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Review Article

Which strength and balance activities are safe and efficacious for individuals with specific challenges (osteoporosis, vertebral fractures, frailty, dementia)?: A Narrative review

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Abstract

Physical activity guidelines advocate the inclusion of strength and balance activities, twice a week, for adults and older adults, but with caveat that in some individuals there will be certain movements and activities that could lead to adverse events. This scoping review summarizes the evidence about how safe and efficacious these activities are in older adults with specific challenges that might make them more prone to injury (e.g. having recently fractured or at risk of fracture (osteoporosis) or those who are frail or who have cognitive impairment). The review identified that for prevention of falls in people with a falls history and/or frailer older adults, structured exercise programmes that incorporate progressive resistance training (PRT) with increasing balance challenges over time are safe and effective if performed regularly, with supervision and support, over at least 6 months. Some minor adverse effects mainly transient musculoskeletal pain) have been reported. For those with a higher risk of falls and fractures (very poor balance, vertebral fractures), supervised structured exercise programmes are most appropriate. People with diagnosed osteoporosis should be as active as possible and only avoid activities with a high risk of falls if they are naïve to those activities. For those in transition to frailty who have poor strength and balance, exercises that are known to help maintain strength and balance (such as Tai Chi) are effective in preventing a decline in falls risk. For the very frail older adult, supervised structured exercise that has PRT, balance training and some endurance work, supervised and progressed by a trained person are advocated.

Keywords: Strength, Balance, Frailty, Falls, Adverse Events

Introduction

For the vast majority of adults and older adults, taking part in activities that improve muscle and bone strength and balance (hereafter MBSBA) will be safe and will help maintain or improve function, irrespective of age or health[1]. However, as we age, we are not a homogenous group and many organisations catergorise older adults (over the age of 50) into three groups, not based on age, but on function and current activity levels. For example, the World Health Organisation describes three groups, the 'physically fit-healthy, the 'physically unfit, healthy' and the 'physically unfit-unhealthy'. The National Service Framework for older people describes 'entering old age', 'those in the transition phase' and 'frailer older people'[2].

The addition of MBSBA to the UKs physical activity guidelines are appropriate to all older people, whichever phase of ageing or specific ageing group they are in. MBSBA are recommended for people with diagnosed osteoporosis[3,4], for those who are frail and sarcopenic[5-8] and for those with

D. Skelton is a Director of a not for profit training company, Later Life Training, which provides training to health and leisure professionals to deliver strength and balance training. A. Mavroeidi has nothing to disclose.

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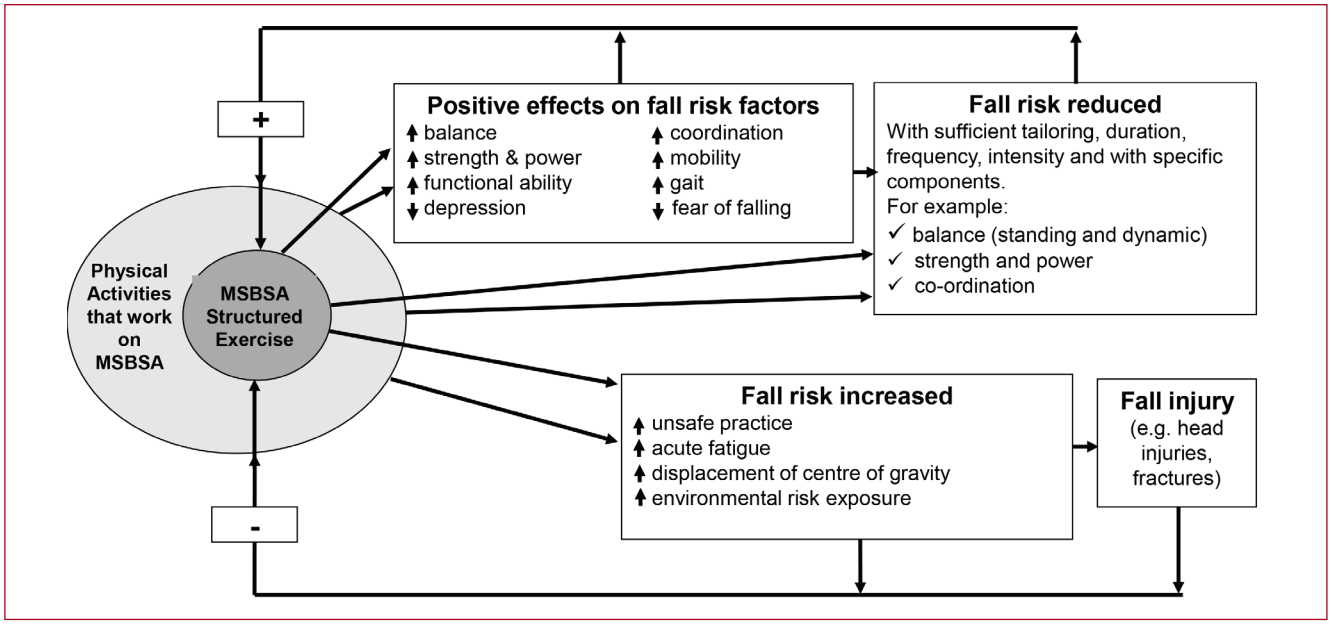

