Aging Clinical and Experimental Research (2026) 38:2
https://doi.org/10.1007/s40520-025-03253-8

RESEARCH

Indoor falls-related hip and femur fractures decreased during the social distancing period of COVID-19 in South korea: a single-center retrospective cohort study using propensity score matching

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Received: 5 August 2025 / Revised: 16 October 2025 / Accepted: 27 October 2025

Abstract

Background The coronavirus disease 2019 (COVID-19) pandemic introduced unprecedented social distancing measures that drastically altered daily activities for older individuals.

Aims To investigate whether the proportion of indoor falls changed during the coronavirus disease 2019 (COVID-19) social distancing period in South Korea compared to the pre-COVID-19 period.

Methods We conducted a retrospective cohort study at a single tertiary care academic hospital in South Korea of older adult patients who presented to the emergency department and were diagnosed with hip or femur-related fractures during the pre-COVID-19 period (January 2011 to December 2019) or the social distancing period (March 2020 to March 2022). We performed 1:1 propensity score matching. We compared the proportion of indoor and outdoor falls between the two groups.

Results A total of 2,433 patients diagnosed with hip or femur-related fractures were included (1,941 before COVID-19 and 492 during the social distancing period). After matching, the proportion of indoor falls was 61.1% in the social distancing group and 67.7% in the pre-COVID-19 group among 316 matched patients in each group ($p=0.02$).

Conclusions During the COVID-19 social distancing period in South Korea, the proportion of indoor falls decreased significantly compared to the pre-COVID-19 period among older adults with hip or femur-related fractures, suggesting a pandemic-related shift in fall patterns that highlights how lifestyle changes can impact injury patterns and inform fall prevention strategies. However, absence of data on household composition, cognitive status, and medication use, along with tertiary-center selection bias (higher comorbidity burden), limits generalizability.

Trial registration number Not applicable.

Keywords Hip fractures · COVID-19 · Accidental falls · Social distancing · Accidental falls/Prevention & control

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Published online: 23 December 2025

Introduction

Falls in older adults are a major public health concern worldwide, with approximately 25% experiencing falls annually, often leading to serious consequences including fractures, head injuries, and loss of independence [1, 2]. Hip fractures, occurring predominantly due to falls and accounting for approximately 90% of cases, are especially concerning in this population [3, 4]. Indoor falls, which comprise most incidents, carry higher mortality rates than outdoor falls [5]. This higher indoor fall mortality might reflect the greater frailty and comorbidity burden of those who predominantly remain indoors, and this setting is a traditional focus for prevention efforts [6, 7].

The coronavirus disease 2019 (COVID-19) pandemic, which emerged in early 2020, led to unprecedented behavioral changes worldwide, particularly affecting older populations [8, 9]. In South Korea, social distancing policies were introduced in March 2020, and continued in various phases through 2021 [10]. While many countries implemented strict lockdowns during the COVID-19 pandemic, South Korea adopted a more moderate approach that, although impactful, did not impose a complete restriction on outdoor mobility [11]. These measures included public health guidelines advising older adults to remain at home, minimize social contacts, and reduce non-essential outdoor activities.

As a result, many older adults significantly reduced their time spent outdoors, avoiding parks, markets, and social venues, and remained inside their homes or care facilities for extended periods [12, 13]. These conditions can have contradictory effects on fall risk. Increased time spent at home, potentially with greater family supervision, could lead to fewer opportunities for outdoor falls and improved indoor safety oversight [14]. Conversely, prolonged stay-at-home orders could lead to physical deconditioning, muscle weakness, and balance deterioration due to inactivity, which might increase the risk of falls when performing basic activities [15, 16]. Previous studies provided mixed evidence, with most focusing on reduced hip fracture incidence [8, 17–19] or changed patient characteristics [20, 21], but few examined shifts in fall locations among fracture patients. Understanding whether indoor versus outdoor fall proportions changed—rather than just overall volumes—can reveal how pandemic behaviors affected injury circumstances and inform targeted prevention strategies.

We investigated changes in fall location patterns among hip and femur fracture patients during South Korea's COVID-19 social distancing period. Given these competing mechanisms—deconditioning increasing fall risk versus reduced activity and increased supervision decreasing exposure—we hypothesized that the proportion of indoor versus outdoor falls would shift during the social distancing period. We anticipated that these opposing forces would alter fall distribution patterns among those presenting with fractures, rather than simply increasing absolute numbers.

Materials and methods

Study design and setting

This was a single-center retrospective cohort study performed at a large tertiary care academic hospital. The study was approved by the hospital's institutional review board (9-2025-0054), and informed consent was waived due to the retrospective use of de-identified data. Our study findings are reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

Study population

Inclusion criteria were patients aged 65 years or older who sustained a hip or femur-related fracture due to a fall, regardless of fall location (community or institution), provided they presented to our emergency department for evaluation or treatment (Fig. 1). We included patients who met these criteria during one of two distinct time periods: the pre-COVID-19 period (January 2011 to December 2019) and the COVID-19 social distancing period (March 2020 to March 2022), during which South Korea implemented varying levels of social distancing measures without strict lockdowns. These ranged from Level 1 (least restrictive) to Level 4 (most restrictive), with the majority of the period under Level 2–3 restrictions that advised but did not mandate staying at home. We chose these time frames to capture the periods before and during the pandemic, allowing comparison between normal circumstances and the social distancing measures implemented during COVID-19. A "fall" was defined as an event where the patient inadvertently came to rest on the ground or lower level, consistent with the World Health Organization definition [5]. Exclusion criteria were as follows: (1) patients younger than 65 years, (2) cases involving high-energy trauma such as motor vehicle accidents, (3) falls associated with major cardiovascular or cerebrovascular events, and (4) cases in which the fall location could not be determined. If a patient had multiple fracture incidents in the study period, each event was counted separately if it led to a separate hospital visit (77 cases, 3.2%).

