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REVIEW ARTICLE

Balance control in elderly people with osteoporosis



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Osteoporosis is a prevalent health concern among older adults and is associated with an increased risk of falls that incur fracture, injury, or mortality. Identifying the risk factors of falls within this population is essential for the development of effective regimes for fall prevention. Studies have shown that muscle quality and good posture alignments are critical for balance control in elderly individuals. People with osteoporosis often have muscle weakness and increased spine kyphosis leading to vertebral fractures and poor balance control, or even falls. Therefore, improving muscle quality, strengthening weak muscles, and correcting postural alignment are essential elements for the prevention of falls and fractures in older adults with osteoporosis. This review reports the necessary information regarding the critical factors of balance control in older adults with osteoporosis, as well as testing the clinical innovations of exercise training to improve the long-term prognosis of osteoporosis in this vulnerable population.

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Elderly patients with osteoporosis and sarcopenia

The population of patients with osteoporosis and sarcopenia continues to increase due to the rapid aging of the population worldwide.^{1,2} Approximately 500,000

people > 65 years of age have been diagnosed with osteoporosis in Taiwan,³ and 25% of these people have a history of spine or hip fracture.⁴ Osteoporosis is the most metabolic bone disease, characterized by decreased bone mass and structural deterioration of bone tissue, which leads to bone fragility and an increased susceptibility to fractures, especially of the spine, hip, and wrist.⁵ Sarcopenia is defined as a low muscle mass resulting from age-related muscle loss, and is often combined with osteoporosis.⁶ Sarcopenia can impair function, which further increases the risk of musculoskeletal injuries and other morbidity, finally resulting in partial or total loss of independence.⁷

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Several factors are part of the cause in the origin of osteoporosis, which is thought to contribute to sarcopenia. These contributing factors include a low level of physical activity, a reduction in dietary protein, chronic inflammation, and hormonal changes. These etiologies may account for the association between sarcopenia and osteoporosis. Therefore, sarcopenia is a risk factor for osteoporosis, and is predominant among individuals with low bone mineral density (BMD).^{2,8,9} Moreover, obesity may offer some protection against osteoporosis. Aubertin-Leheudre et al examined the impact of sarcopenia on BMD in postmenopausal women with obesity and they found that sarcopenia did not influence hip or spine BMD.¹⁰ An increased body weight exerts numerous stresses on bone structure, which may also be beneficial for BMD.

Osteoporotic fractures, such as vertebral compression fractures or hip fracture, are usually associated with significant mortality, morbidity, and low quality of life.¹¹ Osteoporotic fractures have become an enormous burden on health care and health insurance. Thus, the importance of preventing fractures and fall incidents in elderly people with osteoporosis and sarcopenia should not be underestimated. The most diagnosed combination of vertebral compression fracture included a cluster of women > 52 years of age, with a body mass index ≤ 22 kg/m², and a low frequency of exercise.¹² Eighty-two percent of fractures reported in a large study of frail elderly were attributed to falling.¹³ Rehabilitation goals for osteoporotic fractures are pain reduction, improvement and preservation of musculoskeletal function, reducing fall risk, and optimizing quality of life and independence.¹⁴ Hence, fracture and fall prevention is an important issue for the affected population group.

Mechanism of balance control and fall

The definition of a fall is when one experiences an unexpected loss of balance resulting in coming to rest on the

floor, ground, or an object below knee level.¹⁵ The risk for falls increases with age and is a multifactorial issue. Strong risk factors for falls include fall history, impaired gait, mobility disability, poor vision, vestibulopathy, and reduced muscle strength.^{16,17} People diagnosed with osteoporosis often experience muscle weakness, poor balance control,¹⁸ and postural deformity.^{19,20} Impaired balance performance of patients with osteoporosis or sarcopenia has been documented in the literature,^{21–28} although patients may not have “classical motor control” problems that are involved in central nervous system-related disorders.²⁹ The literature has identified that women with osteoporosis have reduced flexibility and mobility that affects their walking, which contributes to a greater risk than in men.³⁰

Control of an upright posture is a complex function achieved through multisensory integration, central motor control, and context-specific response.³¹ During normal aging, physiological changes occur in one’s visual, vestibular, somatosensory inputs, as well as central processing and muscular effectors.³² Moreover, the interjoint coordination is also affected.³³ The reduced congruency between sensory cues combined with physical decline means that upright balance control becomes difficult for older adults (Fig. 1).

