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CONCISE CLINICAL REVIEW

Practical tips for prescribing exercise for fall prevention

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Abstract

Clinical relevance There is strong evidence from meta-analyses that exercise as a single intervention can reduce the number and risk of falls in community-dwelling older adults, yet not all types of exercise are equal.

Observations Programs that include 3 h a week of exercise and provide a high challenge to balance can reduce falls by almost 40%. Reactive and volitional stepping interventions have also been shown to reduce falls by about 50%. Evidence is less clear regarding the efficacy of exercise in individuals who have experienced a stroke, who live in long-term care, who have been recently discharged from the hospital, or who have visual impairments, but there is some evidence that multifactorial programs may be useful.

Conclusion Depending on the population, exercise as a single or as part of a multifactorial intervention may be beneficial in reducing falls.

Keywords Community-dwelling older adults · Exercise · Fall prevention

The consequences of falls

A fall has been defined as "an event which results in a person coming to rest inadvertently on the ground or other lower level and other than as a consequence of the following: sustaining a violent blow, loss of consciousness, sudden onset paralysis, or an epileptic seizure" [1]. Falls and fall-related injuries are a major public health concern; older adults and adults with comorbidities like visual impairments, stroke, Parkinson's disease, and osteoporosis are at significant risk of disability or death due to a fall [2–4]; fall-related injuries account for approximately 90% of hip and wrist fractures and 60% of head injuries [5]. About 30% of community-dwelling older adults (65 years and over) fall at least once a year and 15% at least twice a year [6]. These numbers are much higher in high-risk fallers (i.e., older adults in long-term facilities or with vision impairments); about 50% of older adults living in a long-term facility fall at least once a year [7]. A seminal study that video-recorded falls in long-term care facilities revealed that the most frequent cause of falling for residents was incorrect weight shifting (41% of all falls), followed by trips or stumbles (21%) and loss of support with an external object while sitting down (11%) [5]. **Weight shifting** refers to the transfer of body weight from one limb to another and is essential for functional mobility and a requirement for rising from a chair, walking, turning, and stair climbing [8].

Falls can result from a combination of intrinsic and extrinsic risk factors. A systematic review reported that the following factors had the strongest associations with falls: history of falls (OR = 2.77, 95% CI 2.37–3.25), vertigo (OR 1.80, 95% CI 1.39–2.33), Parkinson's disease (OR = 2.71, 95% CI 1.08–6.84), antiepileptic drugs (OR = 1.88, 95% CI 1.02–3.49), gait difficulties (OR = 2.06, 95% CI 1.82–2.33), and walking aids (OR = 2.18, 95% CI 1.79–2.65) [9]. A person's capacity to maintain balance while in a static position or during movement is often used as an indicator of fall risk. Physiopedia, an open physiotherapy knowledge resource (https://www.physio-pedia.com), defines **balance** as "an individual's ability to maintain their **line of gravity** within their base of support" or "the ability to maintain equilibrium, where **equilibrium** can be defined as any condition in which all acting forces are cancelled by each other resulting in a stable balanced system" [10]. **Base of support** refers to the space beneath a person bounded by all points of contact with the ground: if standing it is the area between the two feet; if on all

The CME questions related to this article can be found at: https://cme.nof.org/default.aspx

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fours, it is the area contained by all limbs; or if sitting in a chair, it is the area under the chair and feet on the ground [11]. Standing with one's feet together or on one foot results in a narrow base of support, whereas standing with feet hip-width apart results in a wider base of support. If the **center of gravity** is an estimated point in the body through which the force of gravity would act, the **line of gravity** is the estimated line perpendicular to the ground representing the downward force of gravity through the center of gravity. Balance can be further subdivided into **static balance**, the ability to maintain the line of gravity over the base of support while in a fixed posture or position, and **dynamic balance**, the ability to maintain the center of gravity over the base of support while the body is moving around and maintain stability even when the center of gravity moves outside of the base of support. Exercise interventions can be designed to target static or dynamic balance, to increase physical activity levels, to reduce fear of falling, or maintain or improve functional mobility.

