Factors Affecting Compliance With Weight-Bearing Restriction and the Amount of Weight-Bearing in the Elderly With Femur or Pelvic Fractures

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Objective To determine the factors affecting the amount of weight-bearing during gait training in the elderly patients who underwent internal fixation after femur or pelvic fractures and how well they performed the weight-bearing restriction as directed by the physiatrist.

Methods In this retrospective chart review study, we measured the amount of weight-bearing on the affected side in 50 patients undergoing internal fixation surgery and rehabilitation after femur or pelvic fracture using a force plate. Patients receiving non-weight-bearing or partial weight-bearing education were considered to perform weight-bearing restriction well when the amount of weight-bearing was <50 lb. Furthermore, regression analysis was performed to determine the effects of postoperative complications, age, cognitive function, and pain on weight-bearing restriction.

Results Variables affecting the amount of weight-bearing were age (r=0.581, p<0.001), weight-bearing education type (r=0.671, p<0.001), manual muscle strength of hip flexion on the non-affected side (r=0.296, p=0.037), hip abduction (r=0.326, p=0.021), knee extension (r=0.374, p=0.007), ankle plantar flexion (r=0.374, p=0.008), right hand grip strength (r=0.535, p<0.001), Korean version of Mini-Mental State Examination (r=0.496, p<0.001), Clinical Dementia Rating (r=0.308, p=0.03), and pain visual analog scale scores (r=0.318, p=0.024). The significant predictor of the amount of weight-bearing among these variables was age (β=0.448, p=0.001). The weight-bearing restriction adherence rate was significantly lower, at 22%, for patients aged ≥65 years as compared to 73% for those <65 years.

Conclusion Age was a major variable affecting the amount of weight-bearing. Compliance with weight-bearing restriction was significantly lower in patients aged ≥65 years than in patients <65 years.

Keywords Weight-bearing, Femoral fractures, Aged, Gait, Rehabilitation
INTRODUCTION

In the United States, an estimated 258,000 hip fractures occurred in the elderly in 2010, and approximately $17-20 billion was paid for the management of hip fracture patients in 2010 [1]. According to multicenter and cohort analysis studies reported in Korea in 2014, the initial age of hip fracture among the Korean elderly population is 79 years, and fractures occur within 9.2-30.2 months after the first fracture [2-5]. As life expectancy increases, the hip fracture incidence is expected to increase as well. By 2030, the number of hip fractures in the United States is expected to increase to 289,000 [6].

The clinical effect of controlling postoperative weight-bearing in rehabilitation after lower limb fractures remains controversial. There is a clear recommendation for early weight-bearing after lower limb fracture, since there is an apparent advantage that early weight-bearing improves bone turnover metabolism and promotes bone growth [7,8]. In a similar perspective, prolonged non-weight-bearing is associated with the occurrence of delayed bony union and worse functional recovery [9].

To date, however, the relationship between the amount of weight-bearing and weight-bearing time as well as bone mineral density or functional recovery is not well-known [10]. A study reported that too heavy weight-bearing at the initial stage after surgery may adversely affect the surgical and reconstructive outcome stability [11]. Some suggested that weight-bearing should be restricted for 2-6 weeks depending on the fracture site [12].

Hoyt et al. [11] reported that although there are differences on the fracture site and operation method, partial weight-bearing or non-weight-bearing postoperatively is usually performed in the rehabilitation stage for patients with lower extremity fracture and reconstructive surgery. In general, patients were encouraged to perform early mobilization and to gradually increase their weight-bearing until they attain full weight-bearing.

A study used instrumented hip implants specially designed for weight-bearing after fracture [13], but the literature and rationale for the weight-bearing time and extent is not clear [14]. Therefore, based on continuous X-ray radiographic examinations, we observed changes in the surgical site such as in the fracture site gap, alignment, displacement, and callus formation. Rehabilitation was subsequently performed based on the experience of the physiatrist. This physiatrist-recommended weight-bearing is a key component in the load and rehabilitation process of the fracture site [15]. However, in the clinical setting, it is difficult to know how much weight-bearing is performed by the patient during the treatment process and whether the weight-bearing is achieved as recommended by the physiatrist.

The purpose of this study was to determine the factors affecting the amount of weight-bearing in the gait rehabilitation process especially in the elderly patients who underwent internal fixation after a femur or pelvic fracture and how well they performed the weight-bearing restriction as directed by the physiatrist.

