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Epidemiology of fragility fractures and fall prevention in the elderly: a systematic review of the literature

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ABSTRACT

Fragility fractures in the elderly is an ongoing concern for orthopaedic surgeons. A 50-year-old woman has a 40% chance of having a vertebral compression fracture in her lifetime. The incidence of vertebral fractures, reported to be more than 10 times higher than that of femoral fractures, is estimated as 1–1.5 million per year in Japan. Vertebral fractures often occur without a fall, whereas the majority of nonvertebral fractures are the consequence of falls; the site of the nonvertebral fracture appears to be dictated by the type of fall. Distal radial fractures commonly occur as a consequence of hand protection during the fall. In older patients, falling load tends to directly affect shoulder and hip joints and lead to proximal humeral and femoral fractures. The incidence of vertebral fractures is increased in women over 50 yr of age, following the same trend as osteoporosis prevalence. Conversely, the mean age for proximal femoral fractures is around 80 yr, and more than 75% of femoral fractures occur in individuals over the age of 75. The prognostic risk of aging is 11-fold greater than that of reduced bone mineral density, and age is another risk factor for femoral fractures. Prophylactic therapy for osteoporosis and femoral fractures was shown to more effective in women in their 70s than in those over the age of 80. Although several approaches, including exercise therapy, vitamin D administration, and environmental adjustment at home, have been reported to be effective in fall prevention, effective fracture prevention approaches in frail elderly individuals have not yet been well established.

Key Words
epidemiology of fracture, vertebral compression fracture, proximal femoral fracture, fall prevention, fracture prevention

INTRODUCTION

In 1994 the World Health Organization (WHO) Study Group published the first diagnostic criteria for osteoporosis that was defined as a bone mineral density (BMD) T-score of –2.5 or less.[1] The WHO report stated that a decrease in BMD of one standard deviation increased the relative risk of osteoporotic fractures by 2.6-fold. While BMD could predict fracture risk, it could not identify individuals who will eventually have a fracture. Thus, fracture risk screening of menopausal women using BMD measurements was not recommended by the WHO.[1] In a follow-up meta-analysis in 2003, the WHO reported the following risk factors for fractures in postmenopausal women: low bone density, age, personal history of fracture, family history of fracture, smoking, heavy drinking, administration of steroids, and rheumatoid arthritis.[2] Importantly, although low bone density carried the highest risk, these eight risk factors were independent from each other.

The large-scale National Osteoporosis Risk Assessment (NORA) investigating[3] the incidence of nonvertebral fractures in a total of 149,524 white women over 50 yr of age (mean age, 64.5 yr) in the United States found that the rate of nonvertebral fractures was more than three times greater in osteoporotic women (T-score ≤ -2.5) than in those with a normal BMD (T-score > -2.5). Although only 18% of the nonvertebral fractures and 26% of the proximal femoral fractures occurred in osteoporotic women, 82% of nonvertebral fractures and 74% of the proximal femoral fractures occurred in women with the normal BMD. In that study, nonvertebral fractures were frequent but in relatively small numbers among the osteoporotic women. An accurate whole feature of fractures may not be possible by the assessment of osteoporotic patients, and strategies to reduce nonvertebral fractures are sorely needed to develop treatment protocols for women with less severe loss of BMD.[3]

The incidence and age distribution of three fractures in the elderly (i.e. vertebral body, proximal femur, and distal radius) has been reported by Riggs *et al.*[4] The incidence of vertebral compression fracture increased with age among women over 50 yr old, following the same trend as osteoporosis prevalence. The BMD change in aging in the vertebral body and proximal femur has almost the same tendency.[4,5] Conversely, the incidence of proximal femoral fractures was low between the ages of 40 and 70 yr, and a steep increase was noted after 75 yr of age. The mean age of proximal femoral fractures was about 80 yr, and over 75% of proximal femoral fractures

