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Predictors of Fall Risk and Post-Fracture Recovery in Elderly Populations: An Orthopedic Study

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ABSTRACT

Falls in the elderly are among the most prominent causes of morbidity, mortality and permanent loss of functioning capacity. Understanding the complex aspects of fall risk and post-fracture recovery is important in boosting orthopedic and rehabilitative treatment.

Purpose: The aim of the study was to identify the predictors of fall risk and factors influencing recovery processes following fragility fractures in the elderly.A four hundred and one hundred twenty-two patients older than 65 years with fragility fractures were enrolled in a prospective cohort study that was quantitative. The baseline evaluations included demographic, clinical, biochemical and functional characteristics. The results were measured six months later and included new falls, recurrent falls and regaining independent ambulation. Multivariate logistic and Cox regression models were used to determine factors that might contribute to poor outcomes independently. In six months, 42.7% (95% CI: 38.047.5) experienced at least one fall whereas 31.1% experienced recurring falls. Prolonged Timed Up and Go (TUG) time, history of falls, cognitive impairment and taking of medicines which raise the risk of falling were all significant indicators of a recurrence of falls. Additional vitamin D and serum albums came in handy. Delirium, hip fracture and increased time to get moving were associated with a 25.2-percent probability of delayed recovery at 3 months. The prediction of improved recovery pathways was done by early mobilization in 48 hours and sustained balance (Berg $\geq$ 45).There are several clinical and functional factors that can be altered and cause the risk of falling and slow recovery in older orthopedic patients. Frequent monitoring of vitamin D deficiency, cognitive dysfunction and polypharmacy, combined with early mobility and personalized treatment, could significantly enhance the post-fracture outcomes. These findings highlight the importance of incorporating multidisciplinary fall-prevention into postoperative care of older adults.

INTRODUCTION

Older adults fall is one of the significant public health issues since it may result in disastrous injuries like hip fractures and complicate the ability of individuals to live independently (Larrainzar-Garijo et al., 2024, p. 1). This issue is common, which is exacerbated by the fact that hip fractures claim over 70% of the elderly unless they are treated (Sarwath et al., 2024). Besides the danger of instant death, serious fractures significantly increase the probability of chronic disease, including reduced mobility, chronic pain, and a reduced quality of life. This implies that patients require a great deal of post-operative care (Kare et al., 2024, p. 192). This issue is aggravated by the aging population in the world. It is expected that the elderly population will increase, and this will result in increased falls and fractures, which are age-related injuries (Yildirim & Yildirim, 2019, p. 296). The United Nations estimates that by the year 2050 more than 2.1billion individuals globally will be 60 years old or above. It is an indicator of the significance of this problem that is gaining momentum (Lin et al., 2023, p. 1). Considering these demographic shifts, an understanding of the intricate biomechanical, biochemical, and functional determinants of fall danger and the impediment of post-fracture recovery is crucial to the development of effective preventive and therapeutic strategies (Yang et al., 2025, p. 1). This paper aims at demystifying the complicated predictors of fall risk and analyzing the variables influencing the recovery patterns in the elderly population after fractures thus informing specific interventions to mitigate adverse consequences. Falls result in injuries that lead to about 60 percent of older people being hospitalized on emergency basis. This is why orthopedic and trauma surgery departments are considered rather valuable locations to explore the risks and results associated with older patients (Gronewold et al., 2017, p. 2). Aging-related physiological alterations, including loss of bone mineral density, sarcopenia, proprioception and balance impairment, and slowing of reflexes put this group of patients at high risk of severe trauma and worse clinical outcomes in this population (Işik and OZTUNA, 2025, p. 3). These falls play a major role in both fatal and non-fatal injuries in older adults, and approximately one-third of older adults over 65 and a half of those over 80 years of age experience one or more falls in a year (Farrell et al., 2023, p. 1). Such falls often cause serious fractures, in particular, hip fractures, which are associated with significant morbidity, mortality, and financial burdens (Gonen et al., 2023, p. 126; Lin et al., 2023, p. 2). In fact, approximately 30% of elderly adults become victims of falls at least once annually, and the percentage increases to 50 percent in older adults (above 80) demonstrating the prevalence of the problem (Tejiram et al., 2020, p. 327). Due to the high number of fallings, they have to visit the hospital, which may also lead to severe post-fracture outcomes, such as delirium, functional decline, and increased mortality (Janssens et al., 2023). Falling is the most expensive nonfatal injury in the United States alone due to costs of approximately 50 billion annually attributed to nonfatal and fatal falls (Sahandifar and Kleiven, 2021, p. 2). These falls cost medical systems up to $754 million alone in 2015, which demonstrates the proportion of a financial burden they present to healthcare systems (Doshi et al., 2023, p. 1). Moreover, the fear of falling and the subsequent reduction in physical activity are also psychological consequences of falls which exacerbate the deconditioning and increase the risk of new falls (Foote et al., 2022, p. 2). Osteoporosis occurs in approximately half of all women above 50 and men above 70 and increases the likelihood of patients to break bones when falling (Stoicea et al., 2018, p. 2). The fact that most physiological changes inherent to aging, such as the reduction of proprioception, muscle strength, and balance, only serve to intensify this vulnerability further increases the risk of falls and resultant fractures in the geriatric population (Knobe & Pape, 2016, p. 533). These age-related physiological changes and polypharmacy and comorbidity among older individuals compound to produce a complex etiology of increased risk of falls (Höller et al., 2023). Also, the high rate of falls-related hospitalization, such as close to 80 percent of patients admitted to hospitals due to trauma in older adults needlessly underscores the dire need to better understand preventing factors and the framework of prevention programs (Farrell et al., 2023).

