Association between falling direction and age in older patients with hip fractures

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German abstract (max. 1800 characters incl. spaces) structured into Hintergrund, Ziel der Arbeit (Fragestellung), Material und Methoden, Ergebnisse und Diskussion. If the abstract is longer, Springer may make cuts.

Hintergrund: Es ist bekannt, dass die Inzidenz von sturzbedingten Hüftfrakturen bei Patienten ab 85 Jahren höher ist als bei Patienten im Alter zwischen 65 und 84. Uns ist jedoch keine Studie bekannt, die den Unterschied zwischen diesen Altersgruppen bei der konkreten Situation des Sturzes zum Thema hat.

Ziel: Unser Ziel war, den Zusammenhang zwischen Alter und Richtung des Sturzes bei Patienten mit Hüftfrakturen zu untersuchen.

Materialien und Methoden: Diese Studie analysiert die medizinischen Aufzeichnungen älterer Patienten mit sturzbedingten Hüftfrakturen, die in den Jahren 2011-2018 im Krankenhaus aufgenommen wurden. Demographische Variablen (Geschlecht, Alter und BMI), medizinische und klinische Variablen (Körpermineraldichte, Art der Fraktur und kognitive Funktion), Lebensstilvariablen (Verwendung von Hilfsmitteln zur Fortbewegung und Wohnort) sowie Sturzmerkmale (Richtung und Ort) wurden dafür extrahiert. Anschließend wurden diese zwischen zwei Gruppen, Patienten im Alter zwischen 65 und 84 (Gruppe 65-84) und Patienten über 84 (Gruppe 85+) Jahren verglichen. Schließlich wurde eine multivariable logistische Regressionsanalyse durchgeführt, um Assoziationen zwischen der Fallrichtung (vorwärts, seitwärts und rückwärts) und anderen Variablen zu untersuchen.

Ergebnisse: Verglichen mit der Gruppe 65-84 war der Anteil der Hüftfrakturen infolge seitlicher Stürze in der Gruppe 85+ niedriger ($P < 0{,}05$), während der Anteil der Hüftfrakturen infolge von Rückwärtsstürzen in der Gruppe 85+ höher war. Die Regressionsanalyse zeigte, dass der Seitwärts- und Rückwärtssturz jeweils nur mit der Altersgruppe assoziiert war.

Schlussfolgerung: Diese Ergebnisse legen nahe, dass die Fallrichtung mit dem Alter assoziiert ist, aber nicht mit den anderen Variablen, die in dieser Studie über ältere Patienten mit Hüftfrakturen auch untersucht wurden.

5 German keywords

Sturz; Stürze bei Senioren, Alter; 80 Jahre und älter; Japan, osteoporotische Frakturen

English abstract

Background: The incidence of fall-related hip fractures in elderly patients aged over 85 years was reported to be higher than that in elderly patients aged between 65 and 84 years. However, in our knowledge, there is no study that reported the difference of this age groups in falling situation.

Objective: we investigated the association between age and falling direction in the patients with hip fractures.

Materials and methods: This study analyzed the medical records of elderly patients with fall-related hip fractures who were hospitalized in 2011–2018. Demographic (sex, age, and BMI), medical and clinical (body mineral density, type of fracture, and cognitive function), and lifestyle variables (use of assistive device for locomotion and place of residence) and characteristics of falling (direction and location) were extracted. These were compared between the patients aged between 65 and 84 (65–84 group) and over 85 (85+ group) years. Multivariable logistic regression analysis was conducted to investigate associations with each falling direction (forward, sideways, and backward) with other variables.

Results: Compared with the 65–84 group, the proportion of hip fractures due to sideways falls was lower in the 85+ group ($P < 0.05$) while the proportion of hip fractures due to backward falls was higher in the 85+ group. The multivariable logistic regression analysis showed the sideways and backward falling were respectively associated with only age group.

Conclusion: These results suggested that falling direction was associated with age but not with other variables investigated in this study in the elderly patients with hip fracture.

(1643/1800 characters)

5 English keywords. In this way, your text can be found more easily in databases using the "Medical Subject Heading" (MeSH)

accidental fall; aged; aged, 80 and over; Japan, osteoporotic fractures

Brief introduction of the subject (599/600 characters)

An incidence of hip fractures has rapidly increased in the elderly aged over 85 years. In addition, impact of hip fractures in patients aged over 85 years was higher than in those between 65 and 84 years.

