Exercise Prescription to Support the Management of Osteoporosis

For Physiotherapists and Exercise Physiologists

February 2024

HEALTHY BONES AUSTRALIA

Protect
Build
Support

Glossary

Acceptability: the degree to which something is approved of by people

Balance exercise: exercise that improves stability and helps keep people upright, thereby preventing falls

Bone adaptation: the process by which bone changes its characteristics (material or structural properties) in response to a mechanical stimulus

Bone geometry: the dimensions of a whole bone or bone section

Bone mineral density (BMD): the density of mineral within a section of bone measured in g/cm^2 typically determined from dual-energy x-ray absorptiometry (DXA) as an estimate of bone mass with results displayed as T-score and Z-score.

Bone strain: bone deformation in response to stress

Comorbidity: a disease or medical condition that is present in a patient simultaneously with another or other conditions

Dynamic loading: pattern of cyclical loading and unloading

Exercise physiologist: a university qualified allied health professional with the knowledge, skills and competencies to design, deliver and evaluate safe exercise as therapy for medical conditions, injuries or disabilities

Fall: an event that results in a person coming to rest inadvertently on the ground or floor or other lower level

Feasibility: degree of being easily or conveniently done

Functional training: a type of exercise that involves conditioning the body specifically for activities performed in daily life, including occupational or sporting activities

Ground reaction force: the resistive force exerted by the ground on a body part that is applying a load to it

Impact exercise: exercise that generates a ground reaction force rapidly

Joint reaction force: the resistive force exerted by a bone when another bone pushes against it at a joint

Minimal trauma fracture: a fracture that occurs following a small amount of force that would not ordinarily be expected to break a bone

Mobility exercise: exercise to improve the ability to move and the range of motion at a joint

Neuromuscular adaptation: the physiological changes that occur in the nervous system and muscles in response to exercise training that improve the efficiency and effectiveness of muscle contractions and movement patterns due to changes in muscle fibre recruitment, motor unit synchronisation, muscle fibre size, and neural pathways

Osteogenic: something that induces the formation of new bone

Osteopenia: condition of low bone mass (T-score between -1.0 and -2.5). Note: a T-score of <-1.5 with a minimal trauma fracture is regarded as 'clinical osteoporosis'

Osteoporosis: condition of reduced bone strength increasing the risk of minimal trauma fracture (T-score less than or equal to -2.5)

Overload: to load a bone more than it is ordinarily exposed to

Physiotherapist: a university qualified allied health professional with the knowledge, skills and competencies to assess, diagnose and treat a range of conditions including sports injuries, musculoskeletal conditions and chronic conditions such as diabetes, obesity, osteoarthritis and stroke with physical methods such as massage, heat treatment, and exercise

Postural control: the ability to maintain an appropriate relationship between the body, body parts (alignment), and the environment

Proactive balance: (or anticipatory balance) is the ability to activate muscles in the legs and trunk in advance of a potentially destabilising force to prevent a fall

Progressive resistance training (PRT): a type of exercise using the muscles to resist or move some type of load that is progressively increased as strength increases

Reactive balance: the ability to activate muscles in the legs and trunk in response to a destabilising force to prevent a fall

Repetition maximum (RM): the maximum weight that can be lifted with correct technique a specified number of times (e.g. 1-RM is the maximum weight that can be lifted once only)

Sensory cue: a stimulus to a sensory system (hearing, sight, etc) to evoke a response

Specificity: the characteristic of something relating uniquely to, being especially suited to, or uniquely influencing a particular condition

Static loading: pattern of loading that is fixed, constant and does not vary over time

Strain frequency: the number of times a strain is experienced by a bone in a set time frame, measured in cycles per second (Hz)

Strain rate: the rate of change in strain in a bone, related to the speed of application of a load

Surface displacements: used in this document to mean movement of a surface on which someone is standing in order to perturb balance

Training maturation: the progression and development of a training program over time based on an individual's changing proficiency in strength, endurance, and coordination, in order to continue stimulating progress and avoid overtraining

Weightbearing activity: activity performed when standing on one or both feet

Background

In Australia, more than two thirds of people over the age of 60 have osteoporosis or osteopenia. An estimated 183,000 fractures related to poor bone health occurred in 2022. Osteoporosis and related fractures affect individuals, their carers, and the wider healthcare system, costing $2.59B per year for fractures alone.

Osteoporosis is commonly managed medically and typically with treatment. Exercise is also essential in the management of osteoporosis but tends to be underutilised due to lack of knowledge and unfounded concerns about the risk of injury. In fact, optimal care of people with low bone mass, osteoporosis and/or increased risk of falling can and should include targeted exercise to help prevent osteoporotic fracture.

Osteogenic exercise is important throughout life – in youth to optimise peak bone mass and in adulthood to minimise loss. The exercise recommendations in the current statement, however, are targeted at older adults as osteoporosis typically occurs in the later years. In light of the increased skeletal fragility of osteoporosis, it is recommended that the following exercise prescription be supervised by a clinical exercise physiologist or physiotherapist. Such expertise is required to assess comorbidities and exercise capacity in order to appropriately individualise the exercise prescription.

Most exercise provides health benefits, and some activity is always better than none. However, specificity and overload are required to improve bone mass and strength, and high challenge balance training is required to prevent falls.

The following document presents a summary of the principles of osteogenic loading and fall prevention, the translation of those principles into clinical practice, evidence-based recommendations for exercise prescription, and special considerations, along with links to several relevant resources for people with or at risk of osteoporosis, falls and fractures.

The document is based on the latest research and developed by an expert Working Group, Advisory Committee and following a National Roundtable.

A double-sided summary has also been developed as a quick reference of the recommendations and caveats for clinical practice.

