Osteoporosis International
https://doi.org/10.1007/s00198-025-07427-y

ORIGINAL ARTICLE

Pre-fracture functional status and 30-day recovery predict 5-year survival in patients with hip fracture: findings from a prospective real-world study

Carmelinda Ruggiero[1] · Marta Baroni[1] · Monica Pizzonia[8] · Andrea Giusti[2] · Giuseppe Rinonapoli[3] · Vittorio Bini[1] · Emilio Martini[4] · Ilaria Giovanna Macchione[1] · Clemens Becker[5] · Opinder Sahota[6] · Antony Johansen[7]

Received: 29 September 2024 / Accepted: 8 February 2025

Abstract

Summary Disability overcomes mortality burden in older adults with hip fracture, expanding unhealthy lifespan. Building comprehensive assessment, pre-fracture functional status and 30-day post-surgical recovery are the most powerful predictors of 5-years survival. A tool supporting estimation of long-term survival may optimize the appropriate delivery of targeted interventions.

Background Older people with hip fractures are highly heterogeneous patients, impacting health and economic systems. The availability of tools to estimate survival may help optimize patients' outcomes and treatment management decisions.

Methods A prospective observational study was conducted on older patients with hip fractures who received baseline and 30-day comprehensive assessment from discharge, focusing on functional status based on Basic Activity of Daily Living (BADL). The primary outcome was to identify predictors of 5-year survival and develop nomograms to be adopted at admission or 30 days after discharge.

Result Among 231 hip fracture patients, 5-year survival was 38.3% in men and 61.9% in women; women experienced a 1.8 higher likelihood of survival than men. Pre-fracture functional status predicted mortality as a function of age. At hospital admission, pre-fracture BADL level was a protective factor (HR 0.742; 95% CI 0.668–0.825), while male gender (HR 1.840; 95% CI 1.192–2.841), age (HR 1.070; 95% CI 1.037–1.105), and multimorbidity (HR 1.096; 95% CI 1.007–1.193) were independent mortality risk factors. At the 30-day follow-up visit, the BADL recovery gap was an independent predictor of 5-year survival (HR 1.439; 95% CI 1.158–1.789), in addition to male gender (HR 1.773; 95% CI 1.146–2.744), age (HR 1.046; 95% CI 1.010–1.083), and pre-fracture BADL (HR 0.621; 95% CI 0.528–0.730), while comorbidity disappeared (HR 1.083; 95% CI 0.994–1.179).

Conclusion More than half of hip fracture patients are still alive 5 years after surgical repair. Pre-fracture functional status and a 30-day functional recovery gap are the main predictors of survival. Nomograms may help to define prognosis and suitable interventions.

Keywords Fragility fractures · Functional autonomy · Hip fracture · Nomogram · Survival

✉ Carmelinda Ruggiero
carmelinda.ruggiero@unipg.it

[1] Orthogeriatric and Geriatric Units, Gerontology and Geriatrics Section, Department of Medicine and Surgery, University of Perugia, S. Maria Misericordia Hospital, C Building, 4° Floor, Room 20, S. Andrea delleFratte, 06156 Perugia, Italy

[2] Unit of Internal Medicine and Metabolic Bone Diseases, Villa Scassi, 16149 Genoa, Italy

[3] Orthopedics and Traumatology Department, University of Perugia, Perugia, Italy

[4] Geriatric and Orthogeriatric Unit, Baggiovara Hospital, Modena, Italy

[5] Department Clinical Gerontology and Geriatric Rehabilitation, Bosch Hospital, Stuttgart, Germany

[6] Department of Healthcare of Older People and Department of Trauma and Orthopaedics, Nottingham University Hospitals NHS Trust, Nottingham, UK

[7] University Hospital of Wales and School of Medicine, Cardiff University, Cardiff, UK

[8] IRCCS Policlinico San Martino Hospital, Genoa, Italy

Published online: 09 April 2025

Introduction

Fragility fractures due to falls will escalate to approximately 6 million cases annually by 2050, worldwide [1], posing severe challenges to medical and economic systems [2]. Though mortality rates range from 12 to 37% within the first year, the burden of disability overcomes that of mortality, especially among individuals aged 65–80 [3]. Furthermore, hip fracture survivors face a high risk of contra-lateral fracture, nearly 70% in the first 2 years [4], and peri-implant fragility fractures leading to complex surgical and medical challenges [5].

The orthogeriatric care model (OGC) has been demonstrated to improve patients' survival and quality of life. Comprehensive geriatric assessment (CGA), as an instrumental tool in the OGC setting, drives patients' management by addressing individual complexity and frailty, and then personalizing care decisions [6, 7]. Pre-fracture functioning and quality of life are pivotal domains of the CGA and may support the adoption of interventions proportional to patients' clinical response and prognosis. To date, few studies report about patients' functional independence prior to experiencing a hip fracture. They poorly investigated the prognostic value of pre-fracture functional level with regard to survival and quality of life, still focusing on the effect of canonical risk factors on mortality [8]. Indeed, prognostic scores are routinely used to estimate short-term mortality associated with fracture and following surgical and anesthesiologist procedures, i.e., including the American Society of Anesthesiologists (ASA) physical status classification system [9], the Multidimensional Prognostic Index (MPI) [10], and the Charlson Complication Index (CCI) [11].

In addition, several nomograms are currently being investigated to predict 1-year mortality following hip fracture [12, 13]. Despite technical soundness, these scores display several limitations due to poor prediction in the acute and post-acute phases and poor feasibility in high-volume trauma wards. Moreover, focusing on the cumulative and relative risk of mortality may frame discussions in a negative fashion, potentially discouraging surgeons and anesthetists from offering interventions and deterring patients and families from agreeing with them. Even if the sickest individual would be at 20 times greater relative risk of dying than the fittest patient, their absolute risk of dying remains small [14]. Therefore, there is an urgent need to predict orthogeriatric patients' long-term prognosis and quality of life beyond the acute phase. On one side, tools improving the detection of patients' prognosis may enable distinction between those requiring restorative interventions, such as total hip replacement rather than hemiarthroplasty [15], or may identify people in need of structured falls and fracture secondary prevention programs [16], from those who can benefit from alternative or palliative care. Effective tools should be designed to capture patients' features relevant to prognosis at the first contact, then enhance decision-making about treatments that support individuals' intrinsic capacities [17, 18], ultimately impacting healthcare outcomes and quality of life.

We sought to investigate predictors of 5-year survival from index events and develop a predictive nomogram model for orthogeriatric patients. Introducing such a nomogram may significantly enhance clinicians' decision-making by optimizing care outcomes through informed decisions on surgery types, rehabilitation programs, or secondary prevention strategies. Furthermore, it may provide a visual representation and personalized benefit-risk assessment tool facilitating the patient-clinician communication alliance for care [19].

Material and methods

Study design and participants

From February 2016 to February 2017, a prospective observational study was conducted among subjects aged > 65 years consecutively admitted to the orthogeriatric outpatient clinic of an academic hospital. Patients hospitalized for hip fragility fractures received orthopedic care management with geriatric consultation and recommendations to return for a 30-day post-surgical assessment, as previously reported [20]. During the 30-day visit, the traumatologist invited patients to the interdisciplinary service (FLS-CP). According to their preferences and goals, some patients opted to join the FLS-CP, receiving a traumatologist's and geriatrician's evaluation based on CGA. They received indications about the healing process, weight-bearing, thromboprophylaxis, exercise, rehab program, drug revision, diet advice, and fall and fracture prevention interventions. All patients returned the summary notes to their GPs involved in the care process. A trained geriatrician with orthogeriatric competencies conducted patient and caregiver assessment and used standard approaches and scales for the interview. The study was consistent with the Helsinki Declaration's ethical standards. The regional healthcare system ethics committee approved the study with registration number 2257/14.

