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Exercise and osteoporotic fracture prevention

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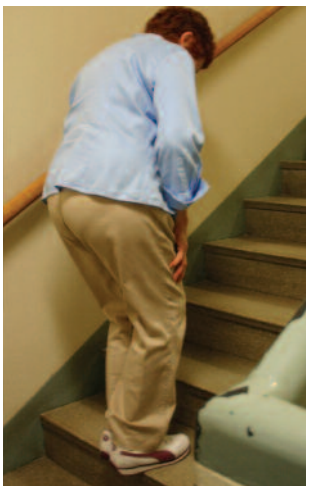

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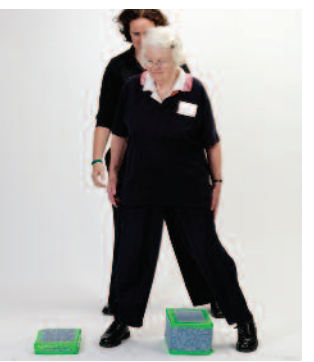

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Patient handouts

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Exercise and osteoporotic fracture prevention

Part 1: the role of exercise

A combination of exercise, adequate nutrition and, when required, pharmacotherapy offers the best approach to optimal bone health and osteoporotic fracture prevention.

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The clinical manifestations of osteoporosis (pain, fracture and subsequent mobility impairment) affect about 2 million Australians currently, and some 20,000 patients each year suffer a hip fracture. GPs have a critical role to play in preventing such fractures. Current evidence suggests exercise is an important strategy to address the major primary risk factors for such fractures. Physical activity is complementary and additive to the nutritional and pharmacological management of osteoporosis but is a vastly underused preventive modality.

The first part of this two-part article reviews the rationale for the use of physical activity in the prevention of osteoporotic fractures in people at mid-life and beyond. The second part of the article (see pages 10 to 18, originally published in *Medicine Today*, January 2007) discusses the development of exercise prescriptions for the general older population and for specific patient groups.

Scope of the problem

The prevalence of osteoporosis-related conditions in Australia is predicted to increase over the next two decades, from 10% of the population currently to 13.2% by 2021.[1] Also predicted to increase is the incidence of osteoporotic fractures, from one every 8.1 minutes in 2001 to one every 3.7 minutes in 2021.

The total costs relating to osteoporosis are currently estimated at $7.4 billion annually, $1.9 billion of which are direct costs.[1] These costs, however, greatly underestimate the suffering caused by osteoporosis-related conditions, such as mobility impairment and activity restriction, pain, fear of falling, need for informal care and support, and loss of self-esteem and emotional wellbeing associated with recurrent injurious falls and fractures. There is, therefore, a great need to better understand osteoporosis and to

IN SUMMARY

- **Osteoporotic fracture is a multifactorial problem requiring a holistic approach to prevention for optimal efficacy and safety.**
- **Targeted exercise addresses many of the risk factors for osteoporotic fracture, including osteopenia, muscle wasting and weakness, falls, poor balance, depression, use of medications for depression and insomnia, sedentariness, fear of falling, mobility impairment and disability.**
- **Concurrent management of fracture risk with a physical activity prescription, adequate nutrition and pharmacotherapy for osteoporosis when required offers the best approach to optimal bone health.**
- **The important elements of the exercise prescription for bone health include high intensity progressive resistance exercise (weight lifting), progressive balance training, moderate to high intensity weight-bearing aerobic exercise and, when feasible, high impact exercise.**

continued

Figure. Resistance training, balance training, weight-bearing aerobic exercise and, when feasible, high impact exercise can improve bone and muscle strength and many other modifiable risk factors for osteoporotic fracture.

implement ways to prevent and recover from these morbid events.

Physical activity reduces fracture risk

Epidemiological studies suggest that regular exercise (primarily in the form of walking) is associated with a reduction in osteoporotic fracture risk of up to 50% in men and women over 65 years of age.[2,3] Currently, there is evidence only for the efficacy of exercise in preventing vertebral fractures;[4] no randomised controlled trials investigating exercise and fracture prevention have been carried out at other specifc sites. However, optimal physical activity participation clearly maximises the attainment of peak bone mass and bone strength, and attenuates age- and menopause-related bone loss. It also improves the overall risk factor profile associated with osteoporotic fracture in older adults (such as low muscle mass and strength, poor gait and balance, and depressive symptoms).

Choosing the right kind of exercise for patients with various health profiles requires an understanding of the effects of specific kinds of exercise on bone formation and remodelling at different stages of life.

Typical patterns of bone loss

In women, bone mass begins to decrease well before the menopause (as early as during their 20s in the femur of sedentary women) and accelerates in the perimenopausal years, with continued decline into late old age. Similar patterns of bone loss are seen in men, although without the acceleration related to loss of ovarian function seen in women.

As with losses of muscle tissue (sarcopenia), many genetic, lifestyle, nutritional and disease and medication-related factors affect the prediction of bone health at a given age. However, a wealth of animal and human data provides evidence for a strong relation between physical activity and bone health/fracture risk at all ages. Mechanical loading of the skeleton generally leads to favourable site-specific changes in bone mineral density (BMD), morphology and strength. In contrast, unloading (in the form of bed rest, immobilisation, casting or spinal cord injury) leads to resorption of bone and increased susceptibility to fracture within a few weeks of unloading. This rapid resorption mimics many years of 'ageing'. Space travel is the most dramatic example of unloading, and much information on the effect of mechanical stresses on bone has been gained from studies of astronauts.

Less extreme variations in mechanical loading patterns seen within normal populations are also associated with differences in bone morphology and strength. Comparative studies of athletic and nonathletic populations usually demonstrate significantly higher BMD in the active cohorts, ranging from 5 to 30% higher, depending on the type, intensity and duration of exercise training undertaken and the characteristics of the athletes studied.[5-9] Exceptions occur with nonweight-bearing activities such as swimming, and in amenorrhoeic athletes or elite distance runners with very low body fat, who often appear similar or worse than controls. Measurable differences in BMD are also observed between habitually active (but nonathletic) and sedentary individuals.[10]

Overall, cross-sectional and prospective cohort data support a strong relation for both men and women between lifetime physical activity patterns and preservation of BMD into old age, as well as a protective effect for hip, humerus and vertebral fracture.[2,3] These reduced risks for fracture remain after adjustment for most major known risk factors for osteoporosis, and are not completely accounted for by differences in BMD, muscle strength or fall rates. It is thought

that other changes in bone structure and geometry (such as greater diameter and stronger trabecular architecture) favourably influence skeletal integrity after exposure to exercise. Also, the positive effects of physical activity on gait mechanics, balance, psychological health and nutritional status may help protect against fractures.

Exercise and optimal bone health

The goals of a physical activity prescription for bone health are to enhance bone strength and also address other potentially modifiable risk factors for osteoporotic fracture relevant to exercise, including muscle wasting, poor gait and balance, visual impairment, poor nutritional intake, depression, postural hypotension, polypharmacy, podiatric problems and environmental hazards (see Figure and Table). This holistic approach to the promotion of physical activity is much broader than the simplistic goal of attenuating osteopenia through exercise. Thus exercise is likely to impact favourably not only on bone health but also on the control of many major chronic diseases, mobility impairment and disability, mental health, and quality of life in older patients. Some terms used in association with exercise are defined in the upper box on this page.

Principles of exercise prescription

There are many unanswered questions regarding the optimal prescription of exercise for bone health, and in particular its ultimate efficacy for fracture prevention. There is, however, evidence that bone responds positively to novel mechanical forces, and that rapid, short bursts of high intensity loading of bones are more effective than sustained, low intensity loading of bones.

Characteristics of exercise that maximise bone adaptation are listed in the lower box on this page.

Exercise terms defined

Weight-bearing aerobic exercise

Use of large muscle groups in a rhythmic pattern in a standing position, at a rate that increases heart rate, blood pressure and breathing to at least a 'moderately hard' level. Examples are brisk walking, hiking, stair climbing, jogging and aerobic dance. (Swimming, cycling, seated steppers and arm exercises are examples of nonweight-bearing aerobic exercises.)

Resistance training (weight lifting exercise)

Use of targeted muscle groups to lift and lower moderate to heavy weights slowly.

Power training

Weight lifting exercise performed so that the lifting phase is done as fast as possible, and the lowering is done slowly.

High impact exercise

Exercises in which the bones of the spine and lower extremities are loaded forcefully and rapidly as the feet hit the ground. Examples include jumping, rope skipping, hopping up or down stairs, jumping off boxes and sports involving jumping, such as basketball.

Balance exercises

Exercises that stress the equilibrium by narrowing the base of support, removing vision, decreasing foot contact with the ground and changing the centre of mass. Examples include standing on one leg with eyes closed, sitting on an exercise ball, heel-to-toe walking, leaning as far as possible in all directions while standing without bending at the waist, tai chi and balancing while placing a pillow or rocker board under the feet.

Principles of exercise that maximise bone adaptation

- Rapid, short bursts of high intensity and/or high impact activities such as jogging, jumping and rope skipping are more stimulating to bone cells than sustained, low impact activity such as walking.
- Effective activity does not have to be weight-bearing. Resistance training is an effective nonweight-bearing activity.
- Aerobic activity that is nonweight-bearing (such as swimming or cycling) does not enhance bone density.
- Lifting heavy weights is more effective than lifting light weights.
- Lifting heavy weights rapidly (power training) seems to be more effective than lifting heavy weights slowly (traditional resistance training).
- Exercising in short bouts with rest periods between has been shown in animal models to be more effective than continuous, long periods of exercise.
- Rapid movements are more stimulating than slow movements.
- Novel forces, such as changing directions and different heights of jumps, are more stimulating than repetitive force patterns.
- As the response of bone to muscle contraction is a local phenomenon, muscles connected to clinically important bones susceptible to osteoporotic fracture (hip, wrist, thoracic spine) need to be targeted specifically to achieve protection at those skeletal sites.

