The incidence and characteristics of falls
in community-dwelling ambulatory stroke survivors

（地域在住の歩行可能脳卒中患者における
転倒発生とその特徴）

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Introduction

Falling is one of the most common injuries that occurs among individuals with stroke.[1] The fall can cause injuries and fractures;[2] especially, the risk of hip fractures in individuals with stroke is 2–4 times higher than that of the general population.[3] Furthermore, the likelihood of acquiring independent walking after a hip fracture is low in individuals with stroke compared with that in the general population.[4] Falling can also cause the fear of falling, depression, and social deprivation, and these conditions may further reduce stroke individuals' daily activity and lead to deconditioning.[2]

Falls frequently occur in individuals with stroke in the hospital and in the community.[2] Regarding falls in stroke survivors during the subsequent period after discharge from hospitals, there have been a relatively sufficient number of prospective studies.[5-11] These studies have revealed that individuals with stroke fell very often in the early period after the discharge; the percentage of individuals who experienced at least one fall 6 months after discharge was up to 73%.[5, 6, 8-11] However, there is still a lack of knowledge about falls in long-standing stroke survivors living in the community. There are only a few prospective studies on this issue.[12-15] In these reports, the incidence rates of falls were reported in only two studies,[12, 13] and one of these studies used a recall method for collecting falls data at every 6

months,[13] which is relatively unreliable.[16] Furthermore, most reports lacked information about the circumstances of falls[13-15] or had very limited samples (≤25 falls).[12] Thus, the incidence rates of falls and detailed circumstances have been not fully understood among individuals with long-standing stroke living in the community. Additionally, although the characteristics of fallers have been examined,[12-15] the physical characteristics in terms of gait ability, balance, and strength in those who are prone to fall have not been sufficiently explored.

Considering that stroke survivors may live for a considerable time in the community, the knowledge of falls and physical characteristics of those who are prone to fall are essential to develop effective preventative strategies against falling. The aims of the study were 1) to elucidate the incidences and circumstances of falls and fall-related injuries, and 2) to explore the characteristics of fallers in community-dwelling ambulatory survivors of stroke.

Methods

Participants

One hundred sixty-four individuals who received rehabilitation at an adult daycare facility between October 1, 2014 and March 31, 2015 and met the following criteria participated in the study. Inclusion criteria were the abilities to walk with or without a cane

and/or an orthosis, to understand the study protocol, and to consent to participate in the study.

Exclusion criteria were as follows: individuals with leg amputation, severe musculoskeletal disorders, and severe psychiatric disorders, In addition, the participants who were absent from the daycare more than 1 month or diagnosed as having recurrent stroke during the follow-up were excluded from the study.

All participants underwent a 3-hour rehabilitation program 1–3 days weekly under Japanese long-term care insurance; the program consisted of a 20-minute supervised rehabilitation program led by a physical therapist or an occupational therapist, and a circuit-based rehabilitation program that included walking, stretching, and muscle strengthening exercises.

This study was approved by the Ethics Committee of the Tokyo Bay Rehabilitation Hospital (number 98-5), and written informed consent was obtained from all the participants before participating the study.

Falls

The baseline evaluation was conducted during the registration period between October 1, 2014 and March 31, 2015. For each participant, falls were monitored for 1 year following

the baseline evaluation. The presence or absence of a fall was confirmed by a fall notebook.

In cases of falls, the time, place, and situation of falling were recorded in the notebook by the

participants themselves and/or by their family members. Participants brought the notebook

every time when they visited the daycare. When falling was confirmed, a staff collected more

detailed information about the fall including the time, place, cause of falling, activity and the

purpose of the activity at the time of the fall, presence or absence of injury, site and type of

injury, and how the participant got up from the floor after falling. The definition of a fall was

"unintentionally coming to rest on the ground, floor, or other lower level; excludes coming to

rest against furniture, a wall, or another structure."[17]

Baseline assessments

For all participants, basic information (age, sex, types of stroke, the side of paresis,

duration from stroke onset, use of a cane and/or an orthosis, and frequency of daycare use)

was collected. Furthermore, the items of motor function in the Stroke Impairment Assessment

Set[18] were assessed to evaluate motor impairments. The 10-m walk test (10MWT), Timed Up

and Go Test (TUG),[19] and five-times-sit-to-stand test (FTSST)[20] were performed to evaluate

gait, balance, and muscle strength/power.