Can exercise help reduce falls?

Effect of exercise on falls among community-dwelling older adults

There is strong evidence that exercise can reduce falls in community-dwelling older adults. A network meta-analysis examined the efficacy of fall prevention interventions in this population and found exercise alone reduced falls by 17% (OR = 0.83, 95% CI 0.70 to 0.99) and decreased injurious falls by 49% (OR = 0.51, 95% CI 0.33 to 0.79) [12]. This analysis also found multifactorial interventions such as exercise combined with vision assessment and treatment reduced the number of falls and injurious falls (OR = 0.68, 95% CI 0.49 to 0.94; OR = 0.17, 95% CI, 0.07 to 0.38, respectively) [12]. Comparable results were also seen with exercise, vision assessment and treatment, and environmental assessment and modification, which decreased the number of falls by 47% (OR = 0.53, 95% CI 0.29 to 0.97) and injurious falls by 70% (OR = 0.30, 95% CI 0.13 to 0.70) [12]. Another meta-analysis reported that exercise for older adults reduced injurious falls (i.e., bruising) by 37%, severe injurious falls (i.e., head injuries) by 43%, and falls resulting in fractures by 61% [13]. The findings were similar when trials with high risk or unclear risk of bias were removed from the analysis, but the heterogeneity between studies was greatly reduced [13]. Another meta-analysis where all types of exercises were pooled revealed that exercise reduced falls in older adults by about 20% (number of trials = 88; n = 19,478; mean age ≥ 65 years; pooled rate ratio = 0.79, 95% CI 0.73 to 0.85, $p < 0.001$), and this estimate was unchanged when only trials with a low risk of bias were included [14].

Effect of exercise on falls among individuals with Parkinson's disease or cognitive impairment

Individuals with Parkinson's disease experience balance dysfunction and postural instability that can increase the frequency of falls and fall-related injuries [15]. A meta-analysis revealed that exercise can prevent falls in individuals with Parkinson's disease (OR = 0.47, 95% CI 0.30 to 0.73) and cognitive impairments (OR = 0.55, 95% CI 0.37 to 0.83) [14]. Another systematic review and meta-analysis of 8 moderate-to-high-quality trials with 483 participants found physiotherapy interventions improved balance in individuals with Parkinson's disease, measured on the Berg Balance Scale, by 5.98 (95% CI 2.29–9.66, $p < 0.005$) compared with the control group; however, there was no significant effect measured on the Falls Efficacy Scale [16]. This systematic review also reported that repetitive high challenge balance training and incremental speed-dependent treadmill training can help improve range of motion, endurance, gait parameters, functional reaching activities, postural stability, and balance [16].

For whom is the effect of exercise on falls less conclusive?

Pooled estimates of 3 comparisons on the effect of exercise on falls in individuals with stroke suggest a potential for benefit, but the confidence intervals are wide and not significant (95% CI 0.42 to 1.32, $p = 0.31$, I^2 39%) [14]. Fall prevention research targeted to individuals with visual impairments is limited [17] and pooled estimates from three trials (n = 539, RR 1.05, 95% CI 0.73 to 1.50, $p = 0.81$, I^2 30%) do not support a definitive effect of exercise on falls [18]. Similarly, the effects of exercise on falls in individuals who have recently been discharged from hospitals are also less conclusive; a meta-analysis of two studies found that home exercise interventions significantly increased the proportion of fallers (OR = 1.74, 95% CI 1.17–2.60) [19], and one of the studies reported that even though mobility improved, the risk of falls increased [20]. The Canadian "Recommendations for Preventing Fracture in Long-Term Care" indicate that the recommendations may need to be different depending on a resident's fall or fracture risk, such that exercise (specifically balance, strength, and functional training) may be effective in lower risk residents for preventing falls and the number of older persons falling, but in high-risk residents, the risk of falls may be increased, so they recommend balance, strength, and functional training exercises only when such exercises are part of a multifactorial intervention to prevent falls [21]. Individuals recently discharged from a hospital may benefit from a physiotherapy-prescribed tailored program or a seated or standing weight-bearing program [20, 22]. Standing strength training resulted in fewer musculoskeletal adverse advents

