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ORIGINAL RESEARCH

Risk factors for ground-level fall injuries during active activity in older patients

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Abstract

In older patients, ground-level falls are the most common cause of injury. Many intrinsic and extrinsic factors influence ground fall injuries. However, the characteristics and severity of ground fall injuries have not been compared according to the activity levels. We compared the characteristics of ground fall injuries by the activity level to establish a preventive strategy for ground fall injuries in older patients. We retrospectively reviewed the records of older patients who were admitted to six university hospitals for ground-level fall injuries from 2011 to 2020. The patients were classified into active and inactive groups. Active activities were defined as paid work, exercise and leisure activities. General and clinical characteristics of both groups for ground-level fall injury were analyzed. Propensity score matching analysis (1:1) was performed for baseline characteristics (sex, age and alcohol consumption). A total of 33,924 patients were enrolled, of which 4887 (14.4%) were classified in the active group. Injury severity was not different between the active and inactive groups. The main factors significantly associated with ground fall injuries during activities in elderly patients were male sex, age from 65 to 74 years and 75 to 84 years compared to greater than 85 years, an injury time other than 00:00–05:59, alcohol consumption, sloping floor and floor type other than concrete. After propensity score matching analysis, the factors associated with ground-level fall injuries in older patients when they were active were a time of injury from 06:00–17:59 compared to 00:00–05:59, slippery floor, slope, the absence of obstacles and type of floor other than concrete. We should establish preventive strategies for reducing ground-level fall injuries in older patients during activity, which could include wearing compatible footwear, caution on sloping areas, and maintenance of unpaved roads.

Keywords

Ground-level fall injury; Older patient; Active; Floor; Time of injury; Severity

1. Introduction

The World Health Organization (WHO) defines a fall as an incident that causes a person to unintentionally come to rest on the ground, floor or other lower level [1]. Most of the injured patients are admitted to emergency departments (ED), and 10–15% of trauma patients of all ages admitted to ED had fall injuries [2]. Ground-level falls are the most common cause of injury, especially in older patients [1, 3–5], because they are more vulnerable to trauma than younger people [6–8]. Currently, the proportion of older patients in the total population is increasing rapidly worldwide [1, 2], and falls in older patients are becoming a growing public health concern [9, 10]. Older patients are more likely to experience severe injuries. Despite being at low risk due to comorbidities, the mortality risk is increased [11], and it can be a major socioeconomic problem [6]. Therefore, studies analyzing the characteristics of fall injuries in older patients and the development of preventive strategies can reduce medical costs. In a previous study, both intrinsic (neurosensory input) and extrinsic (environmental) factors were found to play a role in the fall process, either individually or in combination [12]. The major intrinsic factors were gait characteristics [12], sex [4, 13], alcohol consumption [3], and the use of psychotropic (benzodiazepines and antidepressants) and cardiovascular drugs (beta-blockers and antiarrhythmics) [14]. The major extrinsic factors were slopes [12, 15], the type of surface [1, 3, 9, 16–19], light intensity [20], type of footwear [16, 20], and location of the fall injury [9, 16, 17].

In addition to the other factors, researchers have focused on the difference between indoor and outdoor environments [17, 21]. More falls occur outdoors than indoors because more leisure time physical activity carried a higher risk for outdoor activity [17]. Outdoor falls were more common in

healthy older people, whereas indoor falls were more common in inactive older people [21], indicating an association between poor health and indoor falls [17]. Thus, considering a patient's baseline health status, we can assume that ground falls during inactivity would be more severe. However, patients move faster and more passionately during activity, which can be a risk factor for ground fall severity. Therefore, we investigated the patients' characteristics of fall injury during active activity and inactive activity, and the severity in both groups. The results can be helpful in establishing preventive strategies for fall injuries in geriatric patients, which can reduce the medical costs.

2. Materials and methods

2.1 Study design and setting

Emergency Department-based Injury In-depth Surveillance (EDIIS) data from the Korea Disease Control and Prevention Agency (KDCA) were used in this retrospective case-control study. EDIIS data are currently being collected from 23 hospitals, starting with 6 hospitals in 2006, and the collecting variables were revised in 2011. Common data from 23 hospital Emergency Departments (EDs) and in-depth injury related data in four categories from 4~8 hospital EDs have been collected. In-depth data were classified into traffic accidents; head and neck injury; injury in preschool aged children; and suicide, poisoning, fall from a height and ground fall injury in older people. Since the in-depth data for ground fall injury in older people, which included environments of floor, were collected in only six hospitals, and the study group included patients aged 65 years or older who visited the ED of six university hospitals from January 2011 to December 2020 for ground-level fall injuries (Fig. 1).

