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ORIGINAL ARTICLE

Development of Cut-off Values on the Berg Balance Scale for Predicting Walking Independence in Older Adults with Hip Fracture

Shuntaro Tamura, PhD, PT [a] Kazuhiro Miyata, PhD, PT [b] Sota Kobayashi, MSc, PT [c,d] Ren Takeda, PT [d,e] Hiroki Iwamoto, MSc, PT [f]

Objectives: The aim of the current study was to identify a cut-off value for predicting walking independence at discharge in older adults with hip fracture based on their Berg Balance Scale (BBS) score at admission to a convalescent rehabilitation ward. **Methods:** This was a retrospective, multicenter, observational study of 187 older adults with hip fractures (mean age 83.7, range 66–97 years). Data was collected on the patients' age, sex, treatment, and physical function evaluation. An ordinal logistic regression analysis was used to identify predictors associated with the degree of independence in walking at discharge. Receiver operating characteristic curves were used to estimate cut-off values to predict independent and supervised walking at discharge based on the BBS score at admission. The accuracy of the classification was assessed using the area under the curve (AUC). **Results:** The BBS score at admission was a significant factor predicting the degree of walking independence at discharge (odds ratio = 1.09, 95%CI: 1.06–1.11). The cut-off values of the BBS score at admission for predicting independent walking and supervised walking at discharge were 28 points (AUC = 0.76, 95%CI: 0.69–0.83) and 21 points (AUC = 0.84, 95%CI: 0.77–0.91), respectively. **Conclusions:** The BBS scores of older adults with hip fracture on admission to a rehabilitation ward are useful for predicting the degree of independence in walking at discharge and can help to structure therapy according to the predicted degree of independence.

Key Words: Berg Balance Scale; hip fracture; prognosis; rehabilitation medicine; walking independence

INTRODUCTION

Hip fracture is a frequent injury among older adults.[1] Only about half of adults who experience a hip fracture recover the same level of mobility that they had before the injury, and many need post-injury assistance with daily activities.[2] An individual's ability to walk without assistance and the degree of independence in his/her activities of daily living (ADLs) are reportedly predictors of prognosis at 1 year after hospital discharge in older adults with hip fracture.[3,4]

Balance function is an important factor in predicting walking ability,[5] and the Berg Balance Scale (BBS) is commonly used to assess balance function.[6] There is also a significant positive correlation between the BBS score and walking ability.[7] Although the BBS has been used to predict the walking ability prognosis in stroke patients,[8,9] its use has not been investigated in patients with hip fracture. The factors that influence the prognosis of hip fracture patients include

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[a]Department of Rehabilitation, Fujioka General Hospital, Fujioka, Japan
[b]Department of Physical Therapy, Ibaraki Prefectural University of Health Sciences, Ibaraki, Japan
[c]Department of Rehabilitation, Public Nanokaichi Hospital, Tomioka, Japan
[d]Department of Basic Rehabilitation, Gunma University Graduate School of Health Sciences, Maebashi, Japan
[e]Department of Rehabilitation, Numata Neurosurgery & Heart Disease Hospital, Numata, Japan
[f]Department of Rehabilitation, Hidaka Rehabilitation Hospital, Takasaki, Japan
Correspondence: Shuntaro Tamura, PhD, PT, Department of Rehabilitation, Fujioka General Hospital, 813-1 Nakakurisu, Fujioka, Gunma 375-0015, Japan, E-mail: m12204013@gunma-u.ac.jp
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age, sex, treatment, and pre-injury cognitive and motor function.[10–12] However, some reports state that patients with cognitive impairment achieve the same functional recovery as those without cognitive impairment.[13] It has also been demonstrated that it is useful to provide long-term rehabilitation for older adults with hip fracture, regardless of the degree of cognitive impairment.[14] Moreover, BBS scores are a useful indicator of functional recovery regardless of age, sex, or comorbidities.[15] It may thus be possible to predict the prognosis of functional improvement by using BBS scores.

