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Aging Bones

Osteoporosis and Injurious Falls in the Oldest Women

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Abstract

The risk of injurious falls increases with age. In women younger than 75 yr, much of the attention toward reducing the risk of injurious falls is appropriately directed at identifying and treating osteoporosis. In the oldest women, however, particularly those over 75 to 80 yr of age, strategies must be multifaceted. The prevalence of medical conditions and geriatric syndromes increases with age. Effective interventions to reduce the risk of injurious falls include optimizing medical conditions, assessing geriatric syndromes, addressing pain, improving balance, and reducing polypharmacy. In this article we offer an evidence-based approach to identifying and treating fall risks in the oldest women.

Key Words: Aged; geriatric syndromes; multifactorial assessment; osteoporosis; falls.

Introduction

Falls are the primary cause of injury mortality in women over age 75 yr *(1)*. Nonfatal falls occur in nearly one-third of community-dwelling elders each year *(2)*. Whether injurious or not, falls increase the risk of admission to a skilled nursing facility *(3)*. A hip fracture is particularly costly in terms of its economic and functional burden. Of all the types of fractures, hip fractures account for one-third of the incremental financial costs of osteoporotic fractures *(4)*. With the increasing number and proportion of the "old-old" in our society, and the minimal attention paid to bone health during the early and middle years of aging, osteoporosis and its functional and economic impact are predicted to be a growing burden.

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The etiology of injurious falls in elders is more complex than that in the younger population. The impact of aging on bone integrity is readily observed in the menopausal "young-old" cohort, with osteoporosis being the primary contributor to fracture in women less than 75 yr of age. But in the oldest women, the cohort older than 75, age-related physiology and disease contribute to fracture risk and in fact may be the predominant fracture predictors. Age-related changes in the oldest women include impaired balance, decreased muscle strength, gait alteration, impaired recovery from perturbation, altered vitamin D metabolism, and impaired visual accommodation. Sequelae of chronic diseases common to older adults may exacerbate these problems. For example, macular degeneration may decrease central vision; cognitive impairment may alter judgment; Parkinson's disease impairs balance and gait; diabetic neuropathy or vitamin B_{12} deficiency may alter proprioception and balance; and arthritis may impair joint mobility and muscle strength.

Polypharmacy, often found concomitantly with chronic disease, increases the risk of falls. Geriatric syndromes such as urinary incontinence are associated with falls as well.

Reducing morbidity and mortality from falls in the oldest women requires not only addressing osteoporosis, but also identifying and addressing potential contributions to fall risk based on the interplay of aging and disease in the individual woman. In this article, we offer an evidence-based approach to the treatment of osteoporosis in the old-old, and a guide to individualizing the approach to identifying and treating fall risks in this cohort.

Physiology of Aging Relevant to Injurious Falls

Aging Bone

During aging, bone resorption on the cortical and trabecular surfaces causes the trabeculae to thin and disappear, and the cortex to become porous. These changes further reduce bone strength at a time when increased prevalence of muscle weakness, reduced coordination, and propensity to fall predisposes to hip fractures *(5)*.

The greater strength of the long bones in men compared with that in women is the result of differences in size, not density. The mineral content per unit volume of bone tissue is no different, irrespective of racial origin, sex, or age *(5)*.

Calcium in Women

Two important factors that influence the occurrence of osteoporosis in women are peak bone mass achieved in the first three decades of life and the rate of postmenopausal bone loss associated with aging. Calcium intake and absorption account for 25% of the variance in calcium balance, whereas urinary excretion is responsible for 50%. High intake of sodium and protein can significantly increase calcium excretion. Certain supplements used by elderly women, such as wheat bran, may decrease calcium absorption. Because 99% of the body's calcium is found in bone, calcium demand and utilization are largely determined by skeletal requirements. Disuse, for instance with immobilization, increases bone mineral resorption in women both in the short term (e.g., hospitalization for illness) and in the long term (e.g., institutionalization). Institutionalized, bedbound elderly are particularly at risk of bone loss as a result of immobilization *(6)*.

Vitamin D

Vitamin D has a direct effect on calcium homeostasis, parathyroid hormone (PTH) levels, and muscle function. Calcium absorption from the gut depends on vitamin D. Vitamin D deficiency in older adults can be caused by inadequate intake or decreased sun exposure (specifically to the ultraviolet B required for vitamin D activation) *(7)*. The parathyroid gland responds to functional vitamin D deficiency by secreting excessive serum PTH *(8)*, resulting in increased bone turnover and accelerated bone loss *(9)*. In addition to reducing bone integrity, vitamin D deficiency may increase fall risk by decreasing the number and size of type II muscle fibers *(10)*. Concentrations of 25-hydroxyvitamin D [25(OH)D] well in the normal range, for example greater than or equal to 40 nmol/L, are associated with better lower extremity muscular function regardless of activity level *(11)*.

Musculoskeletal System

Age-related changes that alter balance and gait include decreased muscle strength, vision, vestibular function, and proprioception. Sarcopenia of type II (fast twitch) muscle fibers results in smaller, weaker, and slower muscles. By age 80, isometric muscle strength decreases 50% and the number of muscle fibers decreases 39% *(12–14)*.