Data collection and definitions

Baseline participants' data were gathered from clinical records, including demographics, type of fracture, time to surgery, type of surgery, weight-bearing, and pre-fracture functional level. Classification of hip fractures was consistent with the Orthopaedic Trauma Association [21].

Decisions about the type of surgical repair were made based on a consensus by two surgeons, with prosthetic replacement as the primary surgical indication for a medial fracture and osteosynthesis for a lateral femur fracture. Pre-fracture and 30-day post-surgery functional abilities were classified by using the Basic Activity of Daily Living (BADL) score, ranging from 0 to 6 [22], and the Instrumental Activity of Daily Living (IADL) score, ranging from 0 to 8 [23]. Patients were classified as independent in BADL if they could perform at least five tasks. BADL and IADL tools are presented in the supplementary material (Table 1s). The 30-day BADL recovery gap was defined as the difference between pre-fracture BADL and 30-day post-surgery BADL, meaning that a difference equal to 0 represents a full functional recovery, while a higher difference unveils an incomplete functional recovery. The IADL independence was defined according to gender-specific thresholds as women able to perform at least 6 of 8 and men able to perform at least 3 of 4 tasks [20].

Participants who entered FLS-CP received CGA, with additional information about anthropometric parameters, including body mass index (BMI), hand-grip strength [24], cognition, mood, and behavioral symptoms; the number of comorbidities and comorbidity index (Cumulative Illness Rating Scale) [25]; social-environmental aspects; and other risk factors, previous fractures, and bone fragility diagnostics and treatments. All subjects survived at least 30 days post-fracture. A previous paper from our group reported the attrition from admission due to hip fracture to the 30-day visit for the eligible group [20]. The regional administrative registry provided information about vital status, and the last check of vital status was performed 62 months after the last and 70 months after the first patient's admission to the orthogeriatric outpatient visit, respectively (issue released on 30 March 2022).

Primary and secondary outcomes

The primary endpoint was identifying 5-year survival among orthogeriatric patients who underwent hip fracture repair and attended 30-day follow-up visits. The secondary endpoints were evaluating the impact of pre-fracture or post-operative medical, surgical, and functional characteristics on 5-year survival. The final aim was to develop a nomogram to enhance clinicians' skills in forecasting 5-year survival, starting at admission or the 30-day visit from surgery.

Statistical analysis

The Shapiro–Wilk test assessed the normal distribution of variables. The chi-square test with Yates' continuity correction and Fisher's exact test compared categorical variables, and the Mann–Whitney's *U*-test compared ordinal and non-normally distributed continuous variables. Survival curves were calculated using the Kaplan–Meier product-limit method and the log-rank test to evaluate differences in expected event probability between age groups. Bivariate and multivariate Cox proportional-hazard regression models examined the risk factors affecting the prognosis, incorporating all the variables that showed a significant *p*-value in bivariate analysis.

Time to event was estimated as the difference between the date of death and the date of baseline evaluation for deceased participants and between the last database update (30 March 2022) and the baseline visit for those alive at the end of the follow-up period.

To avoid multicollinearity, highly correlated variables, tested using Spearman's *rho* correlation coefficient, were dropped from the models. Bivariate and multivariate regressions underwent 200 bootstrap resamples to reduce overfit bias, with goodness of fit tested using Harrell's concordance index (C-index). Hazard ratios (HRs) with 95% confidence intervals were calculated. Multivariate Cox regression coefficients were used to develop a survival-based nomogram, internally validated with calibration plots. The agreement of 5-year survival probabilities between estimated outcomes by nomogram and actual observations was determined using the receiver operating characteristics (ROC) curve. Statistical analysis used IBM-SPSS® version 26.0 (IBM Corp., Armonk, NY, USA, 2019). In all analyses, a two-sided p-value < 0.05 was considered significant. Nomogram and calibration plots were carried out using NOMOCOX and PMCALPLOT Stata modules [26], respectively (Stata Corp, 2015; Stata Statistical Software, Release 14; College Station, TX: StataCorp LP).

Results

Table 1 presents participant characteristics for the entire sample and stratified by gender and 5-year vital status, i.e., survivors or decedents, from hospital discharge. Overall, most participants were women (79.6%), with a mean age of 82.7 years. After 5 years, 38.3% (*n* 29) of men and 61.9% (*n* 70) of women were alive (*p* 0.006). Follow-up periods were similar between sexes according to their final vital status. Survivors had a longer follow-up (65.8 ± 3.1 in men and 66.2 ± 3.5 in women; *p* 0.526) than decedents (33.9 ± 13.5 in men and 35.6 ± 13.3 in women; *p* 0.748). Survived women were younger at baseline (80.1 ± 7.7 years vs 86.8 ± 5.6 years; $p < 0.0001$) and at the end of the follow-up (86.0 ± 7.7 years vs 90.2 ± 5.6 years; $p < 0.0001$) compared to the deceased counterparts. Men's age at baseline (84.2 ± 8.5 vs 82.9 ± 4.9; *p* 0.174) was similar, but survivors were older at the follow-up end (90.0 ± 8.4 vs 86.0 ± 4.7; *p* 0.021) than their deceased counterparts.

Pre-fracture independence in BADL was higher in survivors (65%), with 40.2% of women and 46.8% of men

Table 1 Participants' baseline characteristics in the entire sample and grouped by gender and their 5-year vital status