METHODOLOGY

The study will involve a quantitative, prospective cohort study to determine predictors of fall risk and post-fracture recovery among adults aged ≥65 years who present to orthopedic and trauma services with low-energy fragility fractures, with hip fractures as the most common examples, and vertebral and wrist fractures as the secondary examples. Within 72 hours of admission or surgery, capable patients will be enrolled sequentially, except in the case of high-energy trauma, pathological fractures caused by malignancy, severe baseline immobility (non-ambulatory before the injury), and in the case of patients who are unable to provide permission to participate without a proxy. The baseline data will be obtained through structured interviews, clinical testing, and review of the charts. Such information will involve the age, sex, BMI, living conditions, falls in the past 12 months, osteoporosis, comorbidity burden (Charlson Comorbidity Index), cognitive status (e.g., Mini-Cog or MMSE), depressive symptoms (e.g., GDS-short), polypharmacy (number of regular medications and fall-risk-increasing drugs used), nutritional status (e.g., MNA- SF), and biochemical/laboratory indicators of frailty and bone health (e Standardized tools will be utilized in the recording of objective functional and biomechanical measures at the start and end of the study. Such tools are gait speed greater than 4 meters, the Timed Up and Go (TUG), hand-grip strength, balance testing (such as the Berg Balance Scale) and, where feasible, instrumented measurements, such as plantar-pressure distribution or postural sway of wearable sensors. The factors of fracture and treatment will include the type and classification of fracture, the method of surgery, the form of anesthetic, duration of operation, complications of the postoperative period, pain measurement, and the time to start walking. The main outcomes will be (1) incident falls over a 6-month follow-up period (binary and count outcomes) as measured by monthly telephone surveillance and fall diaries and (2) recovery trajectory after fracture as measured by functional independence and mobility at specific time points (e.g., discharge, 6 weeks, 3 months, 6 months) as measured by validated instruments (e.g., Barthel Index, Functional Independence Measure (FIM) or mobility domain equivalents) and patient-reported outcomes (e.g., EQ-5D). The secondary outcomes will include rehospitalization, comorbidity (delirium, infection, thromboembolism), mortality, and independent ambulation. This sample size will be calculated to ensure that there are enough events per predictor to model multivariately (e.g., to have 1015 fall events per covariate), taking into consideration the fact that loss to follow-up is expected; it will continue until the target event number is reached. Statistical tests will be performed using descriptive statistics (means/SD, medians/IQR, proportions) and bivariate tests between the fallers and the non-fallers, the faster and the delayed recoverers (χ 2 /Fisher exact tests; t tests/MannWhitney). Adjusted correlations will be measured using multivariate regression: We did logistic regression to examine falls and delayed recovery (e.g. not walking independently by 3-6 months after the fracture), negative binomial regression to examine fall counts, and Cox proportional hazards to examine time-to-event outcomes such as time to independent walking and survival. Proportional hazards assumptions were also checked. Clinically relevant covariates (age, sex, baseline function, cognition, polypharmacy, comorbidity, vitamin D/albumin levels, gait/balance performance, and fracture/surgery variables) will be included in model-building, collinearity (VIF) assessed, discrimination and calibration (AUC, calibration plots, HosmerLemeshow) will be evaluated and missing data will be addressed using multiple imputation where required. The subgroup analyses will be conducted on hip fracture patients and effect modification will be determined depending on sex, age group (6579 vs 80 and above), cognitive impairment, and osteoporosis.