2.2 Study outcomes

This study was conducted to identify and compare the factors associated with activity during ground-level fall injuries in older patients, which included the severity.

2.3 Variables and measurement

General patient characteristics, including activity during injury occurrence, the season of injury, time of injury, sex, age, occupation, level of education, location of injury occurrence and consumption of alcohol, were examined. In this study, paid work, exercise and leisure activities were defined as active activities. Unpaid work (such as cooking and cleaning), studying, daily activities (such as eating a meal or taking a shower), and religious duties were defined as inactive activities. The patients were classified into the following three groups based on age: 65–74 years, 75–84 years and 85 years and older. The average age of the patients in each group was also determined. The patients were classified into the following four groups by the season when they were admitted to the ED: spring (March–May), summer (June–August), autumn (September–November) and winter (December–February). The patients were classified into the following four 6-hour interval groups based on the time of injury: 00:00–05:59, 06:00–11:59, 12:00–17:59 and 18:00–23:59. The level of education was defined by the highest level achieved, and accordingly, the patients were classified into the following four categories: uneducated or elementary school, junior high school, high school and college. The location of injury occurrence was defined as home or residential facilities, medical facilities, public or commercial facilities, transportation areas, and industrial or agricultural facilities. The floor characteristics during injury were also examined. The floor condition was classified as slippery or non-slippery. The type of floor was concrete and other types, such as wooden and earthen. The slope of the floor, and the

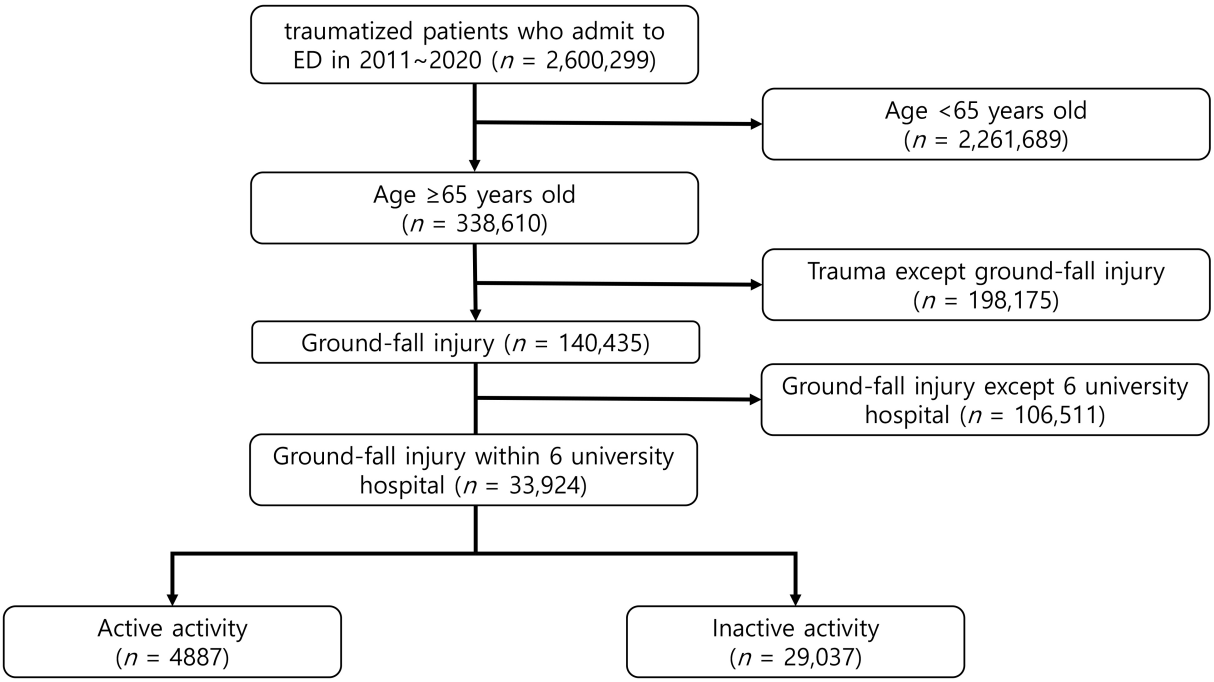

FIGURE 1. Flow chart of the study population. ED: Emergency Department.

presence of obstacles were also examined.