	Entire sample (*n* 231)	Men (*n* 47)		*p*	Women (*n* 184)		*p*
Alive after 5 years, *n* (%)	132 (57.1)	Survivors (*n* = 18)	Decedents (*n* = 29)		Survivors (*n* = 114)	Decedents (*n* = 70)	0.006
Demographic, anthropometric and follow-up data							
Age at baseline, years (mean ± SD)	82.7 ± 7.5	84.2 ± 8.5	82.9 ± 4.9	0.174	80.1 ± 7.7	86.8 ± 5.6	< 0.0001
Body mass index, kg/m^2 (mean + SD)	24.3 ± 3.9	25.2 ± 2.6	23.8 ± 3.4	0.198	23.5 ± 4.2	22.9 ± 3.9	0.233
Age at 30-day post-surgical visit (mean ± SD), years	83.2 ± 7.5	84.6 ± 8.4	83.3 ± 5.0	0.182	80.6 ± 7.7	87.3 ± 5.6	< 0.0001
Age at last follow-up (mean ± SD), years	87.5 ± 7.1	90.0 ± 8.4	86.0 ± 4.7	0.021	86.0 ± 7.7	90.2 ± 5.6	< 0.0001
Follow-up (mean ± SD), months	52.8 ± 17.9	65.8 ± 3.1	33.9 ± 13.5	< 0.0001	66.2 ± 3.5	35.6 ± 13.3	< 0.0001
Functional parameters before and after hip fracture							
Pre-fracture BADL score (mean + SD)	4.5 ± 1.7	5.1 ± 1.4	3.8 ± 1.9	0.012	5.1 ± 1.3	3.6 ± 1.8	< 0.0001
Pre-fracture BADL score ≥ 5, *n* (%)	150 (65)	13 (72)	14 (48)	0.106	93 (81)	30 (43)	< 0.0001
Pre-fracture IADL score (mean + SD)	3.9 ± 3.1	4.0 ± 2.8	2.3 ± 2.5	0.043	5.3 ± 3.0	2.3 ± 2.5	< 0.0001
Hand-grip strength, kg (mean + SD)	14.0 ± 6.8	22.9 ± 10.0	15.9 ± 7.2	0.076	14.9 ± 5.9	10.2 ± 4.8	< 0.0001
Post-fracture BADL score (mean + SD)	2.3 ± 1.8	2.9 ± 2.0	1.5 ± 1.5	0.007	3.1 ± 1.8	1.21 ± 1.1	< 0.0001
Post-fracture IADL score (mean + SD)	1.9 ± 1.9	2.3 ± 2.1	1.3 ± 1.7	0.051	2.6 ± 2.0	0.8 ± 1.0	< 0.0001
Functional recovery gap in BADL score (mean + SD)	2.2 ± 1.4	2.2 ± 1.5	2.3 ± 1.6	0.711	2.0 ± 1.3	2.4 ± 1.5	< 0.0001
Hip fracture-related features							
Hip fracture type, *n* (%)							
Lateral	143 (61.9)	10 (55.6)	13 (44.8)	0.678	74 (64.9)	46 (65.7)	0.999
Medial	88 (38.1)	8 (44.4)	16 (55.2)		40 (35.1)	24 (34.3)	
Surgery, *n* (%)							
Prosthesis	100 (43.3)	10 (55.6)	16 (55.2)	0.678	45 (39.5)	29 (41.4)	0.914
Osteosynthesis	131 (56.7)	8 (44.4)	13 (44.8)		69 (60.5)	41 (58.6)	
Time to surgery, days (mean + SD)	4.0 ± 2.1	4.1 ± 2.6	3.7 ± 1.9	0.815	3.8 ± 2.1	4.4 ± 2.2	0.074
Surgery < 48 h, *n* (%)	54 (23.4)	6 (33.3)	8 (27.6)	0.928	29 (25.4)	11 (15.7)	0.171
Weigth-bearing, *n* (%)							
Delayed	21 (9.1)	1 (5.6)	5 (17.2)	0.384	11 (9.6)	4 (5.7)	0.503
Early	210 (80.9)	17 (94.4)	24 (82.8)		103 (90.4)	66 (94.3)	
Disease-related variables							
Disease, number (mean ± SD)	4.9 ± 2.2	4.6 ± 1.3	5.7 ± 2.7	0.057	4.5 ± 2.2	5.1 ± 2.1	0.209
Comorbidity index (mean ± SD)	6.7 ± 2.7	6.1 ± 2.4	8.1 ± 2.7	0.023	6.2 ± 2.7	7.3 ± 2.3	< 0.0001
Chronic diseases > 4, *n* (%)	117 (50.6)	8 (44.4)	17 (58.6)	0.518	53 (46.5)	39 (55.7)	0.288

Legend: Survivors are participants who were still alive at the end of the follow-up; decedents are those who died during the follow-up. Differences among censored and participants who died have been estimated using the Mann-Whitney test, chi-square test with Yates' correction or Fisher exact test

SD standard deviation, *BADL* Basic Activities of Daily Living, *IADL* Instrumental Activities of Daily Living reporting gender-specific IADL independence. In both sexes, pre- and post-fracture BADL were highly preserved in those who survived compared to those who died. With regards to pre- and post-fracture IADL performance, women who survived confirmed higher scores as compared to those who died, while just a tendency was observed in men. Muscle strength measured by handgrip was significantly higher in survived women than in deceased (14.9 ± 5.9 vs 10.2 ± 4.8; $p < 0.0001$), and a similar trend was observed in men (22.9 ± 10.0 vs 15.9 ± 7.2; p 0.076). The 30-day BADL recovery gap was significant in deceased than survived women (2.4 ± 1.5 vs 2.0 ± 1.3; $p < 0.0001$), but similar in men independent of their final vital status (p 0.711). Survivors and deceased women and men showed a similar proportion of fracture type, surgical repair type, time to surgery, early or delayed weight-bearing, and BMI. The comorbidity index was higher in the deceased as compared to survivors in men (8.1 ± 2.7 vs 6.1 ± 2.4; p 0.023) and women (7.3 ± 2.3 vs 6.2 ± 2.7, $p < 0.0001$), while multimorbidity, defined as the coexistence of more than 4 chronic diseases, was similar between gender and their 5-year vital status.

Predictors of 5-year survival

At hospital admission (Table 2, Model 1), the Cox regression model identified pre-fracture BADL level as protective factor (HR 0.742; 95% CI 0.668–0.825) against 5-year mortality, confirming male gender (HR 1.840; 95% CI 1.192–2.841), age (HR 1.070; 95% CI 1.037–1.105), and multimorbidity (HR 1.096; 95% CI 1.007–1.193) as risk factors. At the 30-day follow-up, the BADL recovery gap added value in predicting mortality (HR 1.439; 95% CI 1.158–1.789) (Table 2, Model 2), confirming the role of male gender (HR 1.773; 95% CI 1.146–2.744), age (HR 1.046; 95% CI 1.010–1.083), and pre-fracture BADL (HR 0.621; 95% CI 0.528–0.730). Although the small sample size, gender-related survival estimates are reported in the supplementary material (Table 2s) of the supplementary material. Notably, the 30-day BADL recovery gap was found an independent risk factor for mortality (HR 1.439; 95% CI 1.158–1.789), with the role of comorbidity disappearing (HR 1.083; 95% CI 0.994–1.179). Both models showed a good C-index (0.74; 95% CI 0.69–0.79and 0.75; 95% CI 0.71–0.80).

Survival analysis by pre-fracture physical functioning

Kaplan-Maier curve examined the participant's survival according to the age tertile distribution and compared participants by thresholds of pre-fracture BADL independence (Fig. 1). The younger participants (aged 60–80 years old and belonging to the lowest tertile), with preserved pre-fracture BADL (≥5) experienced higher survival rates than those with low pre-fracture BADL performance (< 5). The trajectories between the groups spliced after 1 year and progressively amplified (log-rank test $p < 0.0001$; Fig. 1A). After 5 years from baseline, almost 85% of the participants with preserved BADL independence (≥ 5) were still alive compared to 31% of those with impaired BADL (< 5). Participants aged 81–87 years and belonging to the middle tertile showed a similar trend up to 2.5 years from baseline, with survival curves progressively splitting from 2.5 to 5 years (log-rank test p 0.0004, B). About 71% of the middle tertile group with preserved pre-fracture BADL was alive after

Table 2 Predictors of 5-year mortality among orthogeriatric patients in the final Cox regression model

	B (SE)	p-value	HR (95% CI)
Model 1 (at admission)			
Gender			
Female (reference)			0
Male	0.610 (0.222)	0.006	1.840 (1.192–2.841)
Age	0.068 (0.016)	< 0.0001	1.070 (1.037–1.105)
Pre-fracture BADL independence	− 0.298 (0.054)	< 0.0001	0.742 (0.668–0.825)
Chronic diseases, number	0.092 (0.043)	0.033	1.096 (1.007–1.193)
Model 2 (30-day post-surgical visit)			
Gender			
Female (reference)			0
Male	0.573 (0.223)	0.010	1.773 (1.146–2.744)
Age	0.045 (0.018)	0.012	1.046 (1.010–1.083)
Pre-fracture BADL independence	− 0.476 (0.082)	< 0.0001	0.621 (0.528–0.730)
30-day functional recovery gap, Δ	0.364 (0.111)	0.001	1.439 (1.158–1.789)
Chronic diseases, number	0.079 (0.044)	0.069	1.083 (0.994–1.179)

Legend: *B* regression coefficient, *SE* standard error, *HR* hazard ratio, *CI* confidence interval, *Δ* absolute mean difference

5 years, compared to 29% of those functionally compromised at baseline (Fig. 1B). In the oldest group (aged 87 +), the survival curves showed no significant differences according to previous functional status (Fig. 1C).