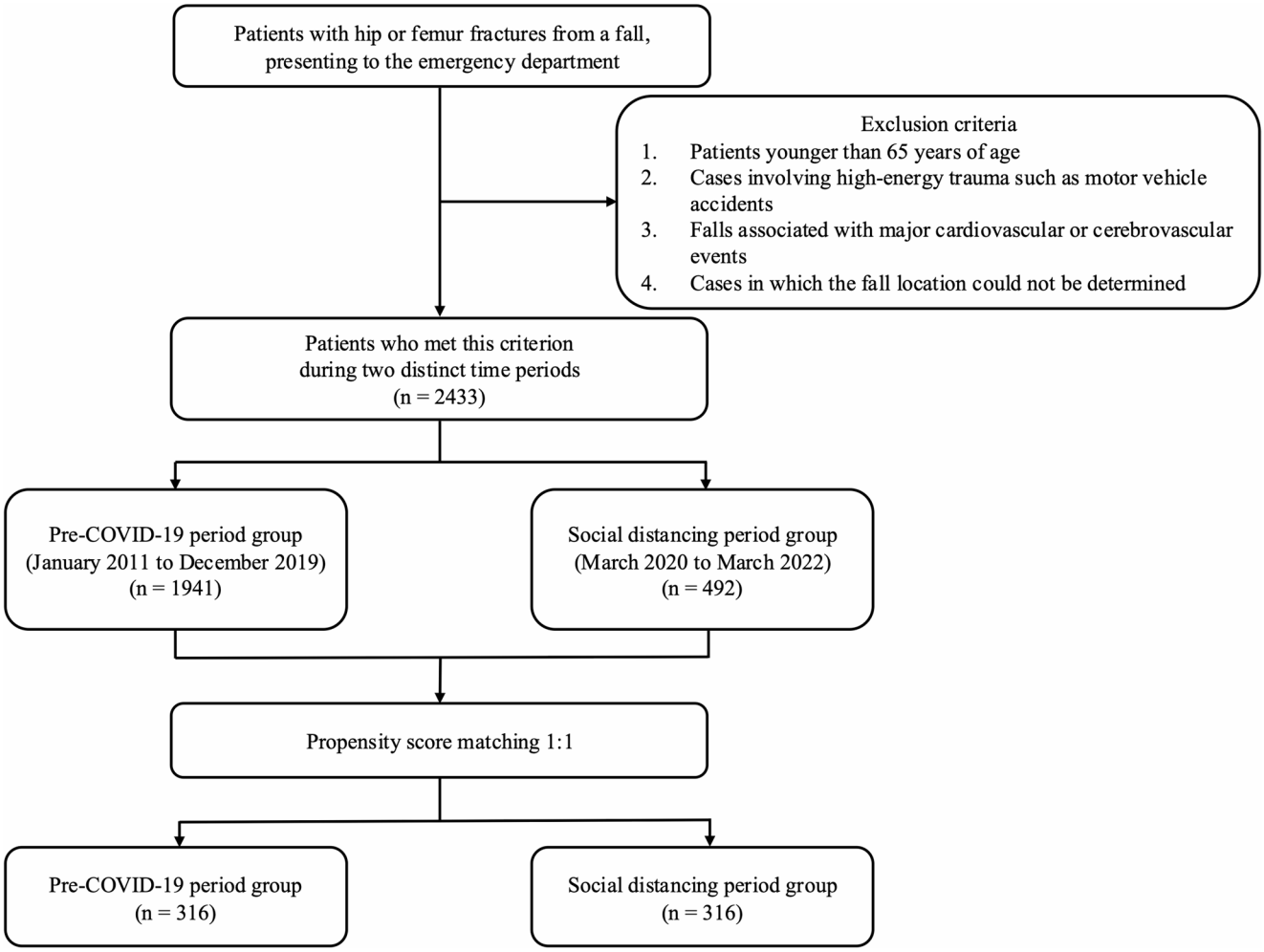

Fig. 1 Study flow diagram of patient selection

Data collection and outcome measures

Data on baseline characteristics and outcomes were extracted from the hospital's electronic medical records and injury registry. Collected variables were age at the time of fracture; sex; body mass index (BMI); Charlson Comorbidity Index (CCI); bone mineral density (BMD) T-score; and fall details of location (indoor vs. outdoor), type of fracture, type of surgical management, and month of visit as confirmed through institutional medical records. Indoor falls included those occurring inside a building (such as the patient's home, a relative's home, or any indoor facility like a bathroom, kitchen, living room, or indoor public space). Outdoor falls were defined as falls occurring outside buildings—for example, on sidewalks, streets, yards, or outdoor public areas [5]. Bone mineral density T-scores were available for 1,898 patients (78.0%) from dual-energy X-ray absorptiometry performed within 6 months of the fracture event.

The primary outcome of interest was whether the fall occurred indoors or outdoors, comparing the two time periods. Secondary outcomes included 1-year mortality, which was determined based on hospital records and corroborated using the date of national health insurance disenrollment as a surrogate marker for death.

