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, published in the December 2006 issue of *Medicine Today*.

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 32. The flowchart on page 33 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.**

continued

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.

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).

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

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).

extensors, knee extensors and flexors) as 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

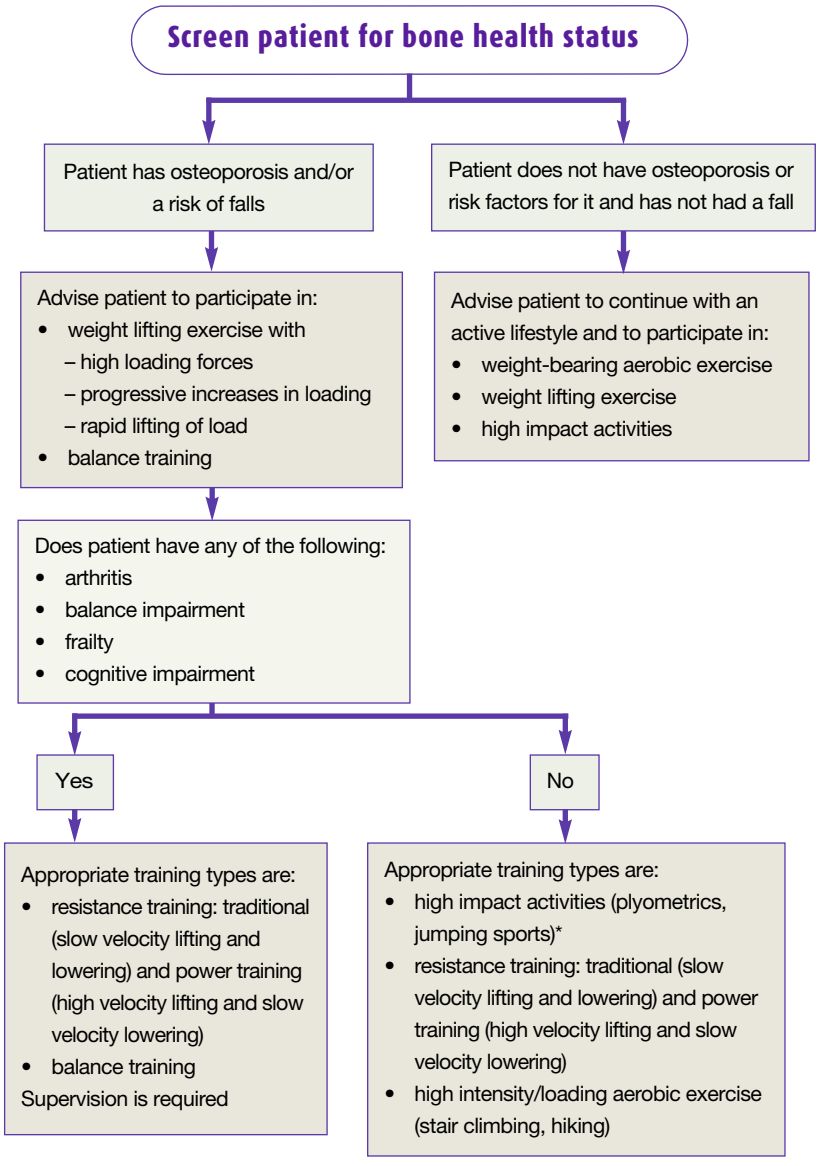
In middle-aged and older adults, high impact exercise is typically prescribed as some form of jumping, including jumping in one place or up and down boxes and stairs, and rope skipping, also known as jump rope (Figure 2).[1,2] Fast heel drops (fast drop with sudden stop, then slow raise) are more suitable, 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.

An approach to exercise prescription for middle-aged and older individuals



* Plyometrics = any exercise where the muscle is stretched (i.e. loaded) before it is contracted, e.g. jumping up a step or off a box.

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

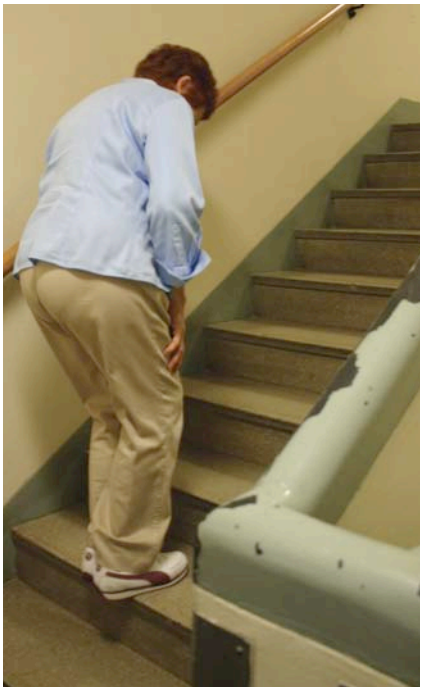


Figure 2. High impact activities such as rope skipping, jumping and hopping increase bone density. Jumping up and down stairs can be incorporated into everyday life.

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

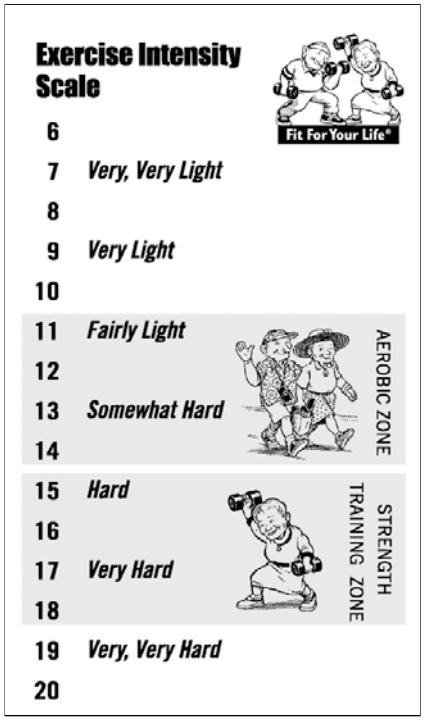


Figure 4. Modified Borg Scale of Perceived Exertion for use with weight lifting and aerobic exercise.[3]

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 excercise 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)

continued

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).

- 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 to be published in the February 2007 issue of *Medicine Today* 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.

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

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