JAMA | Review

Hip Fractures
A Review

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IMPORTANCE More than 14.2 million people worldwide and 280 000 in the US experience a hip fracture each year. The median 1-year mortality rate after a hip fracture is 22% and approximately 42% to 71% of patients regain their prefracture level of basic activities of daily living within 6 months.

OBSERVATIONS Hip fractures are classified as intracapsular or extracapsular and most commonly occur after a fall. Intracapsular hip fractures include femoral neck (34%) and femoral head (rare). Extracapsular fractures consist of intertrochanteric (48%) and subtrochanteric fractures (5.8%). In the US, between 2008 and 2017, hip fractures were associated with 1-year mortality rates of 26.9% among men and 18.5% among women. Older age is a major risk factor for hip fracture, with a hazard ratio of 1.35 (95% CI, 1.25-1.47) per 5-year increase in age. Women have higher incidence of hip fractures than men due to accelerated bone loss after menopause and higher incidence of falls. Other risk factors for hip fractures include low bone mineral density (bone density of 1 SD or below that of healthy young adults measured by dual-energy x-ray absorptiometry), prior fracture, and factors contributing to falls, such as weak muscles, poor visual acuity, and smoking. Surgery for hip fracture typically consists of hip joint replacement or hip joint stabilization, using embedded hardware (open reduction and internal fixation). Patients with hip fracture benefit from physical therapy and fall reduction strategies, such as muscle-strengthening exercises and modifying medications associated with increased fall risk, such as antidepressants, and should be treated with antiresorptive medications, such as bisphosphonates (alendronate, zoledronic acid) or denosumab to prevent subsequent fracture. To prevent a hip fracture, patients with vertebral osteoporosis at the spine may require anabolic therapy, such as teriparatide, abaloparatide, or romosozumab, before starting an antiresorptive. Hip fractures may lead to mobility limitations; declines in physical, emotional, and social functioning; and reduced health-related quality of life.

CONCLUSIONS AND RELEVANCE Hip fractures are common among older people and are associated with a 1-year mortality rate of 22% and with reduced mobility and quality of life. Surgical repair for hip fracture typically consists of joint replacement or open reduction and internal fixation. Hip fracture treatment also includes physical therapy, fall reduction strategies, and medications to protect against fracture, such as bisphosphonates; denosumab; or anabolic drugs, such as parathyroid hormone analogues or romosozumab.

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Approximately 2 hip fractures occur every minute in the US, and approximately 27 per minute worldwide. Most hip fractures occur among older adults with accidental falls.[1] Lifetime risks of hip fracture are 22.9% in women and 10.7% in men at age 50 years and 19.3% and 9.1%, respectively, at age 80 years.[2] Among 66 746 patients with hip fracture, 11 899 (20%) died during 12-month follow-up. Hip fractures cause impaired mobility, pain, and substantial health care costs.[3,4] This review summarizes current evidence regarding the epidemiology, pathophysiology, diagnosis, treatment, and prevention of hip fractures.

Methods

We searched PubMed for English-language studies published between January 1995 and November 2025, using the search terms *hip fracture*, *falls*, *fall risk*, *fracture rehabilitation*, and *fracture liaison service* for clinical trials, observational studies, practice guidelines, meta-analyses, and systematic reviews. Additional articles were identified from references of articles identified in the search. Of 5454 identified articles, 101 were included, consisting of 11 randomized clinical trials, 21 meta-analyses, 15 reviews, 13 clinical guidelines or

position statements, 10 epidemiologic studies, and 16 retrospective observational and 15 prospective observational studies.

Epidemiology

In 2019, approximately 14.2 million people experienced hip fractures and 23.6 million people had a history of hip fracture worldwide.[1] A meta-analysis of 9 US observational studies between 2001 and 2018 among adults 60 years and older found that the mean age at the time of hip fracture was 81 years.[3] The global incidence of hip fractures among adults 55 years and older in 2019 was higher in women (833.9 per 100 000) than in men (510.0 per 100 000).[5]

Between 2005 and 2018, the median 1-year mortality rate after hip fracture was 22% worldwide.[5] In the US, from 2008 to 2017, the 1-year mortality rate after hip fracture was 26.9% among men and 18.5% among women.[3,5] The most common causes of mortality after hip fracture include pneumonia, sepsis, myocardial infarction, pulmonary embolism, and cancer.[6]

After a hip fracture, approximately 20.1% of patients require long-term nursing facility care and 6.6% become newly eligible for Medicaid or for a low-income subsidy under Medicare Part D.[4] Approximately 25.5% of adults who experience a hip fracture have another fracture within the subsequent year.[7] In 3 observational studies from the US and Canada that included 1443 patients with hip fracture, 42% to 71% of patients regained their prefracture level of basic activities of daily living, defined using the Modified Barthel Index or the Katz Activities of Daily Living Scale, by 6 months.[8] Hip fractures in adults 65 years and older are often associated with declines in physical, emotional, and social functioning, along with reduced health-related quality of life.[9]

Pathophysiology of Hip Fracture

Thinning of cortical bone and loss of trabecular bone with aging are associated with osteoporosis and increased susceptibility to hip fracture.[10] Osteoporosis is characterized by low bone mineral density (BMD) and abnormal microarchitecture, with porous cortical bone thinning and a loss and thinning of trabeculae leading to increased susceptibility to fractures.[11] Hip fracture occurs when the force applied to the hip exceeds its strength. Therefore, the key determinants of hip fracture risk are bone strength and excessive forces exerted on the hip during a fall. Some risk factors for hip fracture, such as older age, low level of physical activity, and poor nutrition, contribute to both low bone strength and high fall risk (**Figure 1**).[12]

Clinical Presentation and Diagnosis

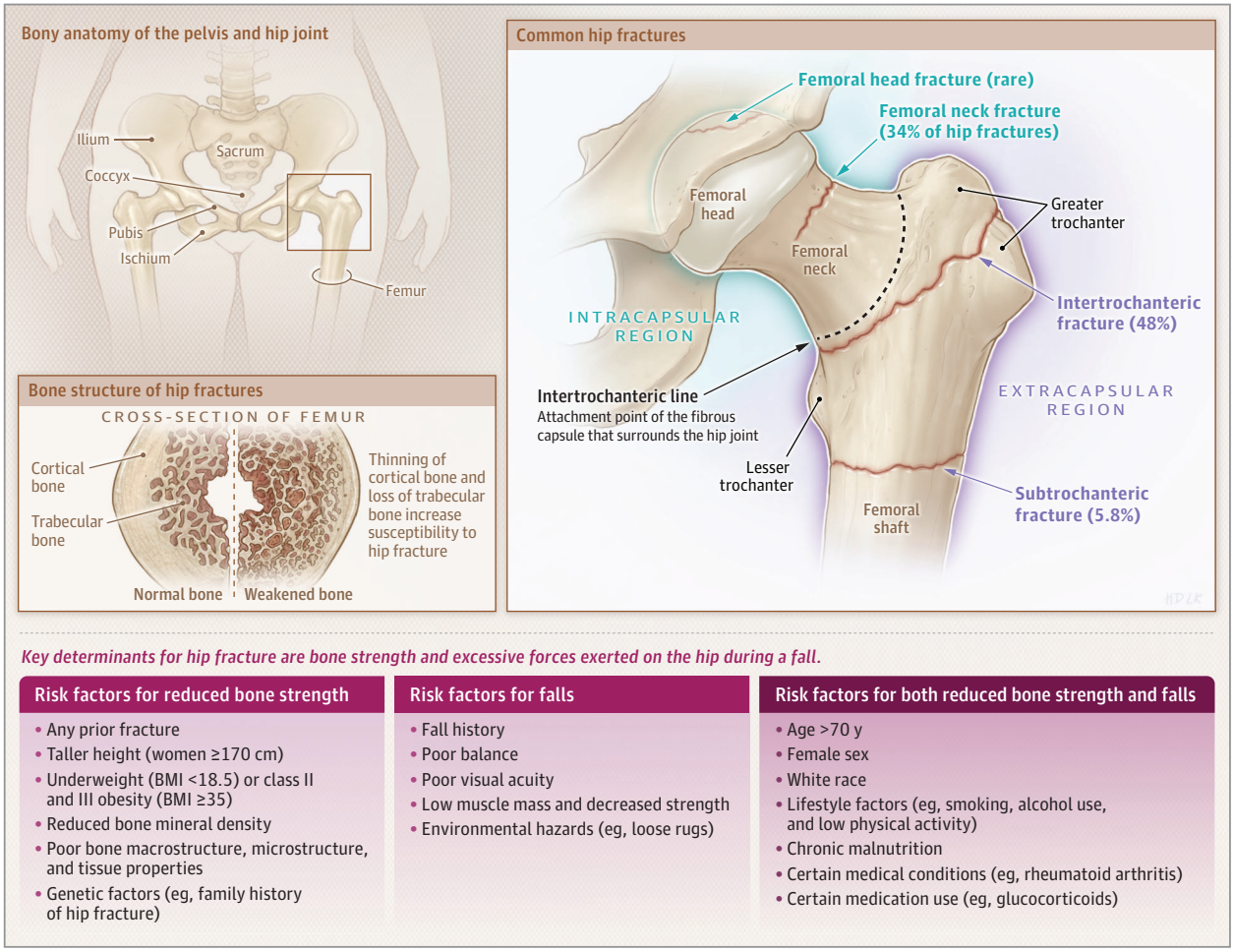
More than 95% of hip fractures occur after a fall[13] and present with hip pain and an externally rotated leg. Plain radiographs are at least 90% sensitive for hip fractures.[14] Only approximately 1% of patients with a likely hip fracture who do not have a fracture on radiograph but for whom the clinician suspects a fracture based on pain and immobility should undergo computed tomography or magnetic resonance imaging.[15] Hip fractures are classified as either intracapsular or extracapsular, depending on whether the fracture is within or outside of the fibrous capsule that surrounds the hip joint. Intracapsular hip fractures include femoral neck fractures (34% of all hip fractures) and femoral head fractures (rare), whereas extracapsular fractures include intertrochanteric (48% of all hip fractures) and subtrochanteric fractures (5.8% of all hip fractures); 11.8% of hip fractures could not be classified (Figure 1).[16]