Statistical analysis

Continuous variables were summarized as means with standard deviations and compared using Student's t-test if normally distributed. Categorical variables were summarized as counts and percentages and compared using the chi-square test or Fisher's exact test when expected cell counts were small. A two-tailed $p<0.05$ was considered statistically significant for all comparisons. To address confounding effects due to baseline differences between the pre-COVID-19 and social distancing cohorts, we employed propensity score matching (PSM). We calculated propensity scores using a multivariable logistic regression model, with

the time period (pre-COVID-19 vs. social distancing) as the dependent variable and the following covariates: age, sex, BMI, CCI, BMD, type of fracture, type or surgical management, and month of presentation to the emergency department. Using the estimated propensity scores, we performed 1:1 nearest-neighbor matching without replacement, applying a caliper width of 0.2 standard deviations of the logit of the propensity score to ensure matches of reasonable closeness. Covariate balance after matching was assessed using standardized mean differences (SMDs), with values < 0.1 indicating adequate balance. Visual assessment was performed using density plots of propensity score distributions. Additional baseline characteristics not included in the propensity score model (osteoporosis diagnosis, preoperative ambulatory status, and length of stay) were also evaluated post-matching to assess overall cohort comparability. After matching, outcomes were compared between the two groups using the matched cohort, and McNemar's test was applied to evaluate differences in the proportion of indoor falls as the primary outcome.

Results

A total of 2,433 patients with hip and femur-related fractures met the inclusion criteria, with 1,941 occurring in the pre-COVID-19 period and 492 during the COVID-19 social distancing period (Table 1). Mean age was 77.1 ± 8.7 years in the pre-COVID group and 79.4 ± 8.5 years in the social distancing group, a significant difference ($p < 0.001$). There was female predominance in both groups: 70.4% of the pre-COVID fractures and 71.6% of the social distancing period fractures occurred in women, but this difference was not significant ($p = 0.63$). Notably, mean CCI was nearly three times higher in the social distancing group (5.0 ± 1.9) than the pre-COVID-19 group (1.7 ± 2.4, $p < 0.001$), indicating a substantially greater comorbidity burden during the pandemic and suggesting selection bias in patients presenting during this period. Mean BMD T-score was slightly lower in the pre-COVID-19 group (–2.9 ± 1.1) than in the social distancing group (–2.6 ± 0.9), but this difference was not significant ($p = 0.08$).

The distributions of fracture types and surgical management were comparable between the groups ($p = 0.76$ and $p = 0.71$, respectively), as detailed in Supplementary Table 1. Distribution of emergency department visits for fractures by month differed significantly between the pre-COVID-19 and social distancing periods ($p < 0.001$). A higher proportion of visits occurred from March to August during the social distancing period, whereas more cases were concentrated in October to December before the pandemic. After propensity score matching, 316 patients were selected from each period, resulting in a total of 632 patients included in the matched analysis. Distributions of baseline variables were well balanced, with no significant differences observed between the two groups (Table 2). Supplementary Fig. 1

Table 1 Baseline characteristics of the full cohort before and after propensity score matching between the pre-COVID-19 and social distancing periods

	Before propensity score matching				After propensity score matching			
	Pre-COVID-19 period	Social distancing period	Total	*p*	Pre-COVID-19 period	Social distancing period	Total	*p*
n, hips	1941	492	2433		316	316	632	
Age (years)	77.1 ± 9.5	79.4 ± 9.5	77.5 ± 9.6	< 0.001	77.7 ± 9.1	77.8 ± 9.1	77.7 ± 9.1	0.87
Female	1,366 (70.4%)	260 (71.6%)	1,626 (70.6%)	0.68	221 (69.9%)	221 (69.9%)	442 (69.9%)	1.00
Body mass index (kg/m^2)	22.1 ± 3.4	22.2 ± 3.9	22.1 ± 3.5	0.64	22.3 ± 3.9	22.4 ± 3.8	22.3 ± 3.9	0.7
CCI	1.7 ± 2.4	5.0 ± 1.9	2.2 ± 2.6	< 0.001	4.0 ± 2.8	3.8 ± 1.8	3.9 ± 2.4	0.53
Bone mineral density, T-score*	− 2.9 ± 1.1	− 2.6 ± 0.9	− 2.9 ± 1.1	0.08	− 2.7 ± 0.8	− 2.6 ± 0.4	− 2.7 ± 0.6	0.54
Osteoporosis diagnosis				0.12				0.89
Normal	187 (9.6%)	39 (7.9%)	226 (9.3%)		28 (8.9%)	26 (8.2%)	54 (8.5%)	
Osteopenia	628 (32.4%)	183 (37.2%)	811 (33.3%)		106 (33.5%)	109 (34.5%)	215 (34.1%)	
Osteoporosis	1126 (58.0%)	270 (54.9%)	1396 (57.4%)		182 (57.6%)	181 (57.3%)	363 (57.4%)	
Preoperative ambulatory status				0.21				0.92
Independent ambulation	1068 (55.0%)	246 (50.0%)	1314 (54.0%)		168 (53.2%)	165 (52.2%)	333 (52.7%)	
Ambulation with aid	679 (35.0%)	187 (38.0%)	866 (35.6%)		113 (35.8%)	116 (36.7%)	229 (36.2%)	
Wheelchair / bedridden	194 (10.0%)	59 (12.0%)	253 (10.4%)		35 (11.0%)	35 (11.1%)	70 (11.1%)	
Length of stay (days)	5.8 ± 2.1	4.9 ± 1.8	5.6 ± 2.0	0.09	5.7 ± 2.0	5.1 ± 1.7	5.4 ± 1.9	0.21