Key Messaging

Degree of Roundtable consensus on each point; A >80%, B 60-79%, C <60%

1. **General principles of osteogenic loading:** The most osteogenic protocol includes low numbers of high intensity loads, including impact and resistance training *[A]*
2. **General principles of fall prevention exercise:** Exercise will prevent falls if undertaken >3 hours per week ongoing (minimum 12 weeks) and include high challenge balance activities *[A]*
3. **General exercise prescription guidelines for osteoporosis:**
   a. Resistance training: 2-3 days per week, 2-3 sets of 5-8 repetitions at 75-85% 1RM of supervised progressive resistance training, including back extension, performed in weight bearing with correct lifting technique. Note: Individuals with very low spine BMD and/or history of vertebral fractures may require lighter weights at higher repetitions emphasising slow controlled movements targeting postural muscles *[A]*
   b. Impact training: Around 50 impacts of 2-4 x body weight magnitude, a minimum of 3 days per week, introduced gradually and titrated for bone fragility *[A]*
   c. Balance exercises: Accumulate at least 3 hours a week of any type of exercise that includes progressive and challenging balance activities in a minimum of 3 sessions
   Note: Exercises undertaken in 3a and b can be included in this 3 hours *[A]*
4. **Person-centred exercise prescription** and positive instructions directed at 'how-to' be active are preferable to 'can't do' messages *[A]*
5. **Special considerations:** Exercise capacity may be influenced by acute and chronic conditions such as osteoarthritis, cardiopulmonary disease, recent fracture, bone lesions, pelvic floor dysfunction, or other musculoskeletal, neurological or cognitive limitations, as well as some medications, which may require referral, rehabilitation and/or modification of an exercise program for osteoporosis *[A]*

General Principles of Osteogenic Loading

During movement, the skeleton is loaded by both muscle and joint or ground reaction forces which induce bone strain (deformation). The principles of osteogenic loading have been derived from the findings of animal studies where loading parameters could be surgically manipulated and bone strain could be directly measured. It is well recognised that bone adapts its mass, density, and geometry in ways that improve overall bone strength in a highly site-specific manner according to the magnitude and rate of application of loading. Within limits, higher strains applied rapidly comprise the most osteogenic load stimuli and weight bearing exercise provides a superior stimulus than non-weightbearing activity. The following section is a brief elaboration of the evidence behind these general principles.

What sort of loading is best?

Bone requires regular dynamic (cyclical) loading[1,2] to stimulate a positive adaptive response or to prevent age-related loss. The observation that static loading will not stimulate bone adaptation[2-7] raises questions about the likely efficacy of isometric loading devices that have been marketed for osteoporosis therapy in recent years.

How much load is required?

There is a strong positive relationship between skeletal load (magnitude of induced strain) and bone response.[8] Indeed exercise loading must exceed habitual loading exposure to induce an adaptive response.[5,6,9]

How fast should I load?

Speed of loading, which can be described in terms of strain frequency or strain rate, is another influential load parameter modulating the adaptive bone response.[10-14] Strain frequency refers to the number of loads applied per second (aka, cycle number; Hz). Animal data show that low magnitude loads may be osteogenic if applied at high frequency,[15] however, such frequencies (> 15 Hz[10]) cannot be actively achieved by humans, limiting the relevance of strain frequency in exercise prescription. Related to strain frequency, strain rate is the time taken to reach peak bone strain (ms) under load and is also positively associated with osteogenesis.[16] Impact loading such as landing from a jump is an example of a high strain rate exercise that may be osteogenic. It is important to note that higher strain rates can induce more microdamage and greater loss of stiffness than lower strain rates,[17-24] so while impact loading appears to be safe under supervision, more safety data is required before high load, high strain rate activities such as power training can be recommended for osteoporosis.

How many loads are needed?

If the principle of overload is applied, very few load cycles are required to stimulate osteogenesis[25,26] as the mechanosensory pathway quickly saturates. This means only low numbers of high strain-inducing exercises are required for a bone response (e.g. brief jumping bouts, or heavy loads). Conversely, even very high numbers of load cycles will fail to stimulate notable bone adaptation if the magnitude of induced strain is insufficient (e.g. marathon running, endurance cycling or swimming[27,28]).

The prescription of osteogenic exercise as therapy for osteoporosis is dependent on the application of these fundamental principals of loading through strong, forceful muscle contractions and weight bearing impact forces that safely exceed habitual patterns of loading.

Translating Osteogenic Principles into Practice

Although the general principles of osteogenic loading have been established for some time, the translation to safe and effective exercise interventions for individuals with osteoporosis has not been straightforward. This is due in part to the heterogeneous nature of exercise; not only the variety of movements possible, but the associated bone loads, and the rates and repetitions at which they can be applied. This has led to the development of a plethora of interventions; not all of which effectively increase indices of bone strength.

The literature is often misinterpreted when it comes to exercise for bone health. There is a notion that *all* physical activity increases bone mass, based on a number of cohort studies that indicate those who self-report long-term engagement in non-specific 'physical activity' across the lifespan have greater bone mass than

those who have been inactive. However, higher-level **evidence** from well controlled intervention trials has shown that non-weightbearing and low-impact exercise such as walking, swimming, Tai Chi, Pilates, yoga, and cycling have little to no ability to improve bone mass in older age.[27,29-33] Therefore, while low intensity exercises have other important benefits such as cardiovascular and metabolic health, they do not comprise a therapeutic recommendation for the purpose of increasing bone mass or even preventing bone loss.

Based on the current body of high-quality evidence, moderate to high intensity resistance training is an effective intervention for osteoporosis and provides the greatest effect when combined with weight bearing impact.[34] In isolation, progressive resistance training utilising both free and machine weights may improve bone, particularly when applied at high loads and moderate-low repetitions (<8 repetitions).[35,36] Impact weightbearing activities such as jump landings have also been shown to be osteogenic when applied at moderate to high intensities (loads greater than twice an individual's body weight).[37] Progressive resistance and impact training at moderate to high intensities provide greater osteogenic effect when combined than in isolation.[38-42] The above-mentioned findings are in keeping with the fundamental principles that short bouts of mechanical loads inducing high magnitude strains at high rates produce the greatest osteogenic effect.