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occurred in individuals over 75 yr of age.[6] Järvinen *et al.*[7] revealed that the incidence of proximal femoral fractures in women was determined to increase 44-fold between the ages of 55 and 85, and the relative risk contribution of aging on the proximal femoral fractures was 11-fold greater than that of reduced BMD.[7–9] Additionally, local factors, such as falling rates and fracture mechanism, were associated with increased risk for proximal femoral fractures.[10] Distal radial fractures occur at a relatively young age; its incidence was not found to increase in the elderly,[11] suggesting that osteoporosis may not be a major contribution in distal radial fractures. Amin *et al.*[12] reported the age- and sex-specific fracture incidence for each of the different sites. They found a strong age-related increase in incidence except in the proximal forearm, tibia, fibula, ankle, and foot. This finding indicated that low BMD does not influence the fracture incidence rates at some anatomical sites.[12] In our experience among 4139 patients who underwent orthopaedic surgery for fractures at Minoh City Hospital between 2002 and 2015 (Figure 1), the number of patients with proximal femoral and distal radial fractures in adults was similar to those reported by Riggs *et al.*[4] and Amin *et al.*[12]

Whereas vertebral compression fractures occur frequently in the absence of a fall, the majority of nonvertebral fractures are the consequence of falls.[13] We postulate that the diversity in the sites and the shapes of nonvertebral fractures is a reflection of the varying injury mechanisms and the direction of the fall.[13] In addition to osteoporosis treatment, fall prevention plays a critical role in fracture prevention in the elderly. Although both operative and nonoperative fracture treatment approaches are well established in orthopaedics, the underlying mechanisms and the epidemiology of fractures are not well known. Epidemiological considerations of four fracture types commonly observed in the elderly, namely fractures of the vertebral body, distal radius, proximal humerus, and proximal femur, are discussed in the following sections.

VERTEBRAL COMPRESSION FRACTURE

A 50-year-old woman has a 40% chance of having a vertebral compression fracture in her lifetime. Epidemiological studies found radiographically diagnosed vertebral compression fractures in 8% to 13% of women in their 60s that increased to 30% to 40% in women in their 70s.[14] The annual incidence of vertebral compression fractures in women in their 70s was reported to be 4000 per 100,000 population per year in a survey in Hiroshima and Nagasaki,[14,15] and 2000–2500 per 100,000 population per year year in Europe,[6] reflecting much a higher incidence of vertebral compression fractures among the Japanese. In contrast, the incidence of proximal femoral fractures was 173 per 100,000 population per year among men in their 70s and 408 per 100,000 population per year among women in their 70s in Japan.[16] Furthermore, there were approximately 150,000 proximal femoral fractures in 2007 in Japan.[17] Altogether, these epidemiological data suggested that the incidence of vertebral compression fractures was approximately 10 times higher than that of femoral fractures, with an estimated 1–1.5 million cases (about 1% of entire population) per year in Japan.

Vertebral compression fracture is radiographically diagnosed as a loss of more than 4 mm or 20% of the vertebral height.[18] The main symptom is lower back pain while rising, which ranges between minimal pain to pain that requires hospital rest. Many vertebral compression fractures are found during radiographic evaluation with no history of a fall; most of these fractures are considered as occult fractures. The incidence of symptomatic patients with vertebral compression fractures seeking medical treatment at Sado Island was reported as 1100 per 100,000 per year among women in their 70s.[19] Symptomatic vertebral fractures were estimated to constitute approximately 25% of all cases in women in their 70s in Japan.[19] The fracture incidence ratio between vertebral fracture and proximal femoral fracture in patients who went to a clinic was reported as 3.29 in Rochester, MN, USA[12] and

FIGURE 1. Incidence rates of three common osteoporotic fractures (proximal femur, distal radius, and proximal humerus) and others in 4139 patients who underwent surgery at Minoh City Hospital from 2002 to 2015.

1.98 in Sado Island, Japan.[19] It confirms the estimation of symptomatic vertebral fracture incidence as 0.3 to 0.4 million per year and all vertebral fracture incidence as 1–1.5 million per year in Japan. In the Swedish part of the Osteoporotic Fractures in Men (MrOS) study, Kherad *et al*.[20] reported that 15% of men had at least one vertebral fracture and that only 10% of these men were aware of their fractures. Vertebral compression fractures recognized only by radiography are of less clinical concern.[14] Black *et al*.[21] investigated the effect of alendronate on vertebral compression fractures in a 3-year, double-blind clinical trial that included 2027 women between the ages of 55 and 81 in the United States.[21] They reported that alendronate decreased the relative risk of radiographic vertebral fractures and clinical vertebral fractures were 0.53 and 0.45, respectively. The ratio of symptomatic clinical fractures was 32.4% of all vertebral fractures.