Appropriate types of exercise

Moderate to high intensity weight-bearing aerobic exercise (such as brisk walking, hiking, stair climbing or jogging), high intensity progressive resistance training (weight lifting) and high impact exercise (such as jumping or rope skipping) increase BMD by 1 to 4% per year in pre- and postmenopausal women.[11-13] More vigorous exercise interventions seem to produce greater effects. The widest range of benefits relevant to fracture protection seems to be provided by weight lifting and balance training exercises. Whether these benefits translate into fracture risk reduction is not yet known, but it is reasonable to use exercise for risk factor modification pending completion of studies.

The types of exercise appropriate for specific risk factors are listed in the Table below, placed in context with other preventive or therapeutic options. It should be noted that prescribing low intensity aerobic exercise alone (such as casual

Table. Osteoporotic fracture risk factor modification: role of exercise

Risk factor for osteoporotic fracture	Preventive or therapeutic options	
	Exercise	Other options
Osteopenia	Resistance training, power training, weight-bearing aerobic training, high impact training	Bisphosphonates, SERMs (raloxifene [Evista]), hormone therapy, tibolone (Livial), strontium ranelate (Protos), vitamin D, calcium
Sedentary behaviour	Exercise counselling/prescription	Time management and behavioural counselling
Falls	Resistance training, balance training	Hip protectors Evaluate and treat postural hypotension Evaluate and treat visual impairment Environmental modification, home safety evaluation Podiatric problems and footwear evaluation Ambulatory assistive devices Reduce polypharmacy
Muscle weakness/sarcopenia	Resistance training, power training	Vitamin D or multinutrient supplementation, nutritional counselling Correction of hormonal deficiencies
Impaired balance	Balance training, tai chi, yoga, resistance training, power training	Hip protectors Environmental modification, home safety evaluation Medication management
Depression, antidepressant medications	Substitute moderate to high intensity aerobic or high intensity resistance training for antidepressant medication	—
Protein and calorie undernutrition, weight loss	Resistance training to increase protein uptake from diet and appetite	Nutritional counselling and support
Polypharmacy	Substitute aerobic or resistance training for medications for depression, insomnia and anxiety	Drug review and modification as appropriate to reduce drugs, minimise CNS side effects, relieve postural hypotension, minimise myopathy and osteopenia, and reduce anorexia
Visual impairment	—	Ophthalmological evaluation and treatment as appropriate Environmental modification, visual aids and ambulatory and ocular assistive devices; avoid bifocals
Smoking and excess alcohol intake	Exercise has been shown to support positive behavioural change in other domains (such as dietary change and smoking cessation)	Reduce or eliminate excess usage

Abbreviation: SERMs = selective oestrogen receptor modulators.

walking) has not been shown to improve gait, balance, muscle mass, muscle strength, bone density, fall risk, clinical depression or fracture rates in older adults. Although this is the most common exercise advice given by GPs (such as 'You should take a walk every day' or 'You should be a little more active'), there is no evidence that giving such advice to older patients will prevent osteoporotic fracture. In fact, advising osteoporotic patients with poor balance to walk more without first improving their balance and strength has been shown to increase the risk of fracture.

Types of exercise to be avoided

Patients at risk for osteoporotic fracture should avoid activities that involve forward flexion of the spine, particularly while carrying an object (for example, lawn bowls, sit ups with straight legs or simply bending over to pick up something from the floor), as this movement in the presence of osteopenia increases the risk of anterior compression fractures of the thoracic vertebrae. Similarly, unsupervised exercise in those with poor balance or a history of osteoporotic fracture is best avoided, as are high risk activities or hazardous environments that may lead to falls.

The potential risks of exercise and suggested means to avoid these complications are discussed in part two of this article (see pages 10 to 18).

Prescribing exercise

It is best to think of exercise like a medication in terms of the type prescribed (modality), dosage (volume, frequency, intensity), how to take it (type of equipment, supervision), interactions (nutritional or pharmacological treatments for osteoporosis, exercise–drug interactions), compliance (behavioural change program accompanying the exercise prescription, practical implementation needs) and side effects (adverse events, risks of participating in exercise).

The elements of the exercise prescription for bone health are discussed in detail in the second part of this article. The most important of these are robust (high intensity) weight lifting exercise, balance training, moderate to high intensity weight-bearing aerobic exercise and, when feasible, high impact exercise. Modifications of the exercise prescription are required for patients with arthritis, neuromuscular disease/frailty and cardiopulmonary disease. These modifications are discussed in part two, as are also safety issues and compliance.

It is part of the GP's role in fracture prevention to provide a detailed exercise prescription for bone health, including written instructions and other educational support materials (see the box on this page and the later section on 'The role of the GP'). For some patients, such as those with cognitive impairment, frailty, balance impairment or severe osteoporosis, the exercise should be performed in a supervised venue at least until the patient is considered safe; the GP should either provide such a venue or refer the patient to one. When referring patients to a fitness centre, the GP will need to specify the nature of the exercises required to ensure that the treatment is evidence-based.

Safety of the exercise prescription

There is plenty of evidence suggesting that weight lifting exercise is safe when prescribed appropriately in older adults. Very little information on high impact exercise is available, but studies to date in postmenopausal women exercising unsupervised in their own homes have not reported injuries. Screening for potential contraindications (such as hernias, aneurysms, acute joint injuries and unstable cardiovascular disease) and supervision in the initial stages are critical for the safety and efficacy of the exercise prescription.

Specific exercise prescriptions for various patient groups are discussed in part two of this article. An example of such a prescription would be a low impact

Fracture prevention using exercise: the role of the GP

- Assess the risk factors for osteoporotic fracture that are present in each individual (including osteopenia, muscle wasting, poor gait and balance, visual impairment, depression, poor nutritional intake, postural hypotension, polypharmacy, podiatric problems, environmental hazards, smoking, alcohol intake).
- Record historical and current physical activity patterns, and discuss with the patient how these patterns compare with the optimal physical activity recommendations for bone health.
- Identify any contraindications to exercise participation or need to modify exercise recommendations to enhance feasibility or prevent injury.
- Determine the patient's preferences for specific types of exercise within the range of possible choices relevant to fracture risk.
- Provide a detailed exercise prescription for bone health, in terms of exercise type, volume, frequency and intensity, including written instructions and other educational support materials.
- Recommend a supervised venue for training until independent and safe. Note that for some frail patients, withdrawal of supervision will not be realistic at any time point.
- When referring patients for physical activity programs, specify the nature of the exercises required (e.g. weight lifting, stair climbing, balance training) to ensure that the treatment is evidence-based.
- Establish a strong behavioural program to accompany the exercise prescription, including recording of adherence, provision of feedback, monitoring and periodic revision of the prescription as the patient's risk profile or health status changes.

continued

Consultant's comment

The GP's role in fragility fracture prevention in osteoporosis is central. Exercise and adequate calcium and vitamin D nutrition are important preventive modalities, and of these exercise is probably the most underutilised. As indicated in this two-part article by Professor Fiatarone Singh, exercise is a useful strategy to address many of the major risk factors for fragility fractures. It is also complementary to the pharmacological and nutritional management of the disease.

The ideal prescription of exercise for optimal bone health is uncertain. However, there is evidence that bone responds most positively to novel mechanical forces, with rapid, short bursts of high intensity loading being most effective. Walking is not enough, but the good news is that many high intensity exercises can be readily and conveniently incorporated into the patient's lifestyle. Resistance exercise programs are particularly useful. The article also provides a guide to balancing and strengthening activities for patients who may not readily have access weight lifting equipment.

Epidemiological evidence shows exercise improves osteoporosis risk factors such as bone mass, muscle strength, balance and falls. There are fewer data regarding effects of exercise on fracture prevention. Large, long term, randomised controlled trials of exercise with fragility fracture itself as a primary endpoint remain a priority for future research in osteoporosis.

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but high loading form of exercise (for example, seated resistance training) for very frail older adults who have osteoarthritis of the hips and knees in addition to being at risk of osteoporotic fractures and falls.

Exercise and other treatments

Exercise does not take the place of nutritional and pharmacological management of osteoporosis, and these treatments should, therefore, be continued when exercise is initiated.

In most trials studying the benefits of exercise, women have received calcium, and in some cases vitamin D, supplementation, and there is evidence that nutritional adequacy in terms of energy, protein, calcium, vitamin D and other micronutrients is necessary for optimal skeletal adaptations. In addition, oestrogen has been shown to be additive to the benefits of exercise on bone in some studies.

More information is needed on the potentially additive effects of exercise and bisphosphonates on bone density and fracture risk. In the meantime, as the effects of bisphosphonates on bone are greater than other currently available treatments, the most rational approach would seem to be to continue these agents and add exercise. Exercise has the added benefits of improving fitness, mental health, neuromuscular function, muscle and fat mass, and general health status in ways that osteoporotic pharmacotherapy alone cannot.

The role of the GP

The GP's role in fracture prevention using exercise is to fully integrate exercise into the rest of the health care of patients at risk. If patients sense that exercise is considered just as essential to their health care as the rest of the prescriptions offered to them, they will be far more likely to adopt and adhere to recommendations. The essential roles of the GP in this regard are given in the box on page 7.

GPs in more remote areas will probably need to develop home exercise programs for their patients because of the lack of access to training facilities. More details of how balance and strengthening activities can be incorporated into lifestyle rather than using exercise equipment are given in part two of this article.

