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ORIGINAL ARTICLE

Factors contributing to fall rate and second fall in older adults after rehabilitation of fractures: A prospective cohort study

Takaaki Sato[1, 2), Eiki Tsushima[2), and Hirofumi Ogihara[3)

Abstract

Objective: This study aimed to investigate the physical performance and cognitive function related to the second fall in older adults who have suffered previous falls and fractures.

Method: This prospective cohort study included older adults who were admitted to hospital with an orthopedic fall-related injury and who completed 12 months of follow-up investigations. We evaluated the Berg Balance Scale (BBS), Timed Up and Go Test, Four-Square Step Test, walking speed, 30-Second Chair-Stand Test, 6-Minute Walk Test, Falls Efficacy Scale, Functional Independence Measure, and Mini Mental State Examination. Telephone interviews were used to investigate the fall status of the subjects monthly for 12 months. Principal component analysis was used to derive orthogonal factor loading. Logistic regression analysis was used to determine which factors were associated with a second fall.

Results: The first three principal components (PC1, PC2, PC3) accounted for 77.2% of the variance in the data at hospital discharge. The principal components biplot, showed that the BBS an independent comprehensive indicator. The logistic regression analysis results showed the BBS score to be a risk factor for falls (odds ratio=0.81, 95% confidence interval=0.64-0.95).

Conclusion: The BBS score was associated with the risk of second falling in older adults with a history of fractures.

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Key words: fracture; balance; orthopedic; fall.

Introduction

The number of older adults with fragility fractures is increasing and may impact healthy aging. The estimated numbers of older adults with new hip fractures in 2012 were 175,700 in Japan[1)]. Some osteoporotic fractures, such as hip and spinal fractures, are associated with high morbidity and mortality and occur more frequently after 50 years of age[2)]. In addition, the re-fracture rate among older adults with hip fractures increases from 1.6% to 11% in a year[3-5)]. Hip fractures are associated with increased medical costs[3)] and, therefore, contribute to the economic burden. Further, the treatment for second fractures may cost more than that for the first ones[4)]. As time progresses and the population ages, falls in older adults will increase social, psychological, and economic burdens for the falling older adults, their families, and the nation.

Hip fractures are a common occurrence among older adults, resulting in various functional disorders, increasing the risk of new falls[6-8)], and complicating independent living[9)]. Proximal femoral fractures reduce quality of life significantly more than other fractures[10)], and it is believed that older adults never regain their pre-fracture condition[11)]. The World Health Organization declared the period between 2020 and 2030 as the “Decade of Healthy Aging,” and the Fragility Fracture Network has proposed the

[1) Department of Physical Therapy, JA Nagano Koseiren Kakeyu-Misayama Rehabilitation Center Kakeyu Hospital
[2) Hirosaki University Graduate School of Health Sciences
[3) Nagano University of Health and Medicine, Faculty of Health Science

Correspondence: E. Tsushima
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implementation of a systematic treatment approach to treat fragility fractures[7,8]. With regard to the effect of rehabilitation in post-fracture older adults, a meta-analysis that investigated the effect of balance training on older adults post hip fractures reported improvements in gait, lower limb muscle strength, and activities of daily living (ADLs) as a result of the training[12]. Therefore, rehabilitation plays a role in enhancing recovery after a fracture.

To prevent second fragility fractures, it is necessary to understand the characteristics of a second fall. It has been observed that several risk factors such as living in a nursing home, female sex, osteoporosis, reduced mobility, and reduced cognitive function increase the likelihood of a second fracture[6,13]. However, the physical performance and balance characteristics that cause subsequent falls after rehabilitation are unknown, and second fall rates are not clearly elucidated. Older adults who experienced a fracture never regain their pre-fracture condition and live in a state of low physical activity and performance, meaning the factors that affect re-fall may be different. Therefore, we believe that clarifying the risk factors for second falls will make it possible to provide rehabilitation treatment specifically designed to prevent second falls in older adults who experienced fracture.

The purpose of this study was to investigate the physical performance and cognitive function related to the second fall and fall rates in older adults who have suffered previous falls and fractures.