MATERIALS AND METHODS

Study patients and setting

A retrospective chart review was performed to evaluate patients who received rehabilitation treatments after sustaining lower extremity fractures at one university hospital between August 2017 and April 2019.

Patients who underwent internal fixation after a femur or pelvic fracture, were evaluated for the measurement of the amount of weight-bearing on the affected side using a force plate after approximately 30 days of surgery, and who received gait rehabilitation therapy in the Department of Rehabilitation Medicine were included. Patients with multiple traumatic injuries, upper extremity fractures, and lower extremity fractures other than those of the femur or pelvis were excluded from this study. This study was approved by the Institutional Review Board of Chungbuk National University Hospital (No. 2017-04-009). The informed consent was waived.

Patient evaluation and data acquisition

Considering the elderly hip fracture complications, such as deep vein thrombosis, nerve injury, and delirium [16], the variables that could affect the amount of weight-bearing were selected, namely lower extremity edema, peripheral nerve injury, Clinical Dementia Rating (CDR), Korean version of the Mini-Mental State Examination (K-MMSE), and Hamilton Depression Inventory (HDI). In addition, fracture site, body mass index (BMI), days since surgery and rehabilitation, visual analog scale (VAS) scores, age, sex, hand grip, and lower extremity strength, which were expected to affect weight-bearing, were add-
We performed a retrospective review of medical records of our clinical series of patients; their baseline characteristics included age, sex, BMI number of days since surgery and rehabilitation, fracture sites (femoral neck, intertrochanteric, subtrochanteric, femoral shaft, and pelvis), weight-bearing education types (none, partial, full), manual muscle strengths (hip flexion, hip abduction, knee extension, and ankle plantar flexion), hand grip strength, K-MMSE, CDR, VAS, HDI and peripheral nerve injuries, and lower extremity edema.

In addition to the above mentioned evaluation, all patients underwent rehabilitation therapy consisting of weight-bearing exercises, strengthening exercises, gait training, aerobic exercise, and functional training once a day for 30 minutes under the supervision of the physical therapist. The physiatrist determined the degree of weight-bearing, non-weight-bearing, partial weight-bearing, and full weight-bearing in gait training based on X-ray radiography (fracture site stability, callus formation) and physical examination (manual muscle test).

After more than 3 weeks of gait training, the amount of weight-bearing on the affected side was measured. We used a force plate (HWK-200RT; Motion Analysis, Rohnert Park, CA, USA) to measure the amount of weight-bearing with walker gait. The force (newton, N) applied to the force plate in real time was checked via the monitor. The maximum peak force on the affected side was measured thrice and the mean value was used for the analysis (Fig. 1).

Partial weight-bearing definition

To determine the partial weight-bearing specific criteria, we asked four physical therapists to apply the force plate test and perform two instructional tasks: toe-touch weight-bearing with walker and 20% partial weight-bearing with walker. A total of 95 and 84 measurements were taken for the toe-touch weight-bearing and 20% partial weight-bearing, respectively. In the toe-touch weight-bearing task, the mean weight-bearing was 103.1±66.9 N, 14.3±9.1% (body weight percentage), and in the 20% partial weight-bearing task, the mean weight-bearing was 225.9±88.9 N, 30.6±9.3%. The mean weight-bearing of 225.9 N (22.59 kg) in the 20% partial weight-bearing task was almost equivalent to the maximum weight load of 50 lb (22.67 kg) for 12 weeks after femur or pelvis internal fixation operation [17]. Therefore, we performed gait training for toe-touch weight-bearing in partial weight-bearing gait training to lower the amount of weight-bearing to less than 50 lb. The cutoff value for whether the 20% partial weight-bearing training was well performed was set to 50 lb (approximately 226 N); patients with weight-bearing greater than 50 lb, despite partial weight-bearing gait training, were considered overweight-bearing and not adequately weight restricted.

Statistical analysis

To analyze the factors affecting the amount of weight-bearing, the Pearson correlation coefficient and multivariate linear regression analyses were performed, and the body weight percentage was used as the amount of weight-bearing. To analyze the difference in adherence to weight-bearing restriction according to age, the chi-square test was performed. A cutoff value of 50 lb, which was the mean weight-bearing in the 20% partial weight-bearing task of four physical therapists, was used for analysis of adherence to weight-bearing restriction. In the adherence analysis, only patients with partial weight-bearing and non-weight-bearing education were included. All statistical analyses were performed using the SPSS version 25.0 for Windows (IBM Corp, Armonk, NY, USA), with a p-value of <0.05.
RESULTS