Some studies revealed that a specific falling direction was associated with greater occurrence of hip fracture, particularly sideways falling. However, these studies did not consider the effect of age.

We expected that the number of non-sideways fall hip fractures would increase in patients aged over 85 years because the ability of postural control in the anterior-posterior direction would deteriorate with age and hip fractures are not only caused by a sideways fall but also by a forward or backward fall.

Main text

1. Background and objective

Age-related diseases for a population over 85 years are problematic issues [1]. In 2018, the global number of elderly people over 85 years is growing faster than those between 65 and 84 [2]. In Japan, the National Institute of Population and Social Security Research estimated that the population over 85 years would increase approximately two-fold by 2040, compared to 2015, yet almost no change in the population between 65 and 84 years [3]. Aging itself can lead to disease, thus there is a greater need for understanding the impact of aging, especially in populations over 85 years old.

Hip fracture is regarded as a worldwide public health concern in the elderly, and mostly occurs by falling. In particular, the incidence of hip fractures has rapidly increased in the elderly aged over 85 years [4]. A prospective observational cohort study revealed that the impact of hip fractures in patients aged over 85 years was higher than in those between 65 and 84 years [5]. This is due to a higher mortality rate, higher comorbidity incidence, greater cognitive impairment, longer inpatient hospital stay, and lower chances discharged to their preinjury residence.

Several epidemiological studies have revealed that a specific falling direction was associated with greater occurrence of hip fracture, particularly sideways falling [6–8]. Furthermore, Schwartz et al. [6] and Hwang et al. [8] conducted multivariable analyses and demonstrated that sideways falling was the most harmful falling direction in patients with hip fractures. However, these studies did not consider how differences in age may be related to falling direction.

A previous study demonstrated that the ability of postural control in the anterior-posterior direction would deteriorate with age [9]. Additionally, approximately 85% of falls were forward and backward in direction, regardless of injury [10]. Moreover, hip fractures are not only caused by a sideways fall, but also by a forward or backward fall. Therefore, we expected that the number of non-sideways fall hip fractures would increase in patients aged over 85 years. If there was a difference in age found to be associated with falling direction, this would provide valuable data and inform strategies to prevent and manage injuries falling based on age group.

Therefore, this study aimed to determine the association between falling direction and age in elderly patients with hip fractures aged 65-84 and over 85 years.

2. Methods

2.1. Study design and participants

This single-center observational study was conducted at a convalescent and rehabilitation center with 94 inpatient beds. The inclusion criteria were patients hospitalized between January 2011 and December 2018 and those with confirmed diagnosis of hip fracture. The selection process of the patients is shown in Fig. 1. Fall was defined as unintentionally reaching the ground or some lower levels, resulting in sustaining a violent blow; loss of consciousness; sudden onset of paralysis, as in stroke; or an epileptic seizure [11]. Study subjects were divided into two groups aged 65–84 (65–84 group) and 85+ (85+ group) years.

2.2. Data collection

Data were collected from the accumulated electronic medical records documented by a doctor, nurses, and physical therapists. The medical records written by the doctor during a medical consultation before operations were firstly searched. The doctors, nurses, physical therapists, patients, their family, and caregivers participated in the consultation. In addition, nursing and rehabilitation records as well as referral letters from previous hospitals of the study patients were searched if necessary information was lacking.

2.3. Variables

The primary outcome was falling direction in one of three categories: forward, sideways, and backward.6–8 Secondary outcomes were the following variables: demographics [sex, age, height, body mass, body mass index (BMI)], medical and clinical variables [total hip bone mineral density (BMD) determined by dual energy X-ray absorptiometry, young adult mean (YAM), type of hip fracture (femoral neck, trochanteric, combination of these fractures, subtrochanteric, or periprosthetic fracture), and Revised Hasegawa's Dementia Scale (HDS-R) as cognitive function]; lifestyle variables [place of residence before injury and use of assistive device for locomotion (cane, walker, wheelchair, orthosis)]; falling location (inside the home or outside). The HDS-R is able to accurately and efficiently screen cognitive impairment, and generally reflects dementia, including mild cognitive impairment [12] Data collection from the registry was approved by the Ethical Committee at the X X X Hospital (MRH190006).