The clinical characteristics of the patients, including the results of ED treatment, injury severity, location of a major injury, method of transportation to the ED, consciousness at the ED, Glasgow Coma Scale (GCS) score, and rate of surgical operation, were examined. The results of ED treatment were classified into the following five groups: discharged from the ED, transferred to another facility, admitted to the general ward, admitted to the intensive care unit (ICU), and death in the ED. Severity was defined as hopeless discharge (which meant that the patient refused admission because of poor prognosis), transfer to another medical facility due to the lack of ICU space or availability of emergency surgery (or further specialized treatment in a tertiary hospital), admission to the ICU, need for emergency surgery, and death in the ED. The patients were classified into the following seven groups based on the location of major injury according to the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10): head and neck (S00-19), thorax (S20-29), abdomen (S30-39), upper extremity (S40-69), hip and thigh (S70-79), lower extremity (S80-99), and multiple regions in the body (T10-14). The method of transportation to the ED was by public ambulance, transfer from another medical facility, or individual transportation. The patients were classified into four groups based on consciousness in the ED according to the Alert, Verbal, Pain, Unresponsive (AVPU) scale. GCS scores were also examined, which were the sum of eye response, verbal response, and motor response scores. Surgery referred only to an operation, not a procedure, such as embolization.

2.4 Statistical analysis

The chi-squared test or Fisher's exact test was used for categorical variables, and the student's *t*-test was used for numerical variables to compare the general and clinical characteristics of the active and inactive groups. Comparison of the proportions between different groups was performed using Pearson's chi-squared test and Fisher's exact test. The normality of the distribution of all variables was tested using the Kolmogorov-Smirnov test, and all variables were normally distributed. Adjustment for different distributions of baseline characteristics (sex, age and alcohol consumption) was performed to reduce bias and potential confounding between two groups using 1:1 propensity score matching analysis with the nearest neighbor method based on a greedy matching algorithm that could sort data by estimated propensity scores. The balance test of covariates in the matched group was evaluated by measuring standardized mean differences. All standardized mean differences in the baseline variables were <0.2. Univariate logistic regression analysis of the general patient and environmental characteristics was performed to identify factors associated with activity during ground-level fall injuries. Multivariate logistic regression analysis (stepwise, forward) was performed by selecting statistically significant variables ($p < 0.05$) in the univariate logistic regression analysis. Education and occupation variables were not included in the logistic regression analysis due to a large number of missing values since these parameters were evaluated only in admitted patients. Data manipulation and statistical analysis were performed using SPSS software, version 24 (SPSS Inc, IBM, Armonk, NY, USA) and R software, version 4.1.2 (R Foundation for Statistical Computing, Vienna, Austria; www.r-project.org). The R "Matchit" package was used for propensity score matching. All reported *p*-values were two-sided, and $p < 0.05$ was considered statistically significant.

3. Results

A total of 33,924 patients were enrolled. There were 4887 (14.4%) active patients and 29,037 (85.6%) inactive patients (Fig. 1).

Active patients were more commonly injured in spring than inactive patients (25.3% *vs.* 22.3%). In contrast, inactive patients were more commonly injured in summer (23.8% *vs.* 22.2%) and autumn (27.2% *vs.* 26.2%). Active patients were more commonly injured from 12:00–17:59 (38.4% *vs.* 36.7%) and 18:00–23:59 (34.8% *vs.* 27.4%), whereas inactive patients were more commonly injured from 06:00–11:59 (28.2% *vs.* 20.3%). The proportion of males in the active patient group (53.6%) was higher than that of females, which was distinct from inactive patients (34.2%). Regarding the age of the subjects, the proportion of patients in the 65–74 years' age range was higher in the active group (62.4%), whereas the proportion of relatively older patients (75–84 years, and older than 85 years) was higher in the inactive group (44.0% and 18.9%). The most common location of injury occurrence in the active group was a transportation area (50.6%) and home or residential facilities in the inactive group (62.8%). The proportion of patients who had consumed alcohol was higher in the active group (26.8%) than in the inactive group (5.7%). The floor characteristics of falls in each group were also investigated. In the active group, the proportions of sloping floors (12.4%) and the presence of obstacles (10.5%) were higher, and the proportion of concrete floor (84.3%) was lower than that in the inactive group (Table 1).