The 10MWT is a measure for one's capability of walking. The participants walked a 16-m flat walkway at both a comfortable speed and maximum speed. The time required to complete the middle 10-m of the 16-m walkway was measured. The mean value of 2 trials for each speed condition was used for analysis. Reliability of the 10MWT has been confirmed in stroke individuals.[21, 22]

The TUG is a measure of one's mobility and balance.[19] The time required to complete a sequence of motions, where one rises from an armchair, walks 3 m, turns, walks back, and sits down again, was measured. The mean time of two trials was used for the analyses. Reliability of the TUG in stroke individuals has been shown.[22]

The FTSST is used to evaluate one's leg muscle strength/power and balance. Participants were asked to stand up and sit down five times as quickly as possible, and the time to complete the test was measured. Reliability and validity of the FTSST in stroke individuals has been demonstrated.[23]

During the 10MWT and TUG, participants were allowed to use a cane and/or an orthosis that they were usually using. During the FTSST, only an orthosis was allowed to be used.

Statistical Analyses

The incidence rates of falls and fall-related injuries were calculated. The sites and types of fall-related injuries and the circumstances of falls were analyzed descriptively.

Participants who fell at least once and fell twice or more during the follow-up were defined as fallers and multiple fallers, respectively, and their characteristics were compared with those of participants without falls (non-fallers). For categorical variables, group comparisons were performed by using the Fisher's exact test. For continuous variables, the Mann-Whitney's U test or unpaired t-test was used depending on the type of variable. Additionally, a receiver operating characteristic (ROC) curve was constructed for variables showing a significant difference between fallers and non-fallers. The accuracy of the variable to distinguish between fallers and non-fallers was assessed by the area under the curve (AUC), and the cut-off value was determined using the Youden index. The sensitivity, specificity, positive predictive value, and negative predictive value were also calculated. All statistical analyses were performed with STATA/SE 13.1 (StataCorp., Texas, USA), and the statistically significant level was 5%.

Results

Participants

Among the 164 participants enrolled, 20 were lost to follow-up because they stopped visiting the daycare facility or died during the follow-up. One hundred forty-four individuals with a mean age of 68 years (range 44-86, standard deviation 10.4) completed the study and were enrolled for the analyses.   The mean duration from the stroke onset was 5.21 years (range 0.5-17.0, standard deviation 3.15). Characteristics of the participants are shown in Table 1.

Incidences of falls and fall-related injury

The total number of falls was 126, and the incidence rate of falls was 0.88 per person-year (0–14 per individual). The numbers of fallers and multiple fallers were 62 (43.1%) and 27 (18.8%), respectively. There were 36 injuries including 4 fractures; the rates of injuries and fractures per fall were 28.6% and 3.2%, respectively. The incidence rates of fall-related injury and fall-related fracture were 25.0 and 2.8 per 100 person-years, respectively. All 4 fractures occurred on the paretic side, and the sites were the elbow, radius, rib, and pubic bone. Other injuries were 19 bruises, 6 abrasions, 3 sprains, 3 wounds, and 1 avulsion of a nail.

Table 1. Characteristics of the participants (n=144)

Characteristics		
Age, years		68.0±10.4
Sex, male/female		82/62
Type of stroke, infarction/hemorrhage/subarachnoid hemorrhage		73/68/3
Side of paresis, right/left		78/66
Duration from onset, years		5.21±3.15
Use of a cane, n (%)		83 (57.6)
Use of an orthosis, n (%)		66 (45.8)
Frequency of adult daycare use		2 (1-2)
	Knee-mouth test	3 (2-4)
	Finger-function test	1.5 (1-4)
Motor function of the Stroke Impairment	Hip-flexion test	4 (3-4)
Assessment Set	Knee-extension test	4 (3-4)
	Foot-pat test	3 (1-4)

Values are presented as number (%), mean±standard deviation, or median (interquartile rage).

Season and time of the falls

The number of falls tended to decrease in the summer, whereas that tended to increase in the winter (Figure 1A). The number of falls was most frequently observed during January and February. There were two distinct peaks of fall occurrence in the morning and afternoon. One peak was found between 8 and 10 am and the other peak was between 14 and 16 pm (Figure 1B).