FRACTURES OF THE DISTAL RADIUS AND PROXIMAL HUMERUS

The distal radius and proximal humerus are the most common sites of upper limb fractures in the elderly. Distal radial fractures occur as a consequence of an attempt to provide protection using the hands during a fall.[22,23] Conversely, direct falls onto the shoulder joint in patients of advanced age tend to result in proximal humeral fractures. Two-thirds of distal radial fractures occur outdoors, whereas most proximal femoral and proximal humeral fractures result from injuries indoors. Distal radial fractures usually are seen in women who have a low BMD but who are active and relatively healthy otherwise, while proximal humeral fractures usually occur in women who have a low BMD and who are less active.[22]

The incidence of distal radial fractures in men is about 100–130 per 100,000 people per year, and the incidence does not increase with age. The incidence of distal radial fractures in women increases in their late 50s, reaching 300–400 per 100,000 people per year among women 60 to 70 yr of age; however, it does not increase in women who are in their 80s and actually tends to decrease after the age of 85.[22] Distal radial fractures occur in relatively active elderly, which was distinctly different from the epidemiology of proximal humeral and femoral neck fractures that occur mostly in individuals 75 yr of age or older, with incidence increasing with age.[11] The main risk factor for both distal radial and proximal humeral fractures is low BMD. The relative risk per each standard deviation decrease in BMD was reported as 1.7 in the forearm and 2.6 in proximal femur, indicating that a lower BMD could be less of a contribution to distal radial fractures than femoral fractures.[24] Other risk factors include falls, heavy drinking, insufficient intake of animal protein, and decreased vision.[22] The incidence of upper limb fractures was higher in other Western countries than in Japan, with especially high rates in Europe and the United States.[11] The same tendency was seen in the incidence of falls, which was also lower in Japan.

PROXIMAL FEMORAL FRACTURE

In 2007 there were approximately 150,000 proximal femoral fractures in Japan. The incidence of femoral trochanteric fracture was about 1.3–1.7 times higher than that of femoral neck fracture.[25] Epidemiological studies have shown that the incidence of proximal femoral fractures increases gradually with age, starting at 40 yr, with a steep increase after 75 yr of age. Age-specific incidence rates of proximal femoral fractures in Japan were as follows: 51.2, 173, 574, and 1289 per 100,000 people per year in men 60, 70, 80, and older than 90 yr of age, respectively; and 90.7, 408, 1478, and 2818 per 100,000 people per year in women 60, 70, 80, and older than 90 yr of of age, respectively.[16] The age-adjusted incidence rates of proximal femoral fractures in Tottori Prefecture, Japan were 57.1 per 100,000 people per year in men and 145.2 per 100,000 people per year in women.[11] The results from several studies indicated regional differences in the incidence of femoral fractures. The fracture incidence in Japan, which was similar to those in Southern Europe and Southeast Asia, was about 50% less than those in the United States and Northern Europe.[11] It was the same tendency to that of falls, which was lower in Japan than in Western countries. Among several factors that are considered to underlie these differences are related to fall rates, elderly care system, floor structure, and sunshine level; however, to date, no clear consensus has been reached.[11]

The main risk factor for proximal femoral fractures is low BMD.[9] Although the risk for proximal femoral fractures is increased 2.6-fold for each standard deviation reduction in BMD of proximal femur, normal BMD does not guarantee the absence fractures, and BMD cannot identify individuals who will have femoral fractures.[1] More than 85% of proximal femoral fractures occur by falls, and the number of falls is another risk factor.[13] Although the incidence of falls is lower in Japan than in Europe,[26] 20% to 25% of the Japanese elderly at home fall at least one time a year. The incidence of falls was significantly higher among individuals over the age of 75 yr than among those younger than 74 yr,[27] which was similar to the incidence of proximal femoral fractures. Case-control studies by Nivett and Cummings,[28] support the view that the mechanics of a fall are the most important determinant of whether it will result in a proximal femoral fracture. Most patients who have a proximal femoral fracture are injured from falling backwards, and striking the greater trochanter part. Figure 2A shows the direction of the fall and the expected mechanism that causes proximal femoral fracture displacements. In minimally displaced intertrochanteric fractures, hyperextension and open valgus displacements are recognized by radiographs striking the greater trochanter (Figure 2B).[29] In minimally displaced femoral neck fractures (Garden stage 1 fracture), hyperextension and valgus compression displacements are recognized by radiographs by the compression load and muscle power (Figure 2C).