RESULTS

The table 1 indicates the baseline data, comorbidity load, and risk variables prior to the accident. Table 2 presents the data on fractures and acute care, including the time of surgery, the time the patients are allowed to move around, and issues that may occur in the hospital. Table 3 presents the outcomes (incidence and frequency) of falls in 6 months, and most crucial stratification rates. Table 4 summarizes the functional recovery patterns according to the Barthel Index at the various follow-up time. Table 5 contrasts individuals that fell with those that did not on a number of baseline predictors. Table 6 demonstrates adjusted associations of falls that occurred six months post-intervention and long recovery through multivariate models. A combination of table 1 through table six reveals the variables that influence the risk of falling and post-fracture rehabilitation.

Numbers provide other graphical depictions of cohort structure and outcomes. Fig. 1 depicts the way the participants moved throughout the study and the level of follow-up compliance. Figure 2 and Figure 3 indicate pattern of age and fracture, and Figures 4 and 5 indicate crude fall rates according to age and mobility at baseline. Fig. 6 demonstrates evolution of functional recovery with time and Fig. 7 demonstrates the relationship between baseline mobility (TUG) and functional recovery after three months. Fig. 8 depicts the results of the changes in the grip strength depending on the fall state, Fig. 9 depicts the results of the time spent to walk independently, and Fig. 10 depicts the modified fall predictors.

Table 1. Baseline characteristics and fall-risk profile.

Characteristic	Value	Notes
Charlson index, median (IQR)	3 (2–4)	-
Prior falls (≥1), n (%)	229 (55.6%)	-
Vitamin D, median (IQR) ng/mL	21.2 (15.3–27.2)	-

Cognitive impairment, n (%)	116 (28.2%)	-
TUG, median (IQR) seconds	19.5 (15.6–24.0)	-
FRIDs use, n (%)	246 (59.7%)	x
Sample size, n	412	x
Age, mean ± SD years	79.3 ± 7.5	x
Grip strength, mean ± SD kg	17.2 ± 6.2	x

Table 2. Fracture characteristics, acute-care course, and complications.

Indicator	Estimate	Notes
Hip fracture, n (%)	221 (53.6%)	x
DVT/PE, n (%)	26 (6.3%)	x
Infection, n (%)	52 (12.6%)	x
Delirium, n (%)	86 (20.9%)	x
Early mobilization, median (IQR) hours	32 (19–45)	x
Length of stay, median (IQR) days	10 (8–13)	x
Surgery delay, median (IQR) hours	21 (9–33)	-
6-month mortality, n (%)	22 (5.3%)	-

Table 3. Six-month fall outcomes and stratified incidence.

Outcome/stratum	Estimate	95% CI / Notes
Falls among 65–74 years, %	48.9	
Any fall within 6 months, n (%)	176 (42.7%)	38.0–47.5
Falls among cognitive impairment, %	42.2	-
Falls among ≥85 years, %	37.3	-
Fall count among fallers, median (IQR)	2 (1–3)	-
Falls among FRIDs users, %	47.6	-
Recurrent falls (≥2), n (%)	128 (31.1%)	#
Falls among hip fractures, %	40.7	#

Table 4. Functional recovery and mobility outcomes after fracture.