Musculoskeletal fragility associated with sarcopenia (loss of muscle mass) and osteopenia (loss of bone mass) can result in fall and fracture. The postural alignment usually changes in elderly people with low BMD. Muscle performance might be altered by the loss of muscle mass and strength. Spinal extensor muscle weakness is associated with hyperkyphosis³⁴ and may limit activities, including bending, reaching, reduced gait speed, greater difficulty climbing stairs, and poorer balance.^{22,30} A flexed posture (kyphosis) is relatively unstable because the center of mass (CoM) in the body is shifted closer to the edge of the support base. Hyperkyphosis changes the joint position sense because of poor alignment of the joints.¹⁹ All these factors could influence control over the CoM position or center of pressure and the ability to recover from balance

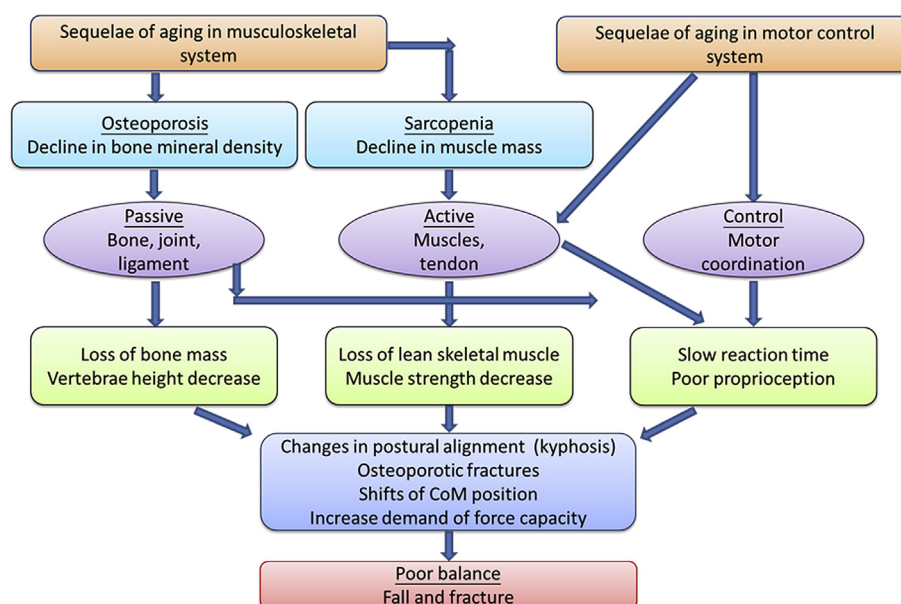


Figure 1 Mechanism of poor balance control in osteoporosis. CoM = center of mass.

perturbation.^{35,36} The mechanism of the balance control problem in osteoporosis is shown in Fig. 1. Numerous determinants of each have been identified, but further work to develop preventative strategies based on these determinants is required.

Age-related alterations of muscle architecture and activation during upright stance might be associated with the decreased balance stability documented in elderly adults. Baudry et al investigated the ultrasonography and electromyography in young and elderly adults when stood upright on a force platform with and without vision.³⁷ The results show that elderly adults increase the stiffness of the muscular portion of the muscle–tendon unit during upright stance, which may make up for the age-related decrease in tendon stiffness.

Muscle performance and balance control

Several studies have implicated the key role of deterioration of musculoskeletal function in older adults for observed age-related deficits in balance stability control.^{38–42} Sarcopenia is a main feature of the aging process. It is characterized by a reduction in muscle mass and muscle strength. Sarcopenia is associated with an increased risk of fractures after a greater predisposition to falls. Fractures may also result from the accelerated bone remodeling that increases bone loss and impairs bone strength. The fractures may also be related to reduced mechanical muscle strength, which may influence the response during the fall process. Furthermore, muscle strength determines the quality of bone modifications such as density, strength and microarchitecture. Variations in the ratios of cortical and muscle areas effectuate to various types of osteoporosis, with varying risks of fractures.⁴³

MacRae et al have documented that lower scores on manual muscle testing of the hip abductors, knee extensors, knee flexors, and ankle dorsiflexors are significantly related to an older adult's fall status.⁴⁰ Runge and colleagues have computed the joint torque from the inverse dynamic during balance recovery and have found that ankle, knee, and hip joint torque generally increase as the velocity of perturbation is raised.⁴⁴ Controlling the balance is a major requirement for postural stability. Other factors should also be considered such as muscle quality and the ability of force usage.