2.4. Statistical analysis

Group 1 was analyzed for differences in all outcomes except for falling direction and location, between the 65–84 and 85+ year groups. Categorical data (sex, type of fracture, place of residence before injury, use of assistive device for locomotion) were analyzed using Fisher's exact test. If Fisher's exact test was significant, residual analysis was conducted to identify specific cells with the greatest contribution. The standardized residual was selected as an option in SPSS 25.0 IBM Corporation, NY, USA) for Windows. Continuous variables (age, body height, body mass, BMI, BMD, YAM, HDS-R) were first tested by Shapiro–Wilk test. For non-normally distributed continuous variables, Mann–Whitney U-test was performed, whereas for normally distributed continuous variables, unpaired t-test was used to compare between the two groups.

Group 2 was analyzed for differences in primary and secondary outcomes between the 65–84 and 85+ group by the same way as the analysis for group 1. The differences of falling direction and location were analyzed by Fisher's exact test and, if necessary, the residual analysis.

Additionally, binary logistic regression analysis was performed to investigate associations of each falling direction (forward, sideways, and backward) with secondary outcomes in group 2. Each falling direction was set as the dependent variable and secondary outcomes were set as independent variables. A univariate logistic regression analysis by Fisher's exact test was performed to present unadjusted odds ratio (OR) and 95% confidence interval (CI). Multivariable logistic regression analysis was also conducted to present adjusted OR and CI using forward selection (likelihood ratio). Secondary outcomes were stratified into two groups respectively as follows. Age was stratified into 65–84 years and 85+ years. Body mass and height was excluded from the dependent variables in consideration of multicollinearity. BMI was stratified into < 23 or ≥ 23, which is the boundary of overweight in the WHO classification for Asian populations [13]. BMD was stratified into < 70% or ≥ 70% of YAM according to diagnostic criteria for primary osteoporosis [14]. Type of fracture was stratified into femoral neck or trochanteric as other types were a very small proportion (5.4%). HDS-R score was stratified into < 20 or ≥ 20, which is the cut-off value of dementia [12]. The place of residence before injury was stratified into institution or not. The use of assistive device was stratified into yes or no. Falling location was stratified into inside or outside. To avoid overfitting, independent variables were analyzed by dividing them into three categories (demographic, medical and clinical, and lifestyle variables and falling location). If the variance inflation factor of each explanatory variable was ≥ 2.0, the explanatory variable was excluded in consideration of multicollinearity. The goodness of fit of each model was assessed using the Omnibus Tests of Model Coefficients and the Hosmer–Lemeshow test.

A post hoc power analysis was performed to calculate the statistical power for primary outcome using G*Power 3.1.9.2. A significant level was set at P value of

<0.05. Absolute values for an adjusted residual of >1.96 were considered statistically significant, with a significance level of 0.05. All statistical tests were performed using the SPSS® software.

3. Results

Among the potentially eligible patients, 306 patients as group 1 and 92 patients as group 2 were finally selected. Table 1 presents the characteristics of patients in this study and statistical results for comparisons between the 65–84 and 85+ groups.

In the group 1, significant differences between age groups were observed in their age, body height, body mass, BMI, total hip BMD, YAM, and HDS-R score and the percentages of sex and femoral neck fracture ($P < 0.05$).

In the group 2, significant differences between age groups were observed in their age, body height, mass, BMI, total hip BMD, YAM, and HDS-R score, as well as percentages of sideways and backward falling ($P < 0.05$). The 65–84 group had the highest percentage (51.4%) of sideways falling compared to other directions. Conversely, the 85+ group had the highest percentage (64.9%) of backward falling compared other directions. The percentage of sideways falling was significantly higher in the 65–84 group than 85+ group ($P < 0.05$) while the percentage of backward falling was significantly higher in the 85+ group than the 65–84 group ($P < 0.05$).

The results of the univariate and multivariate analyses for the demographic variables showed that only the age was respectively associated with sideways and backward falling, as shown in Table 2. With respect to the medical and clinical variables, the lifestyle variables, and falling location, there were no variables significantly associated with all falling directions in both univariate and multivariate analyses (Table 3 and 4).

The post hoc power analysis showed the power of 78.8% with an effect size (Cramer's V) of 0.319 for the primary outcome (falling direction).