Stroke and hip fracture are the major diseases of patients in convalescent rehabilitation wards in Japan. It has been reported that a BBS score of ≥13 points at admission to a convalescent rehabilitation ward is predictive of walking independence at 3 months after admission for individuals with a first stroke;[9] however, the BBS score at admission required for walking independence may differ between patients with stroke and those with a hip fracture because the mechanisms of balance impairment and the recovery process are different in these populations. We conducted the present study to establish a cut-off BBS score at admission that could be used to predict the walking ability at discharge from a convalescent ward in older adults with hip fracture.

MATERIALS AND METHODS

Study design

This was a retrospective, multicenter, observational study. We analyzed the data of older adults who were admitted with a hip fracture to three convalescent rehabilitation wards in Japan during the 26-month period from April 2018 to June 2020. We publicized information about the study, including an opt-out option, and we ensured that patients had the opportunity to decline to participate. The study was approved by the Ethics Review Committees of Fujioka General Hospital, Public Nanokaichi Hospital, and Hidaka Rehabilitation Hospital (approval nos. #194, #20200020, #20200503) and was conducted in compliance with the Declaration of Helsinki.

Subjects and setting

Data were collected from the medical records of the three above-mentioned hospitals. The inclusion criteria for this study were (1) age ≥65 years, (2) sustained a hip fracture due to a fall, (3) first hip fracture, (4) allowed by a physician to walk with full weight from the time of admission, and (5) Functional Ambulation Categories (FAC) score ≤3 at admission. The exclusion criteria were (1) unable to complete an evaluation of balance and walking function with verbal instructions, (2) blindness or severe vision impairment affecting the patient's ability to walk independently, (3) walking impaired by neurological or musculoskeletal diseases other than a hip fracture, (4) missing BBS scores at admission or discharge, and (5) chose not to participate.

The patients were evaluated within 1 week of admission and within 1 week before discharge for balance function by undergoing BBS assessment, for their independence of gait by the FAC, and by a determination of walking aid use. These assessments were performed by a physical therapist with a thorough understanding of the BBS and walking assessment. Rehabilitation was provided daily during hospitalization; the average daily rehabilitation time was >60 min and was aimed at improving balance function, walking, and the ability to perform ADLs. The data collected were: (1) age and sex, (2) treatment of the hip fracture, (3) BBS scores at admission and discharge, and (4) FAC score and walking aid use/non-use at discharge.

Clinical assessments

Berg Balance Scale

The BBS test includes 14 tasks, each rated on a scale of 0–4, with 56 being the maximum total score. The higher the score, the better the balancing ability.[7] The tasks include (1) Change of position: sitting to standing, (2) Standing unsupported, (3) Sitting unsupported, (4) Change of position: standing to sitting, (5) Transfers, (6) Standing with eyes closed, (7) Standing with feet together, (8) Reaching forward while standing, (9) Retrieving an object from floor, (10) Turning trunk (feet fixed), (11) Turning 360°, (12) Stool stepping, (13) Tandem standing, and (14) Standing on one leg. The BBS score has shown high degrees of reliability and validity for older adults.[16,17]

Functional Ambulation Categories

The FAC scale is an assessment that evaluates the ability to walk stably on a straight course, on stairs, and outdoors.[18] The FAC scale categorizes the need for assistance in walking into several classes and classifies walking ability into six levels from 0 (unable to walk) to 5 (able to walk completely independently, including on stairs). FAC scores have high test–retest reliability and inter-rater reliability (Cohen's $\kappa = 0.950$ and 0.905, respectively) for people admitted to a rehabilitation hospital.[19]

Data analysis

By using the Shapiro–Wilk test, we examined the nor-

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mality of the patients' BBS scores and the number of days between injury/surgery and evaluation of their admission and discharge BBS scores. Based on their FAC scores at discharge, we classified the patients into three groups: the independent-walking group (FAC ≥4), the supervised-walking group (FAC = 3), and the assisted-walking group (FAC ≤2), and we compared the patient characteristics and BBS scores at admission among the groups. The Kruskal–Wallis test was used to compare the three groups, and if there was a significant difference, the Bonferroni test was used. Fisher's exact test was used to compare the nominal scales, and if there was a significant difference, the Bonferroni test was used.