Risk Factors for Hip Fracture

Hip fractures are uncommon before age 70 years, but the incidence progressively increases after age 70 years.[17] In a global study of 9 578 000 hip fractures in men and women, 1 189 000 hip fractures occurred in people aged 70 to 74 years and 4 111 000 occurred in people 80 years and older.[18] In men and women with BMD T-scores of less than −2.5 SD, the 10-year probability of hip fracture increased from 5.2% in men and 2.9% in women at age 50 years to 21.2% and 23.8%, respectively, at age 80 years.[19] Female sex is associated with higher rates of hip fracture because of accelerated bone loss after menopause and because older women have higher rates of falling than older men.[20] Based on self-reported race in a large study of women, the highest age-standardized hip fracture incidence rates per 10 000 person-years occurred in women who were White (38% [95% CI, 37%-39%]) compared with women who were Asian (17% [95% CI, 14%-22%]) or Black (9% [95% CI, 8%-11%]).[21] Reasons for racial differences in hip fracture incidence are unclear but may be due to variation in BMD, life expectancy, hip axis length and femoral geometry, skeletal microarchitecture, or genetic factors (**Box**).[22,23]

Certain lifestyle factors have been associated with an increased risk of hip fractures. A meta-analysis of 18 prospective cohorts in men and 23 prospective cohorts in women reported that current smoking was associated with a 1.7-fold increased risk of hip fracture (men, 95% CI, 1.5-2.1; women, 95% CI, 1.5-1.8) compared with people who never smoked, after adjusting for age and time since baseline (absolute rates not available).[24] In 3 longitudinal observational cohorts that included 17 379 men and 13 393 women 20 years or older, men who currently smoked cigarettes had a hip fracture incidence of 1.7 per 1000 person-years vs 0.8 per 1000 person-years in men who had never smoked cigarettes. Among women, hip fracture incidence rates were 3.1 per 1000 person-years for those who smoked cigarettes and 3.5 per 1000 person-years for women who never smoked cigarettes.[25] In a meta-analysis of 8 cohort studies involving 240 871 individuals (64% women), daily alcohol consumption of 3 and 4 standard drinks (1 beer, wine, or mixed drink) was associated with an increased hip fracture risk (risk ratio [RR], 1.33 [95% CI, 1.04-1.69]; RR, 1.59 [95% CI, 1.23-2.05], respectively) compared with people who did not drink any alcohol (absolute rates not available).[26] In pooled data from 3 longitudinal observational cohorts of 17 868 men and 13 917 women, men who consumed 42 to 69 drinks per week had a hip fracture rate of 2.05 per 1000 compared with men who consumed less than 1 drink per week, who had a hip fracture rate of 1.90 per 1000. For women, the rates of hip fracture were not higher with greater alcohol intake, but fewer women consumed as much alcohol as men.[27] In the Swedish National March Cohort, a longitudinal observational cohort of 23 881 participants 50 years and older who were followed up for a mean of 12.2 years, participants in the lowest range of physical activity (<30.8 metabolic equivalent task h/wk) had a hip fracture rate of

Figure 1. Illustration of Hip Fracture Classifications and Risk Factors for Hip Fracture in Older Adults



The key determinants of hip fracture risk are the likelihood of falling and bone strength. Risk factors for falls and bone strength are shown, with determinants influencing the risk of hip fracture through falls and bone strength. The most widely adopted and studied risk assessment tool is the Fracture Risk Assessment Tool, which provides a country-specific estimate of 10-year probability of hip fracture and considers the competing risk of mortality based on various clinical risk factors, including age, sex, height, weight, previous fracture, parent fractured hip, current smoking, glucocorticoid use, rheumatoid arthritis, secondary osteoporosis, and alcohol use, with or without femoral neck bone mineral density.[12]

BMI indicates body mass index (calculated as weight in kilograms divided by height in meters squared).

3.5 per 1000 person-years compared with those with physical activity of more than 44.4 metabolic equivalent task h/wk (2.5 per 1000 person-years).[28]

In a 6-year longitudinal study of 1746 older men and women, low dietary protein intake (63 g/d median intake in the lowest quartile) was associated with greater muscle strength decline (0.17%-0.27% loss per year) in the lowest quartile of protein intake compared with gains of 0.52% to 0.60% per year in the highest quartile.[29] In a cluster randomized trial, 60 accredited residential aged care facilities in Australia (including 7195 predominantly ambulatory residents) were randomized to receive either an intervention that provided additional milk, yogurt, and cheese to increase calcium and protein intake or a control group that received no supplementation. At 2-year follow-up, the intervention reduced hip fracture rates by 46% (1.3% vs 2.4%; $P = .005$) and lowered fall rates by 11% (cumulative incidence, 57% [n = 1879] vs 62% [n = 2423]; $P = .04$).[30]

Although childhood rickets due to severe vitamin D deficiency produces clinically observed muscle weakness, the role of vitamin D deficiency on muscle function in adults is unclear. A systematic review and meta-analysis of 54 randomized clinical trials involving 8747 individuals showed no effect of vitamin D supplementation on measures of muscle function, such as strength and physical performance measures, compared with placebo.[31] In the Vitamin D and Omega-3 Trial (VITAL) of 25 871 participants (men aged ≥50 years and women aged ≥55 years), compared with placebo, vitamin D supplementation did not significantly reduce falls.[32] However, in a clinical trial in which 124 nursing home residents were randomized to receive vitamin D supplementation (200 IU, 400 IU, 600 IU, or 800 IU) or placebo daily for 5 months, compared with placebo, 800-IU vitamin D significantly reduced falls (9 falls among 23 individuals in the 800-IU group vs 31 falls among 25 in the placebo group; $P < .05$).[33]

Medical conditions such as Parkinson disease, chronic liver disease, and diabetes are associated with higher rates of hip fractures,

Box. Frequently Asked Questions About Hip Fracture

How should patients be evaluated for risk of hip fracture?

The risk for hip and other fragility fractures can be evaluated using online risk calculators, such as the Fracture Risk Assessment Tool (FRAX), which offers several versions based on availability of bone mineral density, the patient's country, and self-reported race and ethnicity. Low bone mineral density of the hip measured using dual-energy x-ray absorptiometry is associated with risk for hip fracture.

What are primary prevention measures for patients at high risk of hip fracture?

Patients at high risk of fracture should take calcium and vitamin D supplements if their dietary intake does not meet the recommended daily allowance for calcium (1000 to 1200 mg/d) and vitamin D (600/800-1000 IU/d). Multidimensional fall risk assessment followed by multifactorial interventions reduce falls. High-risk patients should also be treated with an antiresorptive medication, such as bisphosphonates or denosumab, or anabolic drugs, such as parathyroid hormone analogues and sclerostin inhibitors, to decrease the risk of hip fracture.

What are secondary prevention measures for patients with hip fracture?

Secondary fracture prevention includes medications (bisphosphonates [intravenous infusion of zoledronic acid during hospitalization], denosumab, teriparatide, abaloparatide, romosozumab) and fall prevention interventions, such as muscle strengthening of the lower extremities and improving balance.

likely because they are associated with increased rates of falling or reduced bone strength (**Table 1**).[34-39] Medications such as glucocorticoids, aromatase inhibitors (letrozole or anastrozole), and antidepressants (amitriptyline or fluoxetine) have also been associated with an increased risk of hip fractures, most likely due to bone loss or increased risk of falls (Table 1).[39-44]

Risk Factors for Reduced Bone Strength

In a meta-analysis of 53 cohorts including 307 205 people followed up for 2.7 million person-years, the hazard ratio (HR) for incident hip fracture per SD-lower BMD was 2.31 (95% CI, 2.18-2.46) in men and 2.03 (95% CI, 1.91-2.16) in women, with adjustment for age and time since baseline (absolute rates not available).[45] In a meta-analysis of 64 prospective cohorts including 39 358 hip fracture cases, any prior fracture was associated with a 1.43-fold (95% CI, 1.30-1.56) increased risk of hip fracture, even after adjustment for age, time since baseline, and femoral neck BMD.[45] In a longitudinal observational study of community-dwelling individuals (1760 men, 2245 women) followed up for up to 16 years, rates of subsequent fractures after an initial hip fracture were 81 and 89 per 1000 person-years for men and women, respectively.[46] More than 55% of patients with a hip fracture within the past 6 months have an existing vertebral fracture.[47]

Among 796 081 postmenopausal women followed up for 8 years, 5734 (0.7%) sustained a femoral neck fracture, and taller women had a greater adjusted risk (RR, 1.48 [95% CI, 1.39-1.57] per 10-cm increase) (absolute rates not available).[48] The incidence of femoral neck fracture was 730 per 1 111 000 woman-years in the shortest height group (<155 cm) and 1273 per 1 031 000 woman-years in the tallest group (≥170 cm).[48] In contrast, lower body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) is associated with higher hip fracture risk. A meta-analysis of 1 667 922 men and women identified in 32 countries and followed up longitudinally reported that underweight (BMI <18.5) was associated with an increased adjusted risk of hip fracture in both women and men compared with BMI in the normal range (absolute rates not available; HR, 1.69 [95% CI, 1.47-1.69]; HR, 1.46 [95% CI, 1.00-2.13]).[49] Class II or higher obesity (BMI ≥35) was associated with