Patients’ baseline characteristics

Ninety-three patients who received rehabilitation treatments after sustaining lower extremity fractures at one university hospital between August 2017 and April 2019 were evaluated. Fifty patients were included in this study based on the inclusion and exclusion criteria mentioned in the methods section. Twenty-nine (58%) were males and 21 (42%) were females, and the average age was 70.3±16.2 years. The force plate test was performed on an average of 38.2±17.7 days postoperatively. The most frequent fracture was the intertrochanteric fracture in 25 patients (50%) followed by the pelvic fracture in 14 patients (28%). The most frequent weight-bearing education type was partial weight-bearing with 25 patients (50%). CDR was categorized as normal cognition or questionable dementia in most patients with 0 point (26 patients, 52%) or 0.5 point (20 patients, 40%) (Table 1). The amount of weight-bearing according to weight-bearing education type is presented in Table 2.

Factors associated with the amount of weight-bearing

Age, weight-bearing education type, CDR, and VAS showed positive correlation with the amount of weight-bearing, whereas lower extremity strength on the non-affected side, both hand grip strengths, and K-MMSE revealed negative correlation with the amount of weight-bearing (Table 3).

In the multivariate linear regression analysis with seven variables related to the amount of weight-bearing, only two variables, age and weight-bearing education type (none, partial, full) were statistically significant predictors for the amount of weight-bearing (Table 4). The standardized coefficients of weight-bearing education type were 0.418 and the p-value was 0.002. Moreover, the standardized coefficient of age was 0.448 and the p-value was 0.001.

Difference in adherence to non-weight-bearing or partial weight-bearing according to age

To analyze the difference in adherence to weight-bearing restriction according to age, we divided the patient group into two groups, <65 years and ≥65 years. Significant differences in the proportion of patients who had received non-weight-bearing education were not observed between the two groups. The amount of weight-bearing

Table 1. Baseline characteristics of the patients (n=50)

| Variable | Value |
|----------|-------|
| Age (yr) | 70.3±16.2 |
| Sex, male | 29 (58.0) |
| BMI (kg/m²) | 22.8±3.5 |
| Days since surgery | 38.2±17.7 |
| Days since rehabilitation | 24.1±13.7 |
| Sites of fracture | |
| Femoral neck | 3 (6.0) |
| Intertrochanter | 25 (50.0) |
| Subtrochanter | 5 (10.0) |
| Femoral shaft | 3 (6.0) |
| Pelvis | |
| Acetabulum | 12 (24.0) |
| Pubic ramus | 1 (2.0) |
| Ilium | 1 (2.0) |
| Weight-bearing education type | |
| Non-weight-bearing | 13 (26.0) |
| Partial weight-bearing | 25 (50.0) |
| Full weight-bearing | 12 (24.0) |
| Manual muscle strength (affected/non-affected side) | |
| Hip flexion | 3.0±0.9 / 4.4±0.7 |
| Hip abduction | 3.0±1.0 / 4.4±0.9 |
| Knee extension | 3.9±0.7 / 4.7±0.5 |
| Ankle plantarflexion | 4.4±0.9 / 4.8±0.4 |
| Hand grip strength (kg) | |
| Right | 23.8±11.2 |
| Left | 21.8±10.3 |
| K-MMSE | 24.0±6.0 |
| CDR | |
| 0 | 26 (52.0) |
| 0.5 | 20 (40.0) |
| 1.0 | 4 (8.0) |
| VAS | 1.9±1.3 |
| HDI | 7.2±4.8 |
| Presence of peripheral nerve injuries | 6 (12.0) |
| Presence of lower extremities edema | 0 (0) |

Values are presented as mean±standard deviation or number (%).

BMI, body mass index; K-MMSE, Korean version of Mini-Mental State Examination; CDR, Clinical Dementia Rating; VAS, visual analog scale; HDI, Hamilton Depression Inventory.

of patients who were instructed to perform partial weight-bearing or non-weight-bearing was checked if it was <50 lb to confirm the rate of adherence to the weight-
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There was a statistically significant low adherence rate of approximately 22% in patients ≥65 years (p=0.002); however, the adherence rate was about 73% in patients <65 years (Table 5).

Table 2. Amount of weight-bearing according to weight-bearing education type

| Amount of weight-bearing | NWB (n=13) | PWB (n=25) | FWB (n=12) |
|--------------------------|------------|------------|------------|
| Newton                   | 152.1±133.7| 292.7±117.1| 397.9±137.3|
| The percentage of body weight | 22.8±19.1 | 51.2±22.3  | 73.3±17.1  |

Values are presented as mean±standard deviation.

