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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, to be published in the January 2007 issue of *Medicine Today*, 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.**

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 (Sinaki et al. Bone 2002; 30: 836-841); no randomised controlled trials have been carried out at other specific sites and this remains an important gap in our knowledge. 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.

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.

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.[4-8] 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.[9]

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

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.

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.

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.[10-12] 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 mangement 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

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.

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 the January 2007 issue of *Medicine Today*).

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 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

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 36.

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

A list of references is available on request to the editorial office.

DECLARATION OF INTEREST: None.

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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