Table 1. Medical Conditions and Medications Associated With Increased Hip Fracture Risk[34-44]

Disease or medication	Association with bone strength and fall risk
Endocrine disorders	
Types 1 and 2 diabetes	Poor bone quality and increased fall risk due to diabetic neuropathy, diabetic retinopathy, hypoglycemic events, and sarcopenia
Hyperthyroidism	Reduced bone density and muscle weakness
Metabolic disorders	
Chronic kidney disease	Reduced bone density and muscle weakness
Chronic liver disease	Reduced bone density and muscle weakness
Alcohol use disorder	Reduced bone density and increased fall risk due to intoxication
Parkinson disease	Increased fall risk due to postural instability and impaired balance and gait and potentially reduced bone density[a]
Dementia	Increased fall risk due to impaired balance, confusion, muscle weakness, and medication use
Rheumatologic disorder	
Rheumatoid arthritis	Reduced bone density due to chronic inflammation and medication use, such as glucocorticoids, and increased fall risk due to pain and functional impairment
Nutritional/gastrointestinal disorders	
Chronic malnutrition, chronic malabsorption (eg, celiac disease, inflammatory bowel disease)	Reduced bone density and sarcopenia
Medications	
Glucocorticoids (hydrocortisone, prednisone)	Reduced bone density and muscle weakness
Aromatase inhibitors (anastrozole)	Reduced bone density
Androgen deprivation (leuprolide)	Reduced bone density and sarcopenia
Thiazolidinediones (pioglitazone, rosiglitazone)	Reduced bone density
Vasodilators (nitroglycerin, hydralazine)	Increased fall risk due to orthostatic hypotension or fainting
Benzodiazepines (diazepam, clonazepam)	Increased fall risk due to dizziness and sedation
Antidepressants (SSRIs, TCAs)	Increased fall risk due to dizziness, orthostatic hypotension, and sedation; SSRIs reduce bone density[b]
Antipsychotics (haloperidol, quetiapine)	Increased fall risk due to dizziness and sedation

Abbreviations: SSRI, selective serotonin reuptake inhibitor; TCA, tricyclic antidepressant.

[a] Parkinson disease potentially reduces bone density due to reduced weight-bearing physical activity and by the direct effect of dopamine depletion on the skeleton.

[b] SSRIs increase bone turnover, resulting in bone loss and increased risk for fracture.

higher hip fracture risk compared with normal BMI after adjusting for BMD (HR for women, 1.24 [95% CI, 0.97-1.58]; HR for men, 1.70 [95% CI, 1.06-2.75]).[49] In a prospective study of 6785 White women 65 years and older, weight loss of 5% or more was associated with a 79% higher hip fracture risk compared with those with stable or increasing weight, after adjusting for baseline weight, BMD, and multiple clinical risk factors (absolute rates not available).[50]

Genetic factors are associated with risk for hip fracture. In a meta-analysis of 350 542 men and women from 42 cohorts in 29 countries followed up for 2.8 million person-years, history of hip fracture in a parent was associated with an HR of 1.37 (95% CI, 1.23-1.52) for hip fracture independent of BMD (absolute rates not available).[51] In a cohort of 33 432 Swedish twins, the genetic association (heritability: range, 0-1.0, where 1.0 = all the variation in the likelihood of hip fracture within a given population is caused by genetic differences, with no contribution from environmental factors) for hip fractures was higher before age 69 years (heritability, 0.68 [95% CI, 0.41-0.78]) than for hip fractures after age 79 years (heritability, 0.03 [95% CI, 0-0.26]).[52] In a genome-wide association study meta-analysis (5 cohorts from European biobanks that included 11 516 hip fracture cases and 723 838 controls), 5 genome-wide significant loci were associated with increased risk for hip fracture, 4 of which were also associated with lower BMD, and 1 with falls (APOE locus on chromosome 19q13.32).[53] Another combined genome-wide association study and mendelian randomization analysis (N = 43 485) identified that a more obtuse femoral neck-shaft angle and a wider femoral neck may be associated with higher risk of hip fracture (odds ratio, 1.27 [95% CI, 1.12-1.44] vs 0.74 [95% CI, 0.65-0.84]) (absolute rates not available).[54]

Risk Factors for Falling

History of previous falls, poor vision, poor balance, low muscle mass, and decreased muscle strength are associated with increased risk of falling. A meta-analysis of 906 359 women and men from 46 prospective cohorts followed up for 9 102 207 person-years reported that history of previous falls was associated with a 36% increased risk of hip fracture (HR, 1.36 [95% CI, 1.23-1.50]) in women and a 59% increased risk of hip fracture (HR, 1.59 [95% CI, 1.38-1.84]) in men (absolute rates not available).[55] In a prospective cohort of 7575 women 75 years or older (follow-up of 1.9 years, 154 hip fractures), poorer visual acuity was associated with increased risk of hip fracture after adjusting for age, BMD, and additional fall-related risk factors (RR, 2.0 [95% CI, 1.1-3.7] for acuity ≤2/10 vs 7/10; absolute rates not available).[56]

Sarcopenia is typically defined by loss of muscle strength, mass, and function. A meta-analysis of 3 longitudinal studies in older men (mean age, 72-75 years; N = 10 411) reported that associations between sarcopenia and incident hip fracture varied by the criteria used to define sarcopenia and that sarcopenia was significantly associated with hip fracture, even when BMD was included in the statistical model, with the highest estimate being an HR of 2.36 (95% CI, 1.57-3.56) (absolute rates not available).[57]

Assessment of Hip Fracture Risk

Risk assessment tools include the Fracture Risk Assessment Tool (FRAX),[12] Garvan Fracture Risk Calculator,[58] and QFracture[59] (**Table 2**).[60-66] Additionally, the Fracture Risk Assessment in Long-Term Care (FRAiL) tool can assess 2-year hip fracture risk in nursing home residents.[67] FRAX, the most commonly used and studied tool, provides the 10-year probability of hip fracture for individuals aged 40 to 90 years based on clinical risk factors, such as age, sex, BMI, past history of fracture, and family history of fracture with or without femoral neck BMD (Figure 1). In a clinical trial of 12 483 women aged 70 to 85 years randomized to undergo community-based FRAX screening (n = 6233) or usual care (n = 6250), women randomized to undergo FRAX screening had higher use of osteoporosis medication at the end of year 1 compared with usual care (15% vs 4%) and a significantly reduced hip fracture rate (2.6% vs 3.5%) after 5 years (HR, 0.72 [95% CI, 0.59-0.89]).[68] Some bone density devices include software to estimate the texture of gray-level variations of the vertebral spine bone, which provides additional fracture risk information that has been added to FRAX.[69] Where available, existing computed tomography of the hip or spine can be analyzed for bone density using a US Food and Drug Administration–approved biomechanical computed tomography analysis that predicts fracture risk similarly to dual-energy x-ray absorptiometry.[66]

Although falling is a major risk factor for hip fracture, standard diagnostic tests to assess the risk of falling are not available. Fall risk assessment by primary care clinicians is recommended annually for adults 65 years and older or whenever a patient experiences an acute fall, according to the American Geriatrics Society and British Geriatrics Society (AGS/BGS) guideline.[70] The US Centers for Disease Control and Prevention initiated the Stopping Elderly Accidents, Deaths, and Injuries program to help clinicians follow the AGS/BGS guideline.[71] It consists of 2 screening tools: (1) the self-administered and -validated Stay Independent 12-question tool (score ranges from 0-14, with a score of ≥4 indicating significantly increased risk for sustaining a fall) and (2) 3 questions asked by a clinician: "do you feel unsteady when standing or walking?", "do you worry about falling?", and "have you fallen in the past year?"[71] An affirmative response to any of these questions indicates an increased risk of falling. If screening tools suggest an increased risk of falling, further assessment of gait, strength, and balance is needed (**Figure 2**).[71,72] The following tests that objectively evaluate fall risk can be used: Timed Up and Go, 30-Second Chair Stand, and 4-Stage Balance Test (3 tandem stands and a 1-legged stance). An alternative fall risk assessment tool by the World Falls Guidelines Task Force[72] divides assessment into preventive (eg, administered at a visit not related to a fall) encounters vs presentation to a clinician with a fall or fall injury and depends on identifying gait and balance impairment. Identifying abnormalities in strength, balance, and gait provides clinicians with characteristics to target for fall prevention. Multidimensional fall risk assessment followed by multifactorial interventions, some of which are administered by a physical therapist, reduce subsequent falls.[73]

Surgical Management

Most hip fractures require hospitalization and surgical intervention. In a systematic review of 28 prospective observational studies involving 31 242 patients, surgery within the first 48 hours

Table 2. Screening for Hip Fracture Risk[a,b]