Conclusion

Many epidemiological studies suggest that physical activity substantially lowers the risk of osteoporotic fracture in older men and women. In addition, there is a wealth of experimental evidence that exercise can improve the major risk factors for osteoporotic fracture in older adults (that is, bone density, muscle strength, balance and falls). Thus, the incorporation of evidence-based physical activity counselling and implementation strategies into the care of such patients is critical if the personal and societal burden of fragility fractures in Australia are to be reduced.

There is evidence that a stabilisation or increase (by 1 to 2% per year) in bone mass is achievable by resistive, weight-bearing aerobic exercise or high impact exercise. Such effects on bone density may be important for both prevention and treatment of osteoporosis and related fractures and disability. Even if exercise alone is an insufficient stimulus to maintain bone density at youthful levels, the effects of exercise on bone strength, muscle mass, muscle strength, balance, mobility, disability and mental health should, in combination, lower the risk of injurious falls substantially in physically active individuals. However, large, long term, randomised controlled trials of any exercise modality with osteoporotic fracture as a primary outcome have yet to be conducted, and are a priority for advances in this field. MT

DECLARATION OF INTEREST: None

References

1. Sambrook P, Seeman E, Phillips SR, Ebeling P. Preventing osteoporosis: outcomes of the Australian Fracture Prevention Summit. Med J Aust 2002; 176 (8 Suppl): 1-16.
2. Lee S, Dargent-Molina P, Breart G. Risk factors for fractures of the proximal humerus: results from the EPIDOS prospective study. J Bone Miner Res 2002; 17: 817-825.
3. Gregg EW, Cauley JA, Seeley DG, Ensrud KE, Bauer DC. Physical activity and osteoporotic fracture risk in older women. Ann Intern Med 1998; 129: 81-88.
4. Sinaki M, Itoi E, Wahner HW, et al. Stronger back muscles reduce the incidence of vertebral fractures: a prospective 10 year follow-up of postmenopausal women. Bone 2002; 30: 836-841.
5. Kirchner EM, Lewis RD, O'Connor PJ. Bone mineral density and dietary intake of female college gymnasts. Med Sci Sports Exerc 1995; 27: 543-549.
6. Heinonen A, Oja P, Kannus P, Sievanen H, Manttari A, Vuori I. Bone density of female athletes in different sports. Bone MIner 1993; 23: 1-14.
7. Snow-Harter CM. Bone health and prevention of osteopososis in active and athletic women. Clin Sports Med 1994; 13: 389-404.
8. Taaffe DR, Snow-Harter C, Connolly DA, Robinson TL, Brown MD, Marcus R. Differential effects of swimming versus weight-bearing activity on bone mineral status of eumenorrheic athletes. J Bone Miner Res 1995; 10: 586-593.
9. Lima F, De Falco V, Baima J, Carazzato JG, Pereira RM. Effect of impact load and active load on bone metabolism and body composition of adolescent athletes. Med Sci Sports Exerc 2001; 33: 1318-1323.
10. Hagberg JM, Zmuda JM, McCole SD, et al. Moderate physical activity is associated with higher bone mineral density in postmenopausal women. J Am Geriatr Soc 2001; 49: 1411-1417.
11. Kelley GA, Kelley KS, Tran ZV. Resistance training and bone mineral density in women: a meta-analysis of controlled trials. Am J Phys Med Rehabil 2001; 80: 65-77.
12. Wolff I, van Croonenborg JJ, Kemper HC, Kostense PJ, Twisk JW. The effect of exercise training programs on bone mass: a meta-analysis of published controlled trials in pre- and postmenopausal women. Osteoporosis Int 1999; 9: 1-12.
13. Wallace BA, Cumming RG. Systematic review of randomized trials of the effect of exercise on bone mass in pre- and postmenopausal women. Calcif Tissue Int 2000; 67: 10-18.

Exercise and osteoporotic fracture prevention
Part 2: prescribing exercise

Rapid, short bursts of progressive high impact or high intensity resistance exercise have been shown to improve the major primary risk factors for osteoporotic fracture in middle-aged and older adults more effectively than other forms of exercise. High impact exercise and balance training can readily be incorporated into daily activities.

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The clinical manifestations of osteoporosis (pain, fracture and subsequent mobility impairment) cause much personal suffering and impose a significant societal burden. Exercise has been shown to improve the major primary risk factors for osteoporotic fracture in middle-aged and older adults, including bone mineral density (BMD), muscle strength, balance and falls. The implementation of evidence based physical activity programs for the prevention of osteoporotic fractures in the general older population and in specific patient groups is covered in this second part of a two-part article on exercise and osteoporotic fracture prevention. The rationale for the use of exercise was discussed in the first part of the article (see pages 3 to 9, originally published in *Medicine Today*, December 2006).

Developing an exercise prescription

Exercise can be considered like a drug in terms of:

- the type prescribed (modality)
- the dosage (volume, frequency, intensity)
- how to take it (type of equipment, supervision)
- interactions (nutritional or pharmacological treatments for osteoporosis, exercise–drug interactions)
- compliance (behavioural change program accompanying the exercise prescription, practical implementation needs)
- side effects (adverse events, risks of exercise).

Some terms used in association with exercise are defined in the box on page 11. The flowchart on page 12 provides an approach to choosing the appropriate exercise types for individuals with and without osteoporosis or risk factors for it

IN SUMMARY

- **The most important elements of the exercise prescription for bone health are high intensity progressive weight lifting exercise and progressively more difficult balance training, with the addition of high impact exercise (such as jumping) when feasible.**
- **The most economical prescription with the broadest benefits for body composition and bone health as well as neuromuscular function is progressive resistance training as the primary exercise modality.**
- **Continuous progression of weight moved, balance exercise difficulty and jump height is the most critical element of the exercise prescription for bone health; if progression stops, so does adaptation in the bone and muscle.**
- **Given the short time (several minutes per day) that is necessary for effective high impact exercise or balance training, incorporating such episodes into daily activities may be more successful than planning structured exercise classes away from home.**

and/or at risk of falls. Depending on a patient's health status, modifications to standard exercise prescriptions may be required (see later in article and Table 1).

Exercise terms defined

Weight-bearing aerobic exercise
Use of large muscle groups in a rhythmic pattern in a standing position, at a rate that increases heart rate, blood pressure and breathing to at least a 'moderately hard' level. Examples are brisk walking, hiking, stair climbing, jogging and aerobic dance. (Swimming, cycling, seated steppers and arm exercises are examples of nonweight-bearing aerobic exercises.)

Resistance training (weight lifting exercise)
Use of targeted muscle groups to lift and lower moderate to heavy weights slowly.

Power training
Weight lifting exercise performed so that the lifting phase is done as fast as possible, and the lowering is done slowly.

High impact exercise
Exercise in which the bones of the spine and lower extremities are loaded forcefully and rapidly as the feet hit the ground. Examples include jumping, rope skipping, jumping or hopping up or down stairs, jumping off boxes and sports involving jumping, such as basketball.

Balance training
Exercises that stress the equilibrium by narrowing the base of support, removing vision, decreasing foot contact with the ground and changing the centre of mass. Examples include standing on one leg with eyes closed, sitting on an exercise ball, tandem walking (also known as heel-to-toe walking), side stepping, leaning as far as possible in all directions while standing without bending at the waist, tai chi and balancing while placing a pillow or rocker board under the feet.

Modality

Resistance training

Although weight-bearing aerobic exercise, high impact exercise and resistance training have all been shown to maintain or augment bone density in older adults, resistance training has the added benefits of increasing muscle mass and strength, as well as balance to some extent. This combination of effects on body composition and muscle function is a direct antidote to age-associated changes in these domains, and offers potential benefit for many health conditions in addition to osteoporosis. Therefore, the most economical prescription with the broadest benefits for body composition and bone health, as well as neuromuscular function, is resistance training as the primary exercise modality. Adding high velocity forces/movements may further enhance bone strength benefits for the femoral neck or trochanter, improve lower extremity muscle power and augment balance. Thus, traditional weight lifting exercise (slow lifting and lowering) or power training (rapid lifting and slow lowering of the weight), either on machines or using free weights, is the key exercise modality.

The effects of muscle contraction on bone appear to be primarily regional (stimulation of osteoblast function) rather than systemic. Therefore, muscle groups connected to bones of relevance to osteoporotic fracture should be emphasised in a resistance training program (e.g. spinal extensor muscles, hip abductors and extensors, knee extensors and flexors) as



Figures 1a to c. Resistance training exercises using machines or free weights increase both bone density and muscle strength. a (left). Leg press. b (centre). Knee extension. c (right). Hip extension (note the weight bands around the ankles).