and improved balance measures more than the seated program [22]. It may be prudent to consider a multifactorial or multicomponent approach (e.g., exercise plus home safety assessment, address visual impairment) for clinical populations where fall risk is high and the effect of exercise as a single intervention is less well established [23]. However, the effects of exercise in these populations should not be discounted, as multifactorial interventions that are reported as effective often include some form of exercise [12, 21]. That said, it may depend on what is contributing to risk. For example, a randomized control trial in individuals with visual impairment reported that home hazard modification as a single intervention was more effective than when exercise and home hazard modification were combined [24]. If the goal is to prevent or reduce the level of frailty, physical activity interventions were consistently identified in a scoping review as one of the only effective interventions [25].

What types of exercises are effective for preventing falls?

A meta-regression revealed that the most effective programs in community-dwelling older adults were those that involved the following: (1) accumulating at least 3 h a week of exercise; and (2) exercises that provide a high challenge to balance. The combination of an exercise program that includes 3 h a week of exercise and provide a high challenge to balance resulted in a fall risk reduction of almost 40% [14]. High challenge balance interventions were also effective at reducing falls in recurrent fallers [26]. High challenge balance exercises were characterized as those that involve reducing the base of support (e.g., feet closer together or standing on one foot), moving of the center of gravity to the limits of stability (e.g., leaning forward as far as you feel comfortable), or reducing contact with supporting objects (e.g., avoiding holding the wall), or a combination of the above. **Limits of stability** refer to the boundaries a person can move or sway within before having to alter their base of support; for example, if someone was standing upright and leaned forward or to the side as far as they could, there would be a limit of reaching where they would have to stop or adjust their foot position in order to not lose their balance. From a pragmatic perspective, the principle of specificity suggests that to improve balance one has to challenge it, while also minimizing fall risk, fear of falling, and frustration. A suggestion would be to prescribe a level of difficulty where the client/patient moves from steadiness to unsteadiness in a 20:20 ratio, such that the exercise should allow them to feel steady for at least 20% of the time while doing the exercise and feel unsteady for at least 20% of the other time [27]. If they are feeling unsteady for more than 80% of the time, it is probably too hard, while feeling steady for more than 80% of the time means it is too easy [27]. The exercise should feel challenging and the clinician may need to adjust the client's posture, position, or base of support or provide reach for a support object during periods of unsteadiness.

Another meta-analysis reported that reactive or volitional step training can reduce the rate of falls or risk of being a faller by almost 50%, where **reactive or volitional step training** was defined as "training of single or multiple volitional or reactive steps in an upright (standing or walking) position in response to an environmental challenge (e.g., stepping onto a target, avoiding an obstacle, or responding to a perturbation)" [28]. **Anticipatory or volitional balance challenges** involve self-initiated, expected balance challenges or exercises, while **reactive balance challenges** involve an unexpected perturbation that cause a person to lose their balance, or "react" to re-establish balance: examples include a nudge or push, or an unexpected obstacle.