General Principles of Fall Prevention Exercise

Evidence shows that exercise, appropriately prescribed, is the most effective method of preventing falls. Sustained targeted exercise intervention, incorporating challenging balance training, prevents falls in both older people at known increased risk of falling as well as the general population of older people. In contrast to the general principles of osteogenic loading however, the prescription of exercise for the prevention of falls has largely been determined from systematic reviews of intervention trials.

What sort of training is best to prevent falls?

Experimental studies have found that older adults are less able to ignore misleading sensory cues to control their posture,[43,44] but that training can improve this ability. For example, it has been shown that 15 consecutive days of 1 hour multisensory balance training can improve postural responses to surface displacements.[45] The principles of such technical studies have been applied into home- and community-based programs which have revealed that to reduce falls, exercises must include high challenge balance and functional training.

There is evidence that different types of balance training can reduce falls. These include: Tai Chi, which involves slow, controlled body movements; functional training to improve everyday activities such as the ability to stand and walk steadily, rise from a chair and negotiate steps;[46] and voluntary and reactive step training to improve quick and appropriate step responses.[47,48]

Balance training interventions have been conducted in older adults of varying physical capacity. This work has found that while modestly challenging balance programs are sufficient to reduce falls in nursing home residents who live in a low-risk environment, higher challenge balance training is necessary to prevent falls in more able individuals living in the community (higher function but higher risk environment).

The weight of the evidence suggests that to prevent falls in older adults, exercises that involve safely reducing the standing base of support, moving and controlling body position while standing, and standing without using arm supports or reducing reliance on the upper limbs; should be undertaken. When feasible, the addition of progressive resistance training is recommended.[49]

How much, how often and how long is required for exercise to prevent falls?

While laboratory-based studies report neuromuscular adaptations after only short term interventions (i.e. 10-15 hours of training over two weeks),[50] a 2015 meta-analysis of 23 RCTs of balance training on postural control (static/dynamic steady-state, proactive and reactive balance, and performance in balance test batteries) of healthy community-dwelling adults ≥65 years suggests longer duration interventions are necessary.[51] The meta-analysis derived a number of independent characteristics of an effective dose of balance training in this population, including a program duration of 11-12 weeks with a training frequency of three times per week

(or a total number of 36-40 training sessions), and session duration of 31-45 minutes (or a total training duration of 91-120 minutes per week). A recent Cochrane review of 116 trials [46] also concluded that challenging balance exercise programs involving more than 3 hours per week were most effective in reducing falls in community-dwelling older adults.

Ineffective exercises for falls

Programs that do not specifically or sufficiently challenge balance, including resistance training alone, walking, general physical activity and seated exercise training, have been shown to have no, or little ability to prevent falls.

Exercise Prescription

Exercise prescription to support the management of osteoporosis and minimal trauma fracture should include a multifaceted, personalised approach informed by clinical risk factors and client goals to optimise musculoskeletal strength and reduce falls, and to restore function and quality of life post fracture as applicable.

Assessing Risk

To optimise exercise prescription and safety, an initial assessment of osteoporosis risk factors should occur (see Table 1). The determination of fracture risk should be based on a judgement of bone strength (from BMD T-score, previous fracture, recent fracture (refer to Special Considerations, page 9).) and risk of falling (based on fall history, gait speed ≤ 1.0 m/s, the Timed Up and Go test > 12 seconds [52] and/or frailty). Training maturation should also be assessed to determine initial exercise capacity and rate of progression.

Table 1: Risk Factors for Osteoporosis

Personal History	Medical Conditions	Medications
Previous fracture	Malabsorptive disease (e.g. coeliac, Crohn's)	Certain treatments for breast and prostate cancer (e.g. aromatase inhibitors, immunotherapies)
Family history of osteoporosis	Overactive thyroid or parathyroid	Glucocorticoids (steroids)
Loss of height (≥ 3cm)	Rheumatoid arthritis	Anti-epilepsy treatment
Smoking/Excessive alcohol intake	Early menopause/Low testosterone	Thyroxine
Inadequate calcium, vitamin D, sedentary	Chronic kidney disease or liver disease	
Age ≥ 70 year	Diabetes	

Pelvic floor dysfunction is common in the osteoporotic demographic and should be assessed before prescribing heavy lifting and impact training. Resistance and impact exercise are likely to improve symptoms but preliminary targeted pelvic floor training may be required to improve tolerance.

Expertise

The following exercise prescription is designed for application and delivery by clinical exercise physiologists and physiotherapists with assumed expertise to determine the level of client supervision required and the nature of exercise modifications necessary to meet individual client needs. As moderate to high intensity resistance and impact training comprise the fundamental exercise prescription to maximise bone and muscle strength, supervision to ensure optimum technique, loading and progressions is required to minimise risk of injury to individuals at high risk of fracture. If an exercise practitioner does not have those skills, training should be acquired before applying the following prescription.

The following recommendations provide a guide for the prescription of progressive resistance training, impact and balance training exercises for the optimisation of bone strength and prevention of falls and fractures.