	Description	Indicated patient population	Test interpretation
Imaging			
BMD testing by DXA	Areal BMD (g/cm^2) of the hip, which is more strongly associated with hip fracture than BMD at the spine; also reported as T-score, SD above or below bone peak mass; may also be used for monitoring effects therapy	Postmenopausal women aged ≥65 or ≥50 y with risk factors such as parental hip fracture or personal history of low-trauma fracture; men aged ≥70 y	T-score Normal: greater than or equal to −1 Osteopenia: less than −1 but greater than −2.5 Osteoporosis: −2.5 or less is an indication for pharmacologic treatment
Vertebral fracture assessment[60]	Performed with DXA to identify asymptomatic vertebral fractures	T-score less than −1.0 with any of the following: Women aged >70 y, men aged >80 y Height loss Glucocorticoid use Self-reported vertebral fracture	Presence of a vertebral fracture is associated with increased risk of future hip fracture
BMD testing from existing abdominal or pelvic CT scans performed for indications other than bone health[61]	CT-derived hip BMD and T-score comparable to standard DXA measurements CT-derived trabecular BMD (3-dimensional) of the lumbar spine (L1-L3) BMD is classified using the American College of Radiology thresholds, which yield diagnostic category distributions similar to those for WHO DXA T-scores	When a hip CT scan is already available for the populations recommended for DXA testing When a spine CT scan without contrast is already available for the populations recommended for DXA testing	Hip T-score same threshold as for DXA CT-derived trabecular spine BMD Normal bone mass ≥120 mg/cm^3 Low bone mass (osteopenia) 80 mg/cm^3, BMD <120 mg/cm^3 Osteoporosis BMD ≤80 mg/cm^3 is an indication for pharmacological treatment
Fracture risk assessment tools			
FRAX[12]	Calculates 10-y hip and major osteoporotic fracture risk based on clinical risk factors with or without femoral neck BMD based on more than 40 cohorts in nearly 30 countries	Adults aged 40-90 y	Hip FRAX score ≥3% is an indication for pharmacologic treatment
Garvan Fracture Risk Calculator[62]	Calculates 5- and 10-y hip and major osteoporotic fracture risk based on age, sex, prior fracture since the age of 50 y, falls in past year with BMD, or with weight instead of BMD; developed using data from the Dubbo Osteoporosis Epidemiology Study in Australia	Adults aged 50-96 y	Hip score 5-y risk ≥2% or hip score 10-y risk ≥3% is an indication for pharmacologic treatment
QFracture[59,63]	Calculates 1- to 10-y hip and major osteoporotic fracture risk based on various clinical risk factors; BMD is not included; UK-based model developed using a large database of general practice data	UK population aged 30-99 y	10-y Risk for women: threshold for the top 10% at highest risk is 11.1% 10-y Risk for men: threshold for the top 10% at highest risk is 2.6%

Abbreviations: BMD, bone mineral density; CT, computed tomography; DXA, dual-energy x-ray absorptiometry; FRAX, Fracture Risk Assessment Tool; WHO, World Health Organization.

[a] Clinically, testing BMD by DXA is sufficiently precise for interval assessment for screening. Frequency of rescreening is dependent on individual baseline results because patients closer to a treatment threshold warrant screening at shorter intervals.[64,65]

[b] Existing CT scans of the hip or spine can be analyzed for bone density using a US Food and Drug Administration–approved biomechanical CT analysis that predicts fracture risk as well as DXA.[66]

after hip fracture was associated with 20% lower mortality (RR, 0.80 [95% CI, 0.66-0.97]) (absolute rates not available).[74] For example, 1 study reported 5 deaths of 51 (10.6%) for patients who underwent surgery within 48 hours, compared with 9 of 33 deaths (27.3%) in patients whose surgery was performed more than 48 hours after the fracture; however, adjustment for patient factors was not performed.[75] Surgery for hip fracture typically consists of hip joint replacement or hip joint stabilization using embedded hardware (open reduction and internal fixation [ORIF]). ORIF stabilizes the fracture by applying screws, plates, rods, and pins to connect fractured bones. Hip fractures involving the intertrochanteric region of the hip are more commonly treated with ORIF. Hip fractures involving the femoral neck undergo replacement of the proximal femur and the acetabulum (bipolar hip arthroplasty) or replacement of the proximal femur (unipolar hip arthroplasty). In a systematic review of surgical options for 3727 patients with a femoral neck fracture, addition of cement to the hip replacement, compared with no cement, was associated with lower mortality (455 deaths of 1862 patients whose hip arthroplasty involved cement vs 528 deaths of 1865 patients with noncemented hip arthroplasty; RR, 0.86 [95% CI, 0.78-0.96]; 15 studies, 3727 participants), and improved health-related quality of life measured by the EuroQol 5 Dimensions or 12-item Short-Form Survey (standardized mean difference, 0.20 [95% CI, 0.07-0.34]; 3 studies, 1122 participants).[76] Cemented hip arthroplasty is recommended in clinical guidelines to reduce loosening and failure of inserted hardware.[77]

Among 3083 nursing home residents with severe dementia and hip fracture, 6-month mortality rates were 32% among the 85% who underwent surgical repair vs 54% among those who did not undergo

surgery, after adjustment for age, race, dementia severity, and a score associated with death (adjusted HR, 0.88 [95% CI, 0.79-0.98]).[78] Residents who underwent surgery reported less pain (465 of 1603 [29.0%] vs 59 of 191 [30.9%]; adjusted HR, 0.78 [95% CI, 0.61-0.99]) and developed fewer pressure ulcers (200 pressure ulcers in 1603 residents who underwent surgical repair vs 41 in 91 residents who did not undergo surgical repair; adjusted HR, 0.64 [95% CI, 0.47-0.86]).

Thromboprophylaxis

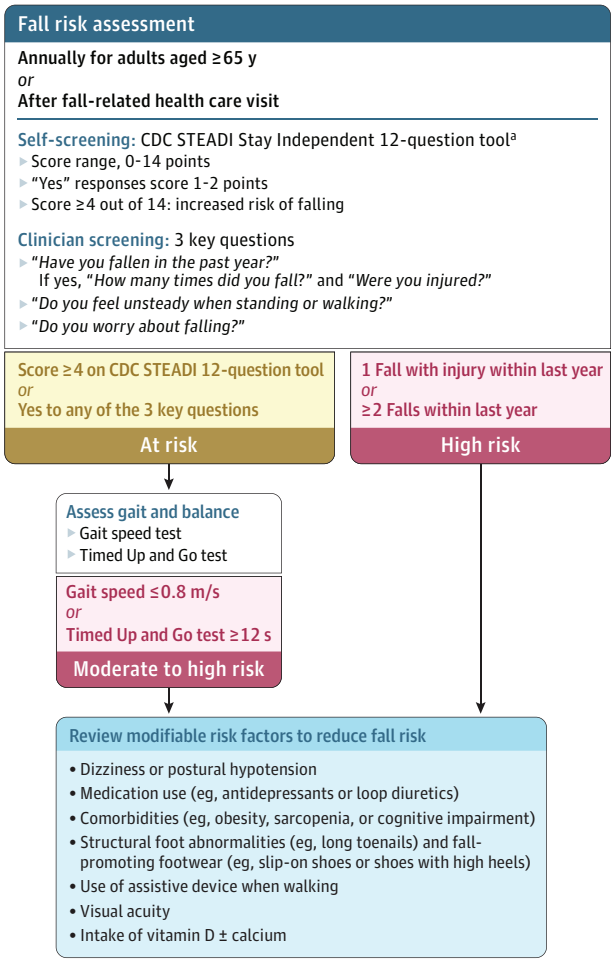
Asymptomatic deep vein thrombosis occurs in up to 50% and fatal pulmonary embolus in 10% of patients within 3 months after hip fracture, which has led to guideline recommendations for thromboprophylaxis among patients after hip fracture, regardless of whether the patient undergoes surgery.[79] Low-molecular-weight heparin, such as enoxaparin 30 to 40 mg subcutaneously every 24 hours, is typically prescribed preoperatively upon hospital admission. Heparin is discontinued within 4 hours of surgery and resumed at least 12 hours postoperatively. Direct oral anticoagulants, such as apixaban, rivaroxaban, and dabigatran, have comparable efficacy and safety to low-molecular-weight heparin.[80] Anticoagulation typically continues for up to 35 days after the procedure.[81] Other aspects of recommended postoperative management include early mobilization to reduce loss of muscle tone and mobility and adequate pain control with nonopioid analgesics or opioid pain medications when necessary to facilitate early mobilization and rehabilitation.[77]

Rehabilitation

After a hip fracture, patients should be evaluated by physical therapists for rehabilitation. Most patients can bear weight on a surgically repaired hip within 1 to 2 days after surgery. Physical therapy sessions to improve mobility may be initiated in the hospital but typically begin in a rehabilitation or skilled nursing facility. Physical therapists tailor therapy according to baseline physical function and comorbid conditions that affect mobility and safety (eg, obesity, sarcopenia, and cognitive impairment).

Interventions focused on improving mobility (ie, balance, walking, and functional tasks [climbing steps]) are associated with greater improvement in walking and mobility in the first 4 weeks after a hip fracture, whether implemented in the hospital or after discharge.[82] Studies that included gait training were associated with a modest improvement in mobility (standardized mean difference, 0.20 [95% CI, 0.05-0.36]; 5 studies, 621 participants). In the largest of 5 studies, the mobility score among the 100 patients randomized to receive gait training was 7.2 compared with the control group of 95 who achieved a mobility score of 6.2.[83] Additionally, when multiple types of exercise, including gait, balance, strength, and functional training, were tested in rehabilitation, there was a substantial, clinically meaningful improvement in mobility (standardized mean difference, 0.94 [95% CI, 0.53-1.34]; 2 studies, 104 participants). In the larger of the 2 studies of multiple exercises, the intervention group (n = 37) achieved a mobility score of 29 out of a maximum of 36 after 6 months vs the control group (n = 43) who achieved a mobility score of 23.3.[84]

Figure 2. Algorithm for the Assessment of Fall Risk



Adapted from the CDC and Montero-Odasso M et al.[71,72] This algorithm has not been evaluated in randomized clinical trials.