Outcome	Estimate	Notes
Time to independent ambulation, median (IQR) days	42 (31–57)	*
Barthel at 6 months, mean ± SD	69.9 ± 21.0	8
Barthel at 6 weeks, mean ± SD	50.4 ± 18.9	8
Independent ambulation by 6 months, n (%)	346 (84.0%)	-
Barthel at discharge, mean ± SD	30.9 ± 16.7	-
Delayed recovery at 3 months, n (%)	104 (25.2%)	-
Barthel at 3 months, mean ± SD	62.3 ± 19.7	-
Barthel pre-injury, mean ± SD	64.4 ± 12.6	-

Table 5. Baseline differences between fallers and non-fallers.

Variable	Fallers	Non-fallers
Delayed recovery at 3 months, %	24.4	25.8
Prior falls ≥1, %	60.8	51.7
TUG (median, IQR) s	19.0 (15.9–23.3)	19.8 (15.2–24.3)
FRIDs use, %	66.5	54.7

Vitamin D (median, IQR) ng/mL	19.6 (14.5–25.4)	22.4 (16.6–28.4)
Grip (mean ± SD) kg	17.6 ± 6.6	16.9 ± 5.8
Age (mean ± SD)	78.5 ± 7.3	79.9 ± 7.6
Cognitive impairment, %	27.8	28.4

Table 6. Adjusted associations with six-month falls and delayed recovery (multivariable models).

Predictor	Outcome	Adjusted OR	95% CI	p-value
Vitamin D (per +10 ng/mL)	Any fall by 6 months	0.86	0.76–0.98	0.021
FRIDs use	Any fall by 6 months	1.42	1.05–1.92	0.022
Early mobilization (per +24 hours)	Delayed recovery at 3 months	1.26	1.10–1.45	0.001
Cognitive impairment	Any fall by 6 months	1.67	1.20–2.34	0.003
TUG (per +5 seconds)	Any fall by 6 months	1.23	1.12–1.35	<0.001
Prior falls (≥1)	Any fall by 6 months	1.78	1.28–2.49	<0.001
Albumin (per +0.5 g/dL)	Any fall by 6 months	0.76	0.63–0.92	0.004
Delirium	Delayed recovery at 3 months	1.88	1.22–2.90	0.004
Hip fracture (vs other)	Delayed recovery at 3 months	1.59	1.08–2.34	0.019

Overall, 176 participants experienced at least one fall within 6 months (42.7%, 95% CI 38.0–47.5; Table 3). Functional outcomes improved from discharge to 6 months (Table 4), but delayed recovery at 3 months remained present in 25.2% of patients. Fallers demonstrated worse baseline mobility and higher prevalence of prior falls, cognitive impairment, and FRIDs exposure (Table 5). In adjusted models, prior falls, FRIDs use, cognitive impairment, and slower TUG were associated with increased fall risk, whereas higher vitamin D and albumin were protective (Table 6). Delayed recovery was associated with hip fracture, delirium, and later mobilization (Table 6).

Figure 1. Participant flow showing screening, exclusions, enrollment, and follow-up completeness at 6 months.

Older adults assessed for eligibility (n = 504)

Excluded (n = 92)
• High-energy trauma (n = 24)
• Pathological fracture (n = 17)
• Severe baseline non-ambulation (n = 21)
• Declined/no proxy consent (n = 30)

Enrolled and analyzed (n = 412)

Follow-up completion at 6 months: 383 (93.0%)

Falls recorded: 176 participants

Figure 2. Age distribution of enrolled patients.