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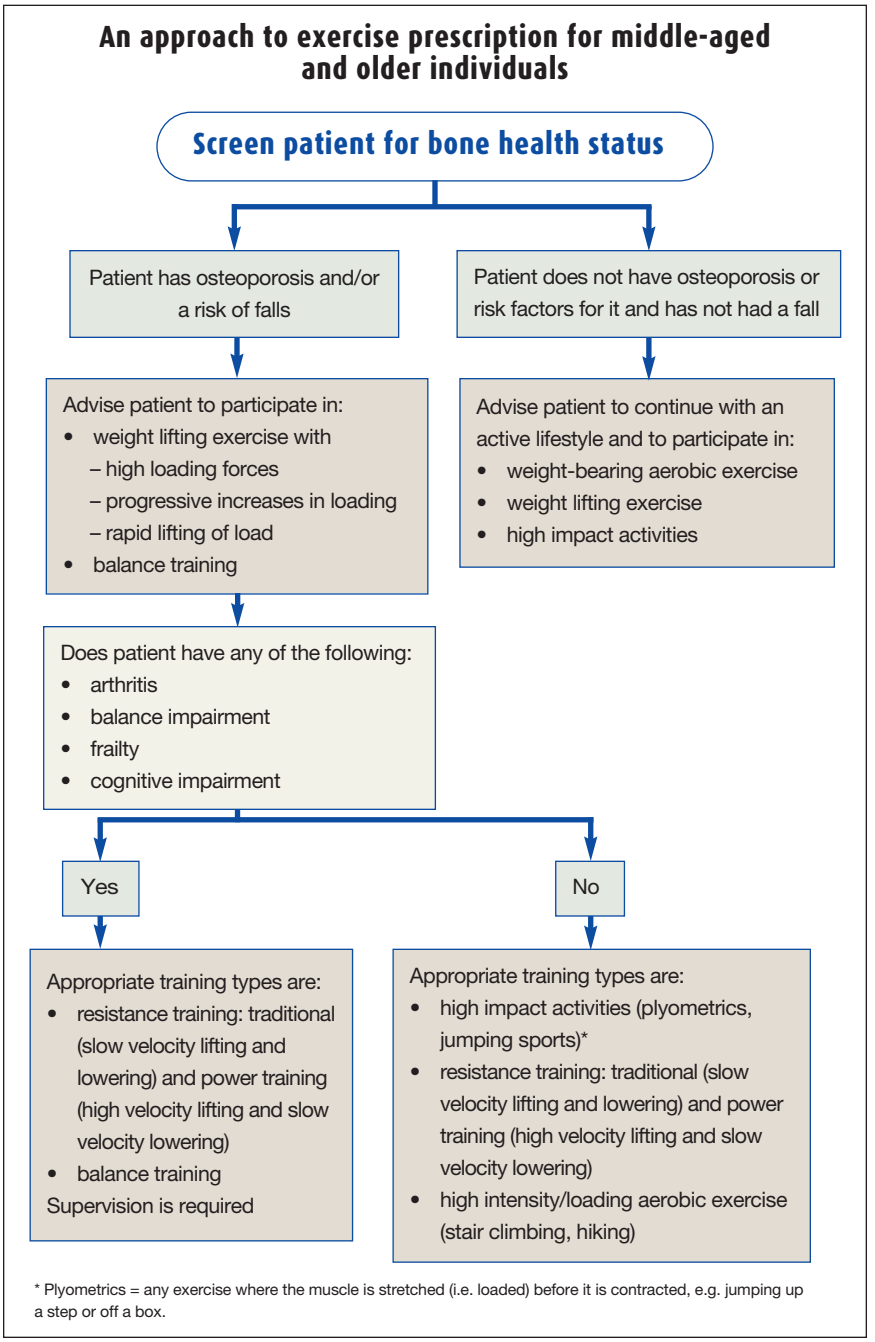

well as those related to gait and balance (ankle plantar flexors and dorsiflexors). Typical exercises would include the machine-based leg press, seated rowing, lat (latissimus dorsi) pull down and knee extension and flexion, the free weight versions of these exercises, and standing calf raises (Figures 1a to c).

High impact exercise

In middle-aged and older adults, high impact exercise is typically prescribed as some form of jumping, including jumping in one place or up and down boxes and stairs, and rope skipping, also known as jump rope (Figure 2).[1,2] Fast heel drops (fast drop with sudden stop, then slow raise) are more suitable, although not as effective, for patients with previous injuries or osteoarthritis of the knees and hips. Jumps and heel drops should be performed with hips and knees fully extended (straight) when landing so that the forces are transmitted to the bones, rather than dissipated by the muscles.

Doing high impact exercise between sets of weight lifting exercise incorporates resistance training and high impact exercise in one session without extending the time required, an economical prescription for busy adults.

Balance training

Balance training will not have any impact on muscle strength, sarcopenia or osteopenia, but will improve balance, mobility and fear of falling, and is thus an additional modality of exercise important for prevention of osteoporotic fractures. There are many ways to improve balance, from yoga and tai chi postures and exercise ball and rocker board exercises, to navigating obstacle courses and integrating one-legged standing postures into daily activities (Figure 3). It is possible to do some weight lifting exercises in the standing position on one leg with reduced hand support, thus completing both resistance training and balance training at the same time.

Aerobic exercise

Aerobic exercise has many health benefits for older patients, but it should be remembered that nonweight-bearing aerobic exercise (cycling, swimming, seated rowing or stepping machines) has little effect on bone health, balance or muscle strength, and should, therefore, not be the primary prescription for these health-related outcomes. Even though walking is a weight-bearing aerobic exercise, it does not increase muscle mass and strength nor improve balance, and it only augments bone density when moderate to high

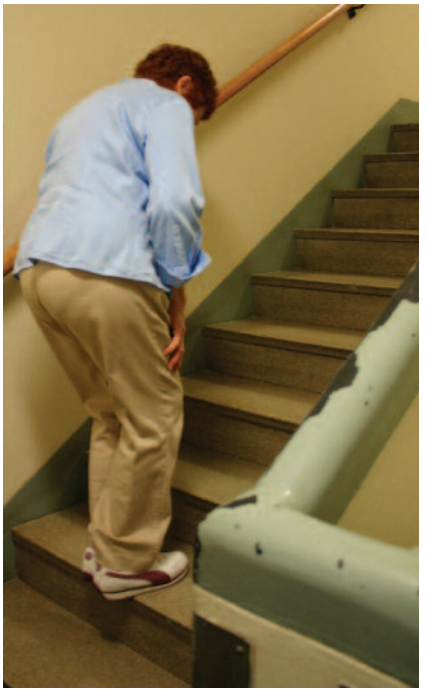

Figure 2. High impact activities such as rope skipping, jumping and hopping increase bone density. Jumping up and down stairs can be incorporated into everyday life.

Figure 3. Balance enhancing exercises such as tandem or heel-to-toe walking improve balance, mobility and fear of falling.

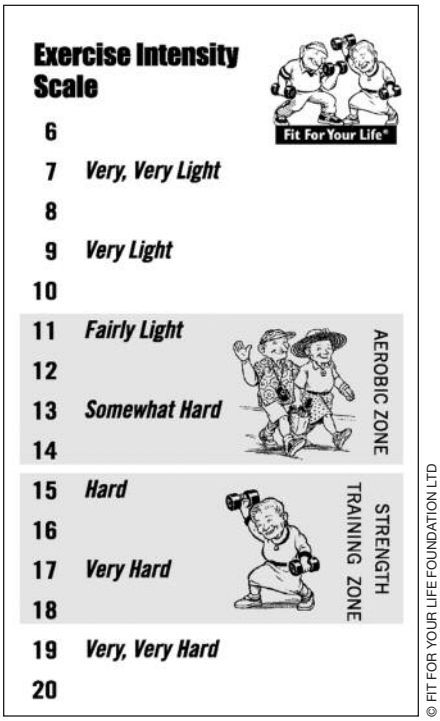

Figure 4. Modified Borg Scale of Perceived Exertion for use with weight lifting and aerobic exercise.[3]

intensities, such as brisk walking, hiking, stairclimbing and jogging, are used. Aerobic exercise is, therefore, much less potent and comprehensive in its effects on the multiple risk factors for osteoporotic fracture. The type of weight-bearing aerobic exercise used will vary with the health status of the patient. For example, obesity and osteoarthritis often contraindicate jogging and stairclimbing as appropriate or feasible exercise.

Dose

Intensity

The physiological responses in bone and muscle are proportional to the magnitude and rate of strain imposed, and successful exercise programs generally use intensities at the higher ranges. Therefore, moderate to high intensity progressive resistance training and/or high impact exercise is recommended as the primary intensity of planned exercise. High intensity progressive resistance training means that the weight feels hard to lift, or is rated about 15 to 18 on the Borg Scale for ratings of perceived exertion when first picked up or pushed at each training session (Figure 4).[3] As soon as the weight used no longer feels hard, the next higher weight increment (machine setting or free weight) should be used. Such continuous progression keeps the intensity at the intended level over time. If progression stops, so does adaptation in the bone and muscle. This is the most critical element of the exercise prescription for bone health.

Jumping programs incorporating 10 to 50 jumps of approximately 8 cm height each day have successfully increased trochanteric BMD by 3 to 4% in women.[4-7] This kind of jump is high impact (producing ground-reaction forces that are three to four times bodyweight) but feasible for nonathletic women and infrequently associated with injuries. Also, programs incorporating these jumps take only about two minutes per day to perform. Such prescriptions may need to be modified in the presence of osteoarthritis of the knee and hip or balance impairments (see Table 1). However, it is possible to jump while holding on to a railing or another person, enabling safe prescribing of this training modality without sacrificing the intensity of the impact on bone and muscle.