Nomogram development

Nomograms for predicting 5-year survival were developed using estimates from the Cox proportional model (Fig. 2). The nomogram for predicting survival likelihood at hospital admission includes four variables: age, sex, pre-fracture BADL, and number of diseases. The nomogram for predicting 5-year survival based on the 30-day post-surgical assessment consists of five variables: age, sex, pre-fracture BADL, comorbidity, and actual BADL recovery gap. The nomogram calculates a score from the sum of the points corresponding to each predictor variable. The probability of 5-year survival at hospital admission (Fig. 2A) and 30 days from hospital discharge (Fig. 2B) was derived from the total score. Calibration plots for internal validation of the two models, i.e., at admission (Model 1) and 30-day post-surgical assessment (Model 2), are reported in the supplementary material (Fig. 1s) of the supplementary materials. The plots showed a good agreement between the estimated and the actual 5-year survival probabilities, with AUC of 0.795 and 0.815 for Model 1 and Model 2, respectively. Table 3 reports the points to be used according to the values assumed by the variables in Model 1 (at admission) and Model 2 (30-day post-surgical visit) of the monograms, respectively.

Discussion

This prospective observational study is looking for predictors of 5-year survival in patients who underwent surgical repair after hip fracture. Overall, women experience a 1.8

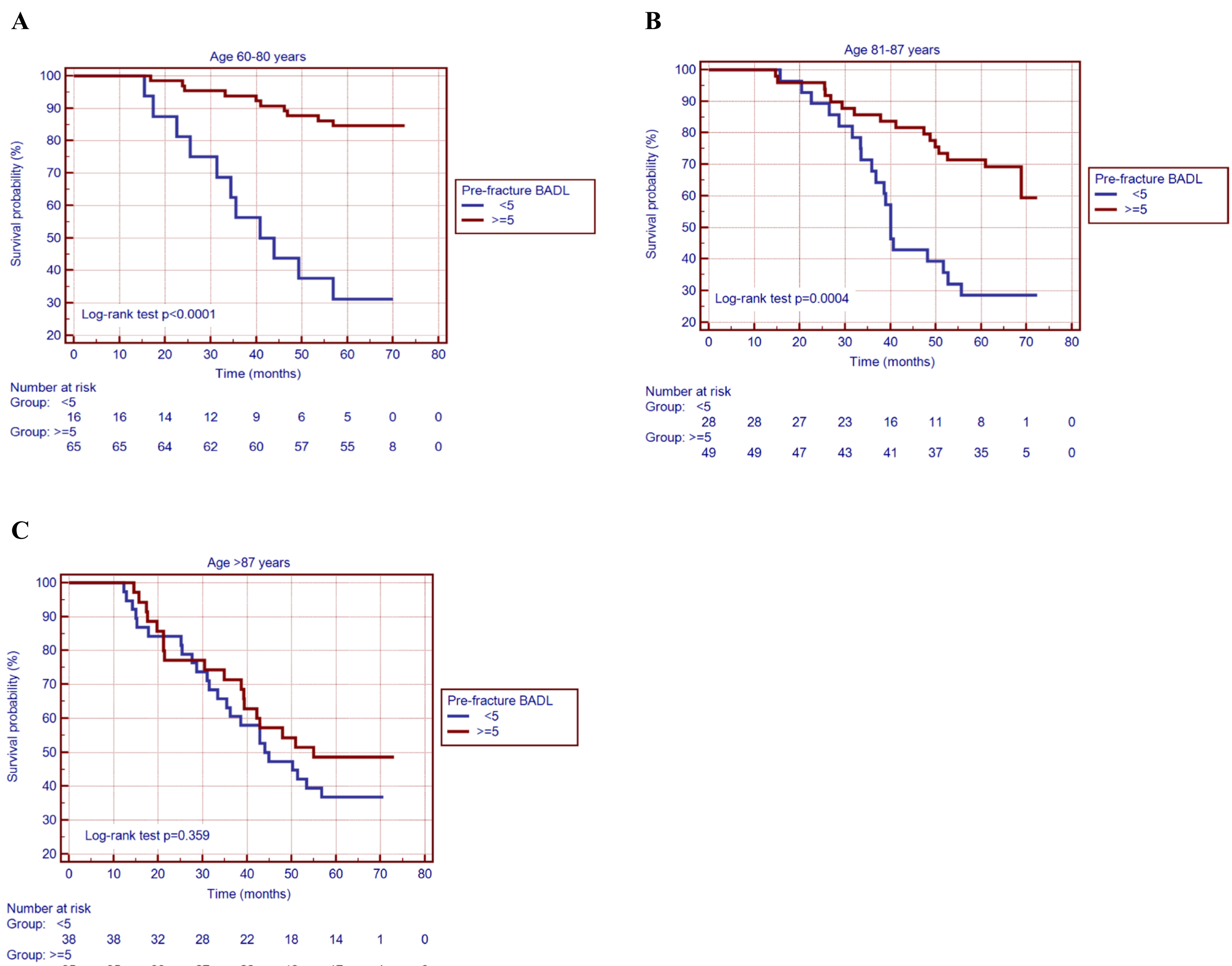


Fig. 1 Kaplan–Meier curves for long-term survival after hip fracture repair by age tertiles at the entry study and pre-fracture functional independence. Legend: pre-fracture functional independence estimated as BADL ≥ 5 vs BADL < 5. Thresholds for age tertile: 60–80 years (**A**), 81–87 years (**B**), more than 87 years (**C**)

higher likelihood of survival compared to men, with about 62% of women and 38% of men still alive after 5 years from the index event. Pre-fracture functional status predicts mortality as a function of age. Patients aged 60–86 years with pre-fracture BADL independence show better survival compared to those with BADL impairment; the survival advantage based on functioning disappears in those aged 86 years and older. The 30-day functional recovery gap is a detrimental factor for mortality, independent of age, gender, pre-fracture BADL performance, and chronic diseases. Building on these findings, we developed a survival nomogram to aid clinicians in estimating long-term survival at both hospital admission and 30-day post-surgical assessment.