4. Discussion

Several studies underpinned the association of falling direction with occurrence of hip fractures [6–8]. All of them showed that sideways falling was commonly the most harmful direction that caused hip fractures. However, these studies also showed that falling directions other than sideways (e.g. forward and backward) caused hip fractures, so it is meaningful to explore the variables which associated with each falling direction in the patients with hip fracture. This study highlighted the association between falling direction in the patients with hip fractures and age (65–84 and 85+ group). The main finding of this study was that patients who were aged 85+ had a higher proportion of backward falling. In multivariate, only age group (65–84, 85+ years) was associated with falling direction in demographic, medical and clinical, lifestyle variables and falling location. Given the worldwide aging population and the fact that the incidence of hip fractures has rapidly increased with aging, the findings of current study are meaningful to prevention of hip fractures because it has not been suggested in any other study that the age was associated with falling direction in the elderly patients with hip fractures.

In this study, backward falling was higher proportion in 85+ group compared to 65–84 years. This might be explained by aging because between-group differences in age were significant ($P < 0.001$). Decline in gait speed was not noticeable between ages 65 and 84, but was highly noticeable after 85 years of age15, which was also in line with the Japanese population [16]. Another study demonstrated that participants were likely to land on their hips and buttocks rather than their abdomen as gait speed decreased [17]. Therefore, the reduction of gait speed in aging might reflect why the 85+ group tends to fall backward and thus sustain additional impact on their hip.

To our knowledge, one study reported the difference of hip fracture patients aged 65-84 years with those aged 85 years and older [5]. In line with this previous study, the proportion of female in the current work was significantly higher, and femoral neck fracture was significantly lower in the 85+ group than in the 65–84 group ($p<0.05$). Additionally, we found lower BMI and BMD in the group 85+ compared to the 65–84 group ($p<0.05$). Because low BMI and BMD were associated with risk of hip fracture [18,19], the 85+ group was found to be high risk for hip fracture.

This study has some limitations. First, the outcome variables did not include the physical function and ability (e.g., range of motion, muscle strength, gait speed, and postural control). Second, other falling characteristics (such as cause of falling, impact site, season, and time) were not determined because information was only obtained from the medical records and not from the patients directly; therefore, the circumstance that resulted in falling in each direction remains unknown. Third, the number of patients with hip fractures in nursing home was small, although a previous study reported that the incidence rate of hip fractures was higher in patients in nursing homes than that in community-dwelling residents [20]. Therefore, the results of this study cannot be applied to the population in nursing homes entirely. Further studies might be required to focus on the difference in different types of residence. Lastly, effect size was not large but moderate.

There were several strengths in this study. First, this study included patients older 85 years, which is a difference on previous studies investigating falling direction. Considering that the incidence of hip fractures increases with age and worldwide aging [20], it is important to identify falling direction in older hip fracture groups. Secondly, we found that among patients with hip fractures, age group (65–84, 85+ years) was associated with falling direction. Previous works demonstrated that in addition to preventing falls and strengthening bones, it is also important to reduce the impact during falling by teaching safe landing strategy [21] and wearing a hip protector [22] in order to prevent the hip fracture. Therefore, future research would strategize and take into account differences in falling direction with age.

5. Conclusion

Our analyses suggested that 1) the falling direction significantly differed between patients with hip fractures in the 65–84 and 85+ groups; 2) compared to the 65-84 group, the proportion of hip fractures due to sideways falls was lower in the 85+ group whereas the proportion of hip fractures due to backward falls was higher in the 85+ group; and 3) sideways and backward falling were associated only with age (65-84 years, 85+ years), and not associated with sex, BMI, BMD, type of fracture, HDS-R (cognitive function), use of assistive device, and falling location. Therefore, a counterplan may be required to prevent hip fractures caused by falling depending on age because this study demonstrated that the age group (65-84, 85+) was associated with sideways and backward falling direction in the patients with hip fractures, respectively.

Conflict of interest: There are no conflicts of interest.