Methods

This was a prospective cohort study. We enrolled subjects who were admitted to the Kakeyu Misayama Rehabilitation Center Kakeyu Hospital between April 2018 and June 2019 with an orthopedic condition resulting from a fall and who completed 12 months of follow-up investigation. The final follow-up investigation was conducted in August 2020, after hospital discharge. If the subjects were admitted to an acute-care hospital and required temporary care before being discharged back home or to a nursing home, they were referred to the hospital to which the principal author was affiliated.

The inclusion criteria were as follows: (1) fracture due to an injury from falling, (2) ≥65 years old, (3) ability to remain standing unassisted, and (4) ability to understand simple instructions. The exclusion criteria were as follows: (1) inability to understand simple instructions and (2) stroke or other neurological disorders (e.g., Parkinson's disease).

A physiotherapist provided oral and written explanations about the study to the participants and obtained their written consent to participate in the study. All of measurements were assessed by a physical therapist at discharge. The subjects underwent a 60-min physiotherapy session and 60-min occupational therapy session daily for 7 days. Physiotherapy sessions included range of motion exercises, strength training, balance training, and locomotion training. Occupational therapy sessions involved range of motion exercises, strength training, and basic and instrumental ADLs.

Telephone interviews were used to investigate the fall status of the subjects monthly for 12 months.

This study was approved by the Kakeyu Misayama Rehabilitation Center Kakeyu Hospital and Hirosaki University Ethics Committee (Approval No.: 2017042 and 2020-017)

Outcome Measures

Characteristics

Demographic information was obtained from the subjects' medical records to their age, sex, height, body weight, body mass index, fracture sites, use of sleeping pills, number of drugs, and days of admission.

***Berg Balance Scale* (*BBS*)**[14]

The BBS consists of 14 items:, sitting unsupported, standing unsupported, standing with eyes closed, standing with feet together, standing on one foot, turning to look behind, retrieving an object from the floor, tandem standing, reaching forward with an outstretched arm, going from sitting to standing and from standing to sitting, transfer, turning 360°, and stepping on a stool; each of which was measured. Each item was assigned a score between 0 and 4 for a total of 0–56 points. Each measurement was taken once.

***Timed Up and Go Test* (*TUG*)**[15]

The TUG was performed with the subject sitting on a 40 cm-high chair without an armrest; the patient was instructed to stand when the signal was given, walk a distance of 3 m at a comfortable pace, turn, walk back, and sit down on the chair again. This test measures the time the subject takes to complete the entire process. The average of two measurements was reported. A stopwatch was used to measure the time.

***Four Square Step Test* (*FSST*)**[16]

In the FSST, four canes were arranged in the shape of a cross, and the time taken for the subject to step clockwise and counterclockwise for two rounds around the four quadrants, starting from the upper left quadrant, was measured. The subject was required to step in each quadrant with both feet. A stopwatch was used to measure the time. The measurement of time was stopped if a subject touched the cane, and the subject was asked to repeat the activity. The average of two measurements was reported.

Walking speed[17]

In the walking speed test, the subjects were asked to walk as fast as possible in a straight line along a 10 m stretch, allowing for a run-up distance of ~3 m. The results of the 10 m walking test were calculated in terms of m/s. A stopwatch was used to measure the time, and the average of two measurements was determined.

***30-Seconds Chair-Stand Test* (*CS-30*)**[18]

The CS-30 measures the number of times a subject can stand up over the course of 30 s from a 43.2 cm-height chair without an armrest. The subjects were asked to cross their arms in front of their chest while standing up off the chair as quickly as possible. The average of two measurements was reported.

***Six-Minute Walk Test* (*6MWT*)**[19]

In the 6MWT, the subjects were asked to walk back and forth for 30 m in a straight line, as quickly as possible over the course of 6 min. A cone was placed at the turning point. A single measurement was taken, and the time was measured using a stopwatch.

***Falls Efficacy Scale* (*FES*)**

The FES consists of 10 items about the subjects' confidence in carrying out a movement. Each item is scored 1 to 4 points, and the total score is 10 to 40 points. The measurement was performed once.

***Functional Independence Measure* (*FIM*)**[20]

In the FIM, 18 sub-items are assigned scores from 1 to 7 points, to obtain a total score between 18 and 126 points. The measurements were performed by an occupational therapist.