To clarify whether the patients' BBS score at admission was associated with the degree of walking independence at discharge, we performed an ordinal logistic regression analysis. The ordinal variable was the degree of independence in walking (independent, supervised, and assisted), and the independent variables were the BBS score at admission and the items that showed significant differences among the three groups.

The cut-off values of the BBS score at admission for classifying the degree of independent walking and supervised walking at discharge were calculated from the receiver operating characteristic (ROC) curves at the point where the ROC curve was closest to the upper left of the graph. It has been shown that older adults who routinely use a wheeled walker achieve greater improvement in walking parameters compared to those who can walk normally.[20] As a result, a person may be able to walk independently or with supervision even with a lower balance function when he or she is using a wheeled walker. We therefore calculated two cut-off values of the BBS score at admission: one for independent walking and another for supervised walking using a wheeled walker at discharge, based only on the patients who were using a wheeled walker at discharge. The accuracy of the classification was verified by the area under the curve (AUC). An AUC value of 0.5–0.7 indicates low prediction accuracy; 0.7–0.9 indicates medium prediction accuracy, and ≥0.9 indicates high prediction accuracy.[21] We also applied k-fold cross-validation to verify the robustness of the model and to avoid overfitting. The original data set was divided into three subsets by random number generation. In each cross-validation, one subset was kept as the test set and the other two subsets were used as the training set. The cross-validation was repeated three times, and each of the three subsets was used as the test set only once. The results for each fold were then averaged to produce a single estimate. All statistical analyses were performed using the R program, ver. 4.1.0 (R Foundation for Statistical Computing, Vienna, Austria). We used $P<0.05$ as the level of significance.

RESULTS

During the recruitment period, 281 individuals were admitted to one of the three hospitals for a first hip fracture; of these, 270 were aged ≥65 years. Among them, eight patients were excluded because their injuries were from causes other than a fall and ten patients were excluded whose walking ability was scored as independent (FAC ≥4) on admission. Consequently, we analyzed data from the 187 patients who had undergone assessment at both admission and discharge and did not decline to participate. **Table 1** summarizes the patients' characteristics. The mean age ± SD was 83.7 ± 6.6 years (range 66–97 years), and most had undergone surgery.

Of the patients who were able to walk independently, eight were completely independent (with a cane, n=5; without an aid, n=3). None of the patients were completely independent in walking with a wheeled walker. Fourteen patients were unable to walk even with assistance when discharged. The BBS scores and the number of days elapsed before evaluation of the patients' admission and discharge BBS scores were not normally distributed ($P<0.01$).

The three groups based on the degree of independence in walking at discharge (independent, supervised, and assisted) exhibited significant differences in the BBS scores at admission, the surgical procedure, and the number of days to evaluation of the discharge BBS. In the comparison between groups by Bonferroni test, the surgical procedures were not significantly different among the groups. The number of days to evaluation of the discharge BBS was significantly lower in the independent-walking group compared to the supervised- and assisted-walking groups ($P<0.01$), and the BBS scores at admission were significantly different among all three groups ($P<0.01$).

The patients' BBS scores at discharge had significantly improved compared to those at admission, regardless of the degree of walking independence or the use/non-use of a wheeled walker at discharge (**Table 2**). The results of the logistic regression analysis indicated that the BBS score at admission was a significant factor affecting the degree of independence in walking at discharge (**Table 3**).