Another meta-analysis suggested that home-based exercises and tai chi can reduce the number and the risk of falls [29]. There is also some evidence from a meta-analysis that yoga interventions result in small improvements in balance in community-dwelling adults 60 years and older and that there is a significant, moderate effect on mobility outcomes like gait speed and timed chair stands [30]. While supervised interventions are ideal for safety reasons and to ensure sufficient intensity and progression, home exercise interventions with intermittent (5–6 sessions over a year) supervision have also been shown to be effective in community-dwelling individuals [24, 31, 32]. Strength training did not emerge as having an additional effect in preventing falls in older adults, but is important for maintaining muscle strength and function for other activities [33]. Multijoint or functional resistance exercises can improve strength in muscles used in everyday activities such as standing from a chair or climbing stairs [33]. Further, strength training exercises can be selected so that they also challenge balance, e.g., step-ups involve movement of center of gravity and reducing base of support, and can be performed with or without a support object. To initiate a resistance training program, one might include one or more of each of the following: a pull exercise (e.g., elastic band row or pulldown, lat pull down, seated or standing row, chin-up), a push exercise (e.g., elastic band press, wall, counter or military pushup, bench press), multijoint lower extremity exercises (e.g., sit-to-stand, box squat or squat, step-ups, lunges), a shoulder raise or press, and exercises for back extensors and abdominals (e.g., bird-dog, supine thoracic and lumbar extension, weighted carry, plank, side plank). Selection of the exercise variation and amount of weight or intensity should be done so that it is sufficiently challenging, where the client can do ≤ 12 repetitions with good form before reaching muscular fatigue. Clinical judgement and supervision may be required to decide to progress to higher intensities, e.g., < 6 repetitions maximum. While there is less evidence supporting the fall

prevention efficacy of exercises for back extensor muscles or abdominal muscles, a systematic review and a recent high-quality randomized control trial suggest that they can improve posture in people with hyperkyphosis, which may indirectly influence balance [3, 34]. Further, hyperkyphosis may be independently associated with incident non-spine fractures [35].

What are examples of balance exercises?

Balance training involves the efficient transfer of body weight from one part of the body to another and may challenge specific systems, such as the vestibular system, the central nervous system, the visual system, and tactile sensation [36]. **Static balance training** challenges balance while the person is standing in one place and requires them to maintain postural control by continuously correcting sway around the body's center of gravity (e.g., standing on one foot). Examples of static balance challenges include standing with a narrower base of support (e.g., feet together, semi-tandem, tandem stance, one foot), while reducing contact with support objects, such as a counter or assistive device, or reducing reliance on systems important for balance, such as closing ones' eyes. **Dynamic balance exercises** involve maintaining stability while the center of gravity is moving, and provide a greater challenge. Examples include lunges and step-ups or activities such as dancing that involve shifting or transferring weight while moving. Tai chi is also considered a dynamic balance challenge because it involves three directional movements. More challenging balance training might include anticipatory postural control challenges, such as obstacle avoidance or changes in the surface or the incline; examples include throwing a ball at an individual and having them catch it or hiking on uneven ground where obstacles are present (see Fig. 1 for more examples). Reactive postural control (e.g., non-volitional response to a sudden loss of balance) can be trained with reactive stepping or perturbation training [28].

Adherence to exercise

Physical activity has numerous physical, psychological, and social health benefits and carefully designed exercise programs can prevent falls, increase muscle strength, and enhance balance in older adults; achieving and maintaining these benefits depend on continued participation. A systematic review found retention and adherence rates to exercise in older adults were suboptimal but some factors associated with improved attendance include supervised programs, higher socioeconomic status, living alone, better health status, better physical ability, better cognitive ability, and fewer depressive symptoms [37]. Strategies that may improve adherence to physical activity interventions in individuals with chronic conditions include self-monitoring, goal-setting, problem-solving, feedback on behavior, social support, instruction on how to perform a behavior, action planning, and graded tasks [38]. Meta-analyses did not show superiority of any task over the other, but the review did find implementing 8 or more tasks had a small significant overall effect (pooled SMD = 0.29, 95% CI