Circumstances of the falls

Table 2 shows the detailed circumstances of falls. Most falls occurred indoors (89 falls, 70.6%), where 28 and 18 falls occurred in the living room and bedroom, respectively. The most direct cause of a fall was losing balance (49 falls, 38.9%), followed by stumbling (25 falls, 19.8%) and slipping (11 falls, 8.7%). One-third of falls occurred during level-ground walking (42 falls, 33.3%). The most common activity at the time of falling was "to go to the toilet," which occurred in 12 falls. After falling, the participants could stand up by themselves in 83 cases of falls (65.9%), whereas they stood up with someone's help in 43 cases (34.1%).
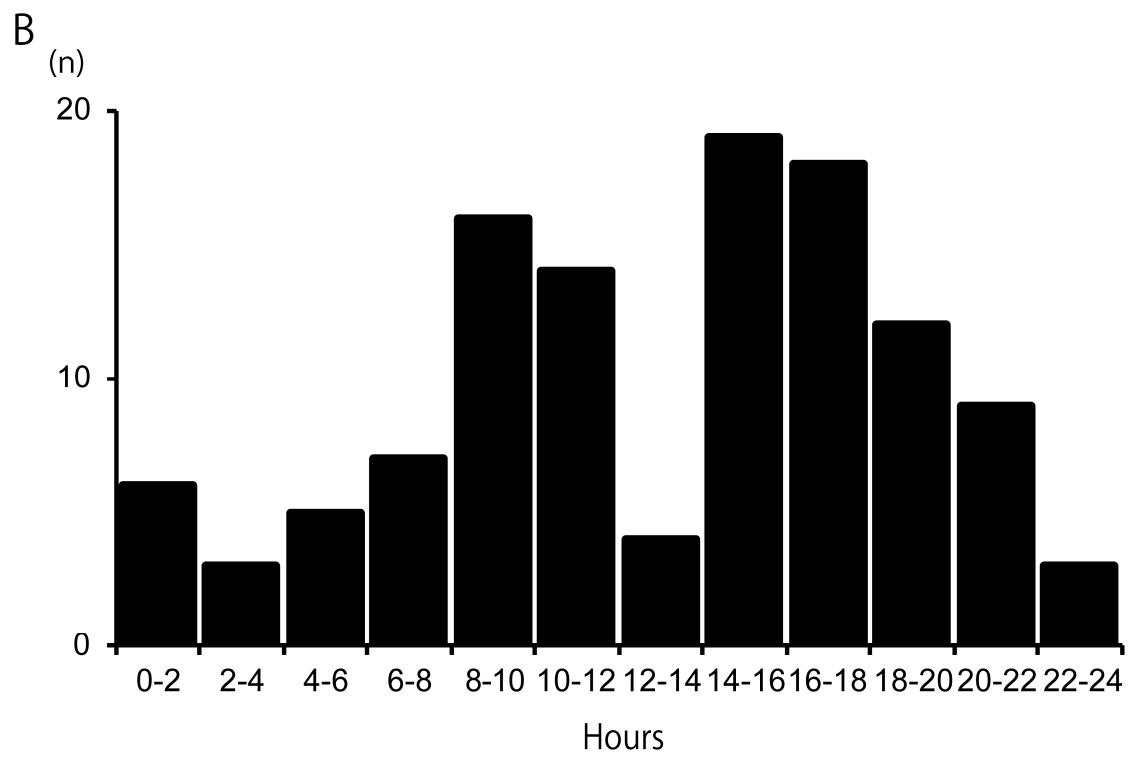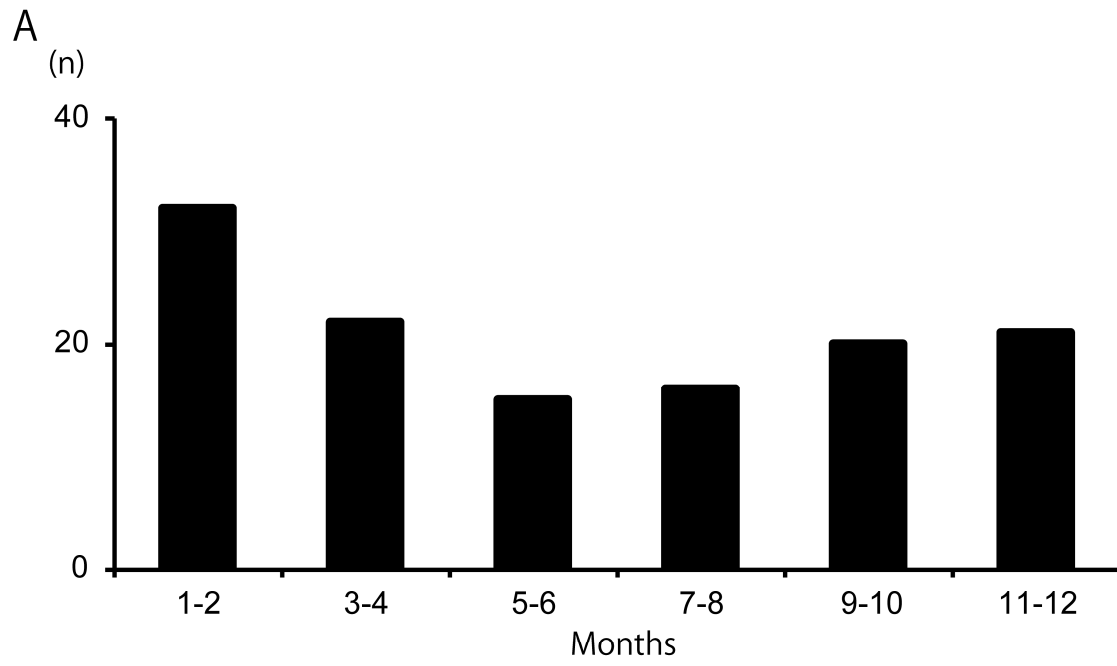
Figure 1 The number of falls every 2 months (A) and 2 hours (B).