NWB, non-weight-bearing; PWB, partial weight-bearing; FWB, full weight-bearing.

Table 3. Factors associated with the amount of weight-bearing

| Variable                                      | Amount of weight-bearing (%)<sup>a</sup> | r     | p-value |
|-----------------------------------------------|------------------------------------------|-------|---------|
| Age                                           | 0.581                                    | <0.001|         |
| Sex                                           | -0.253                                   | 0.076 |         |
| BMI                                           | -0.084                                   | 0.564 |         |
| Days since surgery                            | -0.119                                   | 0.408 |         |
| Days since rehabilitation                    | 0.006                                    | 0.969 |         |
| Sites of fracture                             | -0.198                                   | 0.167 |         |
| Weight-bearing education type                 | 0.671                                    | <0.001|         |
| Manual muscle strength (non-affected side)    |                                         |       |         |
| Hip flexion                                   | -0.296                                   | 0.037 |         |
| Hip abduction                                 | -0.326                                   | 0.021 |         |
| Knee extension                                | -0.374                                   | 0.007 |         |
| Ankle plantarflexion                          | -0.374                                   | 0.008 |         |
| Hand grip strength                            |                                         |       |         |
| Right                                         | -0.535                                   | <0.001|         |
| Left                                          | -0.525                                   | 0.001 |         |
| K-MMSE                                        | -0.496                                   | <0.001|         |
| CDR                                           | 0.308                                    | 0.030 |         |
| VAS                                           | 0.318                                    | 0.024 |         |
| HDI                                           | -0.041                                   | 0.802 |         |
| Peripheral nerve injuries                     | -0.060                                   | 0.681 |         |

BMI, body mass index; K-MMSE, Korean version of Mini-Mental State Examination; CDR, Clinical Dementia Rating; VAS, visual analog scale; HDI, Hamilton Depression Inventory.

<sup>a</sup>The percentage of body weight.

Table 4. Multivariate linear regression analysis for predictors of the amount of weight-bearing

|                      | Standardized β | p-value | Adjusted R² |
|----------------------|----------------|---------|-------------|
| Weight-bearing education type | 0.418          | 0.002   | 0.539       |
| Age                  | 0.448          | 0.001   | -           |

Using a backward stepwise elimination.

Table 5. Difference in adherence to non- or partial weight-bearing according to age

| Measured amount of weight-bearing (lb) | <65 | ≥65 | p-value |
|----------------------------------------|-----|-----|---------|
| <50                                    | 11  | 5   | 0.002   |
| ≥50                                    | 4   | 18  |         |

DISCUSSION

It is generally common to train patients on a specific weight-bearing protocol depending on their clinical conditions, because it helps to heal and restore the fracture site [18]. Furthermore, postoperative weight-bearing restriction in older patients with hip fractures has been generally performed in the clinical practice [19], and was considered an appropriate option in the 2015 OrthoGuidelines of the American Academy of Orthopedic Surgeons [20]; however, it is very difficult for the patient to be trained to achieve the desired weight-bearing [12]. In this study, on average, 30.6±9.3% weight-bearing was measured even if the trained physical therapists were ordered 20% partial weight-bearing in the force plate test. This suggests how difficult weight-bearing restriction is for the patient. In this study, the amount of weight-bearing of patients with non-weight-bearing education type was 22.8±19.1%, partial weight-bearing 51.3±19.1%, and full weight-bearing 73.3±17.1%, respectively (Table 2).

An analysis of this study, which identified the factors affecting the amount of weight-bearing of patients, in
addition to the weight-bearing education type showed that age, lower extremity strength on the non-affected side, bilateral hand grip strength, K-MMSE, CDR, and VAS were identified. However, in the multivariate linear regression analysis of these variables, only age was identified as a statistically significant variable to account for the amount of weight-bearing in addition to the weight-bearing education type. Decreased physical and cognitive functions as well as reduced peripheral nerve sensory feedback may be factors that account for the increased amount of weight-bearing of patients with aging [21]. Because of this change in physical and cognitive functions with aging, muscle strength and cognitive function did not appear to have a direct effect on the amount of weight-bearing in this study.