More patients with head and neck injuries (48.3%) were found in the active group, whereas more patients with thoracic (5.4%) and abdominal (8.5%) injuries were found in the inactive group. In the inactive group, fewer patients were discharged (60.4%), more patients were admitted to general wards (32.4%), and the proportion of those undergoing surgery was higher than that in the active group (20.9%), whereas injury severity did not differ between the groups (Table 2).

The main factors significantly associated with ground fall injuries in elderly patients during activity were male sex, ages between 65–74 years and 75–84 years compared to greater than 85 years, injury time other than 00:00–05:59, alcohol consumption, sloping floor and floor type other than concrete (Table 3, Fig. 2).

There were more inactive patients in this study; thus, propensity score matching analysis (1:1) was performed to adjust for different distributions of baseline characteristics (sex, alcohol consumption and age) (**Supplementary Table 1**).

After propensity score matching, active patients were more commonly injured from 12:00–17:59 (38.4%), whereas inactive patients were more commonly injured from 00:00–05:59 (9.2%) and 18:00–23:59 (38.7%). There was no difference

TABLE 1. General and environmental characteristics of ground fall injuries in older people during active or inactive activities.

	Active (N = 4887)	Inactive (N = 29,037)	*p*-value
Season of injury (%)			
Winter	1288 (26.4)	7760 (26.7)	
Spring	1236 (25.3)	6483 (22.3)	<0.001
Summer	1084 (22.2)	6898 (23.8)	
Autumn	1279 (26.2)	7896 (27.2)	
Time of injury (%)			
00:00–05:59	318 (6.5)	2216 (7.6)	
06:00–11:59	990 (20.3)	8199 (28.2)	<0.001
12:00–17:59	1876 (38.4)	10,667 (36.7)	
18:00–23:59	1703 (34.8)	7955 (27.4)	
Sex, male (%)	2618 (53.6)	9938 (34.2)	<0.001
Average age (yr)	73.3 ± 6.5	77.5 ± 7.5	<0.001
Age, years old (%)			
65–74	3050 (62.4)	10,775 (37.1)	
75–84	1515 (31.0)	12,777 (44.0)	<0.001
≥85	322 (6.6)	5485 (18.9)	
Employed (%)	N = 1411 509 (36.1)	N = 11,177 2157 (19.3)	<0.001
Education (%)	N = 443	N = 5016	
Uneducated or elementary school	206 (46.5)	2749 (54.8)	
Junior high school	92 (20.8)	808 (16.1)	0.006
High school	95 (21.4)	968 (19.3)	
College	50 (11.3)	491 (9.8)	
Location of injury occurrence	N = 4880	N = 29,028	
Home or residential facility	557 (11.4)	18,241 (62.8)	
Medical facility	29 (0.6)	986 (3.4)	
Public facility or commercial facility	769 (15.8)	1131 (3.9)	<0.001
Transportation area	2471 (50.6)	8096 (27.9)	
Industrial facility or agricultural area	1054 (21.6)	574 (2.0)	
Alcohol (%)	N = 4107 1102 (26.8)	N = 22,157 1272 (5.7)	<0.001
Slippery floor (%)	N = 4816	N = 28,333	0.054
Slippery	454 (9.4)	2929 (10.3)	
Slope of floor (%)	N = 4882	N = 29,027	<0.001
Sloping	603 (12.4)	948 (3.3)	
Presence of obstacles (%)	N = 4886	N= 29,026	<0.001
Yes	513 (10.5)	2001 (6.9)	
Type of floor (%)	N = 4877	N = 28,957	<0.001
Concrete	4109 (84.3)	28,409 (98.1)	

TABLE 2. Clinical characteristics of older people with ground fall injuries according to the activity level.

	Active (N = 4887)	Inactive (N = 29,037)	*p*-value
Consciousness at the ED (%)	N = 4246	N = 24,283	
Alert	4090 (96.3)	23,497 (96.8)	
Verbal	109 (2.6)	501 (2.1)	0.206
Pain	38 (0.9)	235 (1.0)	
Unresponsive	9 (0.2)	50 (0.2)	
GCS score	N = 2024 14.9 ± 1.0	N = 12,668 14.9 ± 0.8	0.051
Surgery (%)	N = 4213 543 (12.9)	N = 23,855 4982 (20.9)	<0.001
Major injury location (%)	N = 4876	N = 28,997	
Head and neck	2357 (48.3)	11,519 (39.7)	
Thorax	182 (3.7)	1573 (5.4)	
Abdomen	282 (5.8)	2475 (8.5)	
Upper extremity	726 (14.9)	3653 (12.6)	<0.001
Hip and thigh	554 (11.4)	7021 (24.2)	
Lower extremity	423 (8.7)	1754 (6.0)	
Multiple body regions	352 (7.2)	1002 (3.5)	
Transportation to the ED (%)			
Public ambulance	2036 (41.7)	11,834 (40.8)	
Other medical facility	565 (11.6)	4535 (15.6)	<0.001
Individual transportation	2286 (46.8)	12,668 (43.6)	
Result of ED treatment (%)	N = 4869	N = 29,012	
Discharge	3428 (70.4)	17,533 (60.4)	
Transfer to another facility	87 (1.8)	777 (2.7)	
Admission to general ward	1134 (23.3)	9407 (32.4)	<0.001
Admission to ICU	216 (4.4)	1271 (4.4)	
Death in ED	4 (0.1)	24 (0.1)	
Severe patients (%)	N = 4869 297 (6.1)	N = 29,012 1808 (6.2)	0.724