Figure 1. Potential risks and benefits of muscle and bone strength and balance structured exercise programmes and physical activities that can improve strength and balance. *(Adapted from[14]).*

cognitive impairment[9]. However, all these recommendations come with caveats that in some individuals there will be certain movements and activities that could lead to adverse events (such as falls and musculoskeletal injuries) without good technique or if they are particularly deconditioned. As such, some individuals may be best seeking out MBSBA that are supervised or tailored by professionals with training in exercise prescription for these special populations. The UK's National Service Framework for Exercise Referral acknowledges the experience and knowledge needed to work with people who are transitioning to frailty or who have medical conditions that may require adaptations to exercise programming[10]. It has been acknowledged that for the frailest older adults, those with vertebral fractures or osteoporosis but with poor balance, or those with moderate to severe dementia, structured and supervised exercise may be an important perquisite to safety and efficacy[1,5,9,11,12].

The strength and balance activities that are safe and effective for an older patient who has vertebral fractures or has had a recent hip fracture, will be very different to those for someone who has lower leg weakness but is still independently mobile. Exercise intensity is a major contributor to increased risk of falls and musculo-skeletal injuries at every age[13]. Injury prevention is an important priority and consideration within strength and balance activities[14] and Figure 1 exemplifies that although the benefits outweigh the risks, poor technique, fatigue and the effect this may have on the body's ability to respond to trips, an environment which can increase risk of falls, amongst other potential risks can increase the chances of a fall or injury as a result (Figure 1). Balance activities specifically need to challenge balance and therefore there is an increased risk of falls and fractures. Within strengthening activities, even stiffness and minor overuse injuries reduce enjoyment, may affect compliance and can often be avoided[13].

The safety margin of an exercise dose tends to decline with increasing age[15]. Exertional injuries are more common and are connected mostly with degenerative ageing processes. Acute injuries are more common in older people participating in sport activities which demand high coordination, reaction time, and balance capabilities, such as ball games[15]. Appropriate training programmes, the use of safe and familiar equipment, careful warming up and cooling down, the progressive training of neurophysiological functions (balance, coordination and reaction time) and muscle strength, and careful attention to technique, both for effectiveness and safety are essential aspects of injury prevention during many MBSBA activities[15,16].

This narrative review aims to determine what MBSBA are safe and efficacious in those older adults with specific challenges such as having recently fractured or at risk of fracture (osteoporosis) or those who are frail or who have cognitive impairment. The scoping of the literature in this paper, therefore, considers the safety and efficacy of progressive resistance training (PRT) strengthening exercise, of balance training and in some instances, of multimodal exercise regimens, where the inclusion of PRT and balance training both occurred, sometimes with the addition of aerobic activity. Where possible it describes the safety and efficacy of specific strengthening, balance

improving, or multimodal activities (eg. Tai Chi, Pilates, Yoga, Dance, Whole Body Vibration) as well as structured strength and balance exercise programmes. It also aims to identify practical resources to aid professionals working with older adults.