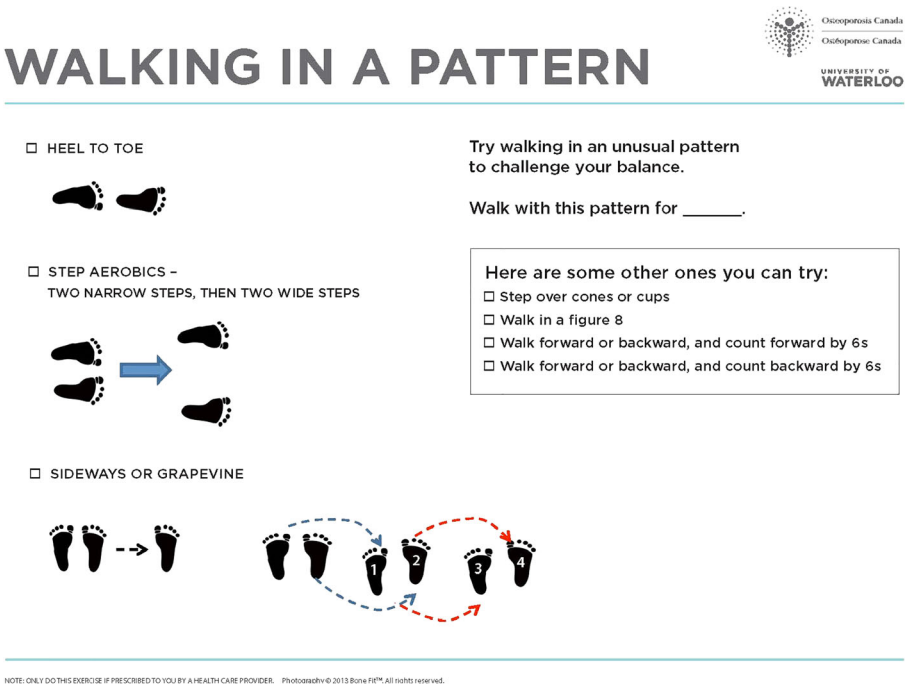

Fig. 1 Illustration of walking patterns to challenge balance

0.19–0.40, $p < 0.001$) compared with using less than 8 (pooled SMD = 0.08, 95% CI 0.11–0.27, $p = 0.41$) [38].

Safety considerations

Adverse event reporting in clinical trials of exercise is suboptimal, although it is improving [39]. Adverse events associated with resistance training were most often non-serious (e.g., muscle strain, pain, or discomfort) and were more common in individuals with impaired health or function or with a sedentary lifestyle, and in trials that applied high-intensity resistance training [39]. For certain populations (e.g., residents in long-term care, in hospital, or recently discharged, stroke, visual impairment), exercise may need to be delivered as part of a multifactorial fall risk assessment and prevention program. Individualizing exercise selection and progression to ensure both safe and sufficient intensity is fundamental to good exercise prescription. Individuals with Parkinson's disease may consider participating in exercise when mobility is best, which may occur approximately 1 h after taking medication, but the best timing in relation to reaction to medications may vary across individuals. There is a need to consider conditions that could be exacerbated during exercise (e.g., respiratory compromise, cardiovascular disease, poor blood glucose control) and the patient's preferences and values (e.g., ability to pay for services or preference for a home- vs. a center-based or a group exercise). However, balance exercises, particularly static balance exercises or slow-moving dynamic balance exercises, would pose less of a risk of dyspnea, angina, or other issues than moderate intensity aerobic exercise, and arguably it is better to first improve gait and balance before prescribing more challenging exercises like brisk walking. Where possible, a clinician should seek out an exercise physiologist, physical therapist, or relevant community program in their local community to coach their patients. Below are some examples of resources that can be used to support exercise prescription when exercise professionals are not available.

External resources

Prevention of Falls Network Earth (ProFaNE) is an online community with a variety of resources related to fall prevention. Cost of access is £12 per annum (http://profane.co/).