Progressive Resistance Training

Frequency	• 2-3 days per week (non-consecutive days)
Dose	• 2-3 sets of 5-8 repetitions (1-2 minutes rest between sets)
Intensity	• Progress to 75-85% of 1RM* **or** • 5 to 8 (hard-very hard) on Borg 0-10 RPE** scale
Exercises	• Prioritise muscle groups attached to or crossing the spine and major joints of the extremities • Example exercises: weighted squats, lunges, deadlift, hip abduction/adduction, hip extension/flexion, leg press, thoracic/lumbar extension, plantar/dorsi-flexion, lat pulldown/bent over row, wall/counter/floor push-up, triceps dips, chest press, and abdominal/core exercises • Use resistance to optimise intensity • Emphasise exercises performed in standing (weight-bearing) position
Considerations	• Teach and emphasise correct lifting techniques at all times • Consider pre-existing musculoskeletal injuries/conditions (e.g. frozen shoulder); monitor and modify posture and techniques as appropriate • For people with prevalent vertebral fractures, or a history of multiple fractures, a low entry weight and slow progression is advised • Avoid excessive spine flexion and twisting • Provide clear instructions on transitions in/out of each exercise • Recommend submaximal testing to predict 1RM for individuals at risk of fracture

**Exercise > 75% 1RM should be supervised for correct technique and progressions.*

***RPE, Rate of Perceived Exertion (RPE) on a scale of 0-10, with 0 being 'nothing at all' and 10 being 'maximal effort' (very, very hard).*

Weight-Bearing Impact Exercise

Frequency	• Minimum 3 days per week
Bout dose	• ~50 impact loads per session • Divide into brief bouts
Intensity	• Increase up to moderate impact (> 2-4 times body weight) as tolerated • Gradual progression – start at low impact, and progress by increasing impact, changing direction, increasing the speed of movement, adding resistance or a step/step height
Exercises	• A variety of vertical and multidirectional weight-bearing impact exercises, as tolerated • Example exercises: foot stomping, heel drops, jumping, bounding, hopping, skipping, and drop jumps
Considerations	• For people with prevalent vertebral fractures, or a history of multiple fractures, a very slow progression from low to moderate impact loading is advised • Individualise impact exercise technique to accommodate specific circumstances and ability • People with frailty or limited function should be fully supervised and progress from low impact as tolerated and safe • For sedentary individuals, consider 6-12 weeks of resistance training to strengthen lower limb muscles prior to commencing exercises that involve more than low impact • Integrate weight-bearing impact exercises in daily routine as brief 'exercise snacks' (e.g. perform while making a tea/coffee or during TV commercial breaks) • Continuing existing habitual weight-bearing activities and sports that include impact (e.g. racquet sports, netball, running) is encouraged, with any necessary sports-specific conditioning or modifications

Exercise to Prevent Falls

A combination of progressively challenging balance and functional exercises is recommended to reduce the risk of falls. The World Guidelines for fall prevention[52] recommend supervised exercises that target balance and strength delivered by appropriately trained professionals and advise that benefits are lost on cessation. Exercises should be challenging but safe, achievable and progressive.

For people who are frail or have limited function and a history of falls, priority should be given to balance and mobility training prior to or alongside the prescription of progressive resistance training. It is important to note that falls are not confined to older adults. Balance begins to deteriorate at a considerably younger age than when falls become prevalent.[53] Thus, balance training should be incorporated into exercise prescription for younger adults to prevent the development of high fall risk in older age.

Balance and Mobility Training

Frequency	• At least 3 sessions per week
Dose	• Progress to accumulate at least 3 hours of exercise per week that includes challenging balance activities (PRT and impact exercise count towards the 3 hrs) • Ongoing
Intensity	• Progressively challenging (close to limit of balance or functional ability) • Begin at 3 and progress to 4 on 5-point global rating scale of balance effect – How hard did you have to work to keep your balance/mobility during this task? It was... 1 = No effort at all; 2 = A little effort; 3 = Some effort; 4 = A lot of effort; 5 = Maximal effort *(https://www.monash.edu/medicine/balance-intensity-scale)*
Exercises	• Incorporate targeted functional exercises to improve: – anticipatory control (e.g. shift centre of mass before voluntary movement, star excursion) – dynamic stability (walking, transfers) – functional stability limits (leaning; reaching) – reactive balance (responding to perturbation) • Example exercises: standing balance with gradual reduction in base of support to standing on one foot, perturbing the centre of mass with leaning and reaching then regaining balance with minimal use of support from the upper extremities (e.g. Tai Chi), single leg stance, tandem stance, tandem walk, backwards, sideways and crossover walks, circle and pivot turns, figure of eight walks, stepping over and avoiding obstacles, walking on uneven surface, dancing, changing environments and speed, adding weight, and dual tasking • Progress by altering or elevating surface (foam mats) and reducing base of support, longer or faster steps, heel-toe walks, raised arms walk, withdrawing vision during balance tasks, and dual tasking (e.g. cognitive task such as counting backwards or naming animals, combined with balance activities) • Integrate challenging balance and functional activities in resistance and weight-bearing elements of the program and/or incorporate into daily activities as 'exercise snacks' (e.g. sit-to-stand, squats, reaching while standing while waiting for the kettle to boil)
Considerations	• Supervision is recommended for clients at high risk of falling • Exercise to strengthen back extensor muscles and improve posture should be considered to reduce falls risk[54] • If undertaking balance training unsupervised, ensure a safe environment (e.g. grab rail or stable support within reach should balance be lost)

As the benefits of exercise for fall prevention are lost on cessation, continuing with appropriate activity at the end of programs is important. If individuals withdraw due to concurrent health issues or caring duties, they should be encouraged to return to exercise, at which time the program should be modified to ensure that the challenge level and dose are appropriate.

Exercise to Improve Posture and Protect the Spine

For people with a history of vertebral fracture, postural problems such as hyperkyphosis or back pain, exercises should be included to strengthen and improve endurance of the back extensor muscles to optimise posture. Education on 'spine caring' approaches that include safe movements for everyday activities should also be provided beyond the exercise prescription.