Materials and methods

This narrative literature review aims to describe and discuss the state of the science of a specific topic or theme from a theoretical and contextual point of view. There have been multiple systematic reviews looking at the efficacy of MBSBA and progressive resistance training (PRT, strength) and balance exercise so these were examined to look for any advice on efficacy and safety in frailer older people and in those who have had previous fractures or who have osteoporosis or dementia. Because there is little research or reviews that specifically focus on risks of injuries or adverse events associated with strength or balance exercise or activities, we elected to perform a scoping review of the literature. We conducted a search on NCBI PubMed, Google Scholar Position Stands and International Reviews of Physical Activity Evidence, Cochrane reviews that contained interventions based on strength and balance interventions or activities (for adverse events and risks of injury) and also on literature on strength and balance interventions (or both, multimodal) for frailer older people, those with osteoporosis and/or vertebral fractures and those with impaired cognition.

Results

These results of this narrative review have been structured first to present the evidence on the value MBSBA in prevention of falls and fractures as these are important for injury prevention in all the patient groups identified. Then evidence for MBSBA in the management of symptoms and specific outcomes for patient groups are presented. Some MBSBA activities have less evidence in these population groups so we present the existing evidence and discuss the need for potential tailoring of these activities and finally we give practical advice on injury prevention.

MBSBA In people with a history of falls

Falls are a leading cause of morbidity and mortality in older adults[17,18]. Not all falls are the same though; falls occur throughout our lives and some falls during MBSBA may almost be inevitable, such as taking part in skiing activities. However, if someone falls crossing their own hallway, or from a minor disruption of balance, then they are in need of MBSBA exercise to help maintain their intrinsic strength and balance enough to keep themselves upright[14]. There is a strong rationale for the commencement of MBSBA in people with a history of falls. Comparisons of fallers versus non-fallers have shown several muscle groups in the lower limb to be weaker, including quadriceps, hip and ankle strength[19,20]. Lower limb power (the speed with which a person can use their muscles) is also weaker in fallers and shows more asymmetry between limbs[20]. It seems likely that lower limb muscle power[14] is important in correcting a displacement or movement error– to prevent a trip an individual must have sufficient lower limb muscle power to get a stabilising leg (or enough upper body power to get a stabilising arm) out fast enough to prevent the fall or reduce the severity of the effects of the fall. Fallers have poorer function and balance than their non-falling counterparts[18].

Despite the considerable evidence that MBSBA is a key component of a multifactorial fall prevention intervention, some exercise-only interventions have shown little or no effect on falls rates despite improvements in known risk factors (eg. strength)[21]. There have been many systematic reviews on exercise to prevent falls. The first significant review showed that there were many exercise programmes that did not have a long enough duration, insufficient or absent PRT, or enough of a balance challenge to reduce falls[22].

One of the first effective falls prevention exercise studies was a home based PRT and balance exercise programme taught to women aged over 80 to do at home by a physiotherapist[23,24]. Exercises were individually prescribed from a set number of warm up, muscle strength and balance training exercises to perform 3 times a week for a year. They were also encouraged to walk outdoors at their desired pace building up to 30 minutes 2-3 times a week. The physiotherapist completed 6 home visits and maintained regular telephone contact for progression and support. The exercise group had a significantly lower rate of falls. This exercise approach, now called the Otago Exercise Programme (OEP), has been further investigated in many RCTs and is cost-effective when delivered with the support and home visits, and with similar progressions in ankle weights and balance challenge[17]. The effect of OEP in people with visual impairment is not so conclusive, with poor adherence rates to the home exercise programme, mostly due to concerns about doing the exercises correctly or needing further support for remembering the exercises[25,26].