Otago Exercise Program This is a home-based exercise program to prevent falls in older adults and consists of individually tailored strength and balance exercises of increasing difficulty combined with a walking plan that has been tested in several clinical trials [24, 31, 40]. A meta-analysis of all the combined data found a 35% reduction in the number of falls and fall-related injuries (IRR = 0.65, 95% CI 0.57–0.75; and IRR = 0.65, 95% CI 0.53–0.81, respectively) [41], and this meta-analysis has been corroborated by a more recent meta-analysis that found pooled estimate decreased fall rates by 32% (RR = 0.68, 95% CI 0.56–0.79) [42]. The risk of a serious or moderate injury as a result of a fall was no different between the Otago exercise group and the control group (RR = 1.05, 95% CI 0.91–1.22). The Otago Exercise Program has also been found to be cost-effective compared with home safety interventions and cataract surgery [43]. A variety of downloadable booklets are available through Later Life Training: http://www.laterlifetraining.co.uk/llt-home-exercise-booklets/. Audio files can be purchased: https://www.laterlifetraining.co.uk/courses/otago-exercise-programme-leader/otago-strength-and-balance-home-exercise-programme-audio/.

LiFE (lifestyle-integrated functional exercise) program LiFE combines behavior change techniques (e.g., planning, self-monitoring, habit formation) with exercise prescription, where participants are taught in 1:1 sessions to integrate balance and strength challenges into daily activities. The participant is taught each movement and develops a plan for when and how to integrate each movement into the day. Examples include practicing the tandem stand in the kitchen while waiting for the kettle to boil or heating food in the microwave. A preliminary trial ($n = 34$) showed a 77% reduction in falls (RR = 0.23, 95% CI 0.07–0.83), but the study was not sufficiently powered [44], while another randomized parallel trial ($n = 107$) by the same authors found a significant reduction of 31% in the rate of falls compared with the control group (IRR = 0.69, 95% CI 0.48–0.99) [32]. For more information about the LiFE program, please visit the following link: https://www.laterlifetraining.co.uk/life-lifestyle-integrated-functional-exercise-reducing-falls-and-improving-function/.

The *Too Fit To Fracture* initiative resulted in the development of physical activity and exercise recommendations for people with osteoporosis, in partnership with Osteoporosis Canada [3, 45]. The recommendations were translated into free downloadable resources (https://osteoporosis.ca/health-care-professionals/clinical-practice-guidelines/exercise-recommendations/). This link includes:

- A one-page summary of the recommendations, with examples (PDF available in English, French, Chinese, and Punjabi), was designed for physicians to embed in electronic medical records as a handout to introduce different types of recommended physical activities and provide a link to additional resources;
- A comprehensive booklet that can be read online or downloaded (available in Canada in print) for patients, available in English and French, provides detailed

guidance on aerobic physical activity, beginner resistance training, and balance exercise, as well as safe movement for people with osteoporosis;
- Videos featuring personal interviews with individuals with osteoporosis explaining their story and demonstrating example exercises prescribed for them. One video focuses on a 90-year-old woman with vertebral fractures and a number of recent falls. The others include a male with secondary osteoporosis, a middle-aged female with osteoporosis, and an older female with osteoporosis.

Clock Yourself An innovative app is available for Android and Apple devices (http://clockyourself.com.au/) that guides users in step training and there is also an accompanying workbook for those who do not use electronic devices. To date, there are no clinical trials that have tested the Clock Yourself app, but the program is similar to the volitional stepping interventions mentioned under "What types of exercises are effective for preventing falls". The user visualizes a clock on the floor and numbers are called at random for the person to step to. The duration and speed are adjustable, and there are five levels designed to progressively introduce more complex tasks (e.g., other physical and cognitive challenges) to train an individual to improve balance and stepping.

Case study

Mrs. A is a 77-year-old, married female who lives at home. Her medical history includes type 2 diabetes mellitus, hypertension, and insomnia. She enjoys gardening, playing with her grandchildren, and walking her dog daily. She has had three falls in the past 6 months and is concerned about her balance. On examination, Mrs. A is observed to have difficulty getting into and out of a chair without using the arms for support.