Volume and frequency

The optimal volume of exercise (i.e. the product of the number of sets completed of each exercise, the number of repetitions completed in each set and the number of exercises, or the total minutes of aerobic exercise) for reduced fracture risk has not yet been determined. However, programs involving resistance training, weight-bearing aerobic exercise and/or high impact exercise on about three days each week have been shown to augment BMD

continued

Table 1. Prescribing exercises for bone health and modifications required for specific patient groups

Exercise modality	Standard or optimal mode	Modification for patients with arthritis
Progressive resistance training	• Prescribe 6 to 10 exercises for major muscle groups, including muscles attaching to greater trochanter and vertebral bodies, as well as those involved in gait and balance. The most important exercises are the machine-based leg press or hip extension, squats, knee extension, knee flexion, hip abduction, hip flexion, dorsiflexion, lat* pull down, back extension, upright seated rowing, abdominal crunch, the free weight versions of these exercises, and standing calf raises • Include novel planes of movement, free weights and standing postures if possible • High intensity (about 80% of peak capacity, progressed continuously) • Use high velocity for concentric (lifting) portion of movement for optimal power development, and slow velocity for lowering weight (i.e. lift rapidly and lower slowly)	• Ensure technique is good to prevent injuries • May need to limit range to pain-free motion, provide good back support, adjust machines or free weights to accommodate joint deformities or restrictions • Intensity may need to be individualised for some exercises • May need to medicate for pain prior to exercise
Aerobic training	• Moderate to high intensity stair climbing, hiking, brisk walking, walking up hills • Weight-bearing • High ground-reaction forces (jogging, running, step aerobics)	• May need to reduce or eliminate weight-bearing or high impact component: substitute brisk walking or walking up hills for stair climbing, step aerobics, jogging, running
High impact exercise	• Jumping, hopping, rope skipping (jump rope) • Progressively increase height of jumps or step boxes, hop on one leg, jump or hop up and down stairs	• May need to reduce or eliminate high ground reaction forces (heel drops instead of jumps) • Substitute power training (rapid concentric muscle contraction against moderate to high load on weight lifting machine) to produce rapid onset of high muscle contraction forces as in take off of jump, but with no impact
Balance training	• Combine progressively more difficult static and dynamic postures (e.g. one-legged standing, tandem walking,† crossover walking,‡ turning, stepping over objects, leaning to limits of sway) • Improve lateral stability (side stepping over objects and leaning) • Reduce base of support (e.g. tandem or one leg standing)† • Perturb centre of mass (lean to limits of sway in all directions, or balance while seated on exercise ball or standing on rocker board) • Withdraw vision (close eyes during exercises) • Decrease proprioception by increasing compliance of standing surface (stand on pads, mattress or pillows) • Add cognitive distractor (e.g. animal naming, mental calculations out loud) to increase difficulty • Incorporate postures from yoga and tai chi or other exercise forms that emphasise the above principles	• May not be able to place full body weight on osteoarthritic joints: use less painful leg to perform one-legged postures, assist weight bearing with use of walking stick • Keep sessions short to avoid pain from prolonged weight bearing • Reduce angle of flexion at knee during tai chi movements

Modification for patients with frailty and/or neuromuscular impairment	Modification for patients with cardiovascular and/or pulmonary disease
• Usually little modification needed • May need to alter certain exercises for neurological impairment • May need to perform exercises in seated rather than standing positions due to fatigue or poor balance • Supervision usually needs to be more intensive for safety and progression	• Usually no modification needed • If angina or ischaemia is provoked by exercise, keep intensity below the level at which this occurs • Avoid breath holding, Valsalva manoeuvre, sustained isometric contractions or tight handgrip during weight lifting
• May need to substitute seated exercises if weakness or poor balance prevents standing postures; however, this limits bony adaptation • May need to begin with low to moderate intensity level and short sessions until improved	• Keep training intensity below the level that causes ischaemia or severe dyspnoea • Walk or exercise beyond the onset of claudication if possible (1 to 2 minutes), then rest and repeat • Avoid breath holding, Valsalva manoeuvre, sustained isometric contractions or tight handgrip during activity
• Start with heel drops instead of jumps • Perform exercises under supervision and while holding on to a support rail initially • Gradually reduce hand support as tolerated	• Keep training intensity below the level that causes ischaemia or severe dyspnoea
• Perform exercises under supervision and while holding on to a support rail initially • Gradually reduce hand support as tolerated	• Usually none

* lat = latissimus dorsi muscles. † Tandem walking and standing = walking and standing with one foot placed directly in front of the other; also called heel-to-toe walking and standing. ‡ Crossover walking = walking with one foot placed to the other side of the other foot.

significantly compared with sedentary controls if continued for at least one to two years.[8-12] In the case of resistance training, this amount of training is also sufficient for the other body composition changes (increased muscle mass, decreased fat mass) and improvements in muscle strength, power and balance as well as depression. Animal studies do not show benefits of very high numbers of repetitions compared with low numbers for aerobic, weight lifting or jumping exercises.

Each of the following recommendations for exercise volume and frequency is supported by clinical trials evidence as being effective for increasing BMD:[4,6-10]

- about 50 jumps three to six days per week
- two or three sets of eight to 10 repetitions of each of six to eight weight lifting exercises three days per week
- 45 to 60 minutes of weight-bearing aerobic exercise three days per week.

Animal models strongly suggest that, for bone strength adaptation, optimal recovery periods are 10 to 14 seconds between loading cycles (repetitions) and at least eight hours between bouts of loading (training sessions).[13] These rest intervals between repetitions are longer than currently prescribed by most practitioners, who wait only one to two seconds. However, long intervals are not detrimental to muscle function outcomes, and are likely to enhance adherence to technique and therefore minimise injury. It has also been shown in animal models that doses of exercise may be broken down into three or more mini sessions, which can be easier to incorporate into a busy day.[14] Therefore, recommending exercise no more frequently than every other day (about three days per week) satisfies both muscle and bone health requirements, and is not overly burdensome to most individuals.

Exercise prescriptions for specific patient groups

Certain patient groups require specific exercise prescriptions. For example, high

continued

impact activities are not suitable, and probably not feasible, for very frail older adults with osteoarthritis of the hips and knees as well as risk of osteoporotic fracture and falling because of the likelihood of exacerbation of arthritis as well as fall-related injuries. In such cases, therefore, a low impact but high loading form of exercise (such as seated and standing weight lifting) would be both effective and tolerable.

A guide to exercises for bone health and the modifications necessary for patients with arthritis, neuromuscular disease/frailty, and cardiopulmonary disease are presented in Table 1.

Risks of exercise

As mentioned in part one of this article, patients at risk for osteoporotic fracture should avoid physical activities involving forward flexion of the spine, particularly while carrying an object, because of the risk of anterior compression fractures of thoracic vertebrae in the presence of osteopenia. Such activities include sit-ups with straight legs, lawn bowls and bending over to pick up something from the floor.

Unsupervised exercise in individuals with poor balance or a history of osteoporotic fracture is also best avoided, as is participation in activities that are at high risk of falls themselves or involve hazardous environments that may lead to falls.

The potential risks of exercise in patients with osteoporosis and suggested means to avoid such complications are summarised in Table 2.

Safety of exercise programs

There are many studies suggesting that weight lifting exercise is safe when prescribed as described above in middle-aged and older adults. Although very little information on high impact exercise is available, studies to date in postmenopausal women exercising unsupervised in their own homes have not reported injuries. Screening for potential contraindications (hernias, aneurysms, acute joint injuries, unstable cardiovascular disease) and supervision in the initial stages is critical for the safety and efficacy of the exercise prescription.

Enhancing compliance

It is common for novice exercisers to lose motivation within the first six months of developing this new behaviour. Ways to enhance long term adherence to this or any health promoting behaviour include the following:

- provide the patient with simple educational materials
- provide a place to carry out the program under supervision

Table 2. Risks of exercise in patients at risk for osteoporotic fracture

Potential risk	Preventive strategy
Injurious fall	Prescribe balance training prior to aerobic training if gait and balance are impaired Prescribe progressive resistance training for sarcopenia and muscle weakness Optimise lighting, visual aids, safety of exercise environment, climate conditions, footwear Tell patients not to exercise when their judgement is impaired due to use of drugs or alcohol, or when their health status changes Review medications for agents that may increase risk of falls, postural hypotension or altered central nervous system function
Spinal compression fractures	Avoid prescribing exercises involving forward flexion with loading of the spine Avoid prescribing exercises involving twisting movements of the spine Emphasise good sitting and standing postures Tell patients to avoid activities involving spinal flexion (e.g. bowling, cycling, golf, gardening, vacuuming) or provide modifications to these activities Tell patients to bend their knees rather than their back when picking up or reaching low objects
Dislocation of total hip prosthesis	Avoid prescribing exercises involving internal rotation and flexion of the hip
Pain from osteoarthritis	Prescribe low impact, high intensity exercises (e.g. weight lifting) rather than high impact exercises (such as jumping, stepping, jogging) Emphasise brief, novel loading of bones with adequate rest periods rather than prolonged, repetitive loading bouts
Pain from hip fracture, spinal osteoporosis or old compression fractures	Rule out new fractures or dislocation of surgical prostheses Brace or support spine during exercise if needed Use analgesia or local pain relieving techniques (e.g. heating, massage)

- ask the patient about the behaviour at each health encounter
- encourage the patient to keep a log of his or her physical activity and regularly review and provide feedback on this
- periodically measure outcomes likely to show change in response to the behaviour (walking speed, balance, muscle strength, depressive symptoms)
- anticipate and provide strategies to overcome common barriers and risks for relapse (such as illness in patient or partner, travel, family commitments, inclement weather, transportation difficulties)
- consider setting up a corner in the waiting room with a demonstration video of bone health-enhancing exercise, brochures to take home and sample exercise equipment or routines that patients can try out in the safety of the office.

Evidence available indicates that although the volume of exercise required for bony adaptation is small (only 12 minutes per week of jumping in one study), the critical factor is the need for progressive high impact or high intensity loading, which is difficult to achieve without good supervision and feedback. There is a great need to improve on behavioural strategies to provide adequate instruction, supervision and compliance with exercise prescriptions, as most trials of exercise for bone health have suffered from high dropout rates and low compliance, even when fully supervised.