The potentially modifiable risk factors for poor muscle strength and quality could be targeted in exercise interventions. Research is needed to determine the threshold of muscle quality and strength capacity associated with functional impairments and reduce the associated cascade of fracture. This information could be used to develop screening guidelines that would assist clinicians with intervention timing. Several studies have suggested that the deterioration of musculoskeletal function in older adults may play a key role in the observed age-related deficits in balance stability control.^{38–42}

Kyphotic posture and balance performance

Lower spinal muscle density often presents in osteoporosis patients, and frequently in those with spinal deformities

such as thoracic kyphosis, it may cause a diminished range of motion.⁴⁵ Reduced bone mass in elderly people may cause progressive microfracture, which may finally lead to vertebral height loss due to gross vertebral compression fracture and spine deformities. Postural deformities such as kyphosis and limited spinal mobility impair the quality of life in older adults with osteoporosis.⁴⁶ Forward head posture, scapula protraction, reduced lumbar lordosis, and decreased standing height are often present in the patients associated with hyperkyphosis.³⁰

Hyperkyphosis is the leading cause of sagittal plane deformity and is associated with impaired mobility, including reduced gait speed, greater difficulty climbing stairs, and poorer balance.^{22,30} Weaker back extensor muscles often result in deformities of the skeleton such as kyphosis, which in turn cause modifications to posture and an increased probability of fall and fracture.⁴⁵ The resulting center of gravity modification worsens the control of body balance.

Reduced flexibility and mobility of trunk affects the walking of people with osteoporosis and contributes toward a greater risk of falling, which leads to bone fractures. Flexibility and balance are necessary to counteract the effects of gravity and other external forces in addition to the normal sagittal alignment of the spine and adequate muscle strength. A reduction in range of motion and deterioration in coordination that affects body balance is a sequence of osteoporosis and aging in general.²² Therefore, optimal exercise programs to strengthen the back extensors are important in the management of deformities related to osteoporosis.

Exercise training for fall prevention

Several clinical guidelines on the management of osteoporosis have highlighted the necessity of exercise.^{47,48} Exercise improves quality of life, particularly in the domains of physical function such as balance and pain relief that can be assessed by the Quality of Life Questionnaire of the European Foundation for Osteoporosis (QUALEFFO-31).^{49,50} Bergland et al⁵¹ have shown that a 3-month course of circuit exercises can improve mobility, balance, and the quality of life for women with osteoporosis and a history of vertebral fractures. The circuit exercises were performed twice weekly, which included 10 minutes warm up with aerobic exercise and 40 minutes walking, stepping, and posture promoting.⁵¹ Burke et al⁵² have also performed an 8-week balance training with muscle strengthening or stretching, twice weekly, for 60 minutes a day. Both strengthening and stretching exercises were effective in improving postural control when compared to the control group.⁵²

Kyphotic posture changes the location of the whole body CoM and could affect the balance stability, therefore, postural correction has been a focus of exercise training in osteoporosis patients, especially in those with vertebral compression fracture. A prospective study observed a reduced incidence of vertebral compression fractures in estrogen-deficient women who participated in a back extensor strengthening program and demonstrated a 10-year long-term effect.⁵³ These benefits primarily result from the bone-formation-friendly mechanical simulation

produced by strengthening force. The force prevents or corrects deformity of the vertebral body by extension of the anterior longitudinal ligament.