Postural and Spine Caring Exercises

Frequency	• 2-3 days per week
Dose	• 2-3 sets of 10-15 repetitions • 1-2 minutes rest between sets
Intensity	• Progress to the intensity (weight and repetitions) that can be achieved with the limits of maintaining correct form and alignment
Exercises	• Target back extensor muscle strength and muscle endurance – Submaximal isometric back extension in neutral position can be a baseline of progression for weak and fearful clients in pain but used sparingly as dynamic movement is the goal • Teach correct form and lifting technique including the 'hip-hinge' • Perform exercises in a slow and controlled manner, limiting rotation (twisting) exercises under load • Educate how to engage core stabilisers during movements • Example exercises: shoulder blade squeeze (prone or standing W scapular retraction), back extension, four-point kneeling bird dog, bridge, supine bridge, supine thoracic press, resistance band shoulder abduction, shoulder press, wall crawls in standing
Considerations	• Avoid prescribing exercises that involve sustained, repeated or end-range flexion or twisting and maximal isometric contractions

Psychosocial Aspects of Exercise Prescription for Osteoporosis

The best exercise program is the one a person will actually do. Adherence to any bone health management plan (be it pharmacotherapy and/or lifestyle modifications) is necessary for efficacy. Many factors will influence adherence to exercise (cost, time, accessibility, relevance, boredom, age, cognition, gender, culture, self-motivation, mental health, etc.) and must be considered when developing an exercise program for bone health. These factors may preclude some individuals from undertaking a high intensity gym-based resistance training program. In that case, a more achievable strategy to minimise fracture risk may be to focus on a fall prevention program alongside bone protective medicines. Group exercise classes with similar participants can be motivating and improve exercise participation and adherence.

Person-centred exercise prescription has the potential to improve health outcomes other than bone. Many people lose confidence after a fracture and withdraw from usual activities. A comprehensive osteogenic loading and balance training program can help not only improve bone strength, but also develop confidence to re-engage with functional and social activities that are important to quality of life. It is preferable to assist a person to continue a favourite physical activity that may not be osteogenic than to discourage involvement if it means the person will do nothing at all. The progressive nature of exercise prescription can help people return to complex movements/leisure-activities by modifying intensity or technique (e.g. reduced end range spinal flexion/rotation) of the activity, or sport-specific training (e.g. golf practice with short irons, progressing to woods). It is important to note that returning to a favourite physical pastime in which a person is experienced presents a lower risk than commencing the same sport as a novice. Nevertheless, positive instructions directed at 'how-to' be active are preferable to 'can't do' messages as the latter can promote fear of exercise and encourage physical inactivity.

Special Considerations

Understanding Capacity

Beyond bone health and balance considerations, exercise capacity may be influenced by training maturation, acute injuries and/or chronic conditions (e.g. osteoarthritis) that may warrant further investigation and rehabilitation. A multidisciplinary approach is recommended, including referral to a Sports and Exercise Physician prior to commencing a program, if warranted.

Common Conditions with Implications for Exercise Prescription

Arthritis: Clients with osteoarthritis may need to modify resistance training exercises to a pain-free joint range (e.g. shallow squats to avoid knee osteoarthritic pain).[55, 56] High impact exercise may need to be reduced in intensity or substituted for power training (e.g. faster muscle contractions against lower loads). For clients with mild knee osteoarthritis, bone benefits are attainable with high impact loading exercise without detriment.[57, 58] Similar modifications are appropriate for rheumatoid arthritis, with standard accommodations for inflammatory flareups. Bar hooks can be used to assist lifting barbells when grip is affected.

Cardiovascular/Pulmonary disease: For resistance training, no modifications are typically required. Intensity should be reduced to avoid exacerbation. Fatigue may necessitate seated rest between sets. Avoid breath holding or Valsalva manoeuvres, isometric contractions held longer than 5 seconds, or tight handgrips during weightlifting.[55, 56]

Shoulder injuries: Shoulder pathology (e.g. subacromial bursitis, osteoarthritis and rotator cuff pathology) may require rehabilitation and/or modification of exercises that involve loading above the shoulder or in abducted or externally rotated positions.

Recent fracture: Clients with a history of minimal trauma fracture should be sufficiently progressed in their post fracture healing to be able to engage in loading of the fracture site. Exercise to improve back extensor endurance, spine mobility and balance can be gradually introduced post vertebral fracture once acute fracture-related pain has diminished or with physician clearance.[59] Slow controlled movements are recommended rather than rapid movements. Post hip fracture, specialist advice is recommended before return to exercise. While healing, exercise that does not excessively load the fracture site can be undertaken. Restoring function and improving quality of life is the initial priority, followed by structured exercise to improve mobility, and ultimately strength with progressive resistance exercise.[60, 61]

Cancer: Aromatase inhibitors, surgeries and/or chemotherapy inducing premature menopause in women with breast cancer, and androgen deprivation therapy in men with prostate cancer, reduce bone mass and therefore increase susceptibility to minimal trauma fracture.[62] Clients with bone metastases must undertake bone loading with care depending on the location of lesions, however, exercise will be beneficial and should be encouraged.[63-65]

Pelvic floor conditions: Exercise is recognised as a vital element of pelvic floor health; however, it is recommended that patients with prolapse, pelvic floor dysfunction, or previous pelvic floor surgery consult a specialist pelvic health physiotherapist for assessment of their individual condition. Concerns that heavy lifting increases risk of pelvic organ prolapse appear to be unfounded.[66]

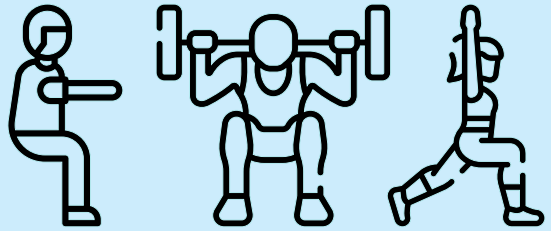
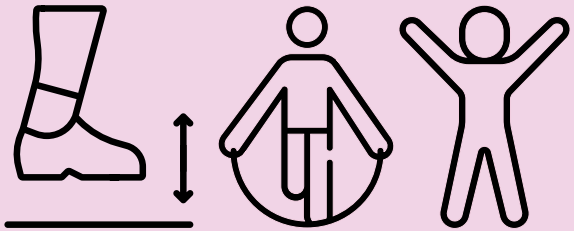
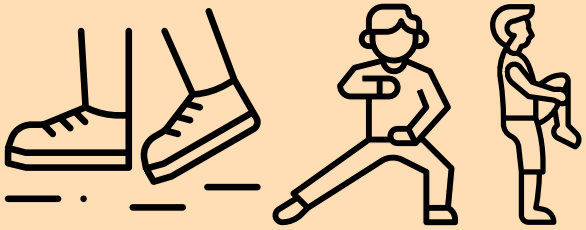
Prevalent hernia and retinal detachment: Valsalva manoeuvre should be avoided during exercise with prevalent hernia. The American Heart Association denotes high intensity (80-100% 1-RM) PRT as a contraindication with retinopathy.