Table 2. Circumstances of the falls (n=126)

Location	n (%)
Indoor	89 (70.6)
Living room	28 (22.2)
Bedroom	18 (14.3)
Corridor	10 (7.90
Stairs	7 (5.6)
Entrance	7 (5.6)
Kitchen	5 (4.0)
Bathroom	3 (2.4)
Balcony	3 (2.4)
Changing room	2 (1.6)
Toilet	2 (1.6)
Others	4 (3.2)
Outdoor	37 (29.4)
Sidewalk	9 (7.1)
Stairs	9 (7.1)

Garden	4 (3.2)
Train station	3 (2.4)
Hotels	2 (1.6)
Garage	2 (1.6)
Restaurant	2 (1.6)
Other	6 (5.4)

Direct cause of the fall

Losing balance	49 (38.9)
Stumbling	25 (19.8)
Slipping	11 (8.7)
Fail to sit down on a chair/sofa/bed	8 (6.3)
Failure to grasp handrail/failure to put a cane on the ground (slipping)	5 (4.0)
Giving way of the knee	4 (3.2)
Losing his/her footing on the step or stairs	4 (3.2)
Other	10 (7.9)
Data missing	10 (7.9)

Activity at the time of the fall	
Walking on level ground	45 (35.7)
Upper limb tasks while standing	10 (7.9)
Walking upstairs/a step	10 (7.9)
Standing up	8 (6.3)
Turning around	7 (5.6)
Sitting down	7 (5.6)
Walking down stairs/a step	6 (4.8)
Cleaning (dusting/using a vacuum cleaner)	4 (3.2)
Stepping over something	3 (2.4)
Picking up a thing from the floor	3 (2.4)
Dressing the lower body	3 (2.4)
Transferring	2 (1.6)
Taking on or off a shoe	2 (1.6)
Taking a bath	2 (1.6)
Other	14 (11.1)

Purpose of the activity	
To go to the toilet	12 (9.5)
To prepare a meal or clean the table	7 (5.6)
To hang or take in the laundry	4 (3.2)
To clean the rooms	4 (3.2)
To change clothes	4 (3.2)
To take a bath	3 (2.4)
To go to bed	3 (2.4)
To perform exercise	2 (1.6)
Other purposes including no particular purpose	74 (58.7)
Unknown	13 (10.3)

Table 3. Comparisons of characteristics between non-fallers and fallers and between non-fallers and multiple fallers

Variable	Non-fallers (n=82)	Fallers (n=62)	p-value (vs. non-fallers)	Multiple fallers (n=27)	p-value (vs. non-fallers)
Age	67.1±10.2	69.2±10.5	0.224	71.3±9.4	0.058
Sex, male/female	48/34	34/28	0.735	14/13	0.655
Type of stroke, infarction/hemorrhage/subarachnoid hemorrhage	41/39/2	32/29/1	0.999	13/12/1	0.999
Side of paresis, right/left	46/36	32/30	0.616	13/14	0.510
Duration from onset, years	5.11±2.64	5.33±3.73	0.698	5.97±4.39	0.347
Use of a cane, n (%)	43 (52.4)	40 (64.5)	0.174	18 (66.7)	0.264
Use of an orthosis, n (%)	39 (47.6)	27 (43.6)	0.736	13 (48.1)	0.999
Frequency of adult daycare use	2 (1-2)	2 (2-2)	0.356	2 (1-2)	0.635