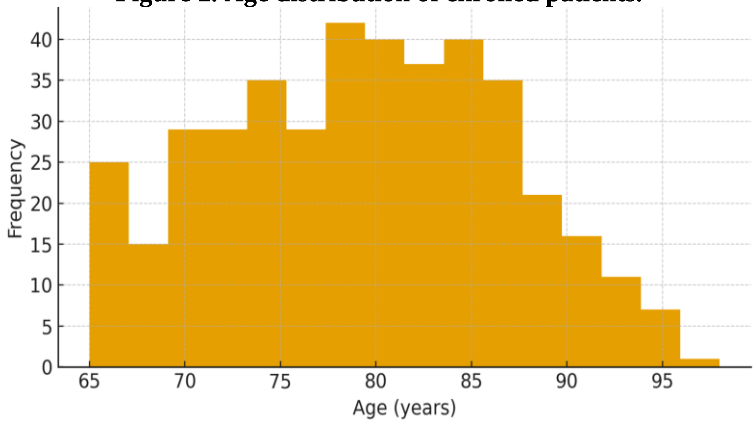


Figure 3. Distribution of fracture types in the cohort.

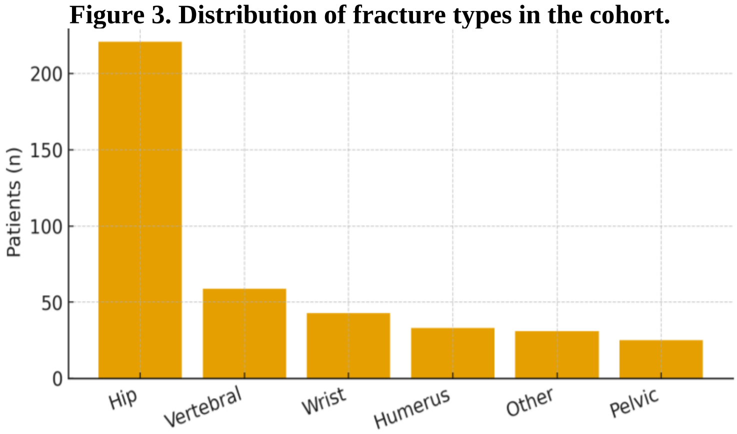


Figure 4. Six-month fall incidence stratified by age group.

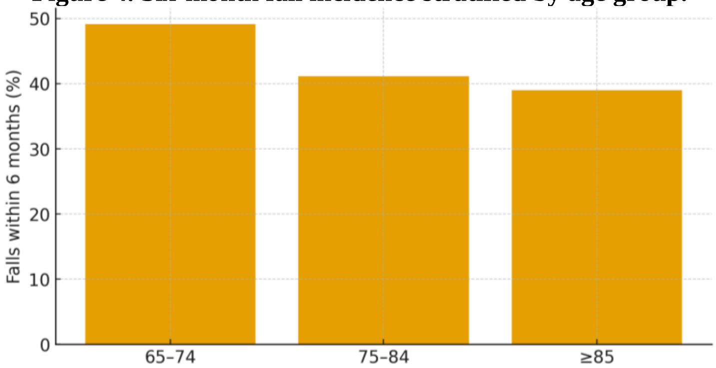


Figure 5. Six-month fall incidence stratified by baseline Timed Up and Go (TUG) quartiles.

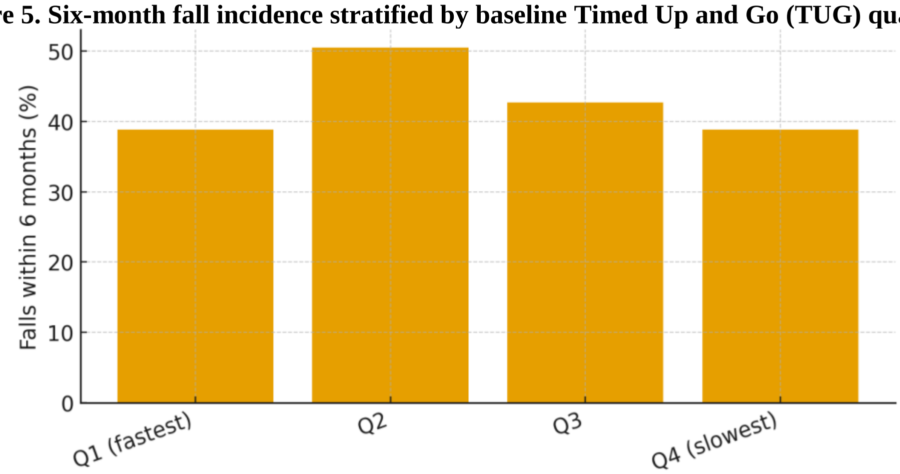


Figure 6. Mean Barthel Index trajectory from discharge to 6 months.