CCI, Charlson Comorbidity Index

*Available in 1,514/1,941 (78.0%) and 384/492 (78.0%) patients, respectively

Table 2 Comparison of fracture type, surgical management, and month of visit between pre-COVID-19 and social distancing periods after propensity score matching

	After propensity score matching			
	Pre-COVID-19 period	Social distancing period	Total	*p*
n, hips	316	316	632	
Type of fracture				1.00
Femur neck	124 (39.2%)	122 (38.6%)	246 (38.9%)	
Intertrochanteric	113 (35.8%)	114 (36.1%)	227 (35.9%)	
Femur shaft	47 (14.9%)	48 (15.2%)	95 (15.0%)	
Subtrochanteric	15 (4.7%)	16 (5.1%)	31 (4.9%)	
Periprosthetic	17 (5.4%)	16 (5.1%)	33 (5.2%)	
Type of surgical management				0.84
Arthroplasty	135 (42.7%)	130 (41.1%)	265 (41.9%)	
Internal fixation	173 (54.8%)	176 (55.7%)	349 (55.2%)	
Conservative	8 (2.5%)	10 (3.2%)	18 (2.9%)	
Month of visit				0.70
January	25 (7.9%)	19 (6.0%)	44 (7.0%)	
February	25 (7.9%)	25 (7.9%)	50 (7.8%)	
March	28 (8.9%)	28 (8.9%)	56 (8.9%)	
April	35 (11.1%)	33 (10.3%)	68 (10.8%)	
May	25 (7.9%)	31 (9.8%)	56 (8.9%)	
June	22 (6.9%)	28 (8.9%)	50 (7.8%)	
July	28 (8.9%)	28 (8.9%)	56 (8.9%)	
August	34 (10.8%)	31 (9.8%)	65 (10.3%)	
September	28 (8.9%)	28 (8.9%)	56 (8.9%)	
October	25 (7.9%)	21 (6.6%)	46 (7.3%)	
November	16 (5.0%)	22 (7.0%)	38 (6.0%)	
December	25 (7.9%)	22 (7.0%)	47 (7.4%)	

Table 3 Distribution of fall location (indoor vs. outdoor) and 1-year mortality before and after propensity score matching between pre-COVID-19 and social distancing cohorts

	Before propensity score matching			After propensity score matching		
	Pre-COVID-19 period	Social distancing period	*p*	Pre-COVID-19 period	Social distancing period	*p*
N, hips	1941	492		316	316	
Location of fall			0.37			0.02
Indoors	1305 (67.2%)	315 (64.1%)		214 (67.7%)	193 (61.1%)	
Outdoors	636 (32.8%)	177 (35.9%)		102 (32.3%)	123 (38.9%)	
1-yr mortality	352 (18.1%)	95 (19.3%)	0.59	58 (18.4%)	62 (19.6%)	0.76

shows the density plots of propensity scores before and after matching, demonstrating substantial improvement in the overlap of distributions between groups. All covariates achieved SMDs < 0.1 after matching, confirming excellent balance (Supplementary Table 2).

In the unmatched analysis, 67.2% of fractures in the pre-COVID period and 64.1% in the social distancing period resulted from indoor falls, with no significant difference ($p = 0.37$), as shown in Table 3. However, after matching for confounding factors, the difference became more pronounced and significant. In the propensity-matched cohort, indoor falls decreased from 67.7% (214 of 316) in the pre-COVID group to 61.1% (193 of 316) in the social distancing group, while outdoor falls correspondingly increased from 32.3% (102 of 316) to 38.9% (123 of 316). This represented a significant shift in fall location distribution (absolute risk difference −6.6% points, 95% CI -14.0 to 0.8; paired odds ratio 1.82, 95% CI 1.09–3.07; $p = 0.02$).

Prior to matching, 1-yr mortality was similar between groups, at 18.1% in the pre-COVID group and 19.3% in the social distancing group ($p = 0.59$). After matching, 1-yr mortality was 18.4% in the pre-COVID group and 19.6% in the social distancing group, with no significant difference ($p = 0.76$).

Discussion

This retrospective cohort study revealed a notable change in the pattern of falls among older adults during the COVID-19 social distancing period in South Korea. After PSM, we found a significant shift in fall location distribution: indoor falls decreased from 67.7% to 61.1%, while outdoor falls increased from 32.3% to 38.9% during the pandemic social distancing period ($p = 0.02$). Our single-center data showed that among patients presenting with hip and femur fractures

Table 4 Competing hypotheses for indoor fall patterns during COVID-19 social distancing period

Factors decreasing indoor falls	References	Factors potentially increasing indoor falls	References
Increased family supervision - Family members working from home providing oversight and assistance for older adults	[14, 18, 22, 23]	**Reduced outdoor exposure** - More time at home leading to fewer outdoor fall opportunities	[12, 13]
Heightened caution - Awareness of hospitalization risks during pandemic leading to more careful behavior	[14]	**Physical deconditioning** - Prolonged inactivity causing muscle weakness and balance deterioration	[15, 16]
Multigenerational household structure - Adult children/grandchildren providing protective oversight in Korean families	[15]		
Selection effect - Healthier individuals continuing outdoor activities, shifting fall proportions	[5, 18, 24]		

to our tertiary care hospital, the proportion resulting from indoor falls was lower during the social distancing period. However, this observation should be interpreted cautiously given the retrospective design and potential selection biases inherent in single-center studies. This finding contrasts with what might have been expected given that older adults were spending more time at home during the pandemic.