Other neurological conditions: Numerous conditions may affect the capacity to ambulate. Appropriately adapted programs and a higher level of supervision is warranted as these clinical groups have more impairments. As the capacity to undertake recommended osteogenic exercises may be diminished, exercise to prevent falls may be a priority. Balance and strength training programs prevent falls in older adults with Parkinson Disease (PD), stroke, and frailty. The effect of exercise on falls in older people with advanced PD is uncertain, but limited data indicate that minimally supervised exercise may increase the risk of falls, so supervision is vital.

Cognitive impairment: The following refers to individuals with mild cognitive impairment and mild to moderate dementia. Impaired cognition significantly increases the risk of both falls and fractures. This population will benefit from exercise but often start at a lower than average level of strength, balance and reaction time. Exercises will likely need to be delivered in a supervised environment and the duration of exercise sessions may be extended to accommodate the time required to reinforce coaching instructions. Rather than introduce new exercises over time, it may be more appropriate to focus on a smaller number of exercises but increase the intensity and duration over time. In those with advanced dementia, a structured exercise program may not be feasible but opportunites still exist to build strength and balance training into everyday functional activities which can be communicated to carers.

QUICK REFERENCE SUMMARY

Three individual exercise sessions per week containing the following components of each exercise type

Type	Dose	Intensity	Exercise Examples	Visual Examples
Progressive resistance training	2-3 sets 5-8 repetitions.	Progress to 75-85% of 1RM or 5 to 8 on Borg 0-10 RPE scale. Higher intensity and fracture risk requires supervision.	Weighted squats, lunges, deadlift, hip exercises, back extension etc.	
Progressive impact training	~50 impacts per session. Best divided into brief bouts.	Gradual progression up to moderate impact *(>2-4 x body weight)* as tolerated.	**Low level:** foot stomping **Moderate level**: low jumps, skipping	
Progressive balance activities	3 hours – can be divided into brief bouts and include PRT and impact training time.	Moderate to high balance challenge.	Heel-to-toe walks, single leg stance, circle and pivot turns, Tai Chi, stepping	

QUICK REFERENCE SUMMARY

Assessing risk

Review individual fracture risk status to optimise exercise prescription.

This should be based on a judgement of:

- Bone strength - based on BMD T-score and/or previous minimal trauma fracture
- Risk of falling – based on fall history, gait speed ≤ 1.0 m/s, the Timed Up and Go test > 12 seconds and/or frailty

Person-centred approach

The best exercise program is one that a person will actually do!

Focus on **'how-to'** not 'can't do' instructions - particularly after fracture.

The below factors should be considered when developing an exercise program:

A comprehensive program can also help **develop confidence** to re-engage with functional and social activities that are important to **quality of life**.

Special considerations

Arthritis – may need to modify resistance training exercises to a pain-free joint range. High impact exercises may need to be reduced in intensity.

Shoulder injuries – may require rehabilitation and/or modification of exercises that involve loading above the shoulder or in abducted or externally rotated positions.

Recent fracture – client should be sufficiently progressed in their post fracture healing to be able to engage in loading of the fracture site. Exercise to improve back extensor endurance, spine mobility and balance can be gradually introduced post-vertebral fracture.

Cancer – clients with bone metastases must undertake bone loading with care depending on the location of lesions, however, exercise will be beneficial and should be encouraged.

Cardiovascular/pulmonary disease – no resistance training modifications typically required. Intensity should be reduced to avoid exacerbation. Fatigue may necessitate seated rest between sets.

Pelvic floor conditions – Exercise is recognised as a vital element of pelvic floor health; however, it is recommended that clients consult a specialist pelvic health physiotherapist for assessment of their individual condition.

National Roundtable Participants

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Links to Existing Resources/ Suggested Reading

- ESSA Position Statement on Exercise Prescription for the Prevention and Management of Osteoporosis
- Strong Steady Straight: UK consensus statement on physical activity and exercise for osteoporosis
- World Guidelines for Fall Prevention