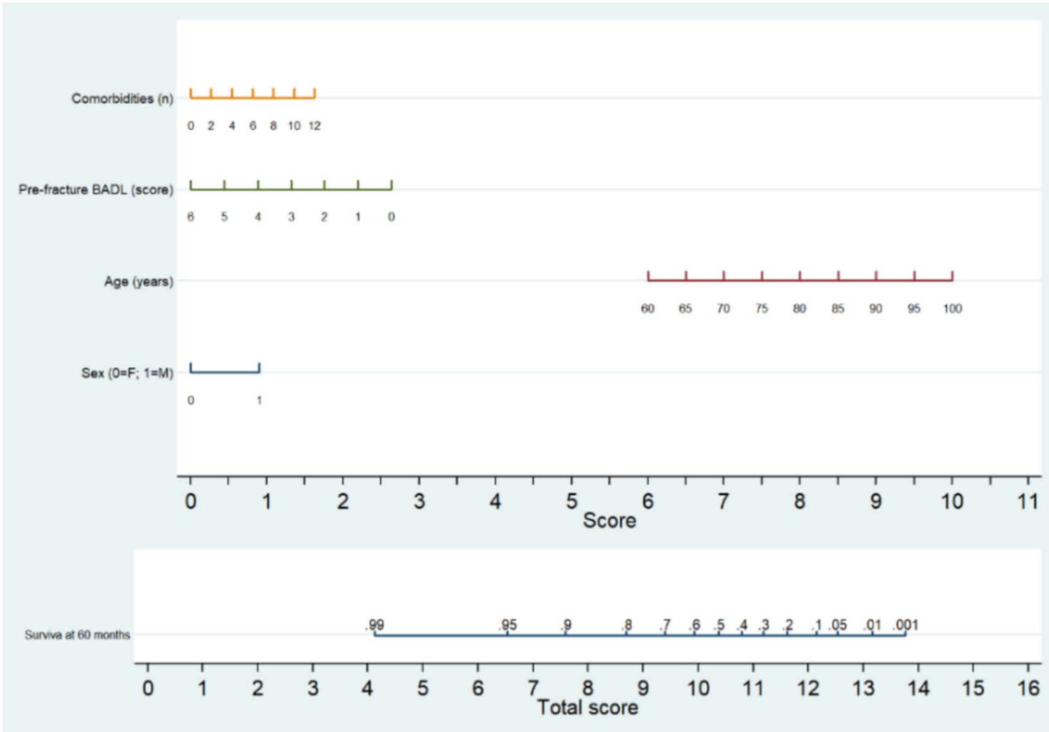
Despite the small sample size of men compared to women, our findings are consistent with previous research reporting higher survival rates in women compared to men following hip fractures. Gender disparity is noticeable from the acute phase, becomes higher in the first three months, and persists up to 15 years post-injury [27, 28]. Women exhibited the expected pattern with older age correlated with high mortality rates. Conversely, men experienced higher mortality risk at younger ages, with older men showing longer survival than their younger counterparts.

The discrepancy in gender-related mortality has been extensively debated. Some researchers attribute the higher mortality risk among younger men to their heavier burden of comorbidity compared to women, independent of specific diseases [28]. Others suggest that differences in body composition, hormonal profiles, and low-grade inflammation may explain gender-related mortality risk [29]. Additionally, unexplained excess mortality among men has been observed in several acute medical conditions, including stroke [30]. More research is warranted to elucidate the pathological pathways underlying the gender effect on mortality.

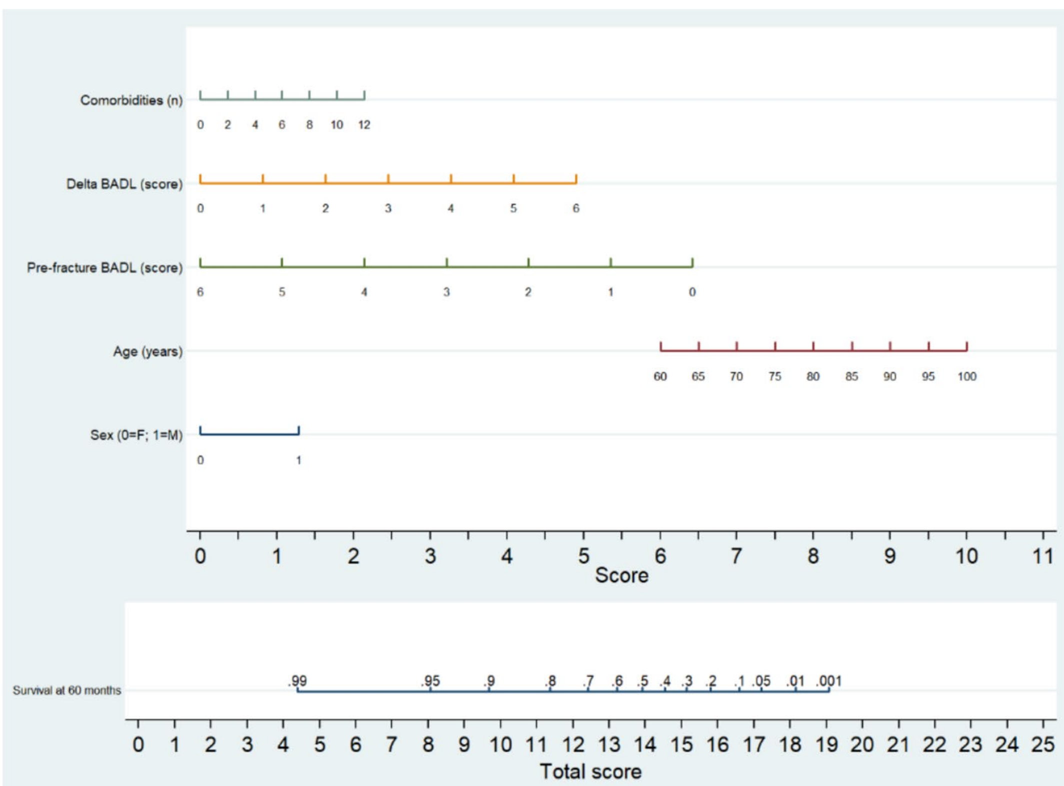
Some studies have explored the relationship between pre-fracture BADL and health-related outcomes in this population subgroup. Aranhoff showed that pre-fracture dependency in BADL predicts increased 1-year mortality [31]. Our research extends the evidence showing that preserved pre-fracture BADL independently predicts 5-year survival. Moreover, the 30-day BADL recovery gap significantly influences 5-year survival independent of several confounders, including comorbidity. Other studies reported that pre-fracture walking outdoors protects against 1-year mortality [32] and that mobility outdoors protects against post-surgical complications, mortality, length of hospital stay, and adverse discharge planning [33]. Conversely, limitations in outdoor mobility were associated with higher mortality [34]. To date, pre-fracture functional status (e.g., mobility outdoors or indoors) is partially considered an effect modifier of the management of patients with HF, influencing for instance surgical technique decisions. Indeed, patients who were able to walk outdoors prior to the fracture are typically recommended for total arthroplasty [35]. Beyond surgical repair, which remains a cornerstone of orthogeriatric care, we hypothesis that several short- and long-term interventions could be implemented and delivered based on patients' functional level and recovery. A critical step in guiding the allocation of interventions proportionate to patients' potential benefits, i.e., intensive rehab programs and optimal secondary prevention of fracture, may be the estimation of individuals' long-term survival probability. Therefore, our first step was to demonstrate the prognostic value of pre-fracture functional status and the 30-day functional gap based on real-world data and develop a tool easily applied by various professionals involved in the patients' care pathway. Although additional studies are warranted in the orthogeriatric field to validate this approach, existing evidence suggests that frailty acts as effect modifier for outcomes related to polypharmacy in long-term care recipients [36], and to the use of direct oral anticoagulants in community-dwelling older adults at risk of stroke [37]. While the proposed tool primarily incorporates non-modifiable variables, i.e., age, gender and pre-fracture functional status, we also demonstrated that the 30-day functional gap is a key determinant of long-term survival. Therefore, one side, pre-fracture functional status could serve as an objective marker of long-term prognosis, informing treatment decisions and resource allocation in a more strategic and forward-thinking manner. On the other side, 30-day functional gap may be an early and dynamic marker of the individuals' response to targeted or intensified interventions aimed to positively enhance patients' survival and quality of life. Then, tailored multimodal interventions based on comprehensive management [38], early rehabilitation [39], and appropriate nutritional support [40], might improve functional gap, survival, and quality of life. However, further research is necessary to evaluate the impact of these interventions on the short-term recovery gap and validate it as a predictor of long-term survival in patients undergoing HF surgery.