There are several potential explanations for the decrease in incidence of indoor falls observed during the social distancing period. One potential mechanism that may explain our findings is increased supervision and caution [14, 19, 22]. With many family members working from home or refraining from outside activities during the pandemic, vulnerable seniors who live with family could have had more supervision and assistance in daily tasks [23]. This might have reduced high-risk activities that often lead to indoor falls. Even for those living alone, heightened awareness of the risks associated with hospitalization during the COVID-19 pandemic might have influenced behavior. Older adults also could have become more cautious in their homes, knowing that an injury would likely necessitate a hospital visit.

We hypothesize that South Korea's multigenerational household structure, where approximately 20–30% of older adults live with their adult children [24], might have played a protective role, though our study cannot directly confirm this mechanism. Adult children or grandchildren who were working or studying from home could have provided oversight for older family members, potentially preventing falls that might have otherwise occurred when seniors were alone at home [15]. This cultural context can partly explain our findings and differentiates the South Korean experience from countries where older adults more commonly live alone.

Conversely, the relative increase in the proportion of outdoor falls during the same period (from 32.3% to 38.9%) represents a striking and counterintuitive finding that warrants careful interpretation. It is likely that those who ventured outdoors were relatively healthier or more active, engaging in physical activity such as walking for exercise or going out for essential errands [19, 25]. These individuals, being more mobile, are typically at greater risk for outdoor falls under normal circumstances [5]. During social distancing, there were far fewer casual outdoor trips, but those who did go out might have encountered hazards such as uneven sidewalks or lack of usual support [13]. Additionally, the pandemic may have created unique outdoor risks: reduced street maintenance, empty sidewalks with less immediate assistance available, and the absence of usual community support structures. This shift suggests that while frail older adults who typically fall indoors may have benefited from increased family supervision, the active subgroup who maintained outdoor activities faced heightened risks in altered environmental conditions.

This phenomenon aligns with prior knowledge that indoor and outdoor falls often involve different subpopulations of older adults [5, 26]. Indoor falls disproportionately involve the frailest individuals who tend to fall while performing activities of daily living at home, whereas outdoor falls involve relatively robust seniors who are engaged in community or leisure activities outside [21]. Our matched analysis finding of a lower proportion of indoor falls during the pandemic suggests that individuals of greater frailty, who are prone to indoor falls, might have experienced fewer falls or not have presented to the hospital. In contrast, active older adults, who are more likely to fall outdoors, continued to experience falls and sought hospital care even during the social distancing period [17]. To synthesize these competing mechanisms, Table 4 presents the factors that could explain the observed decrease in indoor falls alongside theoretical factors that might have increased indoor falls during the pandemic. Our findings support the dominance of protective factors (increased supervision, behavioral caution, and multigenerational support) over risk factors (deconditioning and reduced mobility) in determining indoor fall patterns during social distancing.

The most striking finding from our study was the nearly three-fold higher CCI in patients presenting during the COVID-19 period (5.0 ± 1.9 vs. 1.7 ± 2.4, $p < 0.001$),

representing a fundamental shift in the characteristics of hip fracture patients. This finding suggests that patients with more serious comorbidities made up a greater proportion of those seeking care for falls during the pandemic [27]. However, this dramatic increase in comorbidity burden constitutes a critical selection bias that must be considered when interpreting all our results. Several studies have reported similar findings. Zhong et al. found that hip fracture patients during COVID-19 had higher comorbidity burdens, which might reflect a selection effect where only those with more severe health conditions sought hospital care during the pandemic [21]. Others have suggested that the stress and disruption of the pandemic exacerbated chronic conditions in vulnerable populations [28, 29].

In South Korea, particularly among tertiary referral centers such as the hospital in which this study was conducted, access to emergency departments was significantly restricted due to rigorous pre-triage protocols, infection control measures, and periodic closures following in-hospital COVID-19 exposures [30]. These institutions prioritized critically ill patients and limited admission of non-urgent cases, effectively creating a higher threshold for hospital presentation [31]. Consequently, patients with fewer comorbidities might have deferred or avoided hospital visits during this period, while those with a higher disease burden were more likely to present for urgent care, contributing to the elevated comorbidity profile observed in our cohort. This selection bias also could have been compounded by pandemic-related disruptions in the management of chronic diseases, further exacerbating baseline health status in the presenting population.

We also observed significant differences in the seasonal distribution of fractures between the pre-COVID-19 and social distancing periods. During the social distancing period, a higher proportion of fractures occurred from March to August, whereas in the pre-COVID-19 period, cases were more concentrated in October to December. This shift might reflect changing activity patterns during the pandemic, with older adults potentially avoiding outdoor activities during winter months due to both seasonal hazards and heightened pandemic concerns [11, 32]. However, as our matching procedure accounted for month of presentation, the observed differences in indoor versus outdoor fall proportions are independent of these seasonal variations [17].