In the UK, independent living frequent fallers halved their risk of falls with 9 months of weekly group balance and strength exercises, led by a postural stability exercise instructor, combined with twice weekly home exercises[27]. The women undertaking this falls management exercise (FaME) had significantly lower mortality and morbidity at 3 year follow up than the randomised control group. The exercise intervention consisted of progressive resistance, gait, balance, functional activity, floor work, endurance and flexibility training and was individually tailored in both type and intensity, with most exercises in weight-bearing positions. Specific examples of exercises include single side steps, double sidesteps, flamingo swings, sit to stand and squats. FaME includes the retraining and practice of getting up from the floor and to avoid a 'long lie' after a non-injurious fall[28]. FaME is feasible also in older people with visual impairment[29]. A large RCT comparing FaME and OEP

Effectiveness components of successful falls prevention structured exercise programmes
Highly Challenging balance exercise
High dose (50+ hours) (between 6mo-1yr)
Moderate to High Intensity progressive strength training of lower limbs
> 3 hours per week (can be combination of group and home)
Avoiding brisk walking or walking only programmes
Individually prescribed and supervised/supported by trained health or fitness professionals
Based on [22,32]; PRT = progressive strength training.

Table 1. Key components of strength and balance structured exercise programmes to reduce falls in community dwelling older people at risk of falls.

in low risk (1 fall or less in past year) older people recruited through GP practices found that FaME reduced falls by 26% ($p<0.042$) and increased MVPA by 15 mins per day ($p<0.001$)[30,31]. The OEP group also showed less falls but this was not significant[29,30], however, progression in PRT was rarely beyond 2kg and only 37% completed 75% of the home exercise prescription; and this group failed to increase their self-reported MVPA. This OEP group did not have the same home visit and telephone call support as in the original OEP trials and this may also have been a factor in adherence. The OEP Programme was perhaps not challenging enough for these lower risk participants[29]. This is a reminder that balance challenge differs in different functional levels and so for a programme to be effective it must be tailored to the individuals.

It appears that individualised and supervised MBSBA interventions are most effective for those at risk of falls, including those with significant risk of fracture. Within all studies, around half had an instructor to participant ratio of <10 in the supervised sessions[32]. Table 1 gives the key components of structured MBSBA exercise programmes to reduce falls in community dwelling older people.

Involvement in MBSBA that are not supervised or structured exercise

Interestingly, one long term (ten-year) follow-up of regular *walkers* showed the importance of specificity of strength and balance; although the health and mobility of the walkers was better than that of sedentary individuals, the walkers showed no significant reduction in the number of falls compared to the group who stopped regular walking[33]. *Brisk walking* appears to be detrimental to falls risk, as it is tiring and fatigue inducing and environmental hazards (like uneven pavements) present a greater risk when someone is tired[22,34].

Although *Tai Chi* has been shown to reduce risk of falls in people with mild deficits of strength and balance[18] modified Tai Chi over a 48 week period was not beneficial to reducing falls in an older (70+) group with signs of frailty[35]. It seems if Tai Chi has to be significantly modified to allow those with poor balance to participate (e.g. seated versions or versions without weight transfer) then Tai Chi loses its ability to improve lower limb strength, balance and falls risk.

Seven studies (a mix of RCTs and smaller controlled studies) were considered in a review of the effectiveness of *dancing* on the risk of falls in healthy older people and showed that although these studies showed positive effects on balance and strength, they were all small studies and very different types of dance style and concluded that there was not enough evidence to recommend dance for falls prevention[36]. A more recent review suggests that dance does not appear to reduce falls, but may improve fear of falling[37]. However, one study looked at the provision of dance sessions for residents of retirement villages (twice weekly 1hr social dancing classes, folk or ballroom dancing) over 12 months (80 hrs in total) and showed no reduction in falls risk, apart from a small apparent improvement in gait speed, particularly among ballroom participants[38]. There was an increased risk of falls (RR 1.7-2) compared to those residents who did not take up dancing. The authors suggested that modified dance programmes that contain "training elements" to better approximate structured exercise programs warrant investigation[38].