Decreased muscle strength of the quadriceps and ankle dorsiflexors shortens step length *(15,16)*. Shorter steps, slower speed, and decreased arm swing are characteristics of the "senile" or "cautious" gait most commonly associated with the elderly. After a perturbation, an older person uses multiple steps to try to recover balance and thus is more likely to trip over his or her own foot and to use the upper extremities to deter a fall by grasping at objects *(17)*.

Central Nervous System

Some reduction in visual acuity, contrast sensitivity, and depth perception are considered part of the normal aging process. These changes in vision, along with decreased peripheral sensation, proprioception, and vestibular function, contribute to postural instability and falls *(15,16)*.

Impact of Fracture Type on Geriatric Function

Hip Fractures

Osteoporotic hip fractures are known to cause significant morbidity and increase mortality in older women. Fractures and outcomes are heterogeneous. Elders with higher preinjury functioning are more likely to have nondisplaced femoral neck fractures, which are associated with the lowest mortality (5.7% at 6 mo). Displaced femoral neck fractures are more likely in those with co-existing cardiovascular disease. These persons have the highest 6-mo mortality (15.8%) *(18)*. Persons with neurological co-morbidities are more likely to incur unstable intertrochanteric fractures *(18)*. Early mortality is especially high (28%) for those whose hip fracture occurs in a nursing home where preinjury function is lower than in the community *(19)*. Cardiac and pulmonary complications of hip fracture are common (8 and 4%, respectively), but gastrointestinal tract bleeding, venous thromboembolism, and transient ischemic attacks may also occur. Orthopedic complications include nonunion and avascular necrosis *(12,20)*. By the 1-yr anniversary following a hip fracture, fewer than half have returned to their prefracture ability to perform their activities of daily living (ADLs), such as dressing and transferring *(21,22)*. Multivariate analysis of predictors of poor long-term function include both higher age and lower functional ability prior to the fracture. Gender, comorbidities, and type of fracture are not independently associated with functional outcome *(18)*.

Vertebral Fractures

Although hip fractures are devastating, vertebral fractures are more common and may also cause permanent morbidity and mortality *(23,24)*. The prevalence of vertebral fractures in elders 75 yr and over is 32%. Strenuous activity, lifting a heavy object, a minor fall, or even strenuous flexing may fracture a vertebra in an osteoporotic woman *(12)*.

It is not uncommon for vertebral fractures to go undiagnosed, as they may not be evident on radiographs for up to 4 wk after injury *(12,25)*. Also, high-risk women are often not identified or treated prior to vertebral fracture. For instance, only 34% of women with radiographic vertebral fractures report having preexisting osteoporosis *(26)*. Mid-thoracic and upper lumbar vertebral bodies are the most common sites of fracture. Lower thoracic and lower lumbar areas are less commonly involved, and cervical and upper thoracic fractures are rarely seen *(12)*.

New vertebral fractures, even those not recognized clinically, are associated with substantial back pain and functional limitation *(27)*. Rib against pelvis (RAP) syndrome and costoiliac impingement syndrome are complications of vertebral kyphosis. RAP causes a combination of chest and abdominal pain from the anterior ribs rubbing on the pelvic brim, whereas the costoiliac syndrome causes back and groin pain *(28)*. Kyphosis also decreases vital lung capacity *(12,29)* and increases postural sway, promoting hip movements more than ankle movements to maintain balance *(12,30)*. It is uncommon for vertebral fractures to result in institutionalization, but symptoms from acute and chronic back pain, kyphosis, and height loss *(22,31)* can have a detrimental affect on self-esteem, body image, mood, and sleep *(22,32)*.

Wrist Fractures

Wrist fractures more commonly occur in women in their mid-50s *(33)*. Few patients with forearm fractures are disabled *(34)* compared with women with hip fractures, but one-third or more suffering a wrist fracture have hand pain or weakness as well as an increased likelihood of posttraumatic arthritis *(22)*. Consequently, distal forearm fractures account for 39% of all physical therapy sessions for osteoporotic fractures in the United States. Forearm fractures in an elderly women may have significantly more morbidity due to impairment to perform ADLs, such as preparing meals *(21,22)*, feeding oneself, transferring if using a cane or walker, and dressing.

Minimal Trauma Fractures

Minimal trauma fractures are spontaneous fractures induced by usual lifting, moving, turning, or transferring a bed-bound patient, usually in the nursing home. Often, the occurrence of a traumatic fracture is missed but later discovered after "spontaneous" onset of pain or deformity. The occurrence of a minimal trauma fracture is often met with suspicion of abuse or mistreatment. However, these fractures are not uncommon in long-term facilities and

most have no clear precipitating factors other than severely impaired mobility *(35)*.

Risk Factors

Clinical Predictors of Fracture Risk in Older Women

In a multivariate analysis of more than 600 hip fractures among nearly 7000 Caucasian women, average age 73, followed for 10 yr in the Study of Osteoporotic Fractures (SOF), the three primary predictors were low bone density (increased risk 1.84), diabetes (increased risk 1.83), and Parkinson's disease (increased risk 1.81). Other risk factors were advancing age, previous self-reported fracture after age 50, maternal history of hip fracture after age 50, greater height at age 25, impaired cognition, slower walking speed, nulliparity, and impaired depth perception. Women with several risk factors have a much greater risk of hip fracture than women with similar bone mineral density (BMD), but without the additional risk factors. For example, the 10-yr risk of hip fracture for a woman with an osteoporotic BMD and three or more risk factors is 35%, compared with 10.6% if no risk factors are present *(36)*.