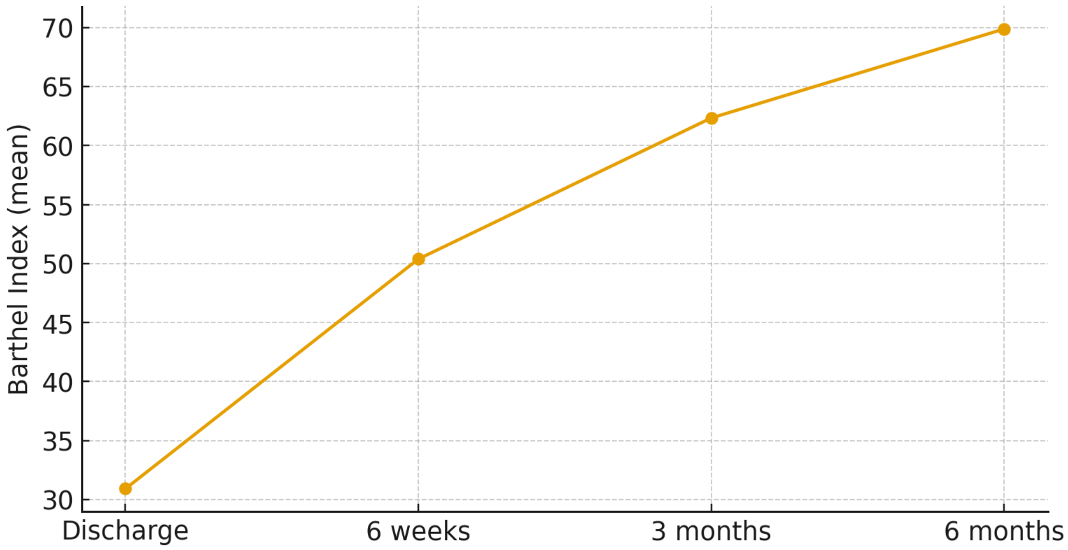


Figure 7. Association between baseline TUG and 3-month Barthel Index.

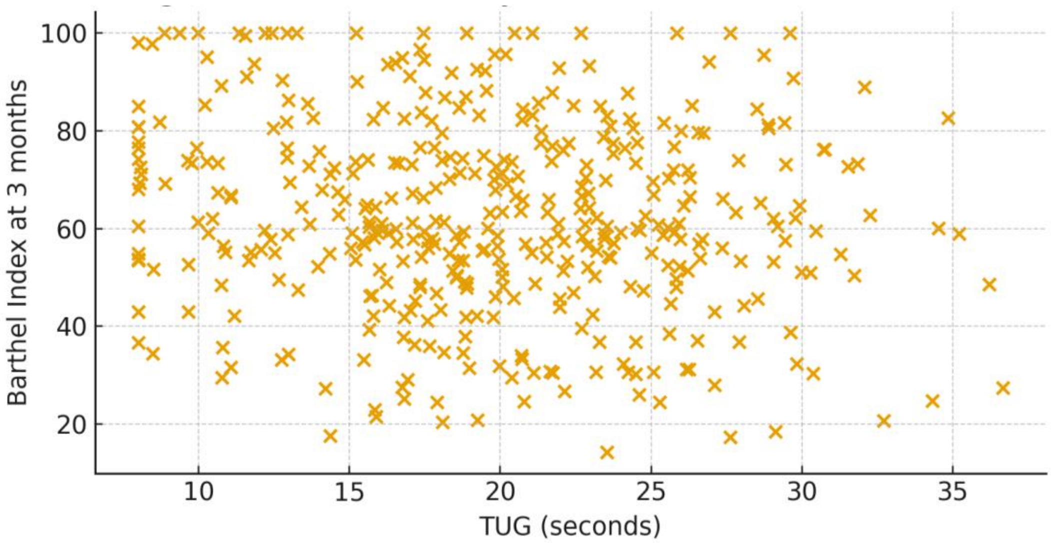


Figure 8. Grip strength stratified by fall occurrence within 6 months.