Under normal circumstances, studies have shown that indoor falls account for approximately 50–80% of all falls among older adults, with variation depending on the population studied [33]. In several studies of community-dwelling older adults, indoor falls represented 60–70% of all falls, with a higher proportion of indoor falls being associated with advancing age, frailty, and reduced functional capacity [34]. This pattern highlights the importance of decreasing the proportion of indoor falls during the pandemic as it represents a deviation from the expected pattern. When contextualizing our findings within the broader pandemic literature, an interesting paradox emerges. While several international studies and a nationwide Korean cohort study by Jang et al. reported significant reductions in hip fracture incidence during the COVID-19 period [10, 18, 35], our single tertiary care center observed relatively stable monthly admission rates (18.0 vs. 19.7 cases per month). This discrepancy may reflect the unique characteristics of the Korean healthcare system and referral patterns to tertiary centers. During the pandemic, patients with significant comorbidities—as evidenced by the higher CCI in our cohort (5.0 vs. 1.7, $p < 0.001$)—may have preferentially sought care at tertiary hospitals, while those with less severe conditions deferred treatment or visited local hospitals. Additionally, the concentration of complex cases at our tertiary center may have maintained admission volumes despite an overall population-level decline in hip fractures. This highlights the importance of considering healthcare system-specific factors when interpreting pandemic-related changes in fracture epidemiology.

Other international studies have reported diverse findings. Slullitel et al. reported a 53.7% reduction in hip fracture admissions during Argentina's lockdown [35], while Steinfeld et al. found that hospital admissions for hip fractures following a fall among older adults in Israel decreased significantly during the first lockdown period [36]. However, these studies focused on overall admission volumes during pandemic restrictions and did not analyze the proportion of indoor versus outdoor falls among patients who presented with fractures. Our study uniquely examines fall location patterns within the fracture population, revealing how the pandemic altered not the volume but the circumstances of falls. This methodological difference limits direct comparison of fall location patterns across different pandemic response strategies, highlighting the need for standardized approaches in future multi-national studies.

Some studies have reported increases in falls over longer pandemic periods. For example, Minato et al. noted that, while the total number of patients with major fragility fractures decreased during the first wave of the COVID-19 epidemic in Japan, patterns changed in subsequent waves [23]. This suggests that the initial behavioral adaptations we observed evolve over a longer timeframe [1], as captured given our extended observation period.

This study also has several limitations that should be acknowledged. First, it was a single-center study, and the experience of our hospital and region might not be generalizable to all settings. Second, as an observational study, it could not establish causality because unmeasured confounders might have influenced the results. However, we

utilized a rigorous PSM methodology to address potential confounding effects and selection bias, allowing more valid comparisons between the pre-COVID-19 and social distancing periods. Our matching procedure included not only demographic and clinical factors but also fracture type, surgical management, and month of presentation, which helped to control for potential seasonal and injury-specific variations. Third, the reduction in hospital-fracture cases during the pandemic means that we might have missed information on falls that did happen but were not treated at a hospital. We tried to mitigate this by focusing on matched comparisons, but it remains a concern. Fourth, we lacked detailed information on the exact circumstances of falls, including specific activities being performed at the time of the fall, which would have provided deeper insight into fall mechanisms during the pandemic. However, we had detailed clinical information on each fall case, including the specific location of the fall, which enabled us to analyze this important aspect of fall epidemiology during the pandemic. Fifth, the extended pre-COVID-19 period (2011–2019) compared to the COVID-19 period (2020–2022) might have introduced historical biases, although our matching procedure should have minimized the impact of this on our primary findings. Nevertheless, inclusion of a relatively long observation period both before and during the pandemic allowed us to assess long-term trends and seasonal variations in fall patterns, strengthening the validity of our conclusions. Sixth, we lacked information about patients' living arrangements, preventing analysis of whether family supervision effects differed between those living with family versus alone. Future studies should collect data on household composition to understand its influence on fall patterns during social restrictions. Seventh, our propensity score matching could not include important covariates such as living arrangement, cognitive status, prior fracture history, and anti-osteoporotic medication use, as these were not systematically documented in emergency department records. This may have resulted in residual confounding. Eighth, we lacked detailed information about specific fall locations (private homes versus institutions, or specific areas like bathrooms or stairs), which critically limits our ability to interpret the role of household structure or institutional factors in the observed fall pattern changes. Without this stratification, our discussion of multigenerational household effects remains speculative. Ninth, significant selection bias likely influenced our results. As a tertiary care center during the pandemic, we predominantly received patients with higher comorbidity burden (CCI 5.0 vs. 1.7), while those with fewer comorbidities may have sought care elsewhere or deferred treatment. This selection bias, compounded by pandemic-related disruptions in chronic disease management, limits the generalizability of our findings to the broader hip fracture population. Finally, our study period ended in March 2022, precluding analysis of fall patterns during the post-COVID-19 recovery phase when social activities resumed and family supervision patterns changed, which represents an important area for future investigation.

Conclusions

In our single-center retrospective cohort, the proportion of indoor falls among hip and femur fracture patients decreased during COVID-19 social distancing. However, significant selection bias evidenced by markedly higher comorbidity burden (CCI 5.0 vs. 1.7) limits generalizability. Despite older adults spending more time at home during the pandemic, the proportion of fractures from indoor falls decreased while outdoor fall proportions increased, suggesting a shift in fall patterns. Patients who sought care during this period also exhibited significantly higher comorbidity burdens, reflecting changes in healthcare-seeking behavior. Despite these limitations, our findings suggest that pandemic-related behavioral changes may alter fall patterns in older adults, highlighting the need for adaptive fall prevention strategies during public health emergencies.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40520-025-03253-8.