Although previous studies showed the role of hand-grip strength in predicting 1-year mortality, walking recovery, and functional outcomes [41], we failed to confirm hand-grip strength as an independent predictor of 5-year mortality. We acknowledge that Short Physical Performance Battery has been ranked as a pivotal predictor of survival among the oldest-old [42] and a valuable tool for risk stratification in older adults with type 2 diabetes [43], but still, it deserves more investigation in this subgroup. Nonetheless, we add to the literature by showing that pre-fracture functional BADL independence and 30-day functional recovery gap are stronger predictors of 5-year mortality than comorbidity, which remained a risk factor at hospital admission, both as score index and number of diseases. Overall, the relationship between pre-fracture functional status and survival trajectories claims for better integration between timely surgery, which remains the

A


Comorbidities (n)
0 2 4 6 8 10 12
Pre-fracture BADL (score)
6 5 4 3 2 1 0
Age (years)
60 65 70 75 80 85 90 95 100
Sex (0=F; 1=M)
0 1
0 1 2 3 4 5 6 7 8 9 10 11
Score
Surviva at 60 months
.99 .95 .9 .8 .7 .6 .5 .4 .3 .2 .1 .05 .01 .001
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Total score

B


Comorbidities (n)
0 2 4 6 8 10 12
Delta BADL (score)
0 1 2 3 4 5 6
Pre-fracture BADL (score)
6 5 4 3 2 1 0
Age (years)
60 65 70 75 80 85 90 95 100
Sex (0=F; 1=M)
0 1
0 1 2 3 4 5 6 7 8 9 10 11
Score
Survival at 60 months
.99 .95 .9 .8 .7 .6 .5 .4 .3 .2 .1 .05 .01 .001
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Total score

◀**Fig. 2** Nomograms predict 5-year survival in older adults undergoing hip fracture surgical repair at admission (**A**) and 30-day post-surgical assessment (**B**). To use the nomogram, the points corresponding to each predictive variable were obtained, and then the sum of the points was calculated as the total score. This total score is represented in the lower axis which is related to the probability of hip fracture people would survive up to 5 years from admission or discharge, respectively. For example, a woman aged 65, affected by 1 chronic disease and with optimal pre-fracture BADL independence level, has a score of 6.65 points (0 + 6.5 + 0.15 + 0) at admission, and then by looking at the nomogram (**A**), the probability of being alive after 5 years from admission is about 95%. If the same woman reports 4 points of functional recovery gap after 30 days from hospital discharge, the score is 9.95 points (0 + 6.5 + 0 + 0.15 + 3.3), suggesting about 90% probability of being alive after 5 years from the 30-day post-surgical assessment (**B**). Table 3 reports the points for each helps to calculate the total score

cornerstone of orthogeriatric care [44], early functional recovery [45], and fracture secondary prevention [46, 47]. Early post-surgical mobility reduces complications and mortality [48] and increases home discharge [45].

Building on our sample's pre-fracture functional features and post-surgical survival trajectories, we call for more adequate strategies supporting individuals' intrinsic capacities [49], enhancing physician decision-making, and tracking the patients' functional outcomes starting at the earliest phase. Accordingly, some national registries have acknowledged this opportunity by setting the assessment of functional outcomes at 30 or 120 days post-hip fracture surgery [50].

Table 3 Points deriving from the nomograms according to the values assumed by the variables in Model 1 (at admission) and Model 2 (30-day post-surgical visit)

Model 1 (at admission)													
Chronic diseases, number	0	1	2	3	4	5	6	7	8	9	10	11	12
Points	0	0.15	0.3	0.4	0.5	0.65	0.8	0.95	1.1	1.25	1.4	1.5	1.6
Pre-fracture BADL, score	6	5	4	3	2	1	0						
Points	0	0.4	0.9	1.3	1.8	2.2	2.6						
Age, years	60	65	70	75	80	85	90	95	100				
Points	6	6.5	7	7.5	8	8.5	9	9.5	10				
Gender, 0 = F; 1 = M	0	1											
Points	0	0.9											
Model 2 (30 days from discharge)													
Chronic diseases, number	0	1	2	3	4	5	6	7	8	9	10	11	12
Points	0	0.2	0.4	0.55	0.7	0.9	1.1	1.25	1.4	1.6	1.8	1.95	2.1
30-day functional recovery gap, Δ score	0	1	2	3	4	5	6						
Points	0	0.8	1.6	2.5	3.3	4.1	4.9						
Pre-fracture BADL, score	6	5	4	3	2	1	0						
Points	0	1.1	2.1	3.2	4.3	5.4	6.4						
Age, years	60	65	70	75	80	85	90	95	100				
Points	6	6.5	7	7.5	8	8.5	9	9.5	10				
Gender, 0 = F; 1 = M	0	1											
Points	0	1.3											

Legend: Δ absolute mean difference

Instructions for solving the survival equation (the calculation is more accurate):Survival at time $t = \exp[-H_0(t) \times \exp(\text{PI})]$. The *exp* function calculate the value of *e* raised to the power of a specific number or expression, where *e* is the base of the natural logarithm, 2.718281828H_0(t) is the baseline cumulative hazard function at time *t* (0.004 for Model 1 and 0.025 for Model 2, both at 60 months). PI is the Prognostic Index ($b_1X_1 + b_2X_2 + \ldots b_nX_n$) in which *b* are the coefficients of variables derived from Cox regression and *X* their valuesModel 1 example: a woman 65 years old, with a pre-fracture BADL independence level of 6, and 1 comorbidity, has an estimated survival probability at 60 months of $\exp[-0.004 \times \exp(0 \times 0.610 + 65 \times 0.068 + 6 \times -0.298 + 1 \times 0.092)] = 0.94$ and an estimated risk of 1–0.94 = 6% of death within 5 yearsModel 2 example: the same woman with 4 points of functional recovery gap after 30 days from hospital discharge has an estimated survival probability at 60 months of $\exp[-0.025 \times \exp(0 \times 0.573 + 65 \times 0.045 + 6 \times -0.476 + 4 \times 0.364 + 1 \times 0.079)] = 0.88$ and an estimated risk of 1–0.88 = 12% of death within 5 years. The regression coefficients are obtained from Table 2

Model 1 (at admission)					
Gender	Age	Pre-fracture BADL	Chronic diseases		5 year Survival
0	65	6	1		0.94
Model 2 (30 days from discharge)					
Gender	Age	Pre-fracture BADL	Delta BADL	Chronic diseases	5 year Survival
0	65	6	4	1	0.88

In this scenario, a nomogram based on easily accessible data collected by non-specialists at hospital admission or 30 days from index surgery may offer an opportunity to improve tailored interventions' delivery. Compared to previous ones, our nomograms have been developed from data prospectively collected [13, 14] and based on CGA, which remains the best approach. Even though nomograms showed optimal predictive accuracy and calibration at internal validation, external validation should be mandatory to establish whether the tools work satisfactorily in different patient populations before their implementation in daily practice.

Conclusions

Pre-fracture functional status and 30-day recovery from surgery are the main predictors of 5-year survival among orthogeriatric patients, and they should be taken into account together with other established risk factors. Focusing on pre-fracture functional status will help identify appropriate strategies and choices to meet high-quality patients' needs and foster systems' resilience. Nomograms based on functional metrics may be innovative tools to implement and orientate decision-making processes. However, more investigations are needed to validate the one we proposed.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00198-025-07427-y.