	Knee-mouth test	3 (2-4)	3 (2-4)	0.852	3 (2-4)	0.423
	Finger-function test	2 (1-4)	1 (1-4)	0.658	1 (1-4)	0.387
Motor function of the Stroke Impairment Assessment Set	Hip-flexion test	4 (3-4)	4 (3-4)	0.781	4 (3-4)	0.601
	Knee-extension test	4 (3-4)	4 (3-4)	0.774	4 (3-4)	0.923
	Foot-pat test	3 (1-4)	3 (1-4)	0.406	3 (1-4)	0.726
10-m gait, sec	Comfortable speed	17.1±14.3	21.4±16.6	0.102	20.2±13.2	0.332
	Maximal speed	14.3±13.4	18.6±18.7	0.123	16.5±12.6	0.464
Timed Up & Go test, sec		15.7±11.3	19.4±16.4	0.133	17.7±11.3	0.419
Five-times-sit-to-stand test, sec		13.1±4.9	15.4±6.6	0.019	15.9±6.8	0.049

Vales are presented as number (%), mean±standard deviation, or median (interquartile rage).

Characteristics of participants who fell

The comparison of participants' characteristics between non-fallers and fallers and between non-fallers and multiple fallers are shown in Table 3. Among the variables, only the time for the FTSST was significantly different between the groups, and it was longer in fallers and multiple fallers than in non-fallers. The ROC curve of the FTSST for distinguishing fallers from non-fallers is presented in Figure 2. The AUC was calculated as 0.61 (95% confidence interval 0.52-0.71). The cut-off value of the FTSST was determined as 12.4 seconds, where sensitivity, specificity, positive predictive value, and negative predictive value were 0.63, 0.60, 0.54, and 0.68, respectively.
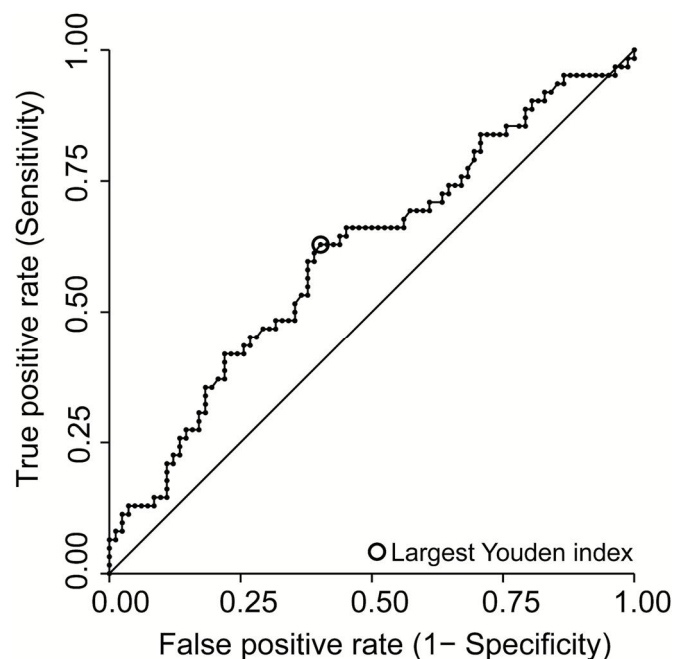

Figure 2 Receiver operating characteristic curve of the five-times-sit-to-stand test

Discussion

The present study elucidated the incidence rates of falls and fall-related injuries, detailed

circumstances of the falls, and physical characteristics of fallers among ambulatory hemiparetic

stroke individuals living in the community. The incidence rates of falls were 0.88; and 3.2% of

falls resulted in fractures. Falls occurs more frequently during activity hours in winter. Falls most

often caused by losing balance during walking indoor, especially on the way to the toilet. After

falling, 34.1% of participants who fell could not stand up by themselves. In the comparisons of

participants' characteristics between groups, the time of the FTSST was significantly longer in

fallers and multiple fallers than in non-fallers.