Bisphosphonates are effective for prevention of proximal femoral fractures in osteoporotic patients. McClung *et al*.[30] reported that risedronate treatment led to a 40% reduction in the incidence of proximal femoral fractures in osteoporotic women over the age of 70 yr, whereas no significant change was observed in those over the age of 80 yr with risk factors other than low BMD.[30] Systematic reviews have revealed that only three studies out of 23 clinical trials included women over 75 yr of age for incidence analysis of proximal femoral fractures.[7,30–32] This discouraging finding was confirmed by a

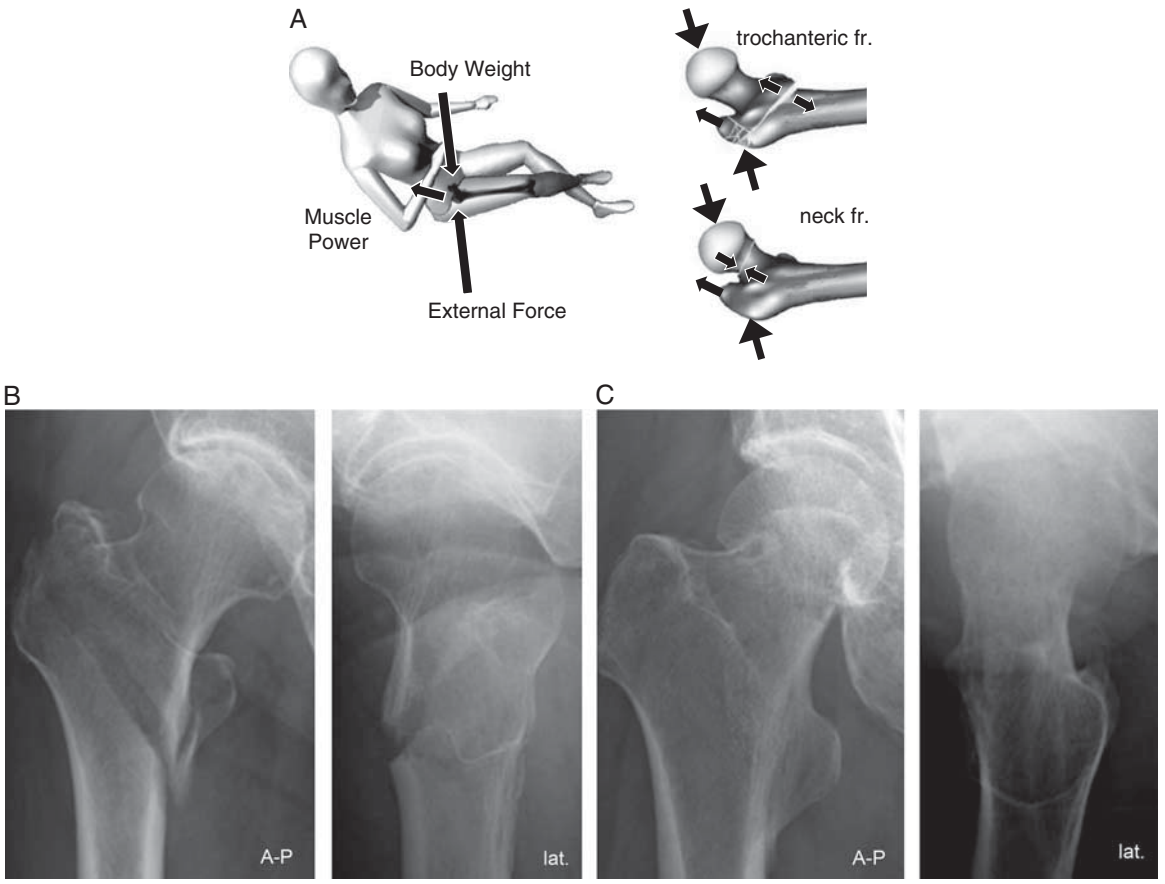

FIGURE 2. (A) Fracture mechanism of hip joint, showing the force generated by the fall position. Hyperextension and valgus displacement of proximal femoral bone after trochanteric and neck fractures are explained by the load of falling position. (B) Typical radiographic images of a trochanteric femoral fracture with minimal displacement. Hyperextension and open valgus displacement are observed in the proximal femur caused by a blow to the greater trochanter during the fall. (C) Typical radiographic images of a femoral neck fracture with minimal displacement (Garden stage 1). Hyperextension and valgus compression displacement are recognized in the femoral neck, resulting from force loading during the fall. (A was redrawn with permission from Dr. Makikawa and the Japanese Society of Safety Promotion).