Given the very short time (several minutes per day) that is needed for high impact or balance training exercises, finding ways to incorporate such episodes into daily activities may be more successful than planning structured exercise classes away from home. For example, inserting a few jumps during television commercials, jumping or hopping rather than walking up a flight of stairs, or standing on one leg while washing the dishes, may provide an effective stimulus if such habits can be effectively behaviourally reinforced. Aerobic exercise can be incorporated into lifestyle by always using stairs instead of elevators/escalators, or walking briskly for 10 minutes or more several times a day.

The GP's role

The role of the GP in fracture prevention using exercise is to fully integrate an exercise prescription into the rest of the health care of patients at risk. Patients who sense that exercise is considered just as essential to their health care as the rest of the prescriptions offered to them will be far more likely to adopt and adhere to recommendations for exercise. The essential roles of the GP in this regard are given in part one of this article but can be summarised as:

- assessing the risk factors
- comparing current physical activity with optimal recommendations
- identifying contraindications to exercise participation or exercise modifications needed
- exercise prescription
- establishing an accompanying behavioural program.

Rural GPs, however, are likely to need to develop home exercise programs because of the lack of suitable training facilities and specialised equipment. Suggestions for incorporating balance training, high impact and strengthening activities into patients' everyday life routines rather than using exercise equipment are given in the box on this page.

The patient handout on pages 19 to 22 (originally published in *Medicine Today,* February 2007) outlines the principles of exercise to prevent osteoporotic fractures and lists exercises that patients can perform without specialised equipment.

Exercise plus other treatments

Exercise does not take the place of adequate nutritional and pharmacological management of osteoporosis, and such treatments should therefore continue when exercise is initiated. As the effects of bisphosphonates on bone are greater than other currently available treatments, the most rational approach would seem to be to continue these agents and add exercise, which will also improve fitness, mental health, neuromuscular function, muscle mass and general health status in ways that osteoporotic pharmacotherapy alone cannot.

The relation of exercise and the nutritional and pharmacological management of osteoporosis is discussed in more detail in the first part of this article.

Incorporating fracture prevention exercises into everyday life routines

Exercise prescriptions can be developed for patients who do not have access to weight lifting and other equipment. The following exercises can be carried out without any specialised equipment.

- Stand on one leg whenever standing at a sink or counter or in a queue.
- Walk heel-to-toe between rooms (heel of one foot directly in front of the toes of the other foot, so that they touch or almost touch).
- Stand up and sit down slowly without using arms.
- Squat to pick up items or reach into low shelf or drawer, rather than bending over.
- Jump up and down steps using both feet to land, advance to one leg. Arthritis or balance impairment may preclude this exercise in some patients. Patients may start by holding on to a railing and advance to no hand support.
- Lift items with one hand instead of both.
- Avoid having poor posture, particularly forward flexion of the spine (use a Swiss ball or a backless chair when sitting).

Conclusion

The most important elements of the exercise prescription for bone health are high intensity weight lifting exercise (resistance training) and balance training, with the addition of high impact exercise when feasible. Weight-bearing aerobic exercise is also important for bone health but will not improve balance, muscle mass or muscle strength, and so should not be used in isolation for osteoporotic fracture prevention.

High intensity weight lifting exercise and high impact exercise improve the major primary risk factors for osteoporotic fracture in middle-aged and older adults (osteopenia, sarcopenia, muscle weakness, poor balance) more effectively and comprehensively than other forms of exercise. Continuous progression (as soon as the exercise no longer feels hard, the difficulty – weight lifted, balance posture, jump height – is increased) is the most critical element of the exercise prescription for bone health; if progression stops, so does adaptation in the bone and muscle. The establishment of a strong behavioural program to accompany the prescription is essential to enhance compliance.

Given the short time (several minutes per day) that is needed for effective balance training or high impact exercise, incorporating such exercise into daily activities may be more successful in suitable patients than planning structured exercise classes away from home.

Further information on exercise and osteoporotic fracture prevention is available from Osteoporosis Australia (www.osteoporosis.org.au) and the Fit For Your Life Foundation (www.fitforyourlife.org). MT

References

1. Bassey EJ, Ramsdale SJ. Weight-bearing exercise and ground reaction forces: a 12-month randomized controlled trial of effects on bone mineral density in healthy postmenopausal women. Bone 1995; 16: 469-476.
2. Hans D, Genton L, Drezner MK, et al. Monitored impact loading of the hip: initial testing of a home-use device. Calcif Tissue Int 2002; 71: 112-120.
3. Borg G. Psychophysical bases of perceived exertion. Med Sci Sports Exerc 1982; 14: 377-381.
4. Heinonen A, Kannus P, Sievanen H, et al. Randomised controlled trial of effect of high-impact exercise on selected risk factors for osteoporotic fractures. Lancet 1996; 348: 1343-1347.
5. Bassey EJ, Ramsdale SJ. Increase in femoral bone density in young women following high-impact exercise. Osteoporos Int 1994; 4: 72-75.
6. Bassey EJ, Rothwell MC, Littlewood JJ, Pye DW. Pre- and postmenopausal women have different bone mineral density responses to the same high-impact exercise. J Bone Miner Res 1998; 13: 1805-1813.
7. Winters KM, Snow CM. Detraining reverses positive effects of exercise on the musculoskeletal system in premenopausal women. J Bone Miner Res 2000; 15: 2495-2503.
8. Kelley GA, Kelley KS, Tran ZV. Resistance training and bone mineral density in women: a meta-analysis of controlled trials. Am J Phys Med Rehabil 2001; 80: 65-77.
9. Wolff I, van Croonenborg JJ, Kemper HC, Kostense PJ, Twisk JW. The effect of exercise training programs on bone mass: a meta-analysis of published controlled trials in pre- and postmenopausal women. Osteoporos Int 1999; 9: 1-12.
10. Wallace BA, Cumming RG. Systematic review of randomized trials of the effect of exercise on bone mass in pre- and postmenopausal women. Calcif Tissue Int 2000; 67: 10-18.
11. Kelley G. Aerobic exercise and lumbar spine bone mineral density in postmenopausal women: a meta-analysis. J Am Geriatr Soc 1998; 46: 143-152.
12. Kelley GA. Aerobic exercise and bone density at the hip in postmenopausal women: a meta-analysis. Prev Med 1998; 27: 798-807.
13. Robling AG, Burr DB, Turner CH. Recovery periods restore mechanosensitivity to dynamically loaded bone. J Exp Biol 2001; 204: 3389-3399.
14. Robling AG, Hinant FM, Burr DB, Turner CH. Shorter, more frequent mechanical loading sessions enhance bone mass. Med Sci Sports Exerc 2002; 34: 196-202.

DECLARATION OF INTEREST: None.

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Exercising to help prevent osteoporotic fractures: guidelines

This handout outlines the principles of exercising to enhance bone health and help prevent osteoporotic fractures.

Sample exercises are given in a separate MedicineToday handout.

Prepared by Professor Maria Fiatarone Singh, the John Sutton Chair of Exercise and Sport Science, School of Exercise and Sport Science, and Professor of Medicine, University of Sydney, NSW.

As we age our bones lose minerals and can become weak and brittle, causing the condition called osteoporosis. The best way to enhance bone health and prevent fractures due to osteoporosis is a combination of exercise, adequate nutrition and, when required, medication. In middle aged and older people, rapid, short bursts of high intensity activity have been shown to improve the density of bone and the strength of muscles more effectively than other forms of exercise. This exercise can be done in structured classes or in the home.

The principles of exercising to promote bone health described in this handout are relevant for healthy adults and for those with osteoporosis or other medical conditions. However, if you have osteoporosis or any other medical conditions you should see your general practitioner for guidance on exercises suited to your needs.

Figure 1. Weight lifting improves bone health. Exercises can be done on weight machines (such as the leg press) or using free weights (dumbbells and ankle weights).

Types of exercise that promote bone health

Weight-bearing aerobic exercise

Weight-bearing exercises are those that use the large muscle groups in a rhythmic pattern and are performed in a standing position. These exercises should be done at a rate that increases your heart rate, blood pressure and breathing to at least a 'moderately hard' level. Examples are brisk walking, hiking, stair climbing, jogging and aerobic dance. Swimming, cycling, seated exercises and arm exercises are nonweight-bearing aerobic exercises and have little effect on bone health. Aerobic exercise is also known as endurance or cardiovascular exercise.

Resistance training

Resistance training is also known as strength training or weight lifting. It is the use of targeted muscle groups to lift and lower moderate to heavy weights. In traditional weight lifting, the weight is lifted and lowered slowly; in power training, it is lifted as fast as possible and then lowered slowly. Exercises can be machine-based (e.g. leg press, seated rowing, pulldown and knee extension) or done using free weights, i.e. dumbbells or ankle weights (e.g. knee extension and flexion, hip extension, flexion and abduction, leg raises, shoulder strengthening, biceps curl and triceps lift).

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High impact exercise

In high impact exercise, the bones of the spine and legs incur high stresses as the feet hit the ground. Examples include skipping with a rope, jumping or hopping (including up and down stairs and on and off boxes) and sports involving jumping, such as basketball and netball. Fast heel drops (fast drop of the heel over the edge of a step, with a sudden stop, then slow raise) are a more suitable form of high impact exercise if you have had a previous injury or have osteoarthritis of the knees or hips.

Balance training

Balance exercises stress the body's sense of balance by decreasing foot contact with the ground, changing the centre of mass and removing vision. Examples include standing on one leg with eyes closed, sitting on an exercise ball, heel-to-toe walking (heel of one foot directly in front of the toes of the other foot, so they touch or almost touch), stepping sideways over an object, leaning as far as possible in all directions while standing without bending at your waist, tai chi and balancing while placing a pillow or rocker board under your feet.