[a]The CDC initiated the STEADI Stay Independent 12-question tool, which is accessible on the CDC website, along with instructions on how to administer the gait and balance impairment tests.

CDC indicates US Centers for Disease Control and Prevention; STEADI, Stopping Elderly Accidents, Deaths, and Injuries.

Lifestyle Interventions After Hip Fracture

After patients with hip fracture complete physical therapy, long-term goals include maintenance of walking ability, restoring ability to climb steps and carry out activities of daily living, and preventing further falls.[73] Hip protectors that pad the trochanter and reduce the risk of hip fracture during a sideways fall have been associated with mixed outcomes in clinical trials.[85] Some of the effects of hip protectors may be due to enhanced institutional safety measures, such as bed alarms, moving residents closer to the nurses' station, and training staff about fall prevention, accompanying their use.[86] After a hip fracture, clinicians should evaluate the patient's medication list and consider reducing or discontinuing medications that may increase fall risk.[87]

Although supplemental calcium and vitamin D alone or in combination have not reduced fractures in randomized clinical

Table 3. Medications for Primary Prevention of Hip Fracture

Medication	Dosing	Mechanism of action	Who should receive the medication	Rate difference in hip fracture[a]	Adverse effects
Antiresorptive medications					
Bisphosphonates	Alendronate 70 mg orally weekly Risedronate 35 mg weekly or 150 mg monthly Ibandronate 150 mg orally monthly or 3 mg IV every 3 mo Zoledronic acid 5 mg IV annually	Inhibits osteoclast activity	Oral or IV may be initiated during hospitalization for hip fracture or oral formulations prescribed on discharge Contraindicated for those with creatinine clearance <35	6 Fewer per 1000 individuals (−11 to −1) in >36 mo bisphosphonates vs placebo (5 trials, 16 634 participants)	Gastrointestinal symptoms, such as acid reflux or indigestion (20%-30% of patients; oral only), myalgias (5% of patients), acute phase reaction with flulike symptoms (25% of patients; IV only), osteonecrosis of the jaw (<0.1% of patients), atypical femur fracture (approximately 0.2% of patients)
Denosumab	60-mg Subcutaneous injection every 6 mo	Monoclonal antibody to RANK ligand	May be initiated during hospitalization for hip fracture, with outpatient follow-up confirmed	4 Fewer per 1000 individuals (−8 to 0) in 36 mo denosumab vs placebo (1 trial, 7808 participants)	Eczema (10% of patients), cellulitis (0.4% of patients), osteonecrosis of the jaw (<0.1% of patients), atypical femur fracture (approximately 0.2% of patients); increased risk of multiple vertebral fractures if dose is delayed
Anabolic medications					
Teriparatide	20-µg Subcutaneous daily self-injection	Parathyroid hormone analogue	May be considered for patients with known low BMD; typically initiated in outpatient setting	4 Fewer per 1000 individuals (−12 to 4) vs placebo in 21 mo (median time) of teriparatide (1 trial, 1637 participants)	Arthralgia (10% of patients), nausea (9%-14% of patients), dizziness (8% of patients)
Romosozumab	210-mg Subcutaneous monthly injection	Monoclonal antibody to sclerostin	May be considered for patients with known low BMD; typically initiated in outpatient setting	12 Fewer per 1000 individuals (−22 to −2) in romosozumab (1 y) followed by alendronate (1 y) vs alendronate (2 y) (1 trial, 4093 participants)	Arthralgia (8%-13% of patients), headache (5%-7% of patients), osteonecrosis of the jaw (rare), atypical femur fracture (rare), major adverse cardiac events (2.5% of patients treated with romosozumab vs 1.9% treated with alendronate)[b]

Abbreviations: BMD, bone mineral density; IV, intravenous.

[a] Data from the meta-analysis by Ayers et al.[92]

[b] Two cases of osteonecrosis of the jaw and 1 atypical femur fracture were observed in a placebo-controlled trial of 3589 women who received romosozumab.[93]

trials,[88] multiple professional guidelines recommend a minimum intake of calcium (1000 to 1200 mg/d) and vitamin D (600/800-1000 IU/d) for all individuals older than 50 years.[89] High-quality evidence is not available regarding optimal nutrition, such as intake of protein, for maintaining muscle strength to prevent hip fractures.[90,91]

Medications for Osteoporosis

Osteoporosis medications are categorized as antiresorptive (decreasing bone resorption), including bisphosphonates, such as alendronate or zoledronic acid, denosumab, or selective estrogen receptor modulators (raloxifene); anabolic medications (medications that stimulate bone formation), such as parathyroid hormone analogues (teriparatide and abaloparatide); or those with both antiresorptive and anabolic properties, such as romosozumab (Table 3).[92,93]

Antiresorptive Medications

Bisphosphonates may be administered orally in weekly doses (alendronate) or monthly doses (risedronate) or intravenously annually (zoledronic acid). Because bisphosphonates are associated with hypocalcemia, a calcium level, 25-hydroxy vitamin D level, and kidney function should be checked prior to administration. Although there is no minimum 25-hydroxy vitamin D level that has been defined by high-quality evidence prior to bisphosphonate initiation, ruling out vitamin D deficiency or insufficiency is standard practice before initiation of a bisphosphonate medication. Bisphosphonates are contraindicated in patients with creatinine clearance less than 35 mL/min. Common adverse effects of oral bisphosphonates include gastrointestinal symptoms, such as acid reflux, an adverse effect that may be minimized by taking the medication with plain water upon rising in the morning; at least 30 minutes before food, beverage, or medication of the day; and staying upright for at least 30 minutes. Alternatively, gastrointestinal symptoms can be prevented by receiving an intravenous bisphosphonate. After hip fracture, these medications can prevent future fractures. Intravenous bisphosphonates also improve survival in patients with hip fracture.[94,95] In a randomized, double-blind trial of 2127 people with hip fracture, compared with placebo, intravenous zoledronate administered within 90 days of hip fracture reduced new clinical fracture by 35% (139 of 1062 [13%] vs 92 of 1065 [8.9%]; $P = .001$) at a median follow-up of 1.9 years.[94] Fewer deaths occurred in the zoledronic acid group (101 of 1054 [9.6%]) compared with the placebo group (141 of 1057 [13.3%]; $P = .01$).

In an observational study of patients hospitalized for acute hip fracture, 652 people treated with zoledronic acid were matched with 6877 control patients for whom antiosteoporosis treatment was indicated but not initiated. Zoledronic acid was associated with lower mortality rates (12.3% vs 20.7%; HR, 0.62 [95% CI, 0.49-0.78]) and lower rates of vertebral fractures (2.0% vs 5.4%; HR, 0.4 [95% CI, 0.22-0.71]) over 2 years.[95] However, zoledronic acid was not associated with significantly lower rates of hip fracture compared with

the control in patients with a history of hip fracture (absolute rates not available).[95]

Denosumab, an antiresorptive medication, is a monoclonal antibody against RANK ligand that is administered subcutaneously every 6 months. Hypocalcemia is a possible adverse effect of denosumab and requires measurement of calcium and 25-hydroxy vitamin D levels prior to administration. In contrast to bisphosphonates, denosumab is not eliminated by the kidneys, and patients with advanced chronic kidney disease may take these medications. However, severe, life-threatening hypocalcemia may occur in patients with advanced chronic kidney disease (estimated glomerular filtration rate <30 mL/min/1.73 m^2). Patients should be counseled that discontinuing or delaying administration of denosumab by even 1 month can cause rapid bone loss due to high bone turnover and multiple vertebral fractures. Therefore, denosumab should be continued indefinitely or an alternative antiresorptive medication should be prescribed to mitigate bone loss if it is necessary to discontinue denosumab.[96]

Although menopausal hormone therapy with estrogen-progestin reduces hip fracture rates,[97] menopausal hormone therapy is not typically prescribed after hip fracture because risks such as coronary heart disease and breast cancer outweigh benefits in older patients. Raloxifene, a selective estrogen receptor modulator, does not reduce rates of nonvertebral fractures[98] and therefore raloxifene is not a first-line therapy for patients with hip fracture.

Anabolic Medications

Anabolic medications include parathyroid hormone analogues (teriparatide or abaloparatide administered as daily subcutaneous injections) and romosozumab (administered as monthly subcutaneous injections). Romosozumab, a sclerostin monoclonal antibody, is the only US Food and Drug Administration–approved medication that has both anabolic and antiresorptive properties.[93] In the inpatient setting, antiresorptive agents, such as bisphosphonates and denosumab, are more commonly selected as first-line therapy after a hip fracture because anabolic therapy may be difficult to prescribe after hospital discharge in part due to patient preference for noninjectable medications and possibly due to insurance coverage.