Literature evaluating the effects of *Pilates* on falls is scarce, and results were not conclusive[39]. Twelve weeks of *Yoga* practice was shown to be as effective as Tai-Chi and standard balance training in improving postural stability in older people[40] but falls were not assessed. In *frailer older people*, the exercise studies that measured falls as an outcome found that home based programmes without standing balance work or very adapted Tai Chi (mostly seated) did not reduce falls[41].

MBSBA for falls prevention in frailer older people, those with osteoporosis or dementia

The meta-analysis in the most recent systematic review on falls rates showed that exercise studies in *residential settings* did not reduce falls (pooled effect 0.9; 95%CI

	How often	Duration/Intensity	Cautions/Considerations
Strength Training	≥ 2 days a week	8-12 reps per exercise for legs, arms, chest, shoulders and back	Build intensity towards 80% 1RM with care over time. Start with body weight, progress to bands and weights. Avoid weighted repetitive exercise with forward flexion
Spinal extensor strength training	Daily	5-10 mins	Prone or supine (floor based) back extensor strengthening or seated with band, to protect spine
Spine Sparing during lifting/twisting	During all everyday activities	-	Safe lifting techniques, avoidance of rapid twisting (especially with weight); tighten abdominals and good posture
Balance Training	Daily	10-15 mins	Progress from static to dynamic. Support options if have poor balance.

Adapted from [12]. 1RM = 1 repetition maximum; reps = repetitions.

Table 2. Recommendations for strength and balance activities for people with osteoporosis.

0.72-1.12)[32]. Four studies showed significant reductions in falls rates and the others were either not significant or increased risk[32]. This is consistent with the Cochrane Review on interventions to prevent falls in residential settings, and suggests a multifactorial approach, including exercise, is best[42]. Much of this may be due to the intervention approach or the inclusion (or not) of MBSBA in these studies, as only 4 included moderate or high intensity PRT and only 5 included highly challenging balance activities.

There are few studies looking at MBSBA for falls prevention in people with *osteoporosis*, most have considered falls risks such as timed up and go or Berg Balance Scale. However, one such study showed that PRT exercise was more effective at reducing pain and the balance and co-ordination exercises were more effective in static and dynamic balance[43]. No one in either group had falls during the study. This is an area ripe for research.

There are also few studies looking at MBSBA for falls prevention in people with *dementia* but MBSBA exercise interventions reduced falls rate (pooled effect 0.55; 95% CI 0.37-0.83) in a recent meta-analysis[32].

Finally, most MBSBA exercise intervention studies, unlike medication studies, are not powered to show a significant effect on *fractures*. The Cochrane review on falls interventions for older people living in the community did a meta-analysis on 6 trials and showed a 66% reduction in fractures with multimodal strength and balance exercise programmes designed to reduce falls[18].

Fear of falling and balance confidence

Fear of falling in community-dwelling older adults ranged from 21% to 85% in one review[44], to 29% in people who had not fallen and 92% in those who had in another[45]. The consequences of fear of falling include an increased falls risk and number of falls, restriction or avoidance of daily activities, loss of independence, reduction in social activity, depression and a reduction in quality of life[46]. Indeed, self-reported unsteadiness is independently associated with increased risk for fear of falling, fear related activity restriction, falls and future disability[47]. Therefore, as an independent risk factor for falls and for lack of activity, it is important to address this. Interventions have included cognitive behavioural therapy, a hip protector intervention, strength and balance exercise programmes and Tai Chi[48]. Exercise and physical activity interventions, including multimodal (gait, balance and functional training), strength or resistance training, Yoga, and 3D training such as Tai Chi and Qigong are associated with a small to moderate reduction in fear of falling[49]. There was weak evidence that the effect of exercise interventions on fear of falling is larger where the intervention involved group exercises rather than individual exercises[49]. Other MBSBA activities may also be efficacious at reducing fear of falling, including Wii training and water based exercise[19]. Characteristics that were common among interventions that demonstrated efficacy included ongoing support such as weekly sessions, extended treatment periods and booster sessions[19]. A lack of balance confidence is also common in older people, but balance confidence is also improved with strength and balance exercise programmes[29] and Tai Chi[50].