There are several risk factors for low BMD (Table 1). It is well known that low weight is one of these, but weight loss may affect fracture risk as well. In a prospective cohort study, even voluntary weight loss in overweight elderly women of 5% or more from baseline increased the rate of bone loss from the hip and is associated with a twofold greater risk of subsequent hip fracture *(37)*.

The impact of lifestyle habits such as alcohol, tobacco, and coffee are controversial. A prospective study suggested that moderate alcohol intake is associated with an increase in trochanteric BMD in elderly ambulatory women, where as higher consumption of more than 30 g/d is associated with a decrease in BMD *(38)*. Alcohol use in the elderly may increase fall risk by impairing cognition and balance, and by interacting adversely with prescription medications. Although smoking status does not predict fracture risk independent of BMD *(36)*, tobacco use is associated with reduction of BMD at the lumbar spine and proximal femur independent of calcium intake or body weight. Smoking cessation may partially reverse this effect *(39)*. Caffeine intake, which increases urinary calcium excretion, has been associated with short-term fracture risk, but not independently associated with long-term risk *(36,40)*. The upper quintile of vitamin A intake, particularly in the retinol form greater than 2000 µg daily, is associated with an increased risk of hip fracture in women *(41)*.

Diseases common to older adults, such as Parkinson's disease, osteoarthritis, stroke, normal pressure hydrocephalus (NPH), and congestive heart failure, can alter gait and increase risk of falls and fracture. Table 2 lists factors associated with increased fall risk. Parkinson's disease may increase

Table 1
Factors Associated With Low Bone Mineral Density

- Advanced age
- Estrogen deficiency
- Previous fracture
- Maternal history of hip fracture
- Loss of 1.5 in. or more of height
- Nulliparity
- Weight loss
- Smoking
- Caffeine
- Glucocorticoids
- Elevated homocysteine levels
- Genetic factors

Table 2
Factors Associated With Falls

- Diabetes mellitus
- Parkinson's disease
- Advanced age
- Gait and balance impairments
- Arthritis
- Sensory and perceptive deficits
- Cognitive impairment
- Depression
- Poor vision
- Polypharmacy
- Medications: psychotropic, antiarrhythmic, and antihypertensive medications, benzodiazepines, diuretics, digoxin
- Dizziness
- Urinary incontinence
- Environmental hazards
- Need for home health care

fall risk through bradykinesia of the lower extremities, freezing, orthostasis, and in some cases cognitive impairment *(42)*. Diabetic neuropathy and vitamin B_{12} deficiency are common causes of severe sensory and proprioception deficits in the elderly. Elders with type 2 diabetes may have a higher BMD but an increased fracture risk, particularly of the hip, proximal humerus, and foot *(43)*. Osteoarthritis of the knee is associated with an increased risk of fractures, particularly vertebral fractures, independent of BMD and postural stability. It is postulated that osteophyte formation is related to decreased mechanical properties of bone, which may be genetically predetermined *(44)*.

Anemia is another common medical condition in the elderly. It is estimated that 10.2% of women 65 yr and older are anemic. In a retrospective observational study of 145 patients hospitalized with a hip fracture, mean age of 82.8 yr, falls were more common in anemic individuals (30 vs 13%; $p = 0.028$) regardless if they were living in the community or a long-term care facility. Further studies are needed to determine if this risk is improved with treatment of anemia *(45)*.

Individuals with homocysteinuria have an increased prevalence of osteoporosis. High serum homocysteine concentrations interfere with collagen crosslinking, increasing the risk of osteoporotic fracture *(46)*. Aging, as well as many chronic conditions, is associated with elevated homocysteine, so an independent causative role in osteoporosis has not been established. Randomized controlled trials are needed to determine a role for folate supplementation to decrease homocysteine concentration.

Long-term use of glucocorticoids for common diseases in the elderly, such as polymyalgia rheumatica and chronic obstructive pulmonary disease, can lead to various adverse effects, including osteoporosis. Glucocorticoid-induced osteoporosis is caused by inhibition of osteoblastic bone formation, which results in decreased BMD and bone strength. Daily oral glucocorticoid doses higher than 5 mg of prednisolone or equivalent increase the risk of fracture within 3 to 6 mo after the start of therapy. High-dose inhaled glucocorticoids may also increase fracture risk. Bisphosphonates are the most effective treatment to prevent the development of osteoporosis during treatment with glucocorticoids, but vitamin D, calcitonin, and hormone therapy (HT) also help prevent bone loss *(20,47)*.

Many predictors of fragility fractures are under genetic control. A recent meta-analysis identified *ESR1* as a susceptibility gene for fractures and the polymorphism *Xba*I as a determinant of fracture risk by mechanisms independent of BMD. Osteoporosis risk may also be modulated by a large number of genetic markers, but large-scale genetic evidence has yet to be analyzed *(48)*.

Geriatric Syndromes

The term "geriatric syndrome" refers to one symptom or complex of symptoms resulting from multiple diseases and multiple risk factors that have a high prevalence in the elderly *(49)*. Recurrent falls are actually considered a geriatric syndrome. Falls are often associated with other geriatric syndromes, including mobility disorders, sensory and perceptive deficits, cognitive impairment, mood disorders, polypharmacy, dizziness, and urinary incontinence.