Repeating dual-energy x-ray absorptiometry scans 1 or 2 years after hip fracture may help guide decisions regarding type of treatment for osteoporosis to assess BMD response and determine optimal therapy duration. However, patients with hip fracture should be treated with medications to prevent subsequent hip fractures, regardless of dual-energy x-ray absorptiometry results. If an anabolic therapy is selected first, this must be followed by antiresorptive therapy (such as bisphosphonates or denosumab) because anabolic therapies are prescribed for a limited duration (24 months for teriparatide, 18 months for abaloparatide, and 12 months for romosozumab) because their anabolic effect diminishes over time. Greater and faster BMD gains at the hip and spine are observed when anabolic therapy is followed by antiresorptive therapy compared with when treatment begins with antiresorptive therapy and is followed by anabolic therapy. Anabolic therapy may be considered in those with known low BMD, such as total hip T-scores less than −2.8 or spine T-score less than −3.0.[99]

Practical Considerations

Orthogeriatric services, consisting of collaborative care involving orthopedic surgeons and geriatricians with expertise treating older patients with fracture, perform preoperative assessment and postoperative management of pain, anticoagulation, and delirium prevention. A meta-analysis of 2 randomized clinical trials of 726 patients randomized to receive comprehensive orthogeriatric care or usual care reported that the primary outcome of change in instrumental activities of daily living at 4 months was improved in the comprehensive orthogeriatric care group, with a between-group difference of 3.56 points (mean [SE], 30.34 [0.95] in comprehensive geriatric care vs 26.77 [0.95] in orthopedic care [95% CI, 0.93-6.20]; $P = .008$).[100]

A fracture liaison service involves a coordinator who collaborates with the orthopedics surgery team and primary care clinicians to facilitate the transition between acute fracture care in the inpatient setting and the ambulatory long-term management of osteoporosis. One systematic review that included 37 randomized or observational studies with 111 381 participants diagnosed with low-trauma fragility fractures and treated with medications for osteoporosis reported that fracture liaison services were associated with lower rates of secondary fragility fracture after 2 years (fracture rate, 67 per 1000 for fracture liaison service vs 121 per 1000 for no fracture liaison service; RR, 0.68 [95% CI, 0.55-0.83]; 13 pooled studies, 33 811 participants).[101]

Limitations

This review has limitations. First, non–English-language articles were not included. Second, some relevant publications may have been missed. Third, not all aspects of hip fractures were discussed. Fourth, the quality of included manuscripts was not evaluated.

Conclusions

Hip fractures are common among older people and are associated with a 1-year mortality rate of 22% and with reduced mobility and quality of life. Surgical repair for hip fracture typically consists of joint replacement or ORIF. Hip fracture treatment also includes physical therapy, fall reduction strategies, and medications to protect against fracture, such as bisphosphonates, denosumab, romosozumab, or parathyroid hormone analogues.

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Submissions: We encourage authors to submit papers for consideration as a Review. Please contact Kristin Walter, MD, at kristin.walter@jamanetwork.org.

REFERENCES

1. GBD 2019 Fracture Collaborators. Global, regional, and national burden of bone fractures in 204 countries and territories, 1990-2019: a systematic analysis from the Global Burden of Disease Study 2019. *Lancet Healthy Longev*. 2021;2(9):e580-e592. doi:10.1016/S2666-7568(21)00172-0

2. Kanis JA, Johnell O, Oden A, et al. Long-term risk of osteoporotic fracture in Malmö. *Osteoporos Int*. 2000;11(8):669-674. doi:10.1007/s001980070064

3. Haleem S, Choudri MJ, Kainth GS, Parker MJ. Mortality following hip fracture: trends and geographical variations over the last sixty years. *Injury*. 2023;54(2):620-629. doi:10.1016/j.injury.2022.12.008

4. Tajeu GS, Delzell E, Smith W, et al. Death, debility, and destitution following hip fracture. *J Gerontol A Biol Sci Med Sci*. 2014;69(3):346-353. doi:10.1093/gerona/glt105

5. Sing CW, Lin TC, Bartholomew S, et al. Global epidemiology of hip fractures: secular trends in incidence rate, post-fracture treatment, and all-cause mortality. *J Bone Miner Res*. 2023;38(8):1064-1075. doi:10.1002/jbmr.4821

6. Katsanos S, Sioutis S, Reppas L, et al. What do hip fracture patients die from? *Eur J Orthop Surg Traumatol*. 2023;33(4):751-757. doi:10.1007/s00590-022-03250-x

7. Weaver J, Sajjan S, Lewiecki EM, Harris ST, Marvos P. Prevalence and cost of subsequent fractures among US patients with an incident fracture. *J Manag Care Spec Pharm*. 2017;23(4):461-471. doi:10.18553/jmcp.2017.23.4.461

8. Dyer SM, Crotty M, Fairhall N, et al; Fragility Fracture Network (FFN) Rehabilitation Research Special Interest Group. A critical review of the long-term disability outcomes following hip fracture. *BMC Geriatr*. 2016;16(1):158. doi:10.1186/s12877-016-0332-0

9. Peeters CM, Visser E, Van de Ree CL, Gosens T, Den Oudsten BL, De Vries J. Quality of life after hip fracture in the elderly: a systematic literature review. *Injury*. 2016;47(7):1369-1382. doi:10.1016/j.injury.2016.04.018

10. Riggs BL, Melton Iii LJ III, Robb RA, et al. Population-based study of age and sex differences in bone volumetric density, size, geometry, and structure at different skeletal sites. *J Bone Miner Res*. 2004;19(12):1945-1954. doi:10.1359/jbmr.040916

11. World Health Organization. Guidelines for preclinical evaluation and clinical trials in osteoporosis. 1998. Accessed November 1, 2025. https://iris.who.int/bitstream/handle/10665/42088/9241545224_eng.pdf

12. Schini M, Johansson H, Harvey NC, Lorentzon M, Kanis JA, McCloskey EV. An overview of the use of the Fracture Risk Assessment Tool (FRAX) in osteoporosis. *J Endocrinol Invest*. 2024;47(3):501-511. doi:10.1007/s40618-023-02219-9

13. Parkkari J, Kannus P, Palvanen M, et al. Majority of hip fractures occur as a result of a fall and impact on the greater trochanter of the femur: a prospective controlled hip fracture study with 206 consecutive patients. *Calcif Tissue Int*. 1999;65(3):183-187. doi:10.1007/s002239900679

14. Cannon J, Silvestri S, Munro M. Imaging choices in occult hip fracture. *J Emerg Med*. 2009;37(2):144-152. doi:10.1016/j.jemermed.2007.12.039

15. Foex BA, Russell A. BET 2: CT versus MRI for occult hip fractures. *Emerg Med J*. 2018;35(10):645-647. doi:10.1136/emermed-2018-208093.3

16. Longo UG, Viganò M, de Girolamo L, Banfi G, Salvatore G, Denaro V. Epidemiology and management of proximal femoral fractures in Italy between 2001 and 2016 in older adults: analysis of the National Discharge Registry. *Int J Environ Res Public Health*. 2022;19(24):16985. doi:10.3390/ijerph192416985

17. Samelson EJ, Zhang Y, Kiel DP, Hannan MT, Felson DT. Effect of birth cohort on risk of hip fracture: age-specific incidence rates in the Framingham Study. *Am J Public Health*. 2002;92(5):858-862. doi:10.2105/AJPH.92.5.858

18. Feng JN, Zhang CG, Li BH, Zhan SY, Wang SF, Song CL. Global burden of hip fracture: the Global Burden of Disease study. *Osteoporos Int*. 2024;35(1):41-52. doi:10.1007/s00198-023-06907-3

19. Kanis JA, Johnell O, Oden A, Dawson A, De Laet C, Jonsson B. Ten year probabilities of osteoporotic fractures according to BMD and diagnostic thresholds. *Osteoporos Int*. 2001;12(12):989-995. doi:10.1007/s001980170006

20. El-Menyar A, Tilley E, Al-Thani H, Latifi R. Females fall more from heights but males survive less among a geriatric population: insights from an American level 1 trauma center. *BMC Geriatr*. 2019;19(1):238. doi:10.1186/s12877-019-1252-6

21. Wright NC, Follis S, Larson JC, et al. Fractures by race and ethnicity in a diverse sample of postmenopausal women: a current evaluation among Hispanic and Asian origin groups. *J Bone Miner Res*. 2024;39(9):1296-1305. doi:10.1093/jbmr/zjae117

22. Bao Y, Xu Y, Li Z, Wu Q. Racial and ethnic difference in the risk of fractures in the United States: a systematic review and meta-analysis. *Sci Rep*. 2023;13(1):9481. doi:10.1038/s41598-023-32776-1

23. Lo JC, Yang W, Park-Sigal JJ, Ott SM. Osteoporosis and fracture risk among older US Asian adults. *Curr Osteoporos Rep*. 2023;21(5):592-608. doi:10.1007/s11914-023-00805-7

24. Kanis JA, Johnell O, Oden A, et al. Smoking and fracture risk: a meta-analysis. *Osteoporos Int*. 2005;16(2):155-162. doi:10.1007/s00198-004-1640-3

25. Høidrup S, Prescott E, Sørensen TI, et al. Tobacco smoking and risk of hip fracture in men and women. *Int J Epidemiol*. 2000;29(2):253-259. doi:10.1093/ije/29.2.253

26. Godos J, Giampieri F, Chisari E, et al. Alcohol consumption, bone mineral density, and risk of osteoporotic fractures: a dose-response meta-analysis. *Int J Environ Res Public Health*. 2022;19(3):1515. doi:10.3390/ijerph19031515

27. Høidrup S, Grønbaek M, Gottschau A, Lauritzen JB, Schroll M; Copenhagen Centre for Prospective Population Studies. Alcohol intake, beverage preference, and risk of hip fracture in men and women. *Am J Epidemiol*. 1999;149(11):993-1001. doi:10.1093/oxfordjournals.aje.a009760

28. Lagerros YT, Hantikainen E, Michaëlsson K, Ye W, Adami HO, Bellocco R. Physical activity and the risk of hip fracture in the elderly: a prospective cohort study. *Eur J Epidemiol*. 2017;32(11):983-991. doi:10.1007/s10654-017-0312-5

29. McLean RR, Mangano KM, Hannan MT, Kiel DP, Sahni S. Dietary protein intake is protective against loss of grip strength among older adults in the Framingham offspring cohort. *J Gerontol A Biol Sci Med Sci*. 2016;71(3):356-361. doi:10.1093/gerona/glv184