References

1. Jaul E, Barron J (2017) Age-Related Diseases and Clinical and Public Health Implications for the 85 Years Old and Over Population. Front Public Heal 5: 335.
2. https://www.prb.org/2018-world-population-data-sheet-with-focus-on-changing-age-structures/. Accessed on 20/07/2020
3. http://www.ipss.go.jp/site-ad/index_english/publication-e.html. Accessed on 20/07/2020
4. Sullivan KJ, Husak LE, Altebarmakian M, Brox WT (2016) Demographic factors in hip fracture incidence and mortality rates in California, 2000--2011. J Orthop Surg Res 11:4.
5. Moon A, Gray A, Deehan D (2011) Neck of Femur Fractures in Patient’s Aged More Than 85 Years—are They a Unique Subset? Geriatr Orthop Surg Rehabil 2:123–127.
6. Schwartz AV, Kelsey JL, Sidney S, Grisso JA (1988) Characteristics of falls and risk of hip fracture in elderly men. Osteoporos Int 8:240–246.
7. Parkkari J, Kannus P, Palvanen M, Natri A, Vainio J Aho H, Järvinen M (1999) Majority of hip fractures occur as a result of a fall and impact on the greater trochanter of the femur: a prospective controlled hip fracture study with 206 consecutive patients. Calcif Tissue Int 65:183–187.
8. Hwang HF, Lee HD, Huang HH, Chen CY, Lin MR (2011) Fall mechanisms, bone strength, and hip fractures in elderly men and women in Taiwan. Osteoporos Int 22: 2385–2393.
9. King MB, Judge JO, Wolfson L (1994) Functional base of support decreases with age. J Gerontol 49: 258–263.

10. Crenshaw JR, Bernhardt KA, Achenbach SJ, Atkinson EJ, Khosla S, Kaufman KR, Amin S (2017) The circumstances, orientations, and impact locations of falls in community-dwelling older women. Arch Gerontol Geriatr 73:240–247.
11. Kennedy TE (1987) The prevention of falls in later life: A report of the Kellogg International Work Group on the prevention of falls by the elderly. Dan Med Bull. 34:1–24.
12. Imai Y, Hasegawa K (1994) The revised Hasegawa’s dementia scale (HDS-R)-evaluation of its usefulness as a screening test for dementia. Hong Kong J Psychiatry 4:20.
13. Nishida C, Yajnik CS, Yudkin JS (2004) WHO expert consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 363:157–163.
14. Soen S, Fukunaga M, Sugimoto T, Sone T, Fujiwara S, Endo N, Ohta H (2013) Diagnostic criteria for primary osteoporosis: year 2012 revision. J Bone Miner Metab. 31:247–257.
15. Lee A, Bhatt T, Smith-Ray RL, Wang E, Pai YC (2019) Gait speed and dynamic stability decline accelerates only in late life: a cross-sectional study in community-dwelling older adults. J Geriatr Phys Ther 42:73–80.
16. Shimada H, Kim H, Yoshida H, Suzukawa M, Makizako H, Yoshida Y, Suzuki T (2010) Relationship between age-associated changes of gait and falls and life-space in elderly people. J Phys Ther Sci. 22:419–424.
17. Smeesters C, Hayes WC, McMahon TA (2001) Disturbance type and gait speed affect fall direction and impact location. J Biomech 34:309–317.
18. Kim SH, Yi SW, Yi JJ, Kim YM, Won YJ (2018) Association between body mass index and the risk of hip fracture by sex and age: a prospective cohort study. J Bone Miner Res 33:1603–1611.

19. Li Y, Lin J, Cai S, Yan L, Pan Y, Yao X, Zeng Y (2016) Influence of bone mineral density and hip geometry on the different types of hip fracture. Bosn J basic Med Sci 16:35.
20. Rapp K, Büchele G, Dreinhöfer K, Bücking B, Becker C, Benzinger P (2019) Epidemiology of hip fractures. Z Gerontol Geriatr 52:10–16.
21. Moon Y, Sosnoff JJ (2017) Safe Landing Strategies During a Fall: Systematic Review and Meta-Analysis. Arch Phys Med Rehabil 98:783–794.
22. de BR, Veldman HD, Witlox AM (2020) Hip protectors are cost-effective in the prevention of hip fractures in patients with high fracture risk. Osteoporos Int 1–13.

Figure legend

Fig. 1 Selection process of the patients for this study

Table 1. Characteristics of patients with hip fractures and comparisons between the elderly patients aged 65–84 and over 85 years.

Abbreviation: SD, standard deviation; BMI, body mass index; BMD, bone mineral density; YAM, young adult mean; HDS-R, Revised Hasegawa's Dementia Scale.

P value: [a]Fisher's exact test, [b]Unpaired t-test, [c]Mann-Whitney test, [d]Residual analysis.