Mobility disorders may be associated with foot disorders. In the elderly, disability and deformity may result from chronic diseases such as diabetes mellitus, peripheral arterial disease, and arthritis. Pain, onychodystrophy, and loss of protective sensation are commonly found during routine podiatric examinations of the elderly *(50)*.

Mobility disorders and resulting falls may be associated with environmental hazards, These include tripping hazards (loose rugs, electrical cords), lack of stair railings or grab bars, slippery surfaces, unstable furniture, and poor lighting. Most environmental hazards are usually found in the bathroom *(51,52)*. Case managers or occupational therapists may identify these hazards during a home visit and suggest alternative solutions.

Fear of falling in itself can interfere with mobility *(53)*. Elderly women are fearful of falling if they have fallen before, have gait abnormalities, and have a poor perception of their physical health, cognitive status, and financial resources *(54)*.

Sensory deprivation, particularly visual, is associated with falls and fractures. Causes of severe visual impairment in the elderly include cataracts, glaucoma, macular degeneration, and diabetic retinopathy. Twenty-nine percent of nursing home residents aged 90 yr and older are blind *(55)*. For those 60 yr and older, visual acuity of 20/25 or greater is not only associated with increased risk of falls and fractures, but increased motor vehicle

accidents, and decreased quality of life *(56)*. Visual factors contributing to poor visual acuity and falls include reduced visual field, impaired contrast sensitivity, and the presence of cataracts *(57)*.

Cognitive impairment may be the result of chronic diseases such as Alzheimer's dementia, vascular dementia, Parkinson's disease, and depression. Research on gait in the setting of dementia demonstrates that gait speed slows and step-to-step variability increases with increasing severity of dementia *(42)*. Cognitive dysfunction may impair judgment and increase risk-taking behavior, leading to falls.

Mood disorders are common in the geriatric population, and medications for these disorders are associated with injurious falls. Tricyclic antidepressants (TCAs) increase the risk of falls through their anticholinergic and cardiovascular side effects. Although selective serotonin reuptake inhibitors (SSRIs) are thought to have a safer side-effect profile compared with TCAs, they are associated with an increased incidence of hip fractures, particularly during the first few weeks of therapy *(58)*. Explanatory hypotheses are that the underlying depression is the actual fall risk factor *(59,60)* and that SSRIs may have similar cardiovascular effects to TCAs *(61)*. Another antidepressant, trazodone, can cause severe orthostasis in antidepressant doses. Used in low doses ($\leq$100 mg/d) for agitation and insomnia, it is often well tolerated in older adults *(59,60)*.

Benzodiazepines used to treat anxiety disorders or insomnia can cause sedation and impaired cognition and are associated with an increased risk for falls. Studies implicate both short- and long-acting benzodiazepines in falls; the dosage may be more important than the half-life. Risks for injurious falls include advanced age, female gender, recent prescription, and history of alcohol abuse *(62)*. In an older community-dwelling population, withdrawing benzodiazepines and decreasing number of medications reduced the risk for falls in the intervention group by 31% *(63)*.

Although among medication classes, the psychotropic drugs have the strongest association with injurious falls in studies, there are problems with other drug classes as well. Some medications may alter bone integrity (e.g., phenytoin) or decrease bone density (e.g., risperdone *[64]*), potentially increasing the risk of injury in a fall. Polypharmacy itself is associated with falls. Taking three or four medications is associated with a much higher risk for fall than taking one or two medications *(65,66)*. As many as one of every seven nursing home residents is hospitalized for adverse drug reactions (ADRs) related to polypharmacy, as well as inattention to contraindications and previous ADRs *(67)*. Hospitalization, with its potential for associated problems such as restraints, delirium, and deconditioning, offers another opportunity for an injurious fall.

Dizziness in the elderly is a common syndrome and is usually multifactorial. Factors associated with dizziness include depressive symptoms, cataracts, impaired balance and gait, postural hypotension, diabetes mellitus, past myocardial infarction, and the use of three or more medications *(68)*.

Urinary incontinence is considered an important geriatric syndrome and a cause of significant morbidity in the elderly. Urge incontinence at least weekly is independently associated with falls. Early diagnosis and treatment of urinary incontinence may reduce falls and improve quality of life *(69)*.

Intervention: Prevention of Injurious Falls

Screening for Osteoporosis

The US Preventive Services Task Force (USPSTF) recommends routine osteoporosis screening with a BMD test for all women aged 65 and older and that screening begin at age 60 for women whose body weight is less than 70 kg (154 lb) or not on hormone therapy (HT) *(70)*. Although women over the age of 80 yr are more likely to have osteoporosis than younger women, there is no evidence that antiresorptive therapy is beneficial if low BMD is not present *(71)*. Therefore, it is reasonable to screen all older women who would be candidates for treatment if osteoporosis is identified, and not treat empirically based on age and risks.