The ROC curves for the degree of independence in walking at discharge are depicted in **Figure 1** and **Table 4**. The cut-off value of the BBS score at admission for independent walking at discharge was 28 points (AUC = 0.76, 95%CI: 0.69–0.83), and that for supervised walking at discharge was

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Table 1. Characteristics of the patients and comparison of groups by degree of walking independence at discharge

	Overall (n=187)	Walking independence at discharge			P-value
		Independent (n=59)	Supervised (n=96)	Assisted (n=32)	
Age (mean ± SD)	83.7 ± 6.6	82.3 ± 6.6	84.1 ± 6.6	85.2 ± 6.0	0.12
Sex (n) Male/female	41/146	10/49	21/75	10/22	0.29
Fracture type (n) Inside/outside	88/99	30/29	44/52	14/18	0.80
Surgical procedure (n)					
Bipolar hemiarthroplasty	75	29	36	10	
Intramedullary nail	96	27	53	16	
Plate fixation	10	0	6	4	< 0.05
Conservative	5	2	1	2	
Other	1	1	0	0	
Days to evaluation of admission BBS after operation or injury (mean ± SD) Median (1st–3rd quartile)	25.6 ± 12.8 22.0 (16.0 – 32.0)	22.7 ± 10.3 20.0 (15.0 -30.5)	27.3 ± 14.0 24.5 (16.0 36.0)	25.7 ± 12.8 22.0 (15.8 – 29.5)	0.23
Days to evaluation of discharge BBS after operation or injury (mean ± SD) Median (1st–3rd quartile)	76.9 ± 25.9 74.0 (60.5 – 93.5)	66.2 ± 24.8 62.0 (54.0 – 72.0)	80.5 ± 25.8 79.0 (63.0 – 98.0)	85.6 ± 22.2 83.5 (71.0 – 100.5)	< 0.01
Admission BBS Score (mean ± SD) Median (1st–3rd quartile)	25.0 ± 13.9 26.0 (12.0 – 37.0)	33.5 ± 11.2 36.0 (27.0 – 42.0)	24.1 ± 12.9 24.0 (12.8 – 34.0)	11.7 ± 9.7 9.0 (4.8 – 18.3)	< 0.01
Discharge walking aid (n) Wheeled walker/cane/no device	60/66/61	17/29/13	34/29/33	9/8/15	0.05
Discharge FAC (n) 0/1/2/3/4/5	14/3/15/96/51/8	0/0/0/0/51/8	0/0/0/96/0/0	14/3/15/0/0	