ED: Emergency Department; GCS: Glasgow Coma Scale; ICU: intensive care unit.

in the proportion of injuries according to the season in the groups. The most frequent location of injury occurrence was transportation areas in the active group (50.6%) and home or residential facilities in the inactive group (45.5%). Regarding floor characteristics, the proportions of injuries on slippery floors (9.4%) and sloping floors (12.4%) were higher in the active group, and the proportions of injuries occurring in the presence of obstacles (22.2%) and concrete floors (97.1%) were higher in the inactive group. More patients with head and neck injuries were found in the inactive group (69.4%), and more patients with injury at other locations were found in the active group. More patients in the active group were transported to an ED from another medical facility (11.6%), and more patients in the inactive group were transported to an ED by a public ambulance (43.7%) or individual transportation (47.0%). Injury severity in the active group was higher than that in the inactive group (6.1% *vs.* 5.1%) (Table 4).

The main factors significantly associated with ground fall injuries in elderly patients during activities after 1:1 propensity score matching were injury time other than 00:00–05:59 h, slippery floors, sloping floors, the absence of obstacles, and floor type other than concrete (Table 5, Fig. 2).

TABLE 3. Individual and environmental factors related to ground fall injuries in older people during active activity.

Univariate	OR	95% CI	*p*-value
Season of injury (%)			
Winter	1.00		
Spring	1.15	1.06–1.25	<0.001
Summer	0.95	0.87–1.03	0.218
Autumn	0.98	0.90–1.06	0.567
Time of injury (%)			
00:00–05:59	1.00		
06:00–11:59	0.84	0.74–0.96	0.012
12:00–17:59	1.23	1.08–1.39	0.002
18:00–23:59	1.49	1.31–1.70	<0.001
Male (%)	2.22	2.09–2.36	<0.001
Age, years old (%)			
65–74	4.82	4.28–5.43	<0.001
75–84	2.02	1.78–2.29	<0.001
≥85	1.00		
Location of injury occurrence			
Home or residential facility	1.00		
Medical facility	0.96	0.66–1.41	0.846
Public facility or commercial facility	22.3	19.7–25.2	<0.001
Transportation area	10.00	9.08–11.00	<0.001
Industrial facility or agricultural area	60.13	52.69–68.63	<0.001
Alcohol (%)	6.02	5.51–6.58	<0.001
Slippery floor (%)	0.90	0.81–1.00	0.054
Slope of floor	4.17	3.75–4.65	<0.001
Presence of obstacles	1.58	1.43–1.76	<0.001
Type of floor	0.10	0.09–0.12	<0.001

OR: Odds Ratio; CI: Confidence Interval.