Acknowledgements The authors acknowledge the contributions of Simona Fabbri and Monia Giorgetti, members of the nursing staff, and the assistance from Fabrizio Ruffini, Head of the Technical and Administrative Support Office for Management Control of the teaching hospital, in supporting the data collection.

Funding Open access funding provided by Università degli Studi di Perugia within the CRUI-CARE Agreement.

Declarations

Conflict of interest None.

References

1. Borgström F, Karlsson L, Ortsäter G, Norton N, Halbout P, Cooper C et al (2020) Fragility fractures in Europe: burden, management and opportunities. Arch Osteoporos 15(1):59. https://doi.org/10.1007/s11657-020-0706-y
2. Harris E, Clement N, MacLullich A, Farrow L (2024) The impact of an ageing population on future increases in hip fracture burden. Bone Joint J 106-B(1):62–68. https://doi.org/10.1302/0301-620X.106B1.BJJ-2023-0740.R1
3. Papadimitriou N, Tsilidis KK, Orfanos P, Benetou V, Ntzani EE, Soerjomataram I et al (2017) Burden of hip fracture using disability-adjusted life-years: a pooled analysis of prospective cohorts in the CHANCES consortium. Lancet Public Health 2(5):e239–e246. https://doi.org/10.1016/S2468-2667(17)30046-4
4. Ratnasamy PP, Rudisill KE, Oghenesume OP, Riedel MD, Grauer JN (2023) Risk of contralateral hip fracture following initial hip fracture among geriatric fragility fracture patients. J Am Acad Orthop Surg Glob Res Rev 7(7):e23.00001. https://doi.org/10.5435/JAAOSGlobal-D-23-00001
5. Bottle A, Griffiths R, White S, Wynn-Jones H, Aylin P, Moppett I et al (2020) Periprosthetic fractures: the next fragility fracture epidemic? A national observational study. BMJ Open 10(12):e042371. https://doi.org/10.1136/bmjopen-2020-042371
6. Pilotto A, Cella A, Pilotto A, Daragjati J, Veronese N, Musacchio C et al (2017) Three decades of comprehensive geriatric assessment: evidence coming from different healthcare settings and specific clinical conditions. J Am Med Dir Assoc 18(2):192.e1-192.e11. https://doi.org/10.1016/j.jamda.2016.11.004
7. Baroni M, Serra R, Boccardi V, Ercolani S, Zengarini E, Casucci P et al (2019) The orthogeriatric comanagement improves clinical outcomes of hip fracture in older adults. Osteoporos Int 30(4):907–916. https://doi.org/10.1007/s00198-019-04858-2
8. Chang W, Lv H, Feng C, Yuwen P, Wei N, Chen W et al (2018) Preventable risk factors of mortality after hip fracture surgery: systematic review and meta-analysis. Int J Surg 52:320–328. https://doi.org/10.1016/j.ijsu.2018.02.061
9. Doyle DJ, Hendrix JM, Garmon EH (2024) American society of anesthesiologists classification. In: StatPearls [Internet]. StatPearls Publishing, Treasure Island (FL) [cited 2024 Mar 4]
10. Zanetti M, De Colle P, Niero M, Gortan Cappellari G, Barazzoni R, Ratti C et al (2023) Multidimensional prognostic index predicts short- and long-term mortality and rehospitalizations in older patients with hip fracture. Aging Clin Exp Res 35(7):1487–1495. https://doi.org/10.1007/s40520-023-02433-8
11. Haugan K, Klaksvik J, Foss OA (2021) 30-day mortality in patients after hip fracture surgery: a comparison of the Charlson Comorbidity Index score and ASA score used in two prediction models. Injury 52(8):2379–2383. https://doi.org/10.1016/j.injury.2021.02.004
12. Chen Q, Hao P, Wong C, Zhong X, He Q, Chen Y (2023) Development and validation of a novel nomogram of 1-year mortality in the elderly with hip fracture: a study of the MIMIC-III database. BMJ Open 13(5):e068465. https://doi.org/10.1136/bmjopen-2022-068465
13. Lu X, Wang Z, Chong F, Wang Y, Wu S, Du Q et al (2022) A new nomogram model for predicting 1-year all-cause mortality after hip arthroplasty in nonagenarians with hip fractures: a 20-year period retrospective cohort study. Front Surg 9:926745. https://doi.org/10.3389/fsurg.2022.926745
14. Johansen A, Tsang C, Boulton C, Wakeman R, Moppett I (2017) Understanding mortality rates after hip fracture repair using ASA physical status in the National Hip Fracture Database. Anaesthesia 72(8):961–966. https://doi.org/10.1111/anae.13908