[e] Because of missing data, the number of subjects in some categories do not equal the total number. Percentages shown are based on actual observations.

Table 2. Association of demographic variables with each falling direction

*$p < 0.05$, **$p < 0.01$ using Chi square test/Binary logistic regression analysis.

a Univariate analysis using Chi square test.

b Multivariate analysis using Binary logistic regression.

Table 3. Association of medical and clinical variables with each falling direction

*$p < 0.05$, **$p < 0.01$ using Chi square test/binary logistic regression analysis.

a Univariate analysis using Chi square test.

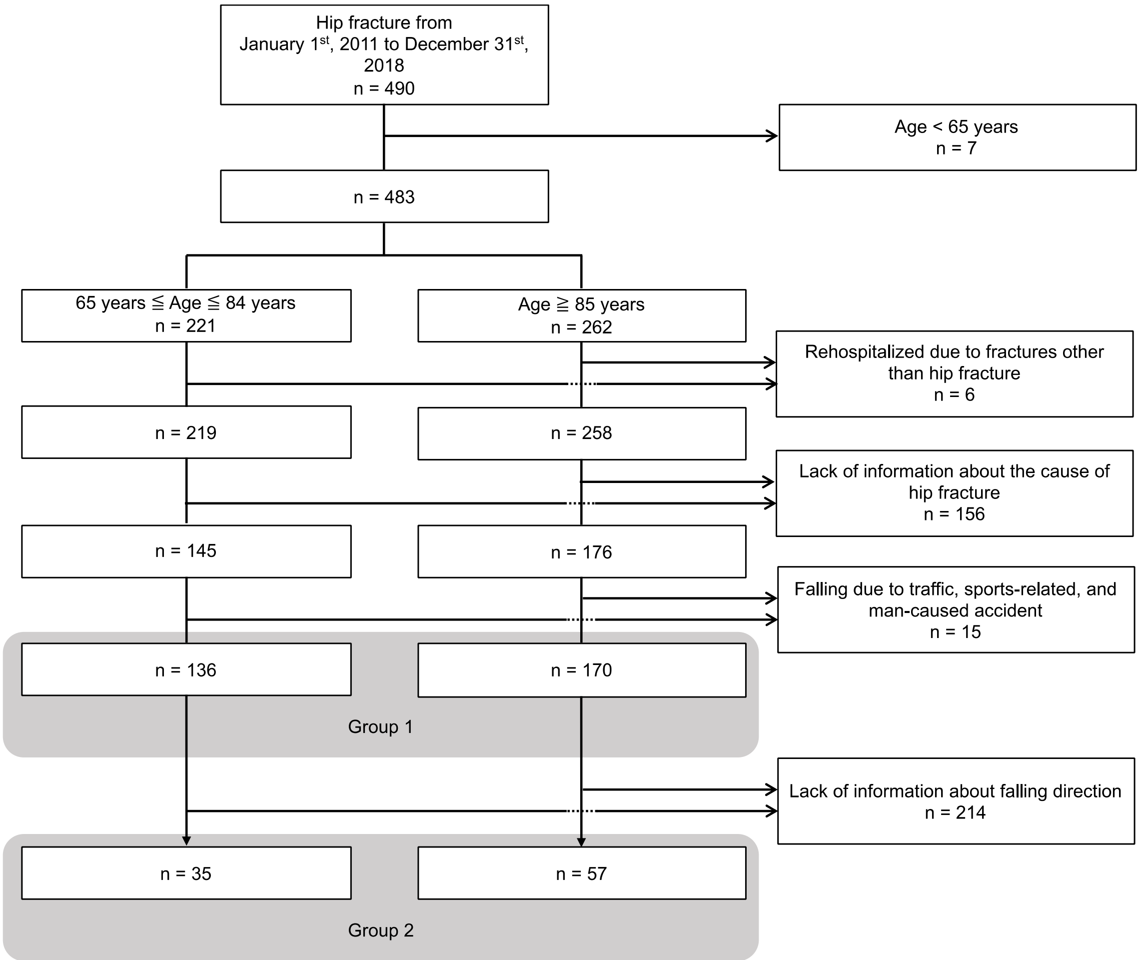
b Multivariate analysis using Binary logistic regression.

Table 4. Association of the lifestyle variables and falling location with each falling direction

*$p < 0.05$, **$p < 0.01$ using Chi square test/Binary logistic regression analysis.

a Univariate analysis using Chi square test.

b Multivariate analysis using Binary logistic regression.