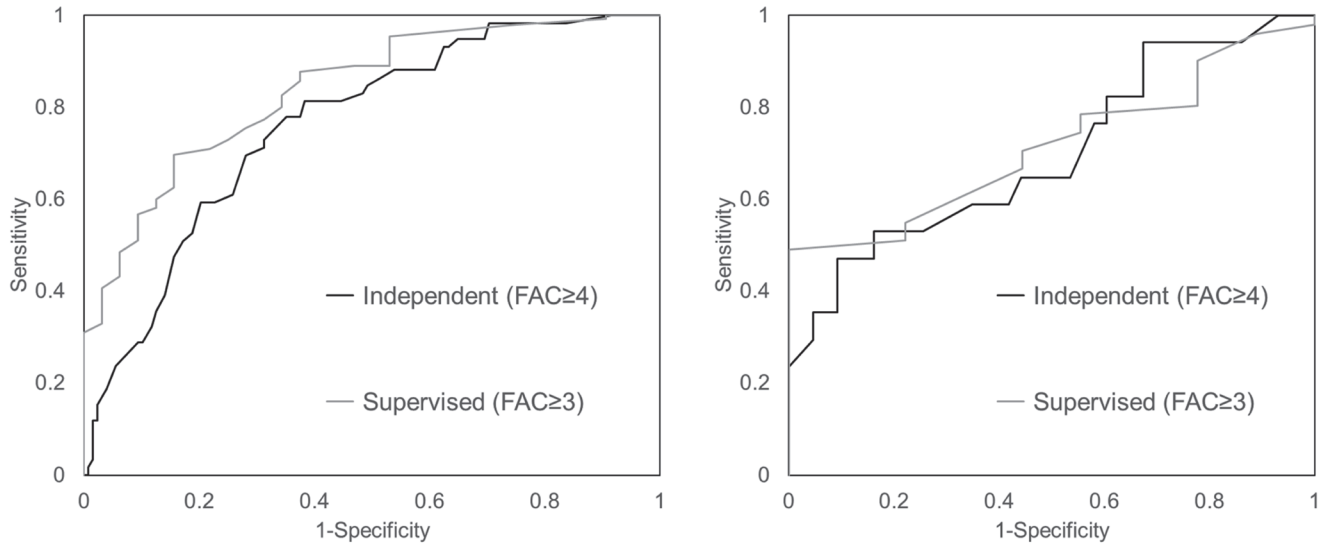

Fig. 1. ROC curves for Berg Balance Scale scores at admission for each degree of walking independence at discharge. The ROC curves show the prediction accuracy (sensitivity and specificity) for (A) the overall population and (B) patients using a wheeled walker for identifying the degree of walking independence.

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Table 2. Patient BBS scores at admission and discharge by degree of walking independence at discharge

		Admission				Discharge			
		All	Independent	Supervised	Assisted	All	Independent	Supervised	Assisted
Overall	BBS Score	25.0 ± 13.9	33.5 ± 11.2	24.1 ± 12.9	11.7 ± 9.7	40.6 ± 12.3*	49.2 ± 5.7*	40.9 ± 8.9*	23.7 ± 13.2*
	Median (1st–3rd quartile)	26.0 (12.0 – 37.0)	36.0 (27.0 – 42.0)	24.0 (12.8 – 34.0)	9.0 (4.8 – 18.3)	44.0 (35.0 – 50.0)	50.0 (47.0 – 53.0)	43.0 (35.0 – 46.3)	27.0 (11.8 – 33.0)
Wheeled walker	BBS Score	19.5 ± 11.6	26.4 ± 13.8	17.9 ± 9.9	12.7 ± 6.0	35.0 ± 9.9*	42.9 ± 5.6*	33.8 ± 8.7*	24.8 ± 9.4*
	Median (1st–3rd quartile)	18.0 (10.8 – 25.3)	25.0 (16.0 – 38.0)	18.0 (8.5 – 24.0)	12.0 (10.0 – 17.0)	37.0 (29.8 – 40.3)	41.0 (38.0 – 41.0)	35.5 (29.3 – 39.8)	28.0 (17.0 - 31.0)

*Significant difference between admission and discharge by Wilcoxon signed-rank test ($P < 0.01$).

21 points (AUC = 0.84, 95%CI: 0.77–0.91). The cut-off value of the BBS score at admission for independent walking with a wheeled walker at discharge was 25 points (AUC = 0.70, 95%CI: 0.54–0.86), and that for supervised walking with a wheeled walker was 19 points (AUC = 0.72, 95%CI: 0.57–0.86).

To verify the robustness of the models and to avoid overfitting, we applied a k-fold cross-validation with k = 3. The ROC curves were plotted again for each model, and the mean AUC for predicting walking independence overall was 0.76; the mean AUC for predicting supervised walking was 0.84. The mean AUC values for both walking independence and supervision for wheeled walkers were 0.71. In the test data, the mean sensitivity and specificity values of the prediction of walking independence overall were 0.74 and 0.67, and those for supervision were 0.69 and 0.78. Considering only the patients using wheeled walkers, the mean sensitivity and specificity values of the prediction of walking independence were 0.48 and 0.73, and those of the prediction of the need for supervision were 0.61 and 0.56.