Dual-energy X-ray absorptiometry (DXA) of the hip or spine is the best predictor of hip or vertebral fractures. If access is limited or difficult, radiographic absorptiometry of the hands may be used as an initial screen for referring patients for DXA of the hip or spine *(72)*. Because of the increased risk of hip fracture and the development of lumbar spine artifact from degenerative arthritis after age 65, measurement of bilateral hip BMD is more helpful in elderly

Table 3
Fall Evaluation

- History of fall circumstances
- List of medications
- Acute/chronic medical problems
- Mobility level
- Orthostatic blood pressure and pulse
- Vision examination
- Gait and balance examination
- Lower extremity joint function
- Complete neurological exam

Table 4
Fracture Prevention

- Calcium 1500 mg/d
- Vitamin D 800–1,000 IU daily
- Address geriatric syndromes
- Optimize medical conditions
- Regular physical activity
- Home hazard assessment
- Stop or reduce psychotropic medication
- Correcting visual impairments
- Appropriate footwear
- Appropriate ambulatory device
- Hip protectors

women than lumbar BMD *(72)*. Lateral vertebral assessment or plain films of the T- or L-spine may be helpful in identifying compression fractures.

Screening for Falls

Ninety percent of hip fractures result from a fall; with one-third of people over age 65 falling each year it is important to identify patients with geriatric syndromes and risk factors for falls. All elderly patients should be asked about falls and balance or gait difficulties and be observed rising from a chair and walking (i.e., "Get up and go") at least once a year. Inability to rise from a chair doubles the risk of hip fracture (SOF Study: relative risk = 2.1; 95% confidence interval [CI]: 1.3, 3.2) *(40)*. If an older person presents for medical attention because of a fall, reports recurrent falls, or demonstrates abnormality of gait/balance, he or she should have a fall evaluation (Table 3). This includes a history of fall circumstances, medications, acute or chronic medical problems, and mobility level; an examination of vision, gait and balance, and lower extremity joint function; examination of basic neurological function (including mental status, muscle strength, lower extremity peripheral nerves, proprioception, reflexes, tests of cortical, extrapyramidal, and cerebellar function); and assessment of basic cardiovascular status, including orthostatic blood pressure and pulse *(2)*. In a review of medical records of community elders, it is rare that the indicated elements of a fall evaluation are documented adequately *(73)*.

Assuring Adequate Calcium Intake

For older women, diet and lifestyle behavior play an important role in preventing fractures (Table 4). Calcium supplementation alone has a small positive effect on BMD, with a trend toward reduction in vertebral fractures *(74)*. Because of decreased calcium intake and calcium absorption along with increased bone turnover, many institutionalized elderly cannot meet their calcium requirements. It is recommended that all women over age 65 be prescribed calcium supplementation at dosages high enough to reach total daily calcium intake of 1500 mg/d. The most common side effect is constipation, which can be problematic, particularly in the institutionalized elderly. Calcium citrate may be better tolerated in older women because it can be taken on a full or an empty stomach and does not require gastric acid for absorption *(75)*.

Assuring Adequate Vitamin D Intake

In general, the optimal level of 25(OH)D is that which maximally suppresses PTH. That level is reported to range from the mid-normal range (30 nmol/L) to the upper limit of the range (80–90 nmol/L). Because many elderly have both low intake of vitamin D and diminished conversion to the active form, supplementation of 800 to 1000 IU vitamin D daily is recommended *(6,77)*. Those persons with diminished glomerular filtration rate (GFR) have a higher prevalence of hypovitaminosis D. The National Kidney Foundation (NKF) recommends screening PTH levels in those with GFRs less than 60 mL/min. Estimating the GFR using the Cockcroft-Gault equation (which incorporates a patient's serum creatinine, age, weight, and gender) may identify many older adults meeting this criteria. If PTH is elevated, the NKF recommends checking a 25(OH)D level and supplementing accordingly

(76). Evidence does not support empiric use of calcitriol (1,25 dihydroxyvitamin D) to treat vitamin D deficiency because of an increased risk of hypercalcemia, nephrolithiasis, and deterioration of renal function *(78)*. However, those with moderate to severe renal impairment may benefit from calcitriol and electrolytes are monitored accordingly.

Exercise

Exercise programs decrease bone resorption, improve biomechanical competence of bone, improve quality of life, and increase muscle strength of the lower extremities *(12,79)*. The Frost hypothesis of minimal effective stimulus suggests that muscular contraction and mechanical loading are needed to maintain healthy bones *(12,80)*. Regular physical activity with aerobics, weight-bearing exercises, and/or resistance exercises is effective in increasing BMD of the spine in postmenopausal women *(81)*.

The type of exercise may modulate bone density. A 9-mo prospective controlled trial of 28 frail elderly women aged 75 and older (mean age 81 yr) trained with resistance and endurance exercises showed greater increases in lumbar spine BMD compared with those assigned a flexibility program (3.5% vs 1.5%, $p = 0.048$). The exercise program lasted 90 to 120 min per session, three times a week. These women were on HT, and it is unknown if the same benefit may be found in women off HT *(82)*.

In a 2-yr randomized controlled trial focused on back extensor exercises, participants performed 10 repetitions per day, 5 d a week in the prone position using a weighted backpack. Eight years after the trial, the exercise group had significantly greater BMD at the lumbar spine *(83)*. Although women in this trial had a mean age of 55 yr, the exercise itself is manageable by many older women. Data are not available, however, for the old-old cohort.