MBSBA In people with diagnosed osteoporosis

A particular concern about taking part in MBSBA, or indeed any physical activity, for people with osteoporosis is the risk of a fall and potentially a life changing hip fracture[14]. A diagnosis of osteoporosis is associated with a 2-3 fold increased risk of sustaining a fragility fracture[51]. More than 95% of hip fractures occur as a consequence of a fall, so strategies to optimise bone strength and reduce fall risk are likely to prevent fractures most effectively[4]. Several studies have shown good benefits of individualized multimodal exercise for osteoporosis patients, such as improved balance and strength after 20 weeks, reduced pain and improved muscle function after only 6 weeks[52].

Two consensus reviews on physical activity and exercises that are safe for people with osteoporosis suggest that anyone with osteoporosis should aim to meet physical

activity guidelines for health, and engage in regular PRT and balance activities to reduce their risk of falls in the future[4,12]. Both reviews recommend high intensity PRT[4,12]. This level of strength training, however, may contribute to a higher chance of musculoskeletal injuries. They recommended that if people are not naïve to physical activities they should be encouraged to participate fully in any activity that may help improve bone strength. Intensity should be progressed carefully, people with *vertebral fractures* or *frailty*, should be supervised but start with body weight and resistance bands[12,53] and high intensity aerobic activity should be avoided as the risk of a fall is high[12,52]. They also suggest that professionals working with people with osteoporosis, or on diagnosis, should consider providing examples of how to move more safely during exercise (eg. weight lifted should be held close to the body and with posture muscles engaged) or activities of daily living[12]. Table 2 summarises the recommendations for MBSBA for people with osteoporosis.

Those who have suffered vertebral fractures are more likely to have kyphosis (forward flexed posture). Kyphotic posture is associated with impaired balance[54]. Specific strengthening exercises of the back extensors strengthen the muscles[55] that oppose kyphotic curvature in the thoracic spine, so back extension strength exercises may indirectly reduce falls risk as well as reduce the future chances of vertebral fracture[55]. In one large study, 64% of people with kyphosis had had a fall in the previous year and 35% of them had an injurious fall[56]. This increased poor balance and risk of falls also suggests care with MBSBA which might lead to exposure to risk of a fall. Exercise that is individually tailored by a physical therapist or instructor with training in osteoporosis, or designed for individuals at high risk of falls and fracture is recommended for *frailer individuals* or those with *vertebral fractures*[4,12].

In those aged 65+, functional status is often affected for up to a year after a fracture leading to reduced physical activity and functional decline[57]. Following a fracture, it is recommended that a physiotherapist directs the exercise prescription and when exercise should start, depending on the healing time and the fracture site[12]. A recent review showed that structured exercise (PRT and multimodal) produced small improvements on overall mobility after hip fracture[58].

Involvement in MBSBA that are not supervised or structured exercise

Two reviews have recommended that people with diagnosed osteoporosis avoid rapid, repetitive, weighted, or end-range (i.e., movement to the end of the range of motion) rotation or flexion of the spine during exercise, such as lifting weights with a flexed spine, sit-ups and end of range yoga and pilates postures[4,12]. They also suggest that high-impact exercises that require rapid and/or loaded twisting, or explosive or abrupt actions (eg. golf, tennis) be avoided unless these activities are important and regularly practiced by the individuals already. Both reviews suggest that if people are naïve to these movements (have not been regularly engaging in practice of these movements) then the risks may outweigh the benefits[4,12]. However, those with a history of participating in a sport or activity will have the skill and body awareness to continue it safely, if they are taught or modifications, such as moving to mid-range only, to ensure spine integrity. Of note here is that there is currently a Consensus Statement being produced by the UK's National Osteoporosis Society on exercise recommendations for people with Osteoporosis that will be finalised late 2018. This will be a more in depth review and consensus of the adverse event literature.

The effect of whole body vibration exercise on BMD in patients with postmenopausal osteoporosis was also reviewed in a recent paper[59]. Seven out of 12 articles showed an improvement in BMD and modifications in bone biomarkers[60].