Hip fracture from
January 1st, 2011 to December 31st, 2018
n = 490
Age < 65 years
n = 7
n = 483
65 years ≦ Age ≦ 84 years
n = 221
Age ≧ 85 years
n = 262
Rehospitalized due to fractures other than hip fracture
n = 6
n = 219
n = 258
Lack of information about the cause of hip fracture
n = 156
n = 145
n = 176
Falling due to traffic, sports-related, and man-caused accident
n = 15
n = 136
n = 170
Group 1
Lack of information about falling direction
n = 214
n = 35
n = 57
Group 2

Figure1.

Table1.

	Group 1	Age group		65-84 group vs. 85+ group	Group 2	Age group		65-84 group vs. 85+ group
		65-84 group	85+ group			65-84 group	85+ group	
	(n = 306)	(n = 136)	(n = 170)	P value	(n = 92)	(n = 35)	(n = 57)	P value
Female (%)	265 (86.6)	111 (81.6)	154 (90.6)	**0.028**[a]	78 (84.8)	28 (80.0)	50 (87.7)	0.376[a]
Age, years (Mean ± SD)	84.8 ± 6.8	78.7 ± 4.5	89.6 ± 3.7	**< 0.001**[c]	85.3 ± 6.5	78.8 ± 4.6	89.2 ± 3.6	**< 0.001**[b]
Body height, cm (Mean ± SD)	148.5 ± 8.6	151.0 ± 9.4	146.4 ± 7.4	**< 0.001**[c]	150.2 ± 8.8	154.7 ± 8.4	147.6 ± 7.9	**< 0.001**[b]
Body mass, kg (Mean ± SD)	45.7 ± 9.3	48.6 ± 10.0	43.5 ± 8.0	**< 0.001**[c]	46.7 ± 9.2	51.4 ± 8.3	43.9 ± 8.6	**< 0.001**[b]
BMI, kg/m^2 (Mean ± SD)	20.7 ± 3.4	21.3 ± 3.6	20.2 ± 3.2	**0.005**[c]	20.6 ± 3.3	21.6 ± 3.2	20.1 ± 3.3	**0.041**[c]
Total hip BMD (g/cm^2)	0.51 ± 0.12	0.54 ± 0.12	0.48 ± 0.12	**0.001**[c]	0.52 ± 0.12	0.55 ± 0.13	0.49 ± 0.13	**0.024**[c]
YAM (%)	58.7 ± 13.2	62.2 ± 12.3	55.9 ± 13.3	**0.001**[c]	63.5 ± 11.9	56.9 ± 14.1	59.6 ± 13.6	**0.016**[c]
Type of fracture								
Femoral neck	106 (34.6)	56 (20.5)	50 (16.4)	**0.031**[d]	35 (38.0)	17 (48.6)	18 (31.6)	0.103[d]
Trochanteric	189 (61.8)	76 (20.5)	113 (35.6)	0.058[d]	52 (56.5)	17 (48.6)	35 (61.4)	0.228[d]
Subtrochanteric	8 (2.6)	3 (0.0)	5 (5.5)	0.689[d]	4 (4.3)	0 (0.0)	4 (7.1)	0.109[d]
Femoral neck & Trochanteric	1 (0.3)	1 (1.4)	0 (0.0)	0.263[d]	1 (1.4)	1 (2.9)	0 (0.0)	0.199[d]
Periprosthetic	2 (0.7)	0 (0.0)	2 (1,2)	0.204[d]	0 (1.1)	0 (0.0)	0 (0.0)	not applicable
Cognitive function								
HDS-R score (Mean ± SD)	19.0 ± 7.9	20.2 ± 7.8	18.1 ± 8.0	**0.023**[c]	20.8 ± 8.0	23.3 ± 7.2	19.1 ± 8.2	**0.011**[b]
Institutionalized (%)	47 (15.4)	15 (11.0)	32 (18.8)	0.060[a]	5 (5.4)	1 (2.9)	4 (7.0)	0.645[a]
Use of assistive device for locomotion[e]								
No assistive device	209 (70.4)	95 (72.5)	114 (68.7)	0.471[d]	71 (78.0)	25 (73.5)	46 (64.8)	0.424[d]
Cane	40 (13.5)	17 (13.0)	23 (13.9)	0.826[d]	9 (9.9)	5 (14.7)	4 (7.0)	0.234[d]
Walker	33 (11.1)	10 (7.6)	23 (13.9)	0.090[d]	11 (12.1)	4 (11.8)	7 (12.3)	0.942[d]
Wheelchair	14 (4.7)	8 (6.1)	6 (3.6)	0.314[d]	0 (0.0)	0 (0.0)	0 (0.0)	not applicable
Ankle-foot orthosis	1 (0.3)	1 (0.8)	0 (0.0)	0.259[d]	0 (0.0)	0 (0.0)	0 (0.0)	not applicable
Falling direction								
Forward (%)					10 (10.9)	2 (5.7)	8 (14.0)	0.230[d]
Sideways (%)					30 (32.6)	18 (51.4)	12 (21.1)	**0.036**[d]
Backward (%)					52 (56.5)	15 (42.9)	37 (64.9)	**0.003**[d]
Falling location, inside (%)					72 (78.3)	24 (68.6)	48 (84.2)	0.152[a]