Jumping exercises with a weighted vest performed 3 d a week has also been shown to have good compliance and maintain hip BMD in a 5-yr randomized controlled trial *(84)*. Women in this study had a mean age of 69 yr; a jumping program may not be feasible for the old-old cohort. Fast-walking programs may have the greatest compliance, is the most similar to an ADL, and may also improve hip BMD *(81)*.

Exercise is an important factor in fall prevention as well as in bone density preservation. In a meta-analysis by Chang et al., a multifactorial risk assessment and management program, including exercise, was the best intervention to reduce the risk of falling (risk ratio 0.82, 95% CI 0.72–0.94, number needed to treat 11). However, it is not possible to identify which components of these interventions was most effective *(85)*. Specific approaches that have demonstrated benefit include muscle strengthening and balance retraining; professional home hazard assessment and modification; and stopping or reducing psychotropic medication *(63,86)*. A recent randomized controlled trial of more than 300 community-dwelling residents aged 70 and older who had fallen or had concern of falling showed a 31% reduction in falls after participating in a small-group-based 7-wk educational program that focused on the above approaches, including making adaptations for low vision *(87)*. Two other randomized controlled trials of community-dwelling frail elderly found decreased rates of falls from 22% to 40% with group exercise programs only *(88,89)*. Because most falls are the result of stumbling or tripping, an exercise program using a treadmill that perturbs gait may reduce falls by improving balance and reaction time in disabled frail elderly *(90)*.

A randomized controlled prospective study of 100 community-dwelling women aged 75 to 85 with low bone mass had fall risk reduced by half with 6 mo of resistance or agility training (addressing postural sway, reaction time, proprioception, and vision) compared with stretching (sham) exercises. Classes were held twice weekly for 50 min. Resistance training included bicep curls, tricep extensions, seated row, latissimus dorsi pulldowns, mini-squats, mini-lunges, hamstring curls, calf raises, and gluteus maximus extensions on a mat. Agility training aimed to improve hand–eye coordination, foot–eye coordination, balance, and reaction time by using activities such as ball games, relay races, dance movements, and obstacle courses. Although the women found agility training to be enjoyable, agility programs require considerable planning and safety precautions, making them more difficult to deliver in the community. However, this study shows that the oldest-old have the interest and capacity to exercise effectively and safely *(91)*.

The Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT) trials examined the effect of balance, flexibility, endurance, resistance training, and general exercise interventions in

reducing the risk of falls in older individuals. The FICSIT did not show a significant effect of endurance, resistance, or flexibility exercises on falls risk, but there was a 10% reduction in falls risk with general exercise programs and a 17% reduction with balance-oriented exercises such as computerized balance training and tai chi in robust elderly *(92,93)*. However, the same reduction in risk of falls using tai chi has not been reproducible in the frail elderly *(93)*. This may be because tai chi reduces falls by improving confidence rather than actual postural balance *(94)*.

Footwear

Appropriate footwear is important in preventing falls. High-heeled shoes can lead to lateral instability, increased postural sway, and reduce step length *(95,96)*. Leather soles can increase risk of slipping. It has previously been thought that bare feet maximize balance and that shoes with thick, soft midsoles interfere with position sense and contribute to instability. However, a recent case–control study found that athletic and canvas shoes—the styles of footwear most commonly worn by older adults—were associated with the lowest risk of falling. Although being barefoot is associated with good balance in the laboratory, without shoes the foot is more susceptible to painful trauma as a cause of falls *(97)*.

Ambulatory Devices

Falls to the side secondary to lateral instability are the cause of the majority of hip fractures. A physical therapy evaluation for the appropriate ambulatory device can enhance balance and ability to bear weight. Sufficient cognitive function, judgment, vision, vestibular function, upper body strength, and physical endurance are needed to use a cane or walker safely *(98)*.

Hip Protectors

Hip protectors have been shown to be cost-effective in preventing hip fractures in ambulatory nursing facility residents *(99)*. A shell of polypropylene or polyethylene attached to each side of an undergarment is anatomically designed to shunt the energy of an impact away from the greater trochanter to the soft tissues anterior, posterior, and superior to the proximal femur and to absorb part of the energy of an impact to the hip. The protective effect is immediate, compared with 1 to 2 yr for medication benefits *(100)*. Hip protectors have been shown to be effective if an institution trains staff and most residents on a unit are wearing them. The effectiveness of hip protectors preventing fractures has not been shown for community-dwelling elderly or individuals in a long-term care facility unless most residents of the unit are wearing them *(101)*. Caution should be used when prescribing a hip protector because not all hip protectors have been rigorously tested and some may even increase the risk of hip fracture *(102)*. Also, in the elderly they may be difficult to don and impractical for those with incontinence or urinary frequency.

Role of Medications for Chronic Disease

β-Blockers and Thiazide Diuretics

Case–control studies have shown that β-blockers taken alone or in combination with thiazide diuretics are associated with reduced fracture. In animal studies, β-blockers risk increase osteoblast proliferation and decrease osteoclast activity, leading to increased bone mass. Thiazide diurectics decrease urinary calcium excretion, leading to a positive calcium balance, but may also have effects on osteoclasts and osteoblasts. Randomized controlled trials are needed to validate any benefit single or combined therapy may have in elderly patients with hypertension and risk factors for osteoporosis *(103)*.