30. Iuliano S, Poon S, Robbins J, et al. Effect of dietary sources of calcium and protein on hip fractures and falls in older adults in residential care: cluster randomised controlled trial. *BMJ*. 2021;375(2364):n2364. doi:10.1136/bmj.n2364

31. Bislev LS, Grove-Laugesen D, Rejnmark L. Vitamin D and muscle health: a systematic review and meta-analysis of randomized placebo-controlled trials. *J Bone Miner Res*. 2021;36(9):1651-1660. doi:10.1002/jbmr.4412

32. LeBoff MS, Murata EM, Cook NR, et al. Vitamin D and Omega-3 Trial (VITAL): effects of vitamin D supplements on risk of falls in the US population. *J Clin Endocrinol Metab*. 2020;105(9):2929-2938. doi:10.1210/clinem/dgaa311

33. Broe KE, Chen TC, Weinberg J, Bischoff-Ferrari HA, Holick MF, Kiel DP. A higher dose of vitamin D reduces the risk of falls in nursing home residents: a randomized, multiple-dose study. *J Am Geriatr Soc*. 2007;55(2):234-239. doi:10.1111/j.1532-5415.2007.01048.x

34. Friedman SM, Menzies IB, Bukata SV, Mendelson DA, Kates SL. Dementia and hip fractures: development of a pathogenic framework for understanding and studying risk. *Geriatr Orthop Surg Rehabil*. 2010;1(2):52-62. doi:10.1177/2151458510389463

35. Hofbauer LC, Busse B, Eastell R, et al. Bone fragility in diabetes: novel concepts and clinical implications. *Lancet Diabetes Endocrinol*. 2022;10(3):207-220. doi:10.1016/S2213-8587(21)00347-8

36. Kanis JA. Diagnosis of osteoporosis and assessment of fracture risk. *Lancet*. 2002;359(9321):1929-1936. doi:10.1016/S0140-6736(02)08761-5

37. Pouwels S, Lalmohamed A, Leufkens B, et al. Risk of hip/femur fracture after stroke: a population-based case-control study. *Stroke*. 2009;40(10):3281-3285. doi:10.1161/STROKEAHA.109.554055

38. Schini M, Vilaca T, Poku E, et al. The risk of hip and non-vertebral fractures in patients with Parkinson's disease and parkinsonism: a systematic review and meta-analysis. *Bone*. 2020;132:115173. doi:10.1016/j.bone.2019.115173

39. Leavy B, Michaëlsson K, Åberg AC, Melhus H, Byberg L. The impact of disease and drugs on hip fracture risk. *Calcif Tissue Int*. 2017;100(1):1-12. doi:10.1007/s00223-016-0194-7

40. Amiche MA, Abtahi S, Driessen JHM, et al. Impact of cumulative exposure to high-dose oral glucocorticoids on fracture risk in Denmark: a population-based case-control study. *Arch Osteoporos*. 2018;13(1):30. doi:10.1007/s11657-018-0424-x

41. Panday K, Gona A, Humphrey MB. Medication-induced osteoporosis: screening and

treatment strategies. *Ther Adv Musculoskelet Dis*. 2014;6(5):185-202. doi:10.1177/1759720X14546350

42. Seppala LJ, Petrovic M, Ryg J, et al. STOPPFall (Screening Tool of Older Persons Prescriptions in older adults with high fall risk): a Delphi study by the EuGMS Task and Finish Group on Fall-Risk-Increasing Drugs. *Age Ageing*. 2021;50(4):1189-1199. doi:10.1093/ageing/afaa249

43. Woolcott JC, Richardson KJ, Wiens MO, et al. Meta-analysis of the impact of 9 medication classes on falls in elderly persons. *Arch Intern Med*. 2009;169(21):1952-1960. doi:10.1001/archinternmed.2009.357

44. Zhou C, Fang L, Chen Y, Zhong J, Wang H, Xie P. Effect of selective serotonin reuptake inhibitors on bone mineral density: a systematic review and meta-analysis. *Osteoporos Int*. 2018;29(6):1243-1251. doi:10.1007/s00198-018-4413-0

45. Kanis JA, McCloskey EV, Johansson H, et al. Predictive value of BMD for hip and other fractures: a meta-analysis to update FRAX. *Osteoporos Int*. 2026. doi:10.1007/s00198-026-07925-7

46. Center JR, Bliuc D, Nguyen TV, Eisman JA. Risk of subsequent fracture after low-trauma fracture in men and women. *JAMA*. 2007;297(4):387-394. doi:10.1001/jama.297.4.387

47. Gonnelli S, Caffarelli C, Maggi S, et al; BREAK Study Group. The assessment of vertebral fractures in elderly women with recent hip fractures: the BREAK study. *Osteoporos Int*. 2013;24(4):1151-1159. doi:10.1007/s00198-012-2119-2

48. Armstrong ME, Kirichek O, Cairns BJ, Green J, Reeves GK; Valerie Beral for the Million Women Study Collaborators. Relationship of height to site-specific fracture risk in postmenopausal women. *J Bone Miner Res*. 2016;31(4):725-731. doi:10.1002/jbmr.2742

49. Harvey NC, Johansson H, McCloskey EV, et al. Body mass index and subsequent fracture risk: a meta-analysis to update FRAX. *J Bone Miner Res*. 2025;40(10):1144-1155. doi:10.1093/jbmr/zjaf091

50. Ensrud KE, Ewing SK, Stone KL, Cauley JA, Bowman PJ, Cummings SR; Study of Osteoporotic Fractures Research Group. Intentional and unintentional weight loss increase bone loss and hip fracture risk in older women. *J Am Geriatr Soc*. 2003;51(12):1740-1747. doi:10.1046/j.1532-5415.2003.51558.x

51. McCloskey EV, Johansson H, Liu E, et al. Family history of fracture and fracture risk: a meta-analysis to update the FRAX risk assessment tool. *Osteoporos Int*. 2025;36(9):1725-1741. doi:10.1007/s00198-025-07607-w

52. Michaëlsson K, Melhus H, Ferm H, Ahlbom A, Pedersen NL. Genetic liability to fractures in the elderly. *Arch Intern Med*. 2005;165(16):1825-1830. doi:10.1001/archinte.165.16.1825

53. Nethander M, Coward E, Reimann E, et al; Estonian Biobank Research Team. Assessment of the genetic and clinical determinants of hip fracture risk: genome-wide association and mendelian randomization study. *Cell Rep Med*. 2022;3(10):100776. doi:10.1016/j.xcrm.2022.100776

54. Faber BG, Frysz M, Zheng J, et al. The genetic architecture of hip shape and its role in the development of hip osteoarthritis and fracture. *Hum Mol Genet*. 2025;34(3):207-217. doi:10.1093/hmg/ddae169

55. Vandenput L, Johansson H, McCloskey EV, et al. A meta-analysis of previous falls and subsequent fracture risk in cohort studies. *Osteoporos Int*. 2024;35(3):469-494. doi:10.1007/s00198-023-07012-1

56. Dargent-Molina P, Favier F, Grandjean H, et al. Fall-related factors and risk of hip fracture: the EPIDOS prospective study. *Lancet*. 1996;348(9021):145-149. doi:10.1016/S0140-6736(96)01440-7

57. Harvey NC, Orwoll E, Kwok T, et al. Sarcopenia definitions as predictors of fracture risk independent of FRAX, falls, and BMD in the Osteoporotic Fractures in Men (MrOS) study: a meta-analysis. *J Bone Miner Res*. 2021;36(7):1235-1244. doi:10.1002/jbmr.4293

58. Bolland MJ, Siu AT, Mason BH, et al. Evaluation of the FRAX and Garvan fracture risk calculators in older women. *J Bone Miner Res*. 2011;26(2):420-427. doi:10.1002/jbmr.215

59. Hippisley-Cox J, Coupland C. Predicting risk of osteoporotic fracture in men and women in England and Wales: prospective derivation and validation of QFractureScores. *BMJ*. 2009;339:b4229. doi:10.1136/bmj.b4229

60. International Society for Clinical Densitometry. Adult positions. Updated 2023. Accessed November 1, 2025. https://iscd.org/learn/official-positions/adult-positions/

61. American College of Radiology. ACR-SPR-SSR practice parameter for the performance of quantitative computed tomography (QCT) bone mineral density. Revised 2023. Accessed July 6, 2026. https://gravitas.acr.org/PPTS/GetDocumentView?docId=11

62. Nguyen ND, Frost SA, Center JR, Eisman JA, Nguyen TV. Development of prognostic nomograms for individualizing 5-year and 10-year fracture risks. *Osteoporos Int*. 2008;19(10):1431-1444. doi:10.1007/s00198-008-0588-0

63. Akyea RK, McKeever TM, Gibson J, Scullion JE, Bolton CE. Predicting fracture risk in patients with chronic obstructive pulmonary disease: a UK-based population-based cohort study. *BMJ Open*. 2019;9(4):e024951. doi:10.1136/bmjopen-2018-024951

64. Berry SD, Samelson EJ, Pencina MJ, et al. Repeat bone mineral density screening and prediction of hip and major osteoporotic fracture. *JAMA*. 2013;310(12):1256-1262. doi:10.1001/jama.2013.277817

65. Gourlay ML, Fine JP, Preisser JS, et al; Study of Osteoporotic Fractures Research Group. Bone-density testing interval and transition to osteoporosis in older women. *N Engl J Med*. 2012;366(3):225-233. doi:10.1056/NEJMoa1107142