***Mini Mental State Examination* (*MMSE*)**[21]

The MMSE consists of 11 questions, related to orientation, memorization, attention, calculation, recalling, naming, repeating, comprehension, reading, writing, and drawing. The total score is 30 points, with a higher score indicating a better

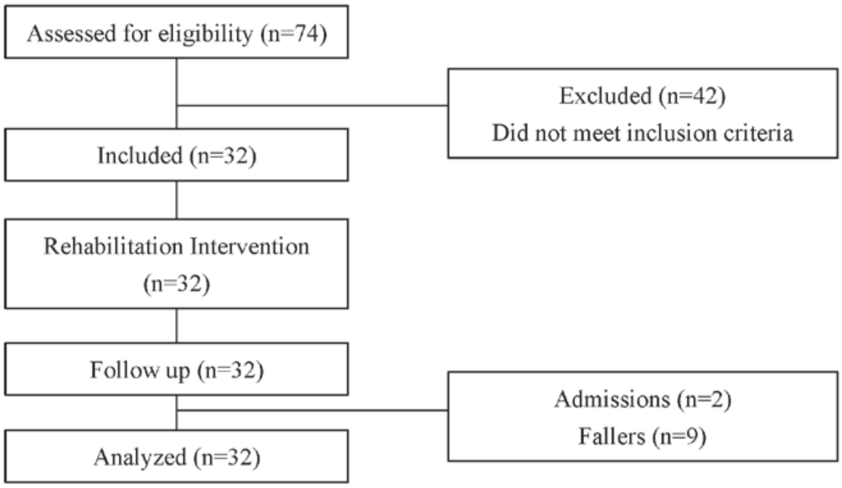

Figure 1 Flow chart of study recruitment and process.

outcome. This was measured once.

Fall history

For the present study, we adopted the definition of a fall as an "event which results in a person unintentionally dropping to the ground or some lower level for reasons other than as a consequence of sustaining a violent blow, loss of consciousness, or sudden onset of paralysis as in a stroke or an epileptic seizure". To investigate the history of a fall, each subject was followed for 12 months with telephone calls every month after discharge from the hospital.

Statistical analysis

The baseline characteristics of the fallers and non-fallers were compared using Student's t-test, the Mann-Whitney U test, and Fisher's Exact test. The fall rate was calculated as the number of subjects who fell/total number of participants ×100. In the principal component analysis (PCA), varimax rotation was used to derive orthogonal factor loading. Principal component scores (PCs) with eigenvalues greater than one were considered to be relevant. A logistic regression analysis was used to determine the risk of a second fall and its association with physical performance, balance, and ADL. Univariable models were used to select the variables to be entered in multivariable models. Only variables that were significant in univariable models at $p<0.1$ were included in the multivariable models. The results were summarized using odds ratios (OR) and 95% confidence intervals (95% CI).

We used R3.6.3 (CRAN, freeware) to perform the above analysis, with a significance level of 5%.

Results

Overall, we screened 74 older adults and enrolled 32 subjects who fulfilled the inclusion criteria of the study and provided consent to participate in the study (Fig. 1). All subjects completed the program without any withdrawals. Table 1 shows the participants' demographic and baseline characteristics. Table 2 shows the results of physical performance, cognitive function, and ADL assessments at discharge.

The fall rate at the 12-month follow-up was 28.1% (fallers, n = 9), and two subjects were re-admitted. None of the fallers suffered a fracture due to falling.

Table 3 shows the factor loading values, proportions of the variance, and cumulative

Table 1. Baseline characteristics of study subjects.

	Total (n=32)	Fallers (n=9)	Non-fallers (n=23)	p-value
Age (y)	85.0 ± 5.3	85.7 ± 3.8	84.8 ± 5.8	p=0.67
Female, n (%)	26 (81.3)	6 (75.0)	20 (87.0)	p=0.62 †
Height (cm)	151.0 ± 8.0	152.0 ± 8.6	150.6 ± 8.0	p=0.71
Body weight (kg)	47.3 ± 7.4	47.8 ± 5.1	47.1 ± 8.2	p=0.82
Body mass index (kg/m^2)	20.8 ± 3.4	20.8 ± 2.7	20.8 ± 3.7	p=0.97
Femoral neck fracture, n	13	5	8	p≒1.000 †
Trochanteric fracture, n	9	1	8	
Vertebral fracture, n	2	0	2	
Pelvic fracture, n	3	2	1	
Other fracture, n	5	1	4	
Use of sleeping pills, n	11	2	9	
Number of drugs	5.0 ± 3.1	5.3 ± 2.7	4.9 ± 3.4	p=0.63
Days of admission (day)	69.9 ± 17.8	74.6 ± 21.7	69.3 ± 17.8	p=0.44

† : Fisher's exact test

Table 2. Each assessment at discharge.