Statins

Statins have been reported to have antiresorptive effects on bone and have been suggested as potential agents in treatment of osteoporosis. In a 1-yr double-blind placebo-controlled trial with simvastatin, 82 postmenopausal women with osteopenia did not have a significant increase in vertebral or femoral BMD *(104)*. Findings do not support the use of statins for prevention or treatment of osteoporosis at this time.

Intervention: Treatment of Osteoporosis and Osteoporotic Disability

In 1994, the World Health Organization (WHO) defined osteoporosis as a T-score of 2.5 or less at any site (spine, hip, mid-radius) and osteopenia as a T-score between −2.5 and −1.0 *(105,106)*. The National Osteoporosis Foundation then developed treatment thresholds by combining BMD measured at the hip

Table 5
Randomized Controlled Trials of Interventions to Prevent Hip Fractures in the Oldest Women

Intervention	Setting	Age	Outcome	RRR	NNT	Comment
Outcomes data available in oldest women						
Calcium, vitamin D for 3 yr *(120)*	Ambulatory women in LTC	Average 84 yr	Hip fracture	28%	21	Control is usual diet.
Safehip *(121)* for 18 mo	LTC residents (3/4 Female)	N/A	Hip fracture	47%	25	Randomization by "cluster."
Multidisciplinary 11-wk program with 34-wk follow-up *(122,123)*	LTC and MMSE <19	65–100 yr	Hip fracture	N/A	5	Randomization by "cluster." Preplanned cognition subgroup.
Hip fracture outcomes data either not available, or data available in the young-old only						
Teriparatide *(124)* 20 µg for 21 mo	Osteoporotic women in community	Mean age 70	Vertebral fracture	65%	11	Insufficient number of hip fractures for analysis. Both groups received calcium and vitamin D.
Alendronate for 4.2 yr *(125)*	Osteoporotic women in community	Ages 51–81	Vertebral fracture	44%	60	Both groups got calcium ± vitamin D.
Risedronate 2.5 or 5 mg/d for 3 yr *(71)*	Osteoporotic women in community	70–79 years	Hip fracture	40%	77	Both groups got calcium ± vitamin D.
Risedronate 5 mg/d for 3 yr *(126)*	Osteoporotic women in community	Mean age 83	Vertebral fracture	44%	16	Both groups got calcium ± vitamin D.
Nasal calcitonin 200 IU/d for 5 yr *(127)*	Osteoporotic women in community	Mean age 68 years	Vertebral fracture	33%	12	No significant reduction in risk nonvertebral fractures. Half of subjects dropped out.
Raloxifene 60 mg/d for 3 yr *(128)*	Osteoporotic women in community	67 yr	Vertebral fracture	30%	29	Relative risk 3.1 for venous thromboembolism. Increased vasomotor symptoms; decreased breast cancer risk.
Estrogen–progestin therapy *(129)*	Postmenopausal women[a]	Mean age 63	Hip fracture	34%	385	Increased deep vein thrombosis, stroke, and breast cancer risks.

[a]Osteoporosis or osteopenia not required to participate. LTC, long-term care; MMSE, Mini-Mental State Examination. Estrogen–progestin therapy: 0.625 mg/d conjugated equine estrogens, plus 2.5 mg/d medroxyprogesterone acetate.

with clinical risk factors for fracture (prior fracture as an adult, family history of fracture, body weight less than 127 lb, cigarette smoking). Women with a T-score of −2.0 or less or −1.5 or less with at least one risk factor should be considered for treatment *(105)*.

Treating osteoporosis in women age 80 and over is challenging because of the dearth of clinical trials demonstrating safety and clinically important outcome data for interventions, particularly for frail institutionalized elders. Table 5 lists both the interventions

shown to reduce hip fracture in women age 80 yr and over, and interventions that reduce fractures either in younger women or at other sites. Of the available pharmaceutical interventions for osteoporosis, only calcium with vitamin D has been shown to reduce hip fracture rate in this high-risk cohort. Bisphosphonates have been demonstrated to reduce hip fracture rate in relatively younger women but in the cohort over age 80, hip fracture data are not available. The osteoblast stimulator, teriparatide, reduces the risk of vertebral fracture but data on hip fracture reduction in the oldest cohort are not available.

There are a variety of challenges in treating osteoporosis with pharmacological therapy. Older women, particularly those less mobile and/or in long-term care, are more likely to have constipation, potentially limiting the tolerability of calcium supplements. Dysphagia and esophageal disorders may limit ability to tolerate the bisphosphonates. Older women are also more likely to have decreased creatinine clearance, limiting the use of bisphosphonates and teriparatide. The increased prevalence of vascular disease and vascular risks in older women limit the utilization of the selective reuptake estrogen modulators, which carry vascular risks comparable to HT (albeit with less breast cancer risk).

Many older women on HT have discontinued it following the publication of the Women's Health Initiative. Unfortunately, stopping HT results in a rapid increase in the rate of bone loss similar to that of early postmenopausal women *(107)*. This accelerated rate of bone loss may not necessarily be seen if the HT is discontinued in a woman who took both HT and alendronate *(108)*.

Physical Therapy

The importance of physical therapy is demonstrated in two randomized controlled trials of frail elderly patients who have had a recent proximal femur fracture surgically repaired and completed standard physical therapy. An extended outpatient rehabilitation with whole-body progressive resistance training reduced disability by improving muscle strength, gait speed, and balance; and improved physical function, mobility, and quality of life *(109)*. A weight-bearing home exercise program prescribed by a physical therapist improved balance and function, but did not affect strength or gait *(110)*.