Age was assessed as an important variable in the amount of weight-bearing, and we divided the patients into two groups, <65 years and ≥65 years, to determine the difference in the rate of adherence to weight-bearing restriction according to age. The percentage of patients who performed well weight-bearing restriction <50 lb was much higher, at 73%, in patients aged <65 years as compared to the 22% in patients ≥65 years, among patients trained with non-weight-bearing or partial weight-bearing. This means that compliance with the weight-bearing restriction is much lower in patients aged ≥65 years. In an additional analysis, the adherence rate was 5% in patients aged ≥75 years and significantly lower than 75% in patients <75 years. Therefore, the compliance with weight-bearing restrictions under the supervision of medical staff in hospitals is low. Obviously, the compliance with weight-bearing restriction is much lower in the absence of medical staff supervision in the environment outside the hospital [22].

As we have seen so far that clinically, compliance with weight-bearing restriction is low [12], and especially much lower in patients aged ≥65 years. Despite this low compliance, complications, such as implant failure, non-union, and delayed-union are very rare [15]. A study on large populations showed that the non-union probability after a femur or pelvic fracture increased at age ≥85 years, but the probability decreased more in patients ≥65 years old than in those <65 years [23]. Therefore, in the rehabilitation of patients aged ≥65 years, a more active training and management system will be needed for specific patients with higher risk, such as those with fracture site instability or large amount of fracture gap, non-union, and malunion, which is more individualized than overall weight-bearing restriction, which is less feasible.

This study has some limitations. First, despite the retrospective nature of the study, the number of patients included in the study was only 50. Fifty patients are not very sufficient for multiple linear regression analysis with seven independent variables [24]. This is because of the limited number of patients who underwent internal fixation, mainly weight-bearing restriction, among femur and pelvic fracture patients who were transferred to the department of rehabilitation medicine. Second, a force plate was used to measure the amount of weight-bearing on the affected side of the patient, but this is an instantaneous measurement rather than a continuous measurement. If a continuous measurement was feasible, it would have been clinically more meaningful. Third, cognitive function is thought to influence the compliance with weight-bearing restriction clinically, but the multivariate linear regression analysis of this study shows that cognitive function does not directly affect the amount of weight-bearing. This may be because the number of patients with low cognitive function was very small, i.e., of the 50 patients, 26 (52%) were normal, 20 (40%) had questionable dementia, and only 4 (8%) had mild dementia [25]. Finally, we did not perform the analysis according to the difference of operation method for femur fracture. Among 36 patients with femur fracture, 33 patients received proximal femoral nail anti-rotation surgery and only 3 patients received screw fixation surgery. Further comparative studies will be needed with a more large-scale patient population.

In conclusion, age is a major variable affecting the amount of weight-bearing, and compared with patients <65 years, compliance with weight-bearing restriction was significantly lower in patients ≥65 years. This study suggests the need for further investigation, and questions the gait rehabilitation therapy validity based on an overall weight-bearing restriction, which has low feasibility. A large-scale prospective study of compliance with weight-bearing restriction according to age and related side effects and clinical outcomes is needed. In addition, the result of this study suggests that a new rehabilitation technique may be needed to control weight-bearing in the elderly patients with lower extremity fractures.
CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

AUTHOR CONTRIBUTION

Conceptualization: Lee GJ, Seo HS. Methodology: Lee GJ, Seo HS, Shon HC. Formal analysis: Lee GJ, Seo HS, Cho HG, Oh MW, Lee CJ. Funding acquisition: Lee GJ. Project administration: Lee GJ, Seo HS. Visualization: Lee GJ, Seo HS, Lee CJ. Writing – original draft: Seo HS, Lee GJ. Writing – review and editing: Seo HS, Lee GJ, Kong HH. Approval of final manuscript: all authors.