recent randomized trial of single-dose zoledronic acid for osteoporosis in frail elderly women (mean age, 85 yr). Although they found that zoledronic acid treatment for over 2 yr led to the strong increase in BMD at the spine and proximal femur, it did not provide significant changes in fracture or mortality rates.[33] A recent Canadian study, including a database of 65,659 proximal femoral fractures, found that despite the presence of about a five-fold change in provincial prescribing rates of osteoporosis drugs for people ages 55 yr or over, there were no differences in proximal femoral fracture rates in either sex or age groups among the provinces in Canada.[32]

FALL PREVENTION IN THE ELDERLY

Vertebral compression fractures, as mentioned earlier, are the most common fragility fractures caused by osteoporosis and occur without a history of fall. Conversely, most non-vertebral fractures result from falls, and the site and type of fracture are dependent on the direction of the fall. In North America and Europe, 25% to 33% of the elderly who live at home experience at least one fall per year; this rate was found to be even higher among the elderly living in a nursing home.[26] Falling events were approximately two times greater for women than for men.[34] Risk factors for falls are muscle weakness, balance disorders, visual impairment, and dementia. Interventions for fall prevention are effective; however, their effectiveness on the incidence for fractures is not clear.[35] According to the Cochrane Collaboration for fall prevention, several combination exercises and grand ultimate fist (Tai Chi) led to approximately 30% reduction in the incidence of falls, and home environment adjustment achieved about 20% reduction.[36,37] The review also found that nonslip shoes and gradual reduction in psychotropic drug dose led to 60% and 65% decreases in the incidence of falls, respectively. Numerous studies demonstrated that exercise training for fall prevention was effective for the elderly living at home and that it was less effective for nursing home residents. The risk ratio of femoral neck fractures based on walking habits was examined in a large-scale survey of 34,500 postmenopausal Caucasian nurses in the United States.[38] That study found that the risk ratio of femoral neck fractures was decreased less than 75% for individuals who walked for more than 1 hr per week as compared to the risk ratio for those who walked less than 1 hr per week. Furthermore, the risk ratio for fractures was

reduced by 61% for subjects who walked faster than those who had a slow walking speed.

Vitamin D levels were reported to be low in women with proximal femoral fractures. In patients with reduced vitamin D level, a muscle-enhancing effect was observed after 6 mo of vitamin D treatment.[39] In a meta-analysis by Bischoff *et al.*[40] the risk ratio of falls was reduced less than 70% by vitamin D administration.[40] Although hip protector mounting has been recommended for reducing the direct impact to the femoral neck, this method was not effective for the elderly at home but was effective for the elderly in a nursing home.[41] There are a number of reports showing that fall and fracture prevention interventions are useful for frail elderly people. While prophylactic approaches for osteoporosis have been in place for years, effective nonvertebral fracture prevention approaches in the frail elderly have not yet been established. Future studies are necessary for the development of more effective exercise intervention methods for nonvertebral fracture prevention.

CONCLUSION

The risk factors for fractures in postmenopausal women are low BMD, age, history of fracture, family history, smoking, heavy drinking, steroids, and rheumatoid arthritis, which are independent from each other. Although low BMD carries the highest risk, BMD could not identify individuals who will have a fracture. The incidence of vertebral fractures is estimated 1–1.5 million cases (about 1% of entire population) per year in Japan. Seventy to eighty percent of vertebral fractures are found by radiographs in patients with no history of a fall; most of these fractures are considered as occult fractures. Two-thirds of distal radial fractures occur outdoors, whereas most proximal humeral and femoral fractures result from injuries indoors. Distal radial fractures occur in relatively active elderly, which is distinctly different from the proximal humeral and femoral fractures occurring mostly in patients over the age of 75 yr. More than 85% of proximal femoral fractures occur by falls, and the number of falls is a risk factor. The force from the greater trochanter part causes proximal femoral fractures and displacements, as a result of backward falls. Bisphosphonates are effective for prevention of femoral neck fractures in osteoporotic women in their 70s, whereas it may not be effective in those over the age of 80 yr. Vitamin D administration reduces the fall risk less than 70%, but it is effective in frail elderly. Exercise training for fall prevention is effective for the elderly living at home and less effective for nursing home residents. Walking habits are also beneficial for fall and fracture prevention. Future studies are necessary for the development of more effective exercise intervention methods for non-vertebral fracture prevention.

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