DISCUSSION

In this study of 187 older adults with hip fracture admitted to a convalescent rehabilitation ward for intensive rehabilitation in Japan, the BBS score at admission was a significant predictor of their degree of walking independence at discharge. The ROC curves indicated that (1) a BBS score ≥28 points at admission could predict that the patient would be able to walk independently at discharge, and (2) a BBS score ≥21 points could predict that the patient would be able to perform supervised walking at discharge. With the use of a wheeled walker, a BBS score ≥25 points at admission could predict the ability to walk independently at discharge, and a BBS score ≥19 points could predict the ability to walk with supervision at discharge.

In a k-fold cross-validation, the mean AUC for all models was >0.70. In the overall patient population, the mean sensitivity and specificity values of the test data for predicting walking independence and supervision were close to the sensitivity and specificity values of the original predictive model. The cut-off BBS scores for the overall patient population thus also exhibited internal validity. In the analysis of only the wheeled walker users, the mean value of the specificity of walking supervision in the test data was lower than the specificity value of the original predictive model. This was because very few individuals using a wheeled walker needed assistance and very few people needed assistance in

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Table 3. Results of the logistic regression analysis for predicting the degree of walking independence at discharge

Variable	B	Odds ratio	95%CI	P-value
Days to evaluation of discharge BBS	–0.01	0.99	0.98 – 1.00	< 0.05
Admission BBS Score	0.08	1.09	1.06 – 1.11	< 0.01

B, regression coefficient; 95% CI, 95% confidence interval.

Table 4. Cut-off values of Berg Balance Scale scores at admission for each degree of walking independence at discharge

	Cut-off value	AUC	95%CI	Sensitivity	Specificity	LR+	LR–
Overall							
Independent	28	0.76	0.69 – 0.83	0.73	0.69	2.34	0.39
Supervised	21	0.84	0.77 – 0.91	0.70	0.84	4.47	0.36
Wheeled walker							
Independent	25	0.70	0.54 – 0.86	0.53	0.84	3.25	0.56
Supervised	19	0.72	0.57 – 0.86	0.55	0.78	2.47	0.58

AUC, area under the ROC curve; LR+, positive likelihood ratio; LR–, negative likelihood ratio.

each test data set.

The cut-off BBS scores for predicting independent and supervised walking obtained in this study may help guide therapists in making decisions about when to discharge older hip-fracture patients and how to support them after discharge. The prediction of independent walking is also useful in decisions regarding where to discharge a patient from the hospital (e.g., the patient's home or another type of healthcare facility). Furthermore, the cut-off value for supervised walking revealed herein is of interest because walking short distances without assistance is an important factor in determining home discharge in older adults.[22]

In the present patient population, the BBS median discharge score (1st–3rd quartile) for those who were able to walk independently was 50.0 points (47.0–53.0). The reported cut-off BBS scores for older adults who suffered a fall were 47.0 points for those living in nursing homes and 48.5 points for those living in the community. Individuals with a BBS score ≥28 at admission are thus likely to be walking independently and at a low risk of falling at discharge.[17,23] In our present investigation, the cut-off BBS score for the use of a wheeled walker had higher specificity than sensitivity. When we examined only the patients who used a wheeled walker, we observed that the quartiles of BBS scores overlapped between the patients who achieved independent walking and those who attained supervised walking and between those with supervised and assisted walking. The same BBS scores may therefore have reflected different degrees of walking independence, and this may have resulted in the low sensitivity values. However, the high specificity may be useful in predicting which patients will need supervision and support for walking, even if they use a wheeled walker at discharge.