The plan for Mrs. A

In accordance with the American Geriatrics Society/British Geriatrics Society Clinical Practice Guideline for the Prevention of Falls in Older Persons, individuals who present with a fall in the past 12 months should have their gait and balance assessed by a clinician [46]. Gait and balance can be evaluated with the Timed Up and Go test [47], the Berg Balance Scale [48], or the Performance-Oriented Mobility Assessment [49], and if needed, a multifactorial fall risk assessment may be done that includes a medical history, a physical exam, a cognitive and functional assessment, history of falls, medications, visual acuity, neurologic impairment, muscle strength, heart rate and rhythm, postural hypotension, feet and footwear, and environmental hazards. Any risks identified are to be treated or addressed as part of a multifactorial intervention, and an individually tailored exercise intervention is recommended as part of that [46].

She reveals that while she walks her dog daily, her walks are less than 10 min; and she has grown increasingly concerned about being slower and a little unsteady at times. Her concerns suggest that balance training should be the primary therapeutic goal. Because she has difficulty with getting in and out of the chair without using arms for support, you will select resistance exercises that also challenge balance, to improve both functional strength and balance. As a starting point, she could learn how to perform a sit-to-stand using a hip hinge (lower extremity functional strength), wall pushups with feet together (upper extremity functional strength), standing theraband pulldown (upper extremity strength), and a step-up, using the handrail for support (lower extremity functional strength and dynamic balance). She should perform 1–2 sets of 8–10 repetitions of each exercise three times per week at an intensity where the last few repetitions are difficult. She should progress the intensity over time by either increasing the number of sets, increasing the amount of resistance, or changing the difficulty of the exercise. She could perform a standing “bird-dog” (alternate arm and leg raise or shoulder flexion and straight leg hip extension while engaging core to maintain neutral spine) at the counter to target back extensors and core, which also challenges balance by reducing base of support, while still holding a support object; hold each repetition for 3 s and perform 2 sets of 5 repetitions on each side to start. For balance training, she could try a heel to toe walk, or **tandem walk** exercise as shown in Fig. 1 (along with other types of patterned walking). To see if this exercise is appropriate, the clinician should ask the client to walk as if on a tightrope (or demonstrate), and observe to see if it provides sufficient challenge, but can also be done safely (e.g., 20:20 rule), while holding onto either a counter or wall, or without a support object. She could also try the Clock Yourself app for 3 min a day. Ideally, she should consult an exercise professional to learn how to perform these exercises with good form, to select an appropriate intensity, and to progress the intensity over time. Sufficient intensity and progression are critical. Most of these exercises are demonstrated in the Osteoporosis Canada videos found here: https://osteoporosis.ca/health-care-professionals/clinical-practice-guidelines/exercise-recommendations/.

Conclusion

There is very strong evidence that exercise as a single intervention is effective for reducing falls in community-dwelling individuals, including several populations that may be higher risk (e.g., individuals with Parkinson’s disease, cognitive impairment). Exercise programs that involve 3 or more hours a week and provide a high challenge to balance are the most effective. Both reactive and volitional stepping interventions

also reduced falls among older adults. It is still unclear whether exercise as a single intervention is effective for reducing falls in individuals who have experienced a stroke, recently discharged from the hospital, or living in long-term care but there is some evidence that multifactorial fall prevention programs may be useful. Individuals who are blind or visually impaired can also benefit from a multifactorial fall prevention program.

Compliance with ethical standards

Conflict of interest Isabel B. Rodrigues has received graduate scholarships from Osteoporosis Canada and the Canadian Institutes of Health Research. Lora M. Giangregorio has received operating funds related to this work from the Ontario Ministry of Health and Long Term Care, Osteoporosis Canada, the University of Waterloo, the Canadian Institutes of Health Research, and the Bloomberg Manulife Prize.

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Learning objectives On completion of this article you should be able to:

1. Understand the findings of recent research regarding the efficacy of exercise to prevent falls in older adults;
2. Identify examples of the type of exercises to reduce the rate of falls and the risk of falling in older adults;
3. Recognize some basic terminology (in bold) related to balance.