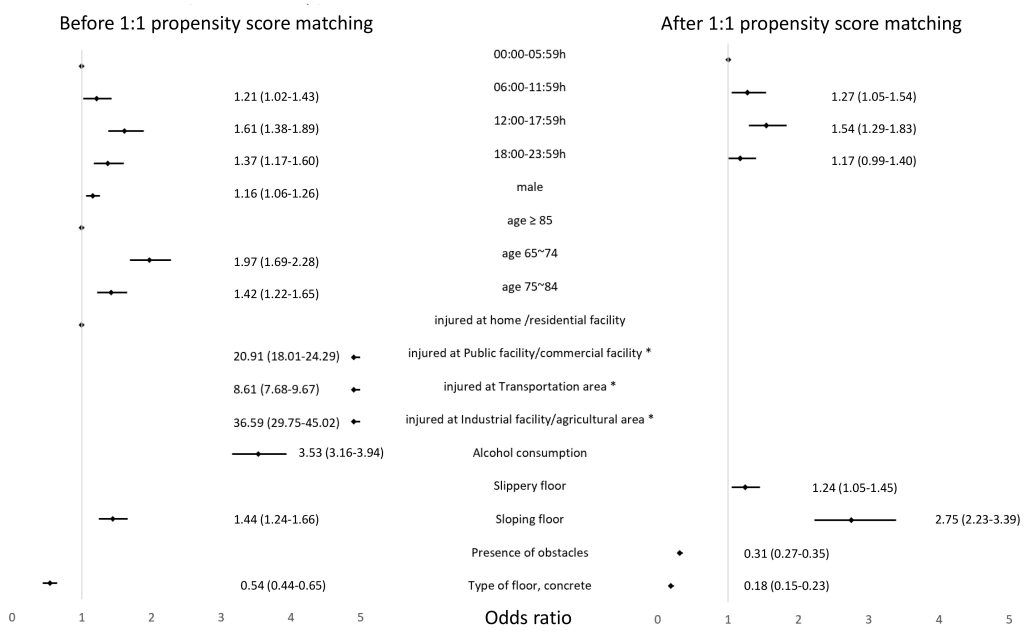

FIGURE 2. Multivariate analysis for individual and environmental factors related to ground fall injuries in older people during active activity. *Odds ratio ≥5.00.

TABLE 4. Characteristics of ground fall injuries in older people during active or inactive activities after 1:1 propensity score matching.

General characteristics	Active (N = 4887)	Inactive (N = 4887)	*p*-value	Clinical characteristics	Active (N = 4887)	Inactive (N = 4887)	*p*-value
Season of injury (%)				Consciousness at ED (%)	N = 4246	N = 4016	
Winter	1288 (26.4)	1271 (26.0)		Alert	4090 (96.3)	3833 (95.4)	
Spring	1236 (25.3)	1201 (24.6)	0.846	Verbal	109 (2.6)	130 (3.2)	0.112
Summer	1084 (22.2)	1119 (22.9)		Pain	38 (0.9)	48 (1.2)	
Autumn	1279 (26.2)	1296 (26.5)		Unresponsive	9 (0.2)	5 (0.1)	
Time of injury (%)				GCS score	N = 2024 14.9 ± 1.0	14.9 ± 1.0	0.940
00:00–05:59	318 (6.5)	450 (9.2)		Surgery (%)	N = 4213 543 (12.9)	N = 3915 529 (13.5)	0.697
06:00–11:59	990 (20.3)	1000 (20.5)	<0.001	Major injury location (%)	N = 4876	N = 4884	<0.001
12:00–17:59	1876 (38.4)	1546 (31.6)		Head and Neck	2357 (48.3)	3389 (69.4)	
18:00–23:59	1703 (34.8)	1891 (38.7)		Thorax	182 (3.7)	134 (2.7)	
Age, years old (%)				Abdomen	282 (5.8)	154 (3.2)	
65–74	3050 (62.4)	3065 (62.7)		Hip and thigh	554 (11.4)	460 (9.4)	
75–84	1515 (31.0)	1506 (30.8)	0.001	Lower extremity	423 (8.7)	225 (4.6)	
≥85	322 (6.6)	316 (6.5)		Multiple body regions	352 (7.2)	97 (2.0)	
Employed (%)	N = 1411 509 (36.1)	N = 1411 255 (23.9)	0.001	Transportation to ED (%)			0.002
Education (%)	N = 443	N = 443		Public ambulance	2036 (41.7)	2135 (43.7)	
Uneducated or elementary school	206 (46.5)	214 (41.6)		Other medical facility	565 (11.6)	456 (9.3)	
Junior high school	92 (20.8)	93 (18.1)	0.171	Individual transportation	2286 (46.8)	2296 (47.0)	
High school	95 (21.4)	137 (26.6)		Result of ED treatment (%)	N = 4869	N = 4875	<0.001
College	50 (11.3)	71 (13.8)		Discharge	3428 (70.4)	3813 (78.2)	<0.001

TABLE 4. Continued.