	Total (n=32)	Fallers (n=9)	Non-fallers (n=23)	
Outcome	mean ± standard deviation	mean ± standard deviation	mean ± standard deviation	p-value
BBS (score)	49.5 ± 5.4	45.6 ± 7.6	51.0 ± 3.4	0.06
TUG (s)	13.9 ± 4.7	16.2 ± 7.0	13.0 ± 3.4	0.21
FSST (s)	13.7 ± 5.7	15.5 ± 6.9	13.2 ± 4.9	0.40
Walking speed (m/s)	0.98 ± 0.3	0.91 ± 0.3	1.0 ± 0.3	0.35
CS-30 (s)	11.0 ± 5.9	7.3 ± 6.3	12.4 ± 5.1	0.026
FES (score)	31.8 ± 6.1	30.6 ± 4.8	32.3 ± 6.6	0.41
6MWT (m)	294.8 ± 89.1	257.9 ± 76.1	309.3 ± 91.1	0.14
MMSE (score)	26.3 ± 3.3	25.3 ± 3.8	26.6 ± 3.2	0.35
FIM (score)	106.0 ± 12.1	98.7 ± 11.5	109.0 ± 11.2	0.011

proportions from the principal component analysis. Three PCs (PC1, PC2, PC3) accounted for 77.2% of the variance in the data at hospital discharge. All three PCs had eigenvalues greater than 1. PC1 was associated with walking speed, 6MWT, BBS, FSST, and TUG. PC2 was associated with MMSE and FIM. PC3 was associated with FES. Figure 2 shows the biplot results for PC1 and PC2. From the results in figure 2, BBS can be seen as a comprehensive indicator that is independent of the other variables. The univariate analyses selected CS-30, TUG, BBS, and FIM as factors related to the presence or absence of falls ($p<0.1$). The logistic regression analysis results indicated that as BBS score at discharge increased, risk of second falls decreased (OR=0.81, 95% CI=0.64-0.95: Table 4).

Discussion

The second fall rate was 28.1%, and none of the older adults analyzed in this study suffered any injuries or fractures after falling again. In older adults, a single fall is known to increase the risk of subsequent falls[22]. Furthermore, it is logical that the risk of subsequent falling increases in older adults who have suffered previous fractures from falling. It has been reported that approximately 31–53.3% of older adults who have suffered hip fractures fall once or more than once between 6 and 12 months after being discharged[23-25], which demonstrates

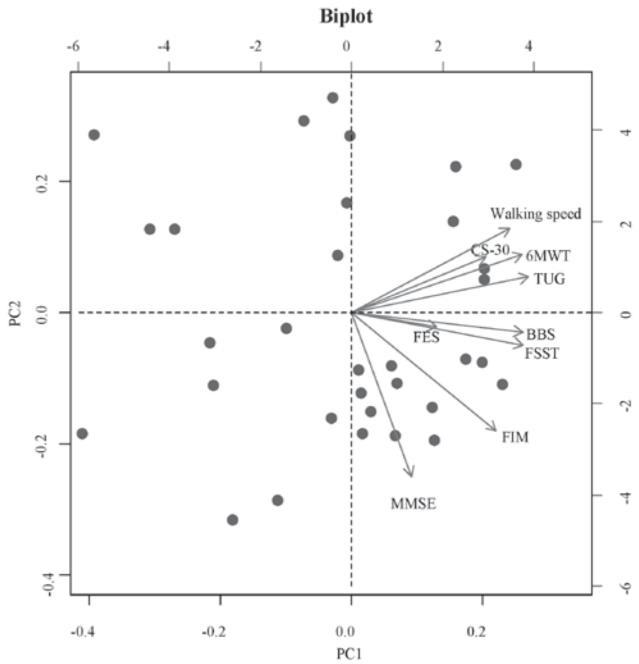

Figure 2 Biplot results for PC1 and PC2.

PC1, =principal component 1. PC 2=principal component 2. BBS=Berg Balance Scale. TUG= Timed Up and Go Test. FSST=Four Square Step Test. CS-30=30-Seconds Chair-Stand Test. 6MWT= Six-Minute Walk Test. FES= The Falls Efficacy Scale. FIM=Functional Independence Measure. MMSE=Mini Mental State Examination.