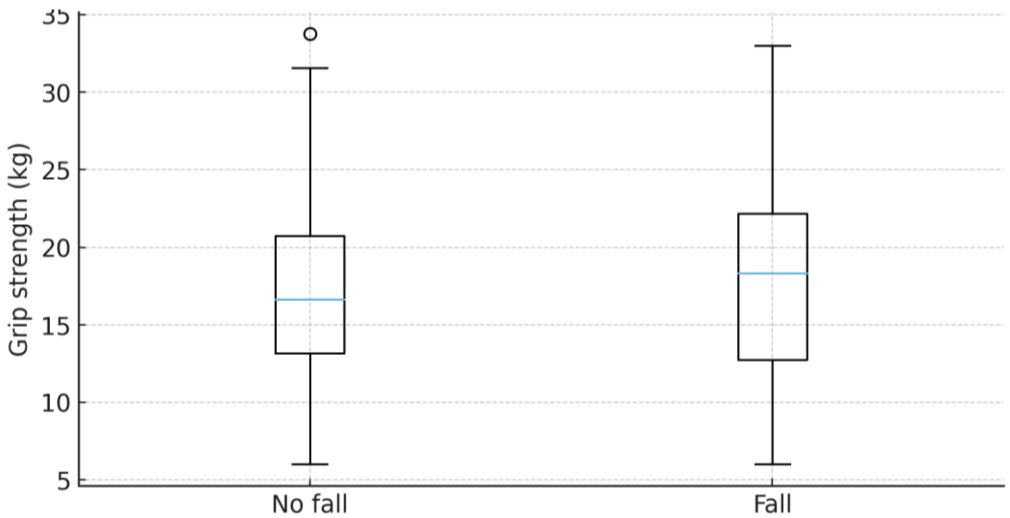


Figure 9. Empirical survival curve for time to independent ambulation (censoring at 6 months).

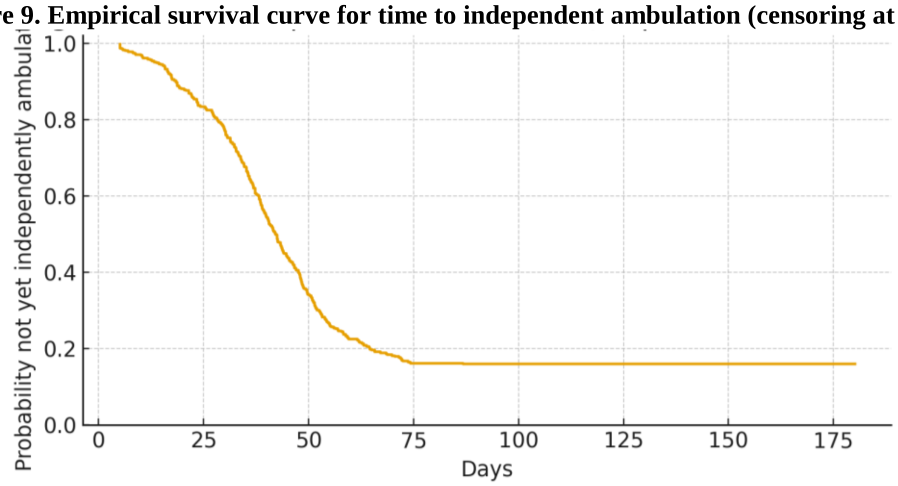
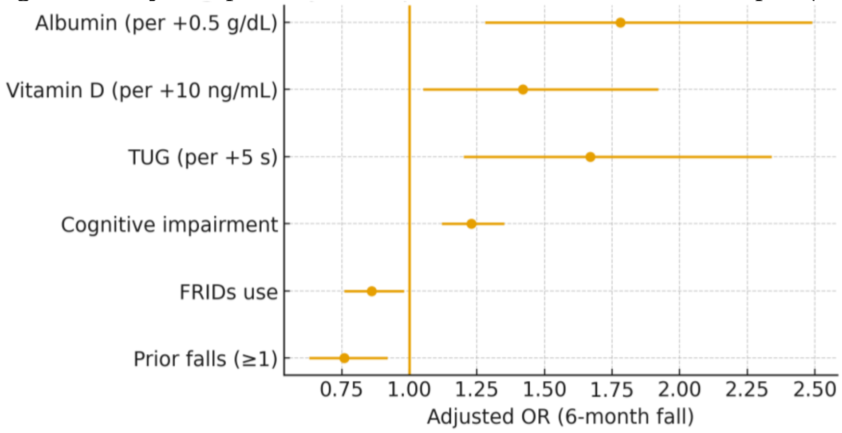