66. Keaveny TM, Clarke BL, Cosman F, et al. Biomechanical Computed Tomography analysis (BCT) for clinical assessment of osteoporosis. *Osteoporos Int*. 2020;31(6):1025-1048. doi:10.1007/s00198-020-05384-2

67. Berry SD, Zullo AR, Lee Y, et al. Fracture Risk Assessment in Long-term Care (FRAiL): development and validation of a prediction model. *J Gerontol A Biol Sci Med Sci*. 2018;73(6):763-769. doi:10.1093/gerona/glx147

68. Shepstone L, Lenaghan E, Cooper C, et al; SCOOP Study Team. Screening in the Community to Reduce Fractures in Older Women (SCOOP): a randomised controlled trial. *Lancet*. 2018;391(10122):741-747. doi:10.1016/S0140-6736(17)32640-5

69. McCloskey EV, Odén A, Harvey NC, et al. A meta-analysis of trabecular bone score in fracture risk prediction and its relationship to FRAX. *J Bone Miner Res*. 2016;31(5):940-948. doi:10.1002/jbmr.2734

70. Eckstrom E, Vincenzo JL, Casey CM, et al. American Geriatrics Society response to the World Falls Guidelines. *J Am Geriatr Soc*. 2024;72(6):1669-1686. doi:10.1111/jgs.18734

71. Centers for Disease Control and Prevention. STEADI–older adult fall prevention. Accessed October 21, 2025. https://www.cdc.gov/steadi/index.html

72. Montero-Odasso M, van der Velde N, Martin FC, et al; Task Force on Global Guidelines for Falls in Older Adults. World guidelines for falls prevention and management for older adults: a global initiative. *Age Ageing*. 2022;51(9):afac205. doi:10.1093/ageing/afac205

73. Guirguis-Blake JM, Perdue LA, Coppola EL, Bean SI. Interventions to prevent falls in older adults: updated evidence report and systematic review for the US Preventive Services Task Force. *JAMA*. 2024;332(1):58-69. doi:10.1001/jama.2024.4166

74. Klestil T, Röder C, Stotter C, et al. Impact of timing of surgery in elderly hip fracture patients: a systematic review and meta-analysis. *Sci Rep*. 2018;8(1):13933. doi:10.1038/s41598-018-32098-7

75. Hapuarachchi KS, Ahluwalia RS, Bowditch MG. Neck of femur fractures in the over 90s: a select group of patients who require prompt surgical intervention for optimal results. *J Orthop Traumatol*. 2014;15(1):13-19. doi:10.1007/s10195-013-0248-9

76. Lewis SR, Macey R, Parker MJ, Cook JA, Griffin XL. Arthroplasties for hip fracture in adults. *Cochrane Database Syst Rev*. 2022;2(2):CD013410. doi:10.1002/14651858.CD013410.pub2

77. American Academy of Orthopaedic Surgeons. Management of hip fractures in older adults: evidence based clinical practice guideline. December 3, 2021. Accessed June 9, 2026. https://www.aaos.org/hipfxcpg

78. Berry SD, Rothbaum RR, Kiel DP, Lee Y, Mitchell SL. Association of clinical outcomes with surgical repair of hip fracture vs nonsurgical management in nursing home residents with advanced dementia. *JAMA Intern Med*. 2018;178(6):774-780. doi:10.1001/jamainternmed.2018.0743

79. McNamara I, Sharma A, Prevost T, Parker M. Symptomatic venous thromboembolism following a hip fracture. *Acta Orthop*. 2009;80(6):687-692. doi:10.3109/17453670903448273

80. Nederpelt CJ, Bijman Q, Krijnen P, Schipper IB. Equivalence of DOACS and LMWH for thromboprophylaxis after hip fracture surgery: systematic review and meta-analysis. *Injury*. 2022;53(3):1169-1176. doi:10.1016/j.injury.2021.11.052

81. Falck-Ytter Y, Francis CW, Johanson NA, et al. Prevention of VTE in orthopedic surgery patients: antithrombotic therapy and prevention of thrombosis, 9th ed: American College of Chest Physicians evidence-based clinical practice guidelines. *Chest*. 2012;141(2 suppl):e278S-e325S. doi:10.1378/chest.11-2404

82. Fairhall NJ, Dyer SM, Mak JC, Diong J, Kwok WS, Sherrington C. Interventions for improving

mobility after hip fracture surgery in adults. *Cochrane Database Syst Rev*. 2022;9(9):CD001704. doi:10.1002/14651858.CD001704.pub5

83. Latham NK, Harris BA, Bean JF, et al. Effect of a home-based exercise program on functional recovery following rehabilitation after hip fracture: a randomized clinical trial. *JAMA*. 2014;311(7):700-708. doi:10.1001/jama.2014.469

84. Binder EF, Brown M, Sinacore DR, et al. Effects of extended outpatient rehabilitation after hip fracture: a randomized controlled trial. *JAMA*. 2004;292(7):837-846. doi:10.1001/jama.292.7.837

85. Sawka AM, Boulos P, Beattie K, et al. Do hip protectors decrease the risk of hip fracture in institutional and community-dwelling elderly? a systematic review and meta-analysis of randomized controlled trials. *Osteoporos Int*. 2005;16(12):1461-1474. doi:10.1007/s00198-005-1932-2

86. Parker MJ, Gillespie WJ, Gillespie LD. Effectiveness of hip protectors for preventing hip fractures in elderly people: systematic review. *BMJ*. 2006;332(7541):571-574. doi:10.1136/bmj.38753.375324.7C

87. Roberts JE, Boudreau RM, Freeland KS, et al. Factors associated with fall risk increasing drug use in older Black and White men and women: the Health ABC study. *BMC Geriatr*. 2024;24(1):773. doi:10.1186/s12877-024-05301-w

88. Bolland MJ, Grey A, Avenell A. Effects of vitamin D supplementation on musculoskeletal health: a systematic review, meta-analysis, and trial sequential analysis. *Lancet Diabetes Endocrinol*. 2018;6(11):847-858. doi:10.1016/S2213-8587(18)30265-1

89. LeBoff MS, Greenspan SL, Insogna KL, et al. The clinician's guide to prevention and treatment of osteoporosis. *Osteoporos Int*. 2022;33(10):2049-2102. doi:10.1007/s00198-021-05900-y

90. Mocini E, Cardinali L, Di Vincenzo O, et al. An integrated nutritional and physical activity approach for osteosarcopenia. *Nutrients*. 2025;17(17):2842. doi:10.3390/nu17172842

91. Papadopoulou SK, Papadimitriou K, Voulgaridou G, et al. Exercise and nutrition impact on osteoporosis and sarcopenia—the incidence of osteosarcopenia: a narrative review. *Nutrients*. 2021;13(12):4499. doi:10.3390/nu13124499

92. Ayers C, Kansagara D, Lazur B, Fu R, Kwon A, Harrod C. Effectiveness and safety of treatments to prevent fractures in people with low bone mass or primary osteoporosis: a living systematic review and network meta-analysis for the American College of Physicians. *Ann Intern Med*. 2023;176(2):182-195. doi:10.7326/M22-0684

93. Cosman F, Crittenden DB, Adachi JD, et al. Romosozumab treatment in postmenopausal women with osteoporosis. *N Engl J Med*. 2016;375(16):1532-1543. doi:10.1056/NEJMoa1607948

94. Lyles KW, Colón-Emeric CS, Magaziner JS, et al; HORIZON Recurrent Fracture Trial. Zoledronic acid and clinical fractures and mortality after hip fracture. *N Engl J Med*. 2007;357(18):1799-1809. doi:10.1056/NEJMoa074941

95. Fan W, Sun X, Leder BZ, et al. Zoledronic acid for hip fracture during initial hospitalization. *J Bone Miner Res*. 2024;39(8):1061-1070. doi:10.1093/jbmr/zjae101

96. Tsourdi E, Zillikens MC, Meier C, et al. Fracture risk and management of discontinuation of denosumab therapy: a systematic review and position statement by ECTS. *J Clin Endocrinol Metab*. 2020:dgaa756. doi:10.1210/clinem/dgaa756

97. Rossouw JE, Anderson GL, Prentice RL, et al; Writing Group for the Women's Health Initiative Investigators. Risks and benefits of estrogen plus progestin in healthy postmenopausal women: principal results from the Women's Health Initiative randomized controlled trial. *JAMA*. 2002;288(3):321-333. doi:10.1001/jama.288.3.321

98. Ettinger B, Black DM, Mitlak BH, et al; Multiple Outcomes of Raloxifene Evaluation (MORE) Investigators. Reduction of vertebral fracture risk in postmenopausal women with osteoporosis treated with raloxifene: results from a 3-year randomized clinical trial. *JAMA*. 1999;282(7):637-645. doi:10.1001/jama.282.7.637

99. Cosman F, Lewiecki EM, Eastell R, et al. Goal-directed osteoporosis treatment: ASBMR/BHOF task force position statement 2024. *J Bone Miner Res*. 2024;39(10):1393-1405. doi:10.1093/jbmr/zjae119

100. Dakhil S, Thingstad P, Frihagen F, et al. Orthogeriatrics prevents functional decline in hip fracture patients: report from two randomized controlled trials. *BMC Geriatr*. 2021;21(1):208. doi:10.1186/s12877-021-02152-7

101. Danazumi MS, Lightbody N, Dermody G. Effectiveness of fracture liaison service in reducing the risk of secondary fragility fractures in adults aged 50 and older: a systematic review and meta-analysis. *Osteoporos Int*. 2024;35(7):1133-1151. doi:10.1007/s00198-024-07052-1