability. However, walking ability also required the involvement of the trunk and upper extremities. Therefore, the findings cannot clearly reflect the roles and contributions of sensorimotor functions of the trunk and upper extremities during walking. Second, a majority of participants walked without a walking device (72%) and were in the chronic stage of stroke (72%) with mild somatosensory impairments (total FMA scores = 11.0 [Q1:Q3 = 9.0:12.0]). Therefore, the findings may not thoroughly reflect all ambulatory individuals in the various stages of stroke, types of walking device used, and severity of stroke. A further study may need to additionally explore the relationship between overall sensorimotor scores on walking ability of ambulatory individuals with stroke who are at various stages of stroke and walking ability.

Conclusion

The improvement of walking ability is one of the optimal goals of stroke rehabilitation. This study explored the correlation between walking ability as measured using the 10MWT and the LE sensorimotor scores. The finding indicated that walking ability correlated predominantly with motor strength, followed by proprioception, and tactile sensation, respectively. The findings suggest the roles and importance of these sensorimotor functions for rehabilitation practice among ambulatory individuals with stroke.

Take home messages

Motor functions, proprioceptive sensation, and tactile sensation are needed to promote walking ability of ambulatory individuals with stroke.

Conflicts of interest

The authors declare no conflict of interest.

Acknowledgements

The researchers sincerely thank for funding support and contribution from ‘Okard: Capacity Strengthening on Rehabilitation Project’ (AID-486-A-17-0004), Laos, Fundamental Fund 2569, and the Improvement of Physical Performance and Quality of Life (IPQ) research group, Khon Kaen University, Thailand.

Funding support

This study was supported through ‘Okard: Capacity Strengthening on Rehabilitation Project’, as part of the cooperative agreement funded by the USAID Agency for International Development (AID-486-A-17-0004), Fundamental Fund 2569, Khon Kaen University, Thailand.

Author contributions

Phouthasone Thavone: Conceptualization, Methodology, Data collections, Formal analysis, Writing – original draft, Final proof of the manuscript.

Gresilia Tambing: Methodology, Data collections, Final proof of the manuscript.

Thaksin Chanata: Methodology, Data collections, Final proof of the manuscript.

Wilairat Namwong: Conceptualization, Methodology, Formal analysis, Writing – Review & Editing, Final proof of the manuscript.

Sugalya Amatachaya: Conceptualization, Formal analysis, Resources, Funding acquisition, Project management, Writing – Review & Editing, Final proof of the manuscript.

Data availability

Data available on request due to privacy/ ethical restrictions

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