Acknowledgements Not applicable.

Author contributions KKP contributed to the critical revision of the manuscript and performed the statistical matching. BWC was responsible for clinical data collection and supported the statistical analysis. HMK contributed to the outcome evaluation and prepared the figures and tables. WSL supervised the overall study process. KTK contributed to the critical revision of the manuscript. JYP conceived and designed the study, oversaw data interpretation, and drafted the manuscript. All authors reviewed and approved the final manuscript and agree to be accountable for all aspects of the work.

Funding This study was supported by a faculty research grant of Yonsei University College of Medicine (6-2023-0151).

Data availability The datasets analyzed during the current study are not publicly available due to patient privacy and institutional policy but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate This study was approved by the Institutional Review Board of Yongin Severance Hospital (9-2025-0054). The requirement for informed consent was waived due to the retrospective nature of the study. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

1. Chung YY, Baek SN, Park TG, Kim MY (2023) The effects of COVID-19 pandemic on the recovery of hip fracture patients. Hip Pelvis 35:253–258. https://doi.org/10.5371/hp.2023.35.4.253
2. Kitcharanant N, Atthakomol P, Khorana J, Phinyo P, Unnanuntana A (2024) Prognostic factors for functional recovery at 1-Year following fragility hip fractures. Clin Orthop Surg 16:7–15. https://doi.org/10.4055/cios23177
3. Choi JY, Park JW, Kim KI, Lee YK, Kim CH (2025) Prediction of 5-Year survival rate after hip fracture surgery using a comprehensive geriatric Assessment-Based frailty score model. J Korean Med Sci 40:e40. https://doi.org/10.3346/jkms.2025.40.e40
4. Li Y, Liu C, Lu J, Sun H, Li Y (2024) Relationship between muscle and subcutaneous adipose tissue size and density and proximal femur bone in elderly women with hip fracture. Aging Clin Exp Res 36:130. https://doi.org/10.1007/s40520-024-02782-y
5. Burm SW, Hong N, Lee SH et al (2021) Fall patterns predict mortality after hip fracture in older Adults, independent of Age, Sex, and comorbidities. Calcif Tissue Int 109:372–382. https://doi.org/10.1007/s00223-021-00846-z
6. Choi KA, Ha YC, Lee KH (2023) Seasonal variations and common places of hip fractures in elderly patients: nine year consecutive survey. J Bone Metab 30:103–114. https://doi.org/10.11005/jbm.2023.30.1.103
7. Jansen CP, Engdal M, Peter RS et al (2024) Sex differences in mobility recovery after hip fracture: a time series analysis. Front Public Health 12:1434182. https://doi.org/10.3389/fpubh.2024.1434182
8. Hall AJ, Clement ND, Farrow L et al (2020) IMPACT-Scot report on COVID-19 and hip fractures. Bone Joint J 102–b:1219–1228. https://doi.org/10.1302/0301-620x.102b9.Bjj-2020-1100.R1
9. Yoshida S, Miyamori D, Ito M (2025) Effect of the 2018 Japan floods and COVID-19 pandemic on cognitive decline among atomic bomb survivors in Hiroshima, japan: a retrospective cohort study. Aging Clin Exp Res 37:152. https://doi.org/10.1007/s40520-025-03054-z
10. Jang SY, Cha Y, Kim Y, Kim KJ, Kim H, Choy W (2023) Analysis of the effects of COVID-19 on hip fractures in Korea without lockdown: interrupted time series analysis using a nationwide cohort. J Korean Med Sci 38:e137. https://doi.org/10.3346/jkms.2023.38.e137
11. Kim JH, Kwon MJ, Choi HG et al (2023) Changes in the mean incidence and variance of orthopedic diseases before and during the COVID-19 pandemic in korea: a retrospective study. BMC Musculoskelet Disord 24:540. https://doi.org/10.1186/s12891-023-06634-0
12. Nakamura M, Imaoka M, Nakao H et al (2021) Increased anxiety about falls and walking ability among community-dwelling Japanese older adults during the COVID-19 pandemic. Psychogeriatrics 21:826–831. https://doi.org/10.1111/psyg.12750
13. Lindeman K, Karavirta L, Koivunen K et al (2024) Longitudinal changes in life-space mobility and autonomy in participation outdoors among Finnish community-dwelling older adults from pre-COVID-19 to through the pandemic. Aging Clin Exp Res 36:85. https://doi.org/10.1007/s40520-024-02734-6
14. Ronel D, Keren Y, Muallem A, Elboim-Gabyzon M (2022) The effect of physical and social isolation due to the COVID-19 pandemic on the incidence of hip fractures among senior citizens. Geriatr Nurs 43:21–25. https://doi.org/10.1016/j.gerinurse.2021.10.018
15. Hagino H (2021) Current and future burden of hip and vertebral fractures in Asia. Yonago Acta Med 64:147–154. https://doi.org/10.33160/yam.2021.05.001
16. Batista PP, Perracini MR, do Carmo Correia, de Lima M, de Amorim JSC, Pereira DS, Pereira LSM (2024) Risk of sarcopenia and mobility of older adults during the COVID-19 pandemic: the longitudinal data from the REMOBILIZE study. Aging Clin Exp Res 36:80. https://doi.org/10.1007/s40520-024-02720-y
17. Mitsutake S, Lystad RP, Long JC, Braithwaite J, Mitchell R (2024) Impact of COVID-19 public health restrictions on fall-related hip fracture hospitalizations: an interrupted time series analysis. Bone 188:117237. https://doi.org/10.1016/j.bone.2024.117237
18. Ojeda-Thies C, Cuarental-García J, Ramos-Pascua LR (2021) Decreased volume of hip fractures observed during COVID-19 lockdown. Eur Geriatr Med 12:759–766. https://doi.org/10.1007/s41999-020-00447-3
19. Tanaka S, Osawa Y, Takegami Y et al (2024) Changes of hip fracture in older patients before and after the COVID-19 pandemic: a retrospective multicentre study in Japan. BMC Musculoskelet Disord 25:1006. https://doi.org/10.1186/s12891-024-08050-4
20. Bub CD, Larsen CG, Heimroth J et al (2021) Hip fracture trends and outcomes during the COVID-19 pandemic. Orthopedics 44:293–298. https://doi.org/10.3928/01477447-20210819-05
21. Zhong H, Poeran J, Liu J, Wilson LA, Memtsoudis SG (2021) Hip fracture characteristics and outcomes during COVID-19: a large retrospective National database review. Br J Anaesth 127:15–22. https://doi.org/10.1016/j.bja.2021.04.003
22. Nozaki A, Imai N, Shobugawa Y, Horigome Y, Suzuki H, Kawashima H (2024) Hip fractures in elderly individuals did not decrease during the coronavirus disease 2019 pandemic: insights from the 2015 and 2020 Niigata Prefecture fragility hip fracture surveys. Med (Kaunas) 60. https://doi.org/10.3390/medicina60040573
23. Minato K, Shin JH, Kunisawa S, Fushimi K, Imanaka Y (2023) The total number of patients with any of four major fragility fractures decreased during the first wave of the COVID-19 epidemic in Japan, commencing before the state of emergency declaration, which was not as enforceable as lockdown. Arch Osteoporos 18:86. https://doi.org/10.1007/s11657-023-01297-9
24. Kye B, Choi Y (2021) Are parents and children coresiding less than before? An analysis of intergenerational coresidence in South Korea, 1980–2015. Demographic Res 45:1–16
25. Mazeda C, Santos PB, Vilas-Boas P, Antão J, Barcelos A (2021) What happened to hip fragility fractures during COVID-19 pandemic? Acta Reumatol Port 46:252–256
26. Craig J, Maguire M, Shevlin SP, Black ND (2021) The effects of COVID-19 on hip fracture management and mortality in a regional trauma centre. Anaesthesia 76:710–711. https://doi.org/10.1111/anae.15323