REFERENCES

1. Roberts KC, Brox WT, Jevsevar DS, Sevarino K. Management of hip fractures in the elderly. J Am Acad Orthop Surg 2015;23:131-7.
2. Lee KH, Kim JY, Yim SJ, Moon DH, Choi GH, Moon KH. Incidence and risk factors of subsequent hip fractures in Korea: multicenter study. J Korean Med Sci 2014;29:992-4.
3. Kim SR, Park YG, Kang SY, Nam KW, Park YG, Ha YC. Undertreatment of osteoporosis following hip fractures in jeju cohort study. J Bone Metab 2014;21:263-8.
4. Ha YC, Park YG, Nam KW, Kim SR. Trend in hip fracture incidence and mortality in Korea: a prospective cohort study from 2002 to 2011. J Korean Med Sci 2015;30:483-8.
5. Park YG, Jang S, Ha YC. Incidence, morbidity and mortality in patients older than 50 years with second hip fracture in a Jeju cohort study. Hip Pelvis 2014;26:250-5.
6. Miyamoto RG, Kaplan KM, Levine BR, Egol KA, Zuckerman JD. Surgical management of hip fractures: an evidence-based review of the literature. I: femoral neck fractures. J Am Acad Orthop Surg 2008;16:596-607.
7. Murphy NM, Carroll P. The effect of physical activity and its interaction with nutrition on bone health. Proc Nutr Soc 2003;62:829-38.
8. Kim CS, Maekawa Y, Fujita M, Sato N, Nishimuta M, Ishizaki Y, et al. Immobilization on the day 14th does not disrupts the basic diurnal rhythm of bone resorption. J Gravit Physiol 2000;7:P125-6.
9. Ariza-Vega P, Kristensen MT, Martin-Martin L, Jimenez-Moleon JJ. Predictors of long-term mortality in older people with hip fracture. Arch Phys Med Rehabil 2015;96:1215-21.
10. Kalmet PH, Meys G, Horn YY, Evers SM, Seelen HA, Hustinx P, et al. Permissive weight bearing in trauma patients with fracture of the lower extremities: prospective multicenter comparative cohort study. BMC Surg 2018;18:8.
11. Hoyt BW, Pavey GJ, Pasquina PF, Potter BK. Rehabilitation of lower extremity trauma: a review of principles and military perspective on future directions. Curr Trauma Rep 2015;1:50-60.
12. Vaserhelyi A, Baumert T, Fritsch C, Hopfenmuller W, Gradl G, Mittlmeier T. Partial weight bearing after surgery for fractures of the lower extremity: is it achievable? Gait Posture 2006;23:99-105.
13. Damm P, Schwachmeyer V, Dymke J, Bender A, Bergmann G. In vivo hip joint loads during three methods of walking with forearm crutches. Clin Biomech (Bristol, Avon) 2013;28:530-5.
14. Kubiak EN, Beebe MJ, North K, Hitchcock R, Potter MQ. Early weight bearing after lower extremity fractures in adults. J Am Acad Orthop Surg 2013;21:727-38.
15. Braun BJ, Veith NT, Rollmann M, Orth M, Fritz T, Herath SC, et al. Weight-bearing recommendations after operative fracture treatment-fact or fiction? Gait results with and feasibility of a dynamic, continuous pedobarography insole. Int Orthop 2017;41:1507-12.
16. Beaupre LA, Jones CA, Saunders LD, Johnston DW, Buckingham J, Majumdar SR. Best practices for elderly hip fracture patients: a systematic overview of the evidence. J Gen Intern Med 2005;20:1019-25.
17. Court-Brown CM, Heckman JD, McQueen MM, Ricci WM, Tornetta P, McKee MD. Rockwood and Green’s fractures in adults. 8th ed. Philadelphia, PA: Wolters Kluwer Health; 2014.
18. Elliott DS, Newman KJ, Forward DP, Hahn DM, Olivere B, Kojima K, et al. A unified theory of bone healing and nonunion: BHN theory. Bone Joint J 2016;98B:884-91.
19. Kammerlander C, Pfeufer D, Lisitano LA, Mehaffey S, Bocker W, Neuerburg C. Inability of older adult
patients with hip fracture to maintain postoperative weight-bearing restrictions. J Bone Joint Surg Am 2018;100:936-41.

20. American Academy of Orthopaedic Surgeons. Appropriate use criteria for postoperative rehabilitation of low energy hip fractures in the elderly. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2015.

21. Kressig RW, Beauchet O. Gait analysis and tailored exercise prescription in older adults. Z Gerontol Geriatr 2004;37:15-9.

22. Hurkmans HL, Bussmann JB, Selles RW, Benda E, Stam HJ, Verhaar JA. The difference between actual and prescribed weight bearing of total hip patients with a trochanteric osteotomy: long-term vertical force measurements inside and outside the hospital. Arch Phys Med Rehabil 2007;88:200-6.

23. Mills LA, Aitken SA, Simpson AH. The risk of non-union per fracture: current myths and revised figures from a population of over 4 million adults. Acta Orthop 2017;88:434-9.

24. Austin PC, Steyerberg EW. The number of subjects per variable required in linear regression analyses. J Clin Epidemiol 2015;68:627-36.

25. Choi SH, Na DL, Lee BH, Hahm DS, Jeong JH, Yoon SJ, et al. Estimating the validity of the Korean version of expanded clinical dementia rating (CDR) scale. J Korean Neurol Assoc 2001;19:585-91.