Additional rehabilitation after vertebral fracture can reduce morbidity. Education about body mechanics during ADLs and recreational activities with emphasis on avoiding bending and twisting to prevent high-risk loading of the vertebral bodies may help decrease back pain *(23)*. Assistive devices such as a shoehorn and long-reach clamps can help by decreasing strenuous flexion during ADLs *(12)*. Coping classes can improve psychological symptoms of anxiety and depression associated with the disfigurement and chronic pain of kyphosis. Exercises such as trunk lifts in the prone position increase back extensor muscle strength, but the improvements were not maintained during self-maintenance and did not improve level of pain with activities *(23)*.

Orthoses

The data supporting management of vertebral fractures with orthoses is limited. Pfeifer et al. reported that wearing a new orthosis for 6 mo was associated with an increase in back extensor strength, abdominal flexor strength, vital capacity and well-being and a decrease in angle of kyphosis, body sway, pain, and limitations of daily living. The thoracolumbar orthosis used in this study weighed 450 g and consisted of an abdominal pad with a light metal splint fitted along the spine. No side effects were reported, and the dropout rate was low at 3% *(111)*. Pilot studies of a similar orthosis, the Posture Training Support, along with an exercise program, significantly improved balance and somewhat improved back strength *(112,113)*. Caution is advised with prescribing support braces for the spine. Unless combined with a posture training program, brace use (*see* Figs. 1 and 2 for examples) can weaken back extensor muscles leading to worsening kyphosis *(12,113)*.

Vertebroplasty

Percutaneous transpedicular polymethylmethacrylate vertebroplasty (PTPV) consists of injecting acrylic cement into a partially collapsed vertebral body to relieve back pain and improve stability. However, there are no studies looking at the oldest-old cohort compared with young-old postmenopausal women in regards to pain, disability, or future fracture risk. There is also a lack of randomized placebo-controlled trials with adequate duration of follow-up. Complications include pressure on the spinal cord or nerve roots, pain and weakness, pulmonary embolism, rib fracture,

Fig. 1. Orthosis for vertebral strengthening in osteoporosis. Anterior view.

Fig. 2. Orthosis for vertebral strengthening in osteoporosis. Posterior view.
Source: www.mediusa.com/orthopedics/performance/spinomed.shtml

infection, and bleeding. PTPV can provide pain relief for patients with refractory pain caused by acute spinal compression fractures, but does not take the place of rehabilitation *(114–117)*.

Pain Control

The potential consequences of inadequately treated chronic pain may include physical deconditioning, gait disturbances, falls, slower rehabilitation, polypharmacy, cognitive impairment/confusion, and malnutrition, as well as sleep disturbances, decreased socialization, and increased health care utilization and costs. For relief of mild-moderate pain, acetaminophen, 2 to 3 g/d, is considered safe in elderly patients who have normal liver function. Nonsteroidal anti-inflammatory drugs (NSAIDs) and cyclooxygenase-2 (COX-2) inhibitors should be used with caution in the elderly secondary to significant risks of gastrointestinal bleeding, renal toxicity, peripheral edema, congestive heart failure, and hypertension. COX-2 inhibitors may also increase risk of myocardial infarction *(118)*.

Tramadol, a weak μ receptor agonist, may be added to acetaminophen or NSAIDs to help with moderate to severe pain with minimal sedation. Concomitant use of TCAs or SSRIs increases risk of seizures *(118)*.

Short-acting opioid analgesics are appropriate for moderate to severe acute pain. After establishing the dose needed, conversion to a sustained-release formula given every 8 to 24 h can be made for chronic pain. Administering opioids in the frail elderly may cause anorexia, hypotension, falls, altered mental status, and bowel ileus. All patients starting opioid treatment should be placed on a bowel regimen to avoid constipation *(118)*.

Certain opioids are inappropriate in the elderly. Propoxyphene is equianalgesic to acetaminophen, but with many more side effects, including mental status change. The metabolite of meperidine can cause delirium and seizures, particularly in the setting of renal insufficiency *(118)*.

There is weak evidence that early therapy during immobilization or post-immobilization with formal therapy, passive motion, or physiotherapy is effective for treating adults with fractures of the distal radius *(119)*. Because of the adverse outcomes of impaired ADLs in the elderly, prevention becomes even more important.

Conclusion

The risk of injurious falls increases with age. In the oldest women, reducing the risk of injurious falls cannot be limited to osteoporosis prevention and treatment. Strategies must utilize a multifaceted assessment, accounting for medical conditions and geriatric syndromes, in order to reduce the rate of falls and injury. Effective interventions also include addressing pain, improving balance, and reducing polypharmacy. Vitamin D may reduce the risk of falls; calcium and vitamin D are both effective in decreasing the risk of injury from falls, including reducing the risk of hip fracture. The benefits of hip fracture reduction in the young-old with bisphosphonates may extend to the old-old cohort, although hip fracture data in that age group are not yet available. Teriparatide has not been studied extensively in the oldest women but probably plays a role in the high-risk patient. Nonpharmaceutical preventive strategies such as hip protectors and the shoulder pack exercises are underutilized and should be considered.

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