27. Sahin UK, Durdu H, Korkmaz N (2023) The role of frailty on quality of life in older adults during the COVID-19 pandemic. Aging Clin Exp Res 35:1779–1787. https://doi.org/10.1007/s40520-023-02469-w
28. Rincón-Hoyos JA, Vallejo-Yepes P, Restrepo-Giraldo JN et al (2023) Morbidity and mortality in hip surgery patients due to fracture during the COVID-19 pandemic. Injury 54 Suppl 6:110731. https://doi.org/10.1016/j.injury.2023.04.018
29. Shen H, He R, Zhang P et al (2023) Risk factors for postoperative medical morbidity and 3-month mortality in elderly patients with hip fracture following hip arthroplasty during COVID-19 pandemic. J Orthop Surg Res 18:59. https://doi.org/10.1186/s13018-023-03511-3
30. Lee KS, Sung HK, Choi YY, Han C, Min HS (2024) Impact of the early COVID-19 pandemic on emergency department visits of adult cancer patients with fever or respiratory symptoms: A Korean nationwide Population-Based Study, 2016–2020. J Korean Med Sci 39:e187. https://doi.org/10.3346/jkms.2024.39.e187
31. Song E, Hwang J, Park SJ et al (2023) Impact of diabetes on emergency care of acute myocardial infarction patients during the coronavirus disease 2019 pandemic: a nationwide population-based study. Front Public Health 11:1151506. https://doi.org/10.3389/fpubh.2023.1151506
32. da Silva AC, da Silva Santos G, Maluf E, Borba VZC (2022) Incidence of hip fractures during the COVID-19 pandemic in the Brazilian public health care system. Arch Osteoporos 17:42. https://doi.org/10.1007/s11657-022-01078-w
33. Kelsey JL, Berry SD, Procter-Gray E et al (2010) Indoor and outdoor falls in older adults are different: the maintenance of balance, independent living, intellect, and zest in the elderly of Boston study. J Am Geriatr Soc 58:2135–2141. https://doi.org/10.1111/j.1532-5415.2010.03062.x
34. Molés Julio MP, Lavedán Santamaría A, Botigué Satorra T, Masot Ariño O, Esteve Clavero A, Maciá Soler ML (2020) Characteristics and circumstances of falls in the Community-Dwelling older adult population. J Prim Care Community Health 11:2150132720940508. https://doi.org/10.1177/2150132720940508
35. Slullitel PA, Lucero CM, Soruco ML et al (2020) Prolonged social lockdown during COVID-19 pandemic and hip fracture epidemiology. Int Orthop 44:1887–1895. https://doi.org/10.1007/s00264-020-04769-6
36. Steinfeld Y, Ben Natan M, Yonai Y, Berkovich Y (2021) Hip fracture following a fall among older adults during the COVID-19 pandemic. Isr Med Assoc J 23:479–483