Table 3. Factor loading values and the proportion of variance explained by principal component analysis.

	PC1	PC2	PC3
Eigenvalue	4.54	1.33	1.06
Proportion of Variance (%)	50.6	14.9	11.8
Cumulative Proportion (%)	50.6	65.4	77.2
Factor loading values			
Walking speed	**0.767**	0.408	0.237
CS-30	**0.649**	0.268	−0.285
6MWT	**0.827**	0.279	0.226
BBS	**0.829**	−0.095	−0.226
FSST	**0.830**	−0.157	0.217
MMSE	0.292	**−0.792**	0.300
TUG	**0.855**	0.174	0.186
FES	0.412	−0.070	**−0.792**
FIM	0.699	**−0.570**	−0.138

Factor loading values greater than 0.5 as the absolute value are in bold

that they have a greater risk of falling than community-dwelling older adults with no experience of fractures. This was approximately twice the fall rate seen in our study (fall rate: 28.1%). Further, between 1.6% and 11% of hip fracture patients experience re-fracture of the hip within one year[26-28], but our results differed from those of previous reports in that there were no cases of fractures in subjects who fell after discharge. However, we believe that the difference in activity levels is also related to the difference in fall rates. While some of the subjects in our study engaged in outdoor activities, as our interviews revealed, few subjects engaged in sports activities. Our results may have been affected by the fact that the activity levels

Table 4. Factors associated with the risk of a fall according to univariate and logistic regression analysis

	OR	95% CI	p-value
Univariate analysis			
CS-30	0.85	0.71-0.98	0.023
BBS	0.81	0.64-0.95	0.009
TUG	1.15	0.97-1.40	0.090
FIM	0.93	0.86-0.99	0.030
Logistic regression analysis			
BBS	0.81	0.64-0.95	0.009

OR, odds ratio; CI, confidence interval.

of our subjects were lower than those of subjects in previous studies[29].

Based on the results of the PCA, we interpreted the BBS as an independent index. If PC1 is considered physical performance and PC2 a life index, the BBS belongs to the former. Furthermore, Fig. 2 shows the BBS eigenvector to be independent of the other vectors. The PCA results provide evidence that the results of the logistic regression analysis of fall risk factors were not coincidental.

Falls are multi-factor events, and it can be difficult to identify a single cause[30,31]. The gold standard for assessing falls are the TUG, BBS, and the functional reach test. The components of the BBS are static stability, underlying motor system, functional stability limits, anticipatory postural control, dynamic stability, and sensory integration. Therefore, compared to the TUG and FSST, the BBS is a comprehensive balance indicator that includes many components[32]. Therefore, for assessing the risk of second falls among older adults, a comprehensive index such as the BBS should be effective. However, due to the relationships between variables in clinical settings, it is unlikely that the evaluation index measured in the present study is independent, and thus, we do not recommend proceeding with treatment based only on BBS results. Previous studies indicate that balance training and rehabilitation help improve balance and reduce the risk of falls in older adults who have suffered hip fractures[12,33]. To reduce the incidence of falls after discharge, it is important to implement balance and ADL training based on the predicted future fall risk determined at the initial stages of hospitalization and to adopt an interdisciplinary approach[34].

A limitation of the present study is its large selection bias. The subjects were post-fracture older adults, but we excluded those people with multiple comorbidities, such as stroke and Parkinson's disease. As we limited the study to older adults without multiple comorbidities, in the future, it would be necessary to investigate further by widening the inclusion criteria for subjects.

Although we reported no incidence of re-fractures during the follow-up period, as there is a trade-off between safety and functional independence in older adults[29], it would be necessary to quantitatively evaluate their daily activity levels and living environments. In addition, the small sample size must be taken into consideration when interpreting the results of this study.

Conclusion

This study investigated repeat fall rates and the factors that contribute to second falls in post-fracture adults aged 65 and over in the first 12 months post rehabilitation. None of the subjects who experienced second falls during the follow-up period suffered any injuries or fractures. The BBS was found to be associated with the risk of second falls in older adults with a history of fractures.

Conflict of Interest: None of the authors have any conflicts of interest directly relevant to the content of this article.

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