According to the previous studies on stroke individuals during the early period after the

discharge ($\leq$ 6 months), the incidence rates of falls per person-year ranged between 1.75 and

5.00.[5, 6, 10] With regard to the long-standing stroke in the community, Jorgensen et al.[12] and Lamb

et al.[13] reported fall incidence rates per person-year as 1.82 and 2.83, respectively. Thus, the

incidence rates in the individuals with long-standing stroke tended to be smaller than that in

stoke individuals during the subsequent period after discharge. Herein, the incidence rate of falls

in the study was 0.88, which was even lower than that reported in long-standing stroke in the

community.[12, 13] There are two possible contributing factors for this difference between our study and the studies by Jorgensen et al.[12] and Lamb et al.[13] First, all of our participants were ambulatory, whereas 45.2% of participants in Lamb et al.'s study could not stand by themselves.[13] Second, all participants in our study participated in rehabilitation programs in an adult daycare. This might have reduced the incidence rates of falls. In comparison to the general population, the fall rate in community-dwelling older people is approximately 0.65/person-year,[24] and the fall rate in the older population (reference) in Jorgensen et al.'s study was even lower at 0.51/person-year.[12] Therefore, the risk of falling among stroke survivors shown herein is substantial compared to that in the general population.

The incidence rate of fracture relative to the number of falls in the present study was 3.2%. This percentage was comparable with those reported in individuals with long-standing stroke in the community.[12] The finding in our study that all the fractures occurred on the paretic side may be due to several contributing factors including the tendency of falling toward the paretic side,[6, 25] difficulty of protecting paralyzed limbs, and decreased bone density on the paretic side.[26]

Falls occurred most often during winter, in January and February; this was also consistent

with the finding of a previous study.[27] The difficulty of motion due to increased layer of clothes worn in winter or increased stiffness of the body because of the cold may have contributed the finding. There were two distinct peaks of fall occurrence, one in the morning and another in the afternoon. Thus, falls occurred during daytime when individuals were active; this finding was also consistent with that of a previous study.[12]

Most fall (70%) occurred indoors while walking. This result was consistent with that of previous reports conducted on individuals with stroke during the subsequent period after discharge[5, 6, 27] In contrast, the finding was somewhat different from the findings among individuals with long-standing stroke, where approximately 50% fell outdoors as frequently as the control [12] or most fell in the garden at home.[25] Although it is difficult to determine the logical reasons for this difference, the different environments and lifestyle among countries can have an effect. Especially, Japanese people usually take off their shoes in their home, and there are many steps in a typical Japanese house. These characteristics can contribute to the difference in the incidence and circumstances of falls.

The current study showed important findings that stroke individuals fell most often in their living room or bedroom while walking, and the most frequent purpose of the activity at the

time of the fall was to go to the toilet. Considering the association between poorer bladder management and the risk of falling,[15] clear and safe routes from the living room or bedroom to the toilet, appropriate ambulatory aids, and proper bladder management may contribute to reducing the risk of falling.

Approximately one-third of participants who fell could not stand up by themselves after the fall. It has been reported that 37–70% of stroke individuals who fell during the subsequent period after discharge could not stand up by themselves.[5, 6, 10] Although the rate in the study was relatively lower than that in these previous reports, the importance of the skills to cope with the situation after falling is the same even for the individuals with long-standing stroke and their family members in community.

Among three physical function tests, a significant difference was observed only in the FTSST between the fall and non-fall groups. The result is consistent with the findings in a kinematic study that the lower rate of rise in force and postural sway while rising/sitting down were associated with risk of falling in stroke.[28] The FTSST has been indicated to reflect muscle strength in lower limbs[23] as well as dynamic balance.[29] Considering that no significant difference was observed between non-fallers and fallers (or multiple fallers) in the 10MWT and TUG, it

was suggested that decreased muscle strength/power may be the key factor for distinguishing fallers from non-fallers. This study, for the first time, calculated the cut-off value of the FTSST for distinguishing between non-fallers and fallers, which was 12.4 seconds. It is very interesting that 12 seconds has been reported as the cut-off value for identifying the risk of falls in older individuals in the community,[30] as well as the cut-off for distinguishing between healthy older people and individuals with stroke.[23] Further study is needed to explore the meaning of this value as a cut-off value seen in various conditions.

The study was conducted in individuals undergoing rehabilitation at one facility, and it was conducted solely in individuals with stroke who were able to walk. Therefore, a future study of various levels of stroke survivors recruited from the community is needed to increase the generalizability of the findings.

In conclusion, the incidence rate of falls was high among community-dwelling ambulatory survivors of hemiparetic stroke. The fallers and multiple fallers showed significantly longer FTSST time compared with non-fallers. Appropriate preventive approaches including mastering the skills to cope with the situation after the falling are required especially for the individuals with reduced lower limb muscle strength.

Acknowledgments

Disclosure statement

The authors declare no conflict of interest.

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