References

1. Hert, J., M. Liskova, and B. Langat, *Influence of long-term, continuous bending on the bone*. Folia Morphol, 1969. **17**: p. 389.
2. Hert, J., M. Liskova, and J. Landa, *Reaction of bone to mechanical stimuli. Part 1. Continuous and intermittent loading of tibia in rabbit*. Folia Morphol, 1971. **19**(3): p. 290-317.
3. Liskova, M., *The thickness changes of the long bone after experimental stressing during growth*. Plzensky Lekarsky Sbornik, 1965. **25**: p. 95-104.
4. Chamay, A. and P. Tschantz, *Mechanical influences in bone remodeling. Experimental research on Wolff's Law*. J Biomech, 1972. **5**(2): p. 173-180.
5. Churches, A.E., et al., *The response of living bone to controlled time-varying loading: Method and preliminary results*. J Biomech, 1979. **12**: p. 35-45.
6. Churches, A.E. and C.R. Howlett, *Functional adaptation of bone in response to sinusoidally varying controlled compressive loading of the ovine metacarpus*. Clin Orthop Relat Res, 1982. **168**(168): p. 265-280.
7. Lanyon, L.E. and C.T. Rubin, *Static vs dynamic loads as an influence on bone remodelling*. J Biomech, 1984. **17**(12): p. 897-905.
8. Rubin, C.T. and L.E. Lanyon, *Regulation of bone mass by mechanical strain magnitude*. Calcif Tissue Int, 1985. **37**(4): p. 411-417.
9. Goodship, A.E., L.E. Lanyon, and H. McFie, *Functional adaptation of bone to increased stress. An experimental study*. J Bone Joint Surg, 1979. **61**(4): p. 539-546.
10. McLeod, K.J., S.D. Bain, and C.T. Rubin, *Dependence of bone adaptation on the frequency of induced dynamic strains*. Trans Orthop Res Soc, 1990. **36**: p. 103.
11. Fritton, S.P., et al., *Persistent, low magnitude strains as the dominant source of mechanical information in a bones 24 hour strain history*. J Orthop Res, 1995. **Feb 13-16**: p. 547.
12. Rubin, C.T., et al., *Non-invasive stimulation of trabecular bone formation via low magnitude, high frequency strain*. Trans Orthop Res Soc, 1995. **February 13-16**(Orlando): p. 548.
13. Harrigan, T.P. and J.J. Hamilton, *Bone strain sensation via transmembrane potential changes in surface osteoblasts: Loading rate and microstructural implications*. J Biomech, 1993. **26**(2): p. 183-200.
14. Scott, G.C. and E. Korostoff, *Oscillatory and step response electromechanical phenomena in human and bovine bone*. J Biomech, 1990. **23**(2): p. 127-143.
15. Rubin, C.T., et al., *Anabolism. Low mechanical signals strengthen long bones*. Nature, 2001. **412**(6847): p. 603-4.
16. O'Connor, J.A., L.E. Lanyon, and H. MacFie, *The influence of strain rate on adaptive bone remodelling*. J Biomech, 1982. **15**(10): p. 767-781.
17. Schaffler, M.B., *Stiffness and fatigue of compact bone at physiological strains and strain rates*. 1985, Morgantown, West Virginia University,.
18. Kenny, P. and J.D. Campbell, *Fracture toughness: An examination of the concept in predicting the failure of materials*. Prog Mater Sci, 1966. **13**: p. 135-181.
19. Piekarski, K., *Fracture of bone*. J Appl Phys, 1970. **41**(1): p. 215-223.
20. Piekarski, K., *Morphology of fracture of bone. Proceedings of the Fourth International Conference on Fracture*, 1976. **1**: p. 607-642.
21. Pope, M.H. and J.O. Outwater, *The fracture characteristics of bone substance*. J Biomech, 1972. **5**: p. 457-465.
22. Margel-Robertson, D. and D.C. Smith, *Compressive strength of mandibular bone as a function of microstructure and strain rate*. J Biomech, 1978. **11**: p. 455-471.
23. Behiri, J.C. and W. Bonfield, *Crack velocity dependence of longitudinal fracture in bone*. J Mater Sci, 1980. **15**(7): p. 1841-1849.
24. Behiri, J.C. and W. Bonfield, *Fracture mechanics of bone: The effects of density, specimen thickness and crack velocity on longitudinal fracture*. Journal of Biomechanics, 1984. **17**: p. 25-34.
25. Rubin, C.T. and L.E. Lanyon, *Regulation of bone formation by applied dynamic loads*. J Bone Joint Surg Am, 1984. **66**(3): p. 397-402.
26. Rubin, C.T. and L.E. Lanyon, *Osteoregulatory nature of mechanical stimuli: Function as a determinant for adaptive remodeling in bone*. J Orthop Res, 1987. **5**(2): p. 300-310.
27. Taaffe, D.R., et al., *Differential effects of swimming versus weight-bearing activity on bone mineral status of eumenorrheic athletes*. J Bone Miner Res, 1995. **10**(4): p. 586-93.