Principles of exercising to enhance bone health

- Short bursts of high intensity and/or high impact activities such as jogging, jumping and skipping are more stimulating to bone than sustained, low impact activities such as walking. The higher the impact, the greater the benefit to the bones.
- Exercise has to get progressively harder to continue to improve bone health. Over time the weights lifted need to be heavier, the incline of walking or jogging steeper, the height of jumps greater and the difficulty of balance exercises more challenging (e.g. by removing hand support).
- Exercise does not have to be weight-bearing to enhance bone health. Resistance training done in the sitting or lying position (nonweight-bearing) improves bone health. However, aerobic activities that are nonweight-bearing (such as swimming or cycling) have little effect on bone health although they are good for aerobic fitness.
- Lifting heavy weights improves bone health more than lifting light weights.
- Rapid movements are more stimulating to bone than slow movements. Lifting heavy weights rapidly (power training) seems to be more effective than lifting heavy weights slowly (traditional resistance training).
- Exercise involving changes of direction and different height jumps is more stimulating to bone than exercise involving repetitive actions.
- Exercising in short bouts with rest periods between seems to improve bone strength more effectively than continuous, long periods of exercise.
- Muscles connected to bones that are prone to osteoporotic fracture (i.e. bones of the hip, wrist and thoracic spine) need to be strengthened to achieve protection for those bones.
- Balance training improves mobility and confidence, reducing falls and the fear of falling.

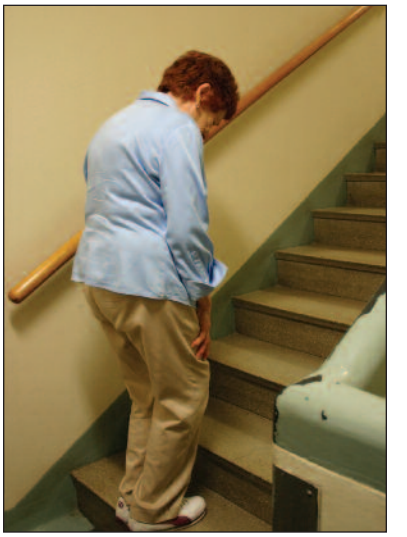

Figure 2. High impact exercise has recently been shown to be particularly beneficial to bone health. Jumping up and down stairs is an example of a high impact activity.

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Guidelines for resistance training using free weights

Equipment

You will need a set of ankle cuffs with removable 0.5 kg weights. Have a total of 10 kg per leg. Also have a set of adjustable dumbbells or fixed weight dumbbells of various sizes ranging from 1 kg to about 20 kg. You will also need a sturdy chair with a straight high back and no arms.

Muscle groups

The major muscle groups to target in a balanced resistance training program are the arm muscles (biceps and triceps), upper torso muscles, lower abdomen muscles, muscles around the hip, thigh muscles (quadriceps and hamstrings) and calf muscles. Details of appropriate exercises are available in the *Medicine Today* patient handout entitled *Exercising to help prevent osteoporotic fractures: exercises*. Physiotherapists and qualified fitness trainers can also give you advice on exercises and may run suitable programs.

Figure 3. Hip extension is one of the several exercises done to strengthen the muscles in the lower back–hip–thigh region, so as to protect the bones of the hip from osteoporotic fracture.

Amount and frequency

Exercise two or three times per week, with at least one day of rest between sessions. Do two or three sets of eight repetitions of each exercise per session, with at least one minute of rest between sets. Each session should take 30 to 45 minutes. Keep a record of each session (date, exercises performed, weights used and numbers of repetitions done).

Technique

Breathe out as you lift a weight and in as you lower it; don't hold your breath. Perform each movement slowly, through the full range of motion, taking about 6 to 9 seconds for each repetition and 2 to 3 seconds of rest between lifts. Don't swing the weight or use momentum to complete the lift.

Progression

For effective resistance training, the weight should feel hard to lift. As soon as lifting the weight for two sets no longer feels hard, move up to the next weight.

Enhancing balance

If necessary, hold on to the back of the chair for support during weight lifting exercises performed in the standing position, such as hip extension, flexion and abduction. As your balance improves, progress from using two hands on the chair to one hand, one fingertip, no hands, and then no hands and eyes closed.

Enhancing bone growth and strength

The rest period between sets of weight lifting exercises can be used for high impact exercise. For example, perform one jump between each set, aiming for a total of about 20 to 60 jumps per week. If wearing ankle weights, keep them on for the jump.

Exercising without any equipment

You can incorporate balance and high impact exercises into your daily activities if you don't have access to weight lifting and other equipment. Some simple exercises are listed here.

- Stand on one leg whenever you are standing at a sink or counter or in a queue.
- Walk heel-to-toe between rooms (place the heel of one foot directly in front of the toes of the other foot, so that they touch or almost touch).
- Stand up and sit down slowly without using your arms.
- Squat to pick up items or reach into low shelves or drawers, rather than bending over.
- Jump up and down steps and stairs using both feet to land; advance to one leg hops. If your balance is poor, start by holding on to a railing.
- Lift items with one hand instead of both.
- Avoid having poor posture, particularly forward flexion of the spine. To improve your sitting posture, sit on a Swiss ball or a backless chair.

Figure 4. Balance exercises such as heel-to-toe walking (above left) and side stepping (above right) improve mobility and confidence, reducing both falls and the fear of falling.

Be careful

- If you have osteoporosis or any other medical conditions, consult your general practitioner before beginning an exercise program.
- If you have poor balance or a history of osteoporotic fracture, you will require specific exercise programs for enhancing bone health and you should always exercise under supervision.
- Exercise under supervision at least until you are sure your technique is correct.
- Everyone at risk for osteoporotic fracture should avoid physical activities involving forward bending of the spine, particularly while carrying an object, because of the risk of compression fractures of the vertebrae. These activities include sit-ups with straight legs, lawn bowls and simply bending over to pick up something from the floor.
- Avoid physical activities that are associated with a high risk of falls.
- Avoid hazardous environments that may lead to falls.

More information

Sample exercises are given in the *Medicine Today* patient handout, *Exercising to help prevent osteoporotic fractures: exercises.* Ask your general practitioner for a copy if you haven't already got one.

Further information can be obtained from the websites of the following organisations:

- Osteoporosis Australia – www.osteoporosis.org.au
- Fit For Your Life Foundation – www.fitforyourlife.org
- Centre for Strong Medicine, Balmain Hospital, Sydney – www.strongmedicine.md
- COTA (Council on the Ageing): Living Longer Living Stronger program – www.cota.org.au

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Exercising to help prevent osteoporotic fractures: exercises

Prepared by Professor Maria Fiatarone Singh, the John Sutton Chair of Exercise and Sport Science, School of Exercise and Sport Science, and Professor of Medicine, University of Sydney, NSW.

This handout provides some exercises that, if performed regularly, will improve the health of your bones and help prevent osteoporotic fractures.

You should read the MedicineToday handout *Exercising to help prevent osteoporotic fractures: guidelines* for more information on strength training, balance training, aerobic exercise and high impact exercise.

Osteoporosis is a condition in which bones become weak and brittle and more likely to break than normal bones. Physical activity helps reduce the rate of bone mineral loss that occurs as we age and which results in osteoporosis. It also helps avoid injury to bones by improving muscle strength and balance. The strength training and balance exercises described in this handout are relevant for healthy middle aged and older people and also for those with osteoporosis or other medical conditions. If you have osteoporosis or any other medical conditions, you should consult your general practitioner before beginning an exercise program as you are likely to need a program designed specifically for you.

Guidelines for strength training (also known as resistance training) using free weights are described in the *Medicine Today* patient handout entitled *Exercising to help prevent osteoporotic fractures: guidelines*, which you should read in conjunction with this handout. To improve strength, balance and bone density, it is important that each exercise you do feels 'hard' (scoring at least 15 on the scale of perceived exertion on the last page of this handout). Also, make sure you are doing each exercise properly – the large photos show the correct technique to use, and the smaller photos give examples of incorrect ways these exercises may be done.

ALL PHOTOGRAPHY BY OLIVER FORD, PHOTOGRAPHIX

Equipment

You will need the following equipment for the strength training exercises:

1. A set of ankle cuffs with removable 0.5 kg weights (a total of 10 kg per leg).
2. A set of adjustable dumbbells or fixed weight dumbbells ranging from 1 kg to about 20 kg.
3. A sturdy chair with a straight high back and no arms.

Putting on the ankle cuffs (photo 1)

Sit on a chair and place each foot on a step so you can easily reach each ankle to fasten the cuff without having to bend forward.

Forward bending of the spine can cause compression fractures of the vertebrae in people at risk of osteoporosis.

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Strength training exercises

You should do two or three sets of eight repetitions of each exercise per session, and two or three sessions per week. In the rest period of at least a minute between each set, you should do one jump or heel drop – see photo 14. Each session should take 30 to 45 minutes.

Each of the exercise descriptions below counts as one repetition.

Calf raise (photos 2a, b and c)

Strengthens the ankle and the calf muscles.

1. Wearing ankle weights, stand holding the back of a chair.
2. Lifting your heels, rise up on the toes of both feet, as high as possible.
3. Hold, then slowly lower your heels.
4. When this is too easy, use one leg at a time, alternately (photo 2c).

Knee flexion (photos 3a and b)

Strengthens the hamstring muscles, which bend the knee.

1. Wearing ankle weights, stand holding the back of a chair, close to it.
2. Bend one knee and slowly lift this foot backwards to as close to the back of your thigh as possible. Keep the upper part of your leg still, and your body upright.
3. Hold, then slowly lower your leg.
4. Repeat for the other leg.