General characteristics	Active (N = 4887)	Inactive (N = 4887)	*p*-value	Clinical characteristics	Active (N = 4887)	Inactive (N = 4887)	*p*-value
Location of injury occurrence	N = 4880	N = 4885		Transfer to another facility	87 (1.8)	79 (1.6)	
Home or residential facility	557 (11.4)	2225 (45.5)		Admission to general ward	1134 (23.3)	806 (16.5)	
Medical facility	29 (0.6)	106 (2.2)		Admission to ICU	216 (4.4)	174 (3.6)	
Public facility or commercial facility	769 (15.8)	283 (5.8)	<0.001	Death at ED	4 (0.1)	3 (0.1)	
Transportation area	2471 (50.6)	2135 (43.7)		Severe patients (%)	N = 4869 297 (6.1)	N = 4875 249 (5.1)	0.039
Industrial facility or agricultural area	1054 (21.6)	136 (2.8)					
Alcohol (%)	1306 (26.7)	1291 (26.4)	<0.001				
Slippery floor (%)	N = 4816	N = 4789	0.006				
Slippery	454 (9.4)	373 (7.8)					
Slope of floor (%)	N = 4882	N = 4885	<0.001				
Sloping	603 (12.4)	181 (3.7)					
Presence of obstacles (%)	N = 4886	N = 4884	<0.001				
Yes	513 (10.5)	1084 (22.2)					
Type of floor (%)	N = 4877	N = 4873	<0.001				
Concrete	4109 (84.3)	4732 (97.1)					

ED: Emergency Department; GCS: Glasgow Coma Scale.

TABLE 5. Individual and environmental factors related to ground fall injuries in older people during activity compared to activity after 1:1 propensity score matching.

Univariate	OR	95% CI	*p*-value
Season of injury (%)			
Winter	1.00		
Spring	1.02	0.91–1.14	0.790
Summer	0.96	0.85–1.07	0.443
Autumn	0.97	0.87–1.09	0.642
Time of injury (%)			
00:00–05:59	1.00		
06:00–11:59	1.43	1.21–1.70	<0.001
12:00–17:59	1.75	1.49–2.05	<0.001
18:00–23:59	1.28	1.09–1.50	0.002
Location of injury occurrence			
Home or residential facility	1.00		
Medical facility	1.16	0.73–1.84	0.528
Public facility or commercial facility	10.16	8.42–12.26	<0.001
Transportation area	4.56	4.01–5.19	<0.001
Industrial facility or agricultural area	27.87	22.22–34.96	<0.001
Slippery floor (%)	1.23	1.06–1.43	0.005
Slope of floor	3.58	3.01–4.26	<0.001
Presence of obstacles	3.58	3.01–4.26	<0.001
Type of floor, concrete	0.16	0.13–0.20	<0.001

OR: Odds Ratio; CI: Confidence Interval.

4. Discussion

This study compared the characteristics of ground fall injuries in older patients during activity with those experienced during inactivity. The time of injury other than midnight (00:00–05:59), relatively younger age, alcohol consumption, sloping floor and floor type other than concrete were associated with ground-level fall injuries in older patients during activity. After 1:1 propensity score matching analysis for three baseline characteristics (age, sex and alcohol ingestion), the injury in older patients due to ground-level falls during activity was significantly associated with an occurrence at 06:00–17:59 compared to 00:00–05:59, slippery floors, slope, the absence of obstacles and floor type other than concrete.

In this study, ground falls during activity occurred more frequently from 06:00–23:59, compared to during inactivity. Ordinarily, people are awake from morning to evening [16]; thus, activities are conducted more frequently during daytime hours than during nighttime hours. Among the elderly, the relatively younger patients were more frequently injured during active activity than the older patients. Older patients spend more time indoors [16, 17], and more leisure time was associated with outdoor fall injuries [17]. Indoor falls were common in inactive older people, in contrast to outdoor falls, which were more common in healthy older people [21]. According to a previous argument, relatively younger people are healthier than older people and more likely to experience outdoor falls, which are related to activities.

Older patients are also more likely to have severe injuries because of the presence of comorbidities [11]. However, in this study, injury severity in the active group was not lower than that in the inactive group. Furthermore, after propensity score matching analysis, injury severity in the active group was higher than that in the inactive group. Activities, such as leisure-time physical activity, carry a higher risk of falls [17]; thus, caution during activity is necessary, despite the healthier condition of relatively younger patients.

A previous study reported that more men were injured due to ground-level fall injuries during activities than women, probably because of differences in daily routines between the two sexes [16]. Alcohol consumption was significantly associated with ground fall injuries during active activities. Another study reported that, in addition to environmental factors, neurosensory input plays a role in the fall process [12], and declines in motor, sensory and cognitive functions increased the risk of falling while walking on different surface conditions [9]. Activities could be conducted on different surfaces compared to where inactivity occurs; thus, motor-sensory dysfunction re-

lated to alcohol consumption more strongly influences falling when they are active.