The goals of rehabilitation exercise are prevention of fall and subsequent new fractures, reduction of kyphosis, enhancing axial muscle strength, and providing correct spinal alignment. Hyperkyphosis is common following osteoporotic vertebral fractures. Correction of kyphosis provides patients with pain relief, increased mobility, and improvement in quality of life. Spinal extensor strengthening can reduce the most disfiguring consequences of aging, such as thoracic hyperkyphosis, vertebral fracture, loss of height, and pain of the anterior rib cage.^{54–56} The incidence of new fractures associated with back extension exercises (16%) is lower than the incidence related to abdominal flexion exercises (89%).⁵⁷ Moreover, back extensor strengthening exercises can reduce the incidence of osteoporotic compression fracture significantly in postmenopausal women over a 10-year period⁵³ and lower the incidence of new fractures in patients with vertebroplasty.⁵⁸

Exercise training of the trunk for core stability has become a well-known fitness trend that has emerged in rehabilitation programs. The core can be described as a muscular box with the abdominals in the front, paraspinals and gluteals in the back, the diaphragm as the roof, and the pelvic floor and hip girdle musculature as the bottom.⁵⁹ Popular fitness programs, such as Pilates, yoga and Tai Chi, follow core-strengthening principles. This box comprises 29 pairs of muscles that help stabilize the spine, pelvis, and kinetic chain during functional movements. Deficient strength in these muscles results in mechanical instability of the spine with compressive forces of as little as 90 N.⁶⁰

Moreover, some evidence in the literature supports the notion that core-stabilization programs may be used to help prevent knee injuries in athletics. Leeton et al performed a prospective study with 140 male and female intercollegiate basketball and track athletes. They found that athletes with anterior cruciate ligament injuries experienced iliotibial band syndrome, patellofemoral pain, and stress fractures in the lower extremity, which significantly decreased strength in hip abduction and external rotation compared with noninjured athletes.⁶¹ Enhanced strength would be beneficial to upright posture and aid balance while walking, thereby decreasing the risk of fall and improving quality of life.⁵³

The sex differences affect the prevalence of osteoporosis, osteoporotic fractures, and fall-related risk factors for incident fractures.^{62,63} During aging, less cortical bone loss occurs in men because there is less endocortical resorption and cortical porosity in men than women. Moreover, trabecular bone loss is similar in men and women, but there is less trabecular architectural disruption in men than in women. Furthermore, older women experience more falls than do older men.⁶⁴ Therefore, weight-bearing exercise and strengthening exercise should be emphasized for women with osteoporosis.^{51,52,65,66}

Many people routinely exercise using fitness programs, such as Pilates, yoga and Tai Chi. However, individuals with osteoporosis need special consideration, including the exercise positions. For example, the increased torque pressure applied to vertebral bodies during spinal flexion exercises may be a risk in yoga or Pilates positions.^{67–70} Tai

Chi is also used to improve balance ability in older populations.^{71–73} However, Tai Chi does not provide much loading on weight-bearing joints as expected, which is a precondition for an effect on bone metabolism.^{74–81}

Assistive device for fall prevention

Besides the exercise training, recent studies have shown that assistive device can also improve balance.^{82,83} Spinal orthoses are commonly prescribed to immobilize the vertebral compression fracture and relieve pain of osteoporotic patients.⁸⁴ Liaw et al have found that the Knight–Taylor spinal brace efficiently improves the static and dynamic balance of patients with osteoporotic vertebral compression fracture.⁸² Spinal bracing can provide spinal stability by compensating for the weak back extensor and decreasing painful guarding of the paraspinal muscles.⁸⁵ The orthoses also provide additional sensory feedback to enhance balance. de Moraes Barbosa and colleagues⁸³ have evaluated the effect of foot orthoses on balance, foot pain, and disability in women with osteoporosis. They have found that the insole with medial arch support and metatarsal pad are effective for improving balance and reducing pain.

Conclusions

Mounting evidence has shown that muscle quality and good posture alignments are crucial for balance control in older adults. People are diagnosed with osteoporosis often combining with muscles weakness, and increased spine kyphosis leading vertebral fractures, and poor balance control, even falls. Therefore, improving muscle quality, strengthening weak muscles and correcting postural alignment are essential elements for fracture and fall prevention in older adults with osteoporosis. A new paradigm of treatment approaches for balance control to reduce the risk of falling and fracture is needed.

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