Table2.

Factors	Forward falling						Sideways falling						Backward falling					
	Univariate analysis[a]			Multivariate analysis[b]			Univariate analysis[a]			Multivariate analysis[b]			Univariate analysis[a]			Multivariate analysis[b]		
	OR	95%CI	P value	Exp B (95%CI)	P value	Exp B	OR	95%CI	P value	Exp B (95%CI)	P value	Exp B	OR	95%CI	P value	Exp B (95%CI)	P value	Exp B
Sex																		
Male																		
Female	0.69	0.13 - 3.63	0.646				0.59	0.19 - 1.90	0.373				1.92	0.61 - 6.06	0.381			
Age																		
65–85																		
≥85	2.69	0.54 - 13.49	0.308				**0.25**	**0.10 - 0.63**	**0.003**	**0.10 - 0.63**	**0.003***	**0.25**	**2.47**	**1.04 - 5.84**	**0.038**	**1.04 - 5.84**	**0.040***	**2.47**
BMI																		
<23																		
≥23	0.70	0.17 - 2.99	0.698				0.62	0.23 - 1.67	0.435				1.80	0.69 - 4.73	0.324			

Table3.

Factors	Forward falling						Sideways falling						Backward falling					
	Univariate analysis[a]			Multivariate analysis[b]			Univariate analysis[a]			Multivariate analysis[b]			Univariate analysis[a]			Multivariate analysis[b]		
	OR	95%CI	P value	Exp B (95%CI)	P value	Exp B	OR	95%CI	P value	Exp B (95%CI)	P value	Exp B	OR	95%CI	P value	Exp B (95%CI)	P value	Exp B
BMD																		
< 70% of YAM	2.67	0.31 - 22.90	0.676				0.88	0.28 - 2.71	1.000				0.81	0.27 - 2.37	0.789			
≥ 70% of YAM																		
Type of fracture																		
Femoral neck	1.01	0.26 - 3.88	1.000				1.81	0.70 - 4.63	0.252				0.59	0.25 - 1.42	0.276			
Trochanteric																		
HDS-R score																		
< 20	1.45	0.39 - 5.44					1.67	0.68 - 4.09	0.359				0.53	0.22 - 1.27	0.191			
≥ 20																		

Table4.

Factors	Forward falling						Sideways falling						Backward falling					
	Univariate analysis[a]			Multivariate analysis[b]			Univariate analysis[a]			Multivariate analysis[b]			Univariate analysis[a]			Multivariate analysis[b]		
	OR	95%CI	P value	Exp B (95%CI)	P value	Exp B	OR	95%CI	P value	Exp B (95%CI)	P value	Exp B	OR	95%CI	P value	Exp B (95%CI)	P value	Exp B
Place of residence, institution																		
Yes	6.58	0.95 - 45.42	0.089				0.50	0.05 - 4.68	1.000				0.49	0.08 - 3.10	0.649			
No																		
Use of assistive device																		
Yes	0.88	0.17 - 4.49	1.000				0.65	0.21 - 2.01	0.590				1.52	0.54 - 4.27	0.456			
No																		
Falling location																		
Inside	0.88	0.17 - 4.57	1.000				0.60	0.20 - 1.82	0.393				1.70	0.57 - 5.07	0.410			
Outside																		