Figure 10. Adjusted predictors of six-month falls shown as a forest plot (odds ratios).



DISCUSSION

The present research was designed to determine the key fall risk predictors, as well as the influence of factors on the healing process after fractures in older adults, to build on the existing corpus of epidemiological evidence highlighting the high fall burden (Zhang et al., 2025, p. 1). Older adults are prone to falls as a leading cause of injury that causes moderate to severe injuries, including lacerations, traumatic brain injuries, and fractures, especially hip fractures, which often require prolonged hospitalization and raise the mortality rates (Song et al., 2024, p. 4). Alongside those acute physical outcomes, falls might have severe psychological consequences, such as the increased fear of falling, which may result in the lack of activity and the increased risk of falling (Álvarez et al., 2023, p. 2). This less movement due to fear leads to increased muscular atrophy and deconditioning, and the future risk of falling is also even greater (Elliott et al., 2022, p. 1). This fact is aligned with the data that correlates the reduced performance of activities of daily living with the increased number of falls (Goffin et al., 2022, p. 983) and highlights the paramount importance of comprehensive interventions. Also, certain physiological changes of advanced age, including muscle weakness, impaired balance, and gait disorders, are recognized as important contributors to the risk of falls among the elderly (Corio, 2023, p. 276). The extrinsic factors often compound these intrinsic variables and affect the multifactorial etiology of falls in older adults (Işik and OZTUNA, 2025, p. 8). Some comorbidities such as hypertension and diabetes mellitus have also been identified as critical predicted risk factors of falls among older individuals (Farrell et al., 2023, p. 2). Quite a lot of research has shown that elderly age, specifically among geriatric polytrauma patients, is already associated with a higher risk of mortality, and an increased serum glucose-potassium ratio has been suggested to be considered as a predictor of trauma patients, in general (Torun et al., 2023, p. 2). It has been repeatedly shown in past research that poor balance and postural Hypotension are significant contributors that increase the risk of falls in older individuals (Khatib et al., 2024, p. 17). It highlights the necessity of multidimensional risk evaluation and interventions to reduce the burden of trauma and improve the outcomes of the susceptible population (Işik and ÖZTUNA, 2025, p. 2). Moreover, there are additional cognitive impairment and depression which are also notable reasons that contribute to a higher risk of falls either by influencing gait stability and quick response time (Martí-Marco et al., 2025). The combination of these cognitive and psychological factors makes the process of fall prevention complicated, and a holistic approach that scrutinizes both physical and psychological well-being is required (Işik and OZTUNA, 2025, p. 12).

CONCLUSION

The paper highlights the critical role of early functional examination and targeted treatment in the prevention of falls and improvements in the recovery outcomes of elderly orthopedic patients. Two in every five individuals who participated in the study fell within six months and this indicates the level of chances that these individuals would fall once again despite receiving assistance during the initial occurrence. The first items on the list of preventative efforts should be independent predictors such as slower mobility (TUG), cognitive impairment, a prior fall, and taking a large number of drugs that increase the risk of falling. Protective variables such as increased vitamin D levels and albumin, early mobilization and good balance, on the other hand, reveal the significance of making the changes that might be possible. The multidisciplinary approach based on the use of evidence-based practices, such as drug optimization, physiotherapy, dietary correction, and cognitive training, can also reduce the number of falls and the necessity to have help with the daily activity to a minimum. These findings can be used in clinical practice to develop predictive risk models and tailored rehabilitation protocols to support independence and improve the quality of life of older individuals after a fracture.

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