In stroke survivors admitted to a convalescent rehabilitation ward, the cut-off BBS score at admission for predicting walking independence was 13 points, whereas in older adults with a hip fracture, the cut-off value was higher at 28 points.[9] This difference may have occurred because the mean age ± SD of the present patients was 83.7 ± 6.6 years, which is rather high, and because there is a phase during the first 3 months of stroke recovery when significant improvement in walking function can be expected in stroke survivors.[24]

We observed a difference of 7 points between the cut-off value for independent walking and the cut-off value for supervised walking, and a difference of 6 points between the cut-off values when a wheeled walker was used. The minimum detectable change for BBS scores in the range 0–24 is 4.6 points, and that for the range 25–34 is 6.3 points.[25] Therefore, the difference between the cut-off BBS scores on admission predicting independent walking and supervised walking at discharge was greater than the measurement error. However, the difference between the cut-off values for independent walking with and without the use of a wheeled walker was 3 points, and the difference between the cut-off values for supervised walking with and without the use of a wheeled walker was 2 points. These differences fall within the range of the measurement error, but a patient's ability to walk even with the use of an assistive aid such as a wheeled walker is beneficial for improving his or her activity level at

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the discharge site.

Regardless of the degree of independence in walking at discharge, the BBS scores of the present series of older adults with hip fractures improved between admission to discharge. It is important to implement exercises aimed at improving balance function even for people who are predicted to be unable to walk independently, because higher BBS scores contribute to the improvement of engaging in ADLs.[26]

In the current study, the BBS score at admission and the number of days to the discharge BBS evaluation were the factors influencing the degree of walking independence at discharge. A study of patients in a geriatric rehabilitation unit also showed that the patients' walking function improved with a shorter length of stay, but this may be because the patients whose walking function improved at an early phase were discharged with a shorter length of stay.[27] We could not evaluate the cognitive function of the present patients, but it has been reported that (i) cognitive function was not a significant factor in predicting unassisted walking among individuals with stroke, and (ii) only balance function was a significant factor.[28] The prediction of walking independence at discharge using only the BBS score at admission could therefore be sufficient, but cognitive function may have an effect on the classification from independent walking to outdoor walking and/or on the speed of walking.

The surgical procedure and fracture type were shown not to be significant factors in our present analyses. A systematic review of pre-discharge predictors of physical function in older adults after hip fracture surgery indicated that the fracture type was not associated with post-discharge physical function.[29] Another study observed that the difference between extracapsular and intracapsular fractures was not a predictor of patients having difficulty walking.[30] The surgical procedure and fracture type were also found not to be significant factors in the present study.

There are several limitations to this study. (1) It was a retrospective analysis, and we were not able to collect comprehensive information on factors that affect walking independence such as the patients' walking ability before the fracture, the aids they used, the presence of frailty, the nutritional status, and cognitive function. We were thus unable to adjust for the effects of confounding factors that may affect walking independence. (2) The influence of the surgical procedure and that of residual postoperative pain on walking independence were not directly taken into account; however, we believe that these factors are indirectly reflected in the BBS scores. (3) We excluded individuals with comorbidities that might affect gait function, and we were thus unable to determine the impact of comorbidities. For example, if a patient had muscle weakness prior to the hip fracture due to one or more comorbidities, or if there was motor paralysis or sensory impairment due to neurological disease, the recovery process may be affected. The generalizability of our findings is thus limited. (4) We were not able to fully test the reliability of the BBS and FAC data for assessments across institutions. However, since the BBS and FAC scale are reportedly highly reliable, it may be useful to use the cut-off values obtained in this study at other institutions.[17,19] (5) We defined walking independence as an FAC score ≥4, but this definition may not be sufficient for defining the walking ability of older adults living in the community. It will be necessary to also evaluate walking function based on walking speed and distance.

CONCLUSION

The BBS score at admission to a convalescent rehabilitation ward was found to be a significant predictor of improvement in walking among older adults with a hip fracture. BBS scores ≥28 points at admission to a convalescent rehabilitation ward could predict independent walking at discharge, and scores ≥21 points could predict supervised walking at discharge. For patients using a wheeled walker, BBS scores ≥25 points could predict independent walking, and BBS scores ≥19 points could predict supervised walking. Although there are many factors that influence the degree of walking independence, the moderate predictive accuracy of the cut-off values obtained from the BBS assessment of balance function alone may be useful in making simple clinical decisions.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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