28. Nagle, K.B. and M.A. Brooks, *A systematic review of bone health in cyclists. Sports Health*, 2011. **3**(3): p. 235-243.
29. Martyn-St James, M. and S. Carroll, *Meta-analysis of walking for preservation of bone mineral density in postmenopausal women*. Bone, 2008. **43**(3): p. 521-31.
30. Rector, R.S., et al., *Participation in road cycling vs running is associated with lower bone mineral density in men*. Metab, 2008. **57**(2): p. 226-232.
31. Hatori, M., et al., *The effects of walking at the anaerobic threshold level on vertebral bone loss in postmenopausal women*. Calcif Tissue Int, 1993. **52**(6): p. 411-414.
32. Chan, K.M., et al., *A randomized, prospective study of the effects of Tai Chi Chun exercise on bone mineral density in postmenopausal women.* Arch Phys Med Rehabil, 2004. **85**(5): p. 717-722.
33. Woo, J., et al., *A randomised controlled trial of Tai Chi and resistance exercise on bone health, muscle strength and balance in community-living elderly people*. Age Ageing, 2007. **36**(3): p. 262-268.
34. Kistler-Fischbacher, M., B.K. Weeks, and B.R. Beck, *The effect of exercise intensity on bone in postmenopausal women (part 2): A meta-analysis*. Bone, 2021. **143**: p. 115697.
35. Maddalozzo, G.F. and C.M. Snow, *High intensity resistance training: Effects on bone in older men and women*. Calcif Tissue Int, 2000. **66**(6): p. 399-404.
36. Nelson, M.E., et al., *Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures: a randomized controlled trial*. JAMA, 1994. **272**(24): p. 1909-1914.
37. Allison, S.J., et al., *High impact exercise increased femoral neck bone mineral density in older men: A randomised unilateral intervention*. Bone, 2013. **53**(2): p. 321-8.
38. Watson, S.L., et al., *High-intensity resistance and impact training improves bone mineral density and physical function in postmenopausal women with osteopenia and osteoporosis: The LIFTMOR randomized controlled trial*. J Bone Miner Res, 2018. **33**(2): p. 211-220.
39. Harding, A.T., et al., *A comparison of bone targeted exercise strategies to reduce fracture risk in middle aged and older men with osteopenia and osteoporosis: LIFTMOR M semi randomized controlled trial*. J Bone Miner Res, 2020. **35**(8): p. 1404-1414.
40. Kistler-Fischbacher, M., et al., *A comparison of bone-targeted exercise with and without antiresorptive bone medication to reduce indices of fracture risk in postmeopausal women with low bone mass: The MEDEX-OP randomized controlled trial*. J Bone Miner Res, 2021. **36**(9): p. 1680-1693.
41. Engelke, K., et al., *Exercise maintains bone density at spine and hip EFOPS: A 3-year longitudinal study in early postmenopausal women*. Osteoporos Int, 2006. **17**(1): p. 133-142.
42. Milliken, L.A., et al., *Effects of exercise training on bone remodeling, insulin-like growth factors, and bone mineral density in postmenopausal women with and without hormone replacement therapy*. Calcif Tissue Int, 2003. **72**(4): p. 478-484.
43. Peterka, R.J. and F.O. Black, *Age-related changes in human posture control: Sensory organization tests*. J Vestib Res, 1990. **1**(1): p. 73-85.
44. Woollacott, M.H., A. Shumway-Cook, and L.M. Nashner, *Aging and posture control: changes in sensory organization and muscular coordination*. Int J Aging Hum Dev, 1986. **23**(2): p. 97-114.
45. Hu, M.H. and M.H. Woollacott, *Multisensory training of standing balance in older adults: II. Kinematic and electromyographic postural responses*. J Gerontol, 1994. **49**(2): p. M62-71.
46. Sherrington, C., et al., *Exercise for preventing falls in older people living in the community: an abridged Cochrane systematic review*. Br J Sports Med, 2020. **54**(15): p. 885-891.
47. Okubo, Y., D. Schoene, and S.R. Lord, *Step training improves reaction time, gait and balance and reduces falls in older people: a systematic review and meta-analysis*. Br J Sports Med, 2017. **51**(7): p. 586-593.
48. McCrum, C., et al., Perturbation-based balance training: *Principles, mechanisms and implementation in clinical practice*. Front Sports Act Living, 2022. **4**: p. 1015394.
49. Sherrington, C., et al., *Exercise to prevent falls in older adults: an updated systematic review and meta-analysis*. Br J Sports Med, 2017. **51**(24): p. 1750-1758.
50. Gatts, S.K. and M.H. Woollacott, *Neural mechanisms underlying balance improvement with short term Tai Chi training*. Aging Clin Exp Res, 2006. **18**(1): p. 7-19.
51. Lesinski, M., et al., *Effects of balance training on balance performance in healthy older adults: A systematic review and meta-analysis*. Sports Med, 2015. **45**(12): p. 1721-1738.
52. Montero-Odasso, M., et al., *World guidelines for falls prevention and management for older adults: A global initiative*. Age Ageing, 2022. **51**(9).
53. Isles, R.C., et al., **Normal values of balance tests in women aged 20-80**. J Am Geriatr Soc, 2004. **52**(8): p. 1367-72.
54. Sinaki, M., *Exercise for patients with osteoporosis: management of vertebral compression fractures and trunk strengthening for fall prevention*. PM R, 2012. **4**(11): p. 882-888.
55. Hoffman, T.C., et al., *Prescribing exercise interventions for patients with chronic conditions*. CMAJ, 2016. **188**(7): p. 510-518.
56. Fiatarone Singh, M.A., *Nutrition and Bone Health, in Nutrition and Bone Health*, M.F.N. Holick, J. W.,, Editor. 2015, Humana Press: New York, NY, USA. p. 505-542.
57. Multanen, J., et al., *Effects of high-impact training on bone and articular cartilage: 12-month randomized controlled quantitative MRI study*. J Bone Miner Res, 2014. **29**(1): p. 192-201.
58. Hartley, C., et al., *High-impact exercise increased femoral neck bone density with no adverse events on imaging markers of knee osteoarthritis in postmenopausal women*. J Bone Miner Res, 2020.
59. Ponzano, M., et al., *International consensus on the non-pharmacological and non-surgical management of osteoporotic vertebral fractures*. Osteoporos Int, 2023. **34**(6): p. 1065-1074.
60. Fairhall, N.J., et al., *Interventions for improving mobility after hip fracture surgery in adults*. Cochrane Database Syst Rev, 2022. **9**(9): p. CD001704.
61. Diong, J., N. Allen, and C. Sherrington, *Structured exercise improves mobility after hip fracture: A meta-analysis with meta-regression*. Br J Sports Med, 2016. **50**(6): p. 346-55.
62. Saad, F., et al., *Cancer treatment-induced bone loss in breast and prostate cancer*. J Clin Oncol, 2008. **26**(33): p. 5465-5476.
63. Hart, N.H., et al., *Exercise for people with bone metastases: MASCC endorsed clinical recommendations developed by the International Bone Metastases Exercise Working Group*. Support Care Cancer, 2022. **30**(9): p. 7061-7065.
64. Weller, S., et al., *Exercise for individuals with bone metastases: A systematic review*. Crit Rev Oncol Hematol, 2021. **166**: p. 103433.
65. Campbell, K.L., et al., *Exercise recommendation for people with bone metastases: Expert consensus for health care providers and exercise professionals*. J Oncol Pract, 2022. **18**(5): p. 361-E709.
66. Forner, L.B., E.M. Beckman, and M.D. Smith, *Symptoms of pelvic organ prolapse in women who lift heavy weights for exercise: A cross-sectional survey*. Int Urogynecol J, 2020. **31**(8): p. 1551-1558.

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