After performing 1:1 propensity score matching for age, sex and alcohol consumption, the time of injury and environmental factors were associated with ground fall injuries during activity. Daytime, which is from 06:00–17:59, was associated with ground fall injuries during activities compared to midnight because ordinary people are more active in the daytime. More ground fall injuries while being active occurred on slippery floors and floor type other than concrete. These floor types included soil, ballast and multi-surface terrains, which are more slippery than concrete or asphalt. The slip potential was associated with ground-reaction forces [15]; thus, slippery floors are a risk factor for fall injuries [1, 16]. During an activity, people move and work more actively, and fast movements can increase the slip potential more strongly than inactivity. A sloped floor was also a significant risk factor for falls when they were active. A slope increases the slip potential by reducing the ground reaction force, which decreases body balance and can cause fall injuries [12, 15]. As an example, ground-level fall injuries on a sloped roof are an important safety concern for construction workers [15].

In contrast to previous studies, this study found that the presence of obstacles inversely affected ground-level fall injuries during activities. In the swinging phase during walk, stumbling was triggered by obstacles, and patients experienced ground-level falls [16]. For example, door sills were a risk factor for injurious falls [18]. In addition, visual acuity and depth perception decline in older people, and this skill is very important in negotiating obstacles [18]. As per our assumption, relatively safety environment, such as absence of obstacles, can trigger safety frigidity, which can reduce concentration during active activities. Further studies should be conducted to assess the association between the obstacles and ground fall injuries during activities.

There were some limitations to this study. First, this study was conducted in 6 university hospitals; thus, generalizability at various levels of the hospital could be weak. Categorization of ground fall patients was based on the activity during injury, but there could be some inconsistency between the natural activity level and activity during injury because of limitations of this retrospective case-control study. Medication history was not investigated. Several previous studies have identified medications as a risk factor in fall injuries [4, 14, 22], especially the fact that antiarrhythmics, non-selective beta-blockers, benzodiazepines, psychotropics and antidepressants increased the fall risk in elderly people [14]. Studies have also shown that cognitive impairment increased the fall risk in elderly people [23]. Different shoes can also affect the balance differently, and improperly worn shoes can be a risk factor for fall injuries [12, 16]. Low levels of education were also associated with falls due to problems in understanding the preventive measures [16, 18]. Medication history and information on shoes were not included in this study, and the level of education was not analyzed because many values were missing. Finally, muscle strength can be a significant risk factor for falls [4]. In future, further studies should include a detailed medication history. Furthermore, the patient's natural activity level should be evaluated. In addition to characteristics of the floor, the type of shoes should be evaluated, as it has an effect on ground-level fall injury.

5. Conclusions

In the case of ground-level fall injuries in older patients, the factors associated with trauma during activity were daytime injury, slippery floor, slope, the absence of obstacles, and floor type other than concrete. Injury severity in the active group was not lower than that in the inactive group, despite the relatively younger age. Based on our study, preventive strategies should be established for reducing ground-level fall injuries in older patients during activity, especially in sloping areas and slippery floors. Preventive strategies should include wearing compatible footwear, caution regarding sloping areas, and maintenance of unpaved roads. Fall prevention toolkits for patients who are vulnerable to ground-level fall injuries can be helpful to increase the awareness of injury. For patients who take a variety of medications, a recommendation for deprescription of unnecessary medications can also be helpful.

AVAILABILITY OF DATA AND MATERIALS

The Korea Disease Control and prevention Agency (KDCA) has the authority to access and use these data. Data of this study can be requested through the Department of Injury Prevention of the KDCA by E-mail (kcdcinjury@korea.kr) or website (http://www.kdca.go.kr).

AUTHOR CONTRIBUTIONS

JSH, SHK and SPK—designed the research study. JSH, SHK, SCL, SPK, GCC, MJK, DHL and YRK—performed the research. JSH and SHK—provided help and advice on this study; analyzed the data; wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was reviewed and approved by Ulsan University Hospital Institutional Review Board (UUH-IRB-2022-06-039). Data used in this study were anonymized before using them. All methods in this study were performed in accordance with the guidelines of the Declaration of Helsinki. The requirement for obtaining informed consent was waived by the Institutional Review Board due to the retrospective nature of this study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.signavitae.com/mre-signavitae/article/1716736766057037824/attachment/Supplementary%20material.docx.

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