Hip abduction (photos 4a and b)

Strengthens the muscles that pull the legs out to the side.

1. Wearing ankle weights, stand holding the back of a chair, close to it.
2. Without bending your knee or waist, move one leg straight out to the side, keeping your toes pointing forwards.
3. Hold, then slowly lower your leg.
4. Repeat for the other leg.

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Hip flexion (photos 5a and b)

Strengthens the muscles that bring the knee towards the chest.

1. Wearing ankle weights, stand side on to the back of a chair, resting one hand on the chair back.
2. Without bending at the waist or letting go of the chair, bring one knee at a time as close to your chest as possible.
3. Hold, then slowly lower your leg.
4. Repeat for the other leg.

Hip extension (photos 6a and b)

Strengthens the muscles in the buttocks and lower back.

1. Wearing ankle weights, stand holding on to the back of a chair, and bend forward about 45 degrees at the waist.
2. Slowly lift one leg straight out behind you as high as possible. Keep your knee straight and foot pointing downwards, and don't move your upper body.
3. Hold, then slowly lower your leg.
4. Repeat for the other leg.

Knee extension (photos 7a and b)

Strengthens the quadriceps muscle, which straightens the knee.

1. Wearing ankle weights, sit in a chair with a good upright posture and the back of your knees resting against the chair seat.
2. Raise one foot in front of you until your knee is as straight as possible, keeping your thigh on the chair and your toes pointing up. Pull your toes towards your head as far as possible.
3. Hold, then slowly lower your leg.
4. Repeat for the other leg.

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Leg lifts (photos 8a, b and c)

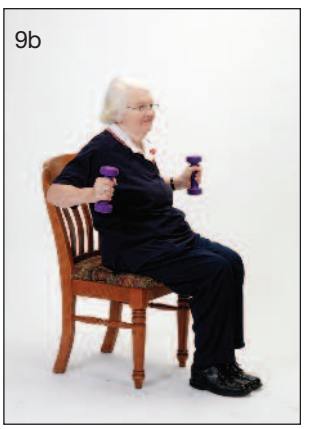
Strengthens the abdominal muscles to improve posture.

1. Wearing ankle weights, sit in a chair and slide forwards so your buttocks are near the front edge and your back is resting against the chair back. Hold on to the sides of the seat for balance.
2. Slowly lift both feet 5 to 10 cm off the ground, then straighten your legs out in front of you.
3. Hold, then slowly lower your feet to the ground.
4. If this is too difficult, remove the weights or lift one leg at a time.

Seated row (photos 9a and b)

Strengthens the muscles of the upper torso for control of balance and posture.

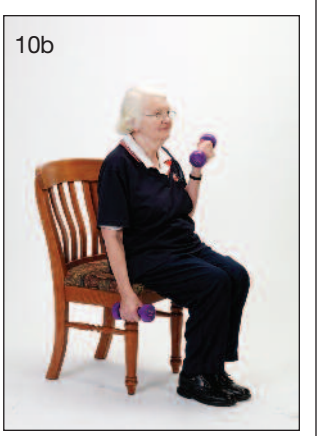
1. Holding dumbbells, sit forward in a chair with a good upright posture.
2. Hold the dumbbells perpendicular to the ground with elbows bent, so that the dumbbells are touching each other about 10 cm in front of your chest.
3. Slowly bring your arms out to the side as though you are drawing a circle around your body. Try to squeeze your shoulder blades together.
4. Bring your arms back directly in front of your chest.



Biceps curl (photos 10a and b)

Strengthens the upper arm muscles that flex the elbow.

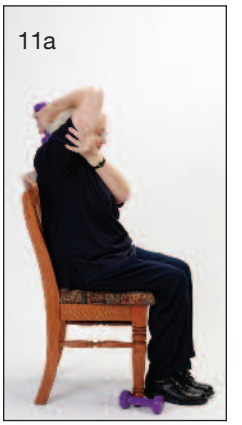
1. Holding dumbbells, sit in a chair with a good upright posture.
2. Bend one elbow to lift the dumbbell towards your shoulder. Don't move the upper arm or shoulder during the lift.
3. Hold, then slowly lower the dumbbell.
4. Repeat for the other arm.

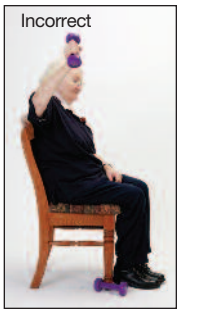


Triceps lift (photos 11a and b)

Strengthens the muscles at the back of the upper arm that straighten the elbow.

1. Sit in a chair with a good upright posture, arms by your side.
2. Holding a dumbbell in one hand, raise that arm over your head. Using your other arm to hold your elbow close to your ear, slowly bend the elbow so the dumbbell moves down to behind your neck.
3. Slowly raise your arm straight above your head.
4. Hold, then slowly bend your elbow to lower the dumbbell back behind your neck.
5. For this exercise, do all the repetitions for a set with one arm before changing to the other arm (i.e. eight times with one arm, then eight times with the other arm).

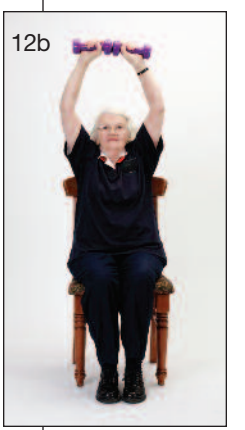




Overhead press (photos 12a and b)

Strengthens the shoulder and upper arm muscles.

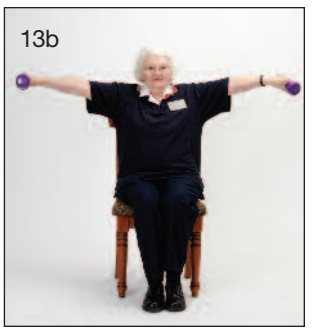
1. Holding dumbbells, sit in a chair with a good upright posture, arms by your side.
2. Raise both arms, bending the elbows so the dumbbells are held level with your ears.
3. Slowly raise both arms straight above your head.
4. Hold, then slowly lower your arms to level with your ears.



Side arm raise (photos 13a and b)

Strengthens the deltoid muscles that lift the arms out to the side.

1. Holding dumbbells, sit in a chair with a good upright posture, arms by your side.
2. Raise your arms out to the side as high as your shoulders, keeping the elbows straight.
3. Slowly lower your arms to the chair.



Jump (photo 14)

High impact exercise stimulates bone cells, increasing bone density.

Perform one jump in the rest period between each set of each strength training exercise – so you do about 15 to 30 jumps per session. Land with your knees straight and on both feet.

If you have previous injuries or more than mild knee or hip osteoarthritis then heel drops are more suitable. For heel drops, stand on a step with your heels overhanging the edge. Rapidly drop your heels, with a sudden stop. Then slowly raise them.

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Balance exercises

Balance exercises are best done before strength training exercises to minimise fatigue and the risk of falling. You should do one set of five repetitions of each exercise per session.

Tandem walking (photo 15)

Also known as heel-to-toe walking.

1. Walk for 3 to 4 metres placing the heel of one foot directly in front of the toe of the other, just touching.
2. Have a chair, rail or another person close by in case of overbalancing.

Crossover walking (photo 16)

1. Walk sideways for 3 to 4 metres crossing one leg in front of the other, placing your feet parallel to each other with the toes level.
2. Have a chair, rail or another person close by in case of overbalancing.

Sideways stepping over object (photo 17)

1. Walk sideways over three or four objects of differing heights, placing your feet parallel to each other with the toes level.
2. Have a chair, rail or another person close by in case of overbalancing.

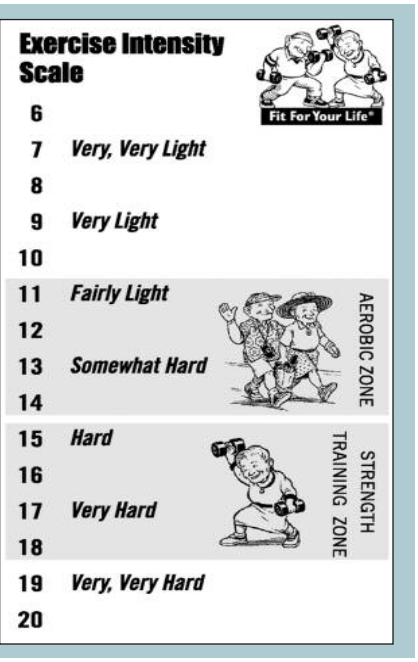
Standing on one leg, eyes closed (photo 18)

1. With your eyes closed and one hand resting on the back of a chair for support, stand on one leg for 30 seconds.
2. Repeat for the other leg.
3. To increase difficulty, add a mental task such as naming animals or subtracting 7's from 200.
4. To further increase the difficulty, reduce the hand support from one hand to one finger to one fingertip to no hands.

Exercise intensity scale

At each exercise session, rate the difficulty of the first time you do each exercise on this scale.

When your rating for an exercise falls below a score of 15, increase the difficulty by moving up to the next higher weight, decreasing the hand support (from two hands to one hand, to one finger, to one fingertip to no hands), standing on one leg or jumping higher, depending on the exercise.



More information

Further information can be obtained from the websites of the following organisations:

- Osteoporosis Australia – www.osteoporosis.org.au
- Fit For Your Life Foundation – www.fitforyourlife.org
- Centre for Strong Medicine, Balmain Hospital, Sydney – www.strongmedicine.md
- COTA (Council on the Ageing): Living Longer Living Stronger program – www.cota.org.au

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