15. Investigators HEALTH, Bhandari M, Einhorn TA, Guyatt G, Schemitsch EH, Zura RD et al (2019) Total hip arthroplasty or hemiarthroplasty for hip fracture. N Engl J Med 381(23):2199–2208. https://doi.org/10.1056/NEJMoa1906190
16. Johansen A, Sahota O, Dockery F, Black AJ, MacLullich AMJ, Javaid MK et al (2023) Call to action: a five nations consensus on the use of intravenous zoledronate after hip fracture. Age and Ageing 52(9). [cited 2024 Jun 26]. https://doi.org/10.1093/ageing/afad172
17. Belloni G, Cesari M (2019) Frailty and intrinsic capacity: two distinct but related constructs. Front Med (Lausanne) 6:133. https://doi.org/10.3389/fmed.2019.00133
18. Astrone P, Perracini MR, Martin FC, Marsh DR, Cesari M (2022) The potential of assessment based on the WHO framework of intrinsic capacity in fragility fracture prevention. Aging Clin Exp Res 34(11):2635–2643. https://doi.org/10.1007/s40520-022-02186-w
19. Masarwa R, Ben Natan M, Berkovich Y (2024) Telling the truth to patients before hip fracture surgery. BMC Med Ethics 19(25):71. https://doi.org/10.1186/s12910-024-01067-3
20. Ruggiero C, Baroni M, Talesa GR, Cirimbilli A, Prenni V, Bubba V et al (2022) The interdisciplinary fracture liaison service improves health-related outcomes and survival of older adults after hip fracture surgical repair. Arch Osteoporos 17(1):135. https://doi.org/10.1007/s11657-022-01171-0
21. Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF (2018) Fracture and dislocation classification compendium-2018. J Orthop Trauma 32(Suppl 1):S1-170. https://doi.org/10.1097/BOT.0000000000001063
22. Activities of daily living - StatPearls - NCBI Bookshelf [Internet]. [cited 2024 Feb 23]. https://www.ncbi.nlm.nih.gov/books/NBK470404/. Accessed 19 Feb 2025
23. Sheehan CM, Tucker-Drob EM (2019) Gendered expectations distort male-female differences in instrumental activities of daily living in later adulthood. J Gerontol B Psychol Sci Soc Sci 74(4):715–723. https://doi.org/10.1093/geronb/gbw209
24. Malhotra R, Tareque MdI, Tan NC, Ma S (2020) Association of baseline hand grip strength and annual change in hand grip strength with mortality among older people. Archives of Gerontology and Geriatrics 86:103961. https://doi.org/10.1016/j.archger.2019.103961
25. Nagaratnam N, Gayagay G (2007) Validation of the Cumulative Illness Rating Scale (CIRS) in hospitalized nonagenarians. Arch Gerontol Geriatr 44(1):29–36. https://doi.org/10.1016/j.archger.2006.02.002
26. Zlotnik A, Abraira V (2015) A General-purpose nomogram generator for predictive logistic regression models. Stand Genomic Sci 15(2):537–546. https://doi.org/10.1177/1536867X1501500212
27. Haentjens P, Magaziner J, Colón-Emeric CS, Vanderschueren D, Milisen K, Velkeniers B et al (2010) Meta-analysis: excess mortality after hip fracture among older women and men. Ann Intern Med 152(6):380–390. https://doi.org/10.7326/0003-4819-152-6-201003160-00008
28. Kannegaard PN, van der Mark S, Eiken P, Abrahamsen B (2010) Excess mortality in men compared with women following a hip fracture. National analysis of comedications, comorbidity and survival. Age and Ageing 39(2):203–209. https://doi.org/10.1093/ageing/afp221
29. Chang C-S, Liu I-T, Liang F-W, Li C-C, Sun Z-J, Chang Y-F et al (2022) Effects of age and gender on body composition indices as predictors of mortality in middle-aged and old people. Sci Rep 12(1):7912. https://doi.org/10.1038/s41598-022-12048-0
30. Olsen TS, Dehlendorff C, Andersen KK (2007) Sex-related time-dependent variations in post-stroke survival–evidence of a female stroke survival advantage. Neuroepidemiology 29(3–4):218–225. https://doi.org/10.1159/000112464
31. Aharonoff GB, Koval KJ, Skovron ML, Zuckerman JD (1997) Hip fractures in the elderly: predictors of one year mortality. J Orthop Trauma 11(3):162–165. https://doi.org/10.1097/00005131-199704000-00004
32. Bui M, Nijmeijer WS, Hegeman JH, Witteveen A, Groothuis-Oudshoorn CGM (2023) Systematic review and meta-analysis of preoperative predictors for early mortality following hip fracture surgery. Osteoporos Int. https://doi.org/10.1007/s00198-023-06942-0
33. Stubbs TA, Doherty WJ, Chaplin A, Langford S, Reed MR, Sayer AA et al (2023) Using pre-fracture mobility to augment prediction of post-operative outcomes in hip fracture. Eur Geriatr Med 14(2):285–293. https://doi.org/10.1007/s41999-023-00767-0
34. Pioli G, Lauretani F, Pellicciotti F, Pignedoli P, Bendini C, Davoli ML et al (2016) Modifiable and non-modifiable risk factors affecting walking recovery after hip fracture. Osteoporos Int 27(6):2009–2016. https://doi.org/10.1007/s00198-016-3485-y
35. Stirton JB, Maier JC, Nandi S (2019) Total hip arthroplasty for the management of hip fracture: a review of the literature. J Orthop 16(2):141–144. https://doi.org/10.1016/j.jor.2019.02.012
36. Zazzara MB, Villani ER, Palmer K, Fialova D, Corsonello A, Soraci L et al (2023) Frailty modifies the effect of polypharmacy and multimorbidity on the risk of death among nursing home residents: results from the SHELTER study. Front Med (Lausanne) 1(10):1091246. https://doi.org/10.3389/fmed.2023.1091246
37. Joosten LPT, van Doorn S, van de Ven PM, Köhlen BTG, Nierman MC, Koek HL et al (2024) Safety of switching from a vitamin K antagonist to a non-vitamin K antagonist oral anticoagulant in frail older patients with atrial fibrillation: results of the FRAIL-AF randomized controlled trial. Circulation 149(4):279–289. https://doi.org/10.1161/CIRCULATIONAHA.123.066485
38. Neuburger J, Currie C, Wakeman R, Johansen A, Tsang C, Plant F et al (2017) Increased orthogeriatrician involvement in hip fracture care and its impact on mortality in England. Age Ageing 46(2):187–192. https://doi.org/10.1093/ageing/afw201
39. Agarwal N, Feng T, Maclullich A, Duckworth A, Clement N (2024) Early mobilisation after hip fracture surgery is associated with improved patient outcomes: a systematic review and meta-analysis. Musculoskeletal Care 22(1):e1863. https://doi.org/10.1002/msc.1863
40. Liu M, Yang J, Yu X, Huang X, Vaidya S, Huang F et al (2015) The role of perioperative oral nutritional supplementation in elderly patients after hip surgery. Clin Interv Aging 11(10):849–858. https://doi.org/10.2147/CIA.S74951
41. Probert N, Andersson ÅG (2023) Functional outcome in patients with hip fracture from 2008 to 2018, and the significance of hand-grip strength - a cross-sectional comparative study. BMC Geriatr 23(1):686. https://doi.org/10.1186/s12877-023-04398-9
42. Cacciatore S, Calvani R, Marzetti E, Picca A, Russo A, Tosato M et al (2024) Physical performance is associated with long-term survival in adults 80 years and older: results from the ilSIRENTE study. J Am Geriatr Soc. https://doi.org/10.1111/jgs.18941
43. Montesanto A, Lagani V, Spazzafumo L, Tortato E, Rosati S, Corsonello A et al (2024) Physical performance strongly predicts all-cause mortality risk in a real-world population of older diabetic patients: machine learning approach for mortality risk stratification. Front Endocrinol (Lausanne) 15:1359482. https://doi.org/10.3389/fendo.2024.1359482
44. Klestil T, Röder C, Stotter C, Winkler B, Nehrer S, Lutz M et al (2018) Impact of timing of surgery in elderly hip fracture patients:

a systematic review and meta-analysis. Sci Rep 8(1):13933. https://doi.org/10.1038/s41598-018-32098-7

45. Mashimo S, Kubota J, Sato H, Saito A, Gilmour S, Kitamura N (2023) The impact of early mobility on functional recovery after hip fracture surgery. Disabil Rehabil 45(26):4388–4393. https://doi.org/10.1080/09638288.2022.2151652
46. Wang C-Y, Fu S-H, Yang R-S, Chen L-K, Shen L-J, Hsiao F-Y (2020) Timing of anti-osteoporosis medications initiation after a hip fracture affects the risk of subsequent fracture: a nationwide cohort study. Bone 1(138):115452. https://doi.org/10.1016/j.bone.2020.115452
47. Cohen JS, Agarwal AR, Kinnard MJ, Thakkar SC, Golladay GJ (2023) The association of postoperative osteoporosis therapy with periprosthetic fracture risk in patients undergoing arthroplasty for femoral neck fractures. J Arthroplasty 38(4):726–731. https://doi.org/10.1016/j.arth.2022.10.042
48. Kamel HK, Iqbal MA, Mogallapu R, Maas D, Hoffmann RG (2003) Time to ambulation after hip fracture surgery: relation to hospitalization outcomes. J Gerontol A Biol Sci Med Sci 58(11):1042–1045. https://doi.org/10.1093/gerona/58.11.m1042
49. Lee WJ, Peng LN, Lin MH, Kim S, Hsiao FY, Chen LK (2024) Enhancing intrinsic capacity and related biomarkers in community-dwelling multimorbid older adults through integrated multidomain interventions: ancillary findings from the Taiwan Integrated Geriatric (TIGER) trial. J Am Med Dir Assoc 25(5):757-763.e4. https://doi.org/10.1016/j.jamda.2023.10.006
50. Johansen A, Ojeda-Thies C, Poacher AT, Hall AJ, Brent L, Ahern EC et al (2022) Developing a minimum common dataset for hip fracture audit to help countries set up national audits that can support international comparisons. The Bone & Joint Journal 104-B(6):721–728. https://doi.org/10.1302/0301-620X.104B6.BJJ-2022-0080.R1