MBSBA in frailer older people

Diagnosed frailty is characterised by a loss of physiological reserve such that even minor immobilisations or infections can render a person unable to rise independently out of a chair, or remain independent[11]. The most frequent frailty definition focuses on the evaluation of five domains: weight loss, exhaustion, low leisure time activity, low gait speed, and low grip strength[61]. Frailer older people have worse balance scores than those in transition (pre-frail) older people[62], particularly in the presence of foot health problems[63]. Foot pain and peripheral neuropathy were strongly associated with balance, activity levels, fear of falling and poor mobility[63]. One study looking at activities prior to hip fracture, found that 11% of fractures occurred during 'balance-challenging activities', with no further detail except that for someone frail, this could be as simple as carrying something and not having access to a walking aid or handrail[64].

One of the first PRT studies in care home residents (mean age 90) showed that a 3 month supervised PRT exercise programme doubled their leg strength[65]. Another study showed improvements in activities of daily living and indoor mobility in patients with dementia in care homes[66]. In over 75 year olds, PRT over 12 weeks regains 20 years worth of lost strength[67], although functional ability improves better if functional strength training is used rather than just focusing on building strength in individual muscle groups[68]. PRT and multimodal strength and balance exercise is recommended to counteract age-related muscle wasting and sarcopenia[69], because of its ability to promote net muscle protein growth[70], and combined with balance exercise, to manage frailty[2].

PRT performed alone or in a multimodal exercise intervention leads to improvements in muscle strength (7-37%), muscle mass (3-7.5%), muscle power (8%), and in functional capacity (5-58%), although some studies did not show enhancements[8]. The studies that showed positive

Who	Duration (months)	Type	Freq. (x per week)	Time per session (mins)
Aged 70-85 Mobility Limited (Chale et al. 2013)	6	PRT, supervised and progressive	3	45-60
Sarcopenic women (Kim et al. 2012, 2013; Shahar et al. 2013)	3	Multi-component	2	60
Sarcopenic men (Zdzieblik et al. 2015)	3	Multi-component	3	60
Retirement Village (Daly et al. 2014)	4	Multi-component	2	60
Retirement Care (Oesen et al. 2015)	6	PRT	2	45-60
Frail women (Kim et al. 2015)	3	Multi-component	2	60
Frail (Tieland et al. 2012)	6	PRT	2	45-60
Care homes (Rosendahl et al. 2006)	3	Multi-component	2.5*	60
Care homes (Bonnefoy et al. 2003)	9	Multi-component	3	60
Hospitalised men (Miller et al. 2006)	3	PRT	3	45-60

*Key: PRT – Progressive Resistance Training; Multimodal = strength and balance exercise programme; * 5 times per fortnight. Adapted from [7], where individual study references can be found.*

Table 3. Effective frequency, duration and time for positive outcomes to muscle strength in frailer older people.

outcomes had a frequency of 1-6 sessions per week, a training volume of 1-3 sets of 6-15 repetitions and intensity of 30-70%1-RM, with supervision in progression[8]. One-hour supervised PRT sessions on alternate days of the week, with a 10 min aerobic warm up first and leaving a 2-minute rest break between sets, 2-3 times per week, were associated with improvements to falls risk (timed up and go, functional reach, tandem walk balance test), reductions in activity limitation, improved capacity to rise out of a chair, ambulate and make turns, standing balance and gait speed[71].

Although higher training intensities are superior to lower intensities in terms of maximal strength per se, the intensity appears less important for improving physical function strength[72]. It appears that PRT mimicking activities of daily living, such as sit to stands, and functional repetitive movements using body weight and resistance, confers greatest benefits on function[68]. Power training (incorporating speed and propulsive movements into the PRT) has been shown to be a particularly effective method for improving strength, power and functional performance in frailer older people[68,72,73] including those living in residential care[74]. Propulsive power training appears to confer similar benefits to muscle size as more traditional strength training[73]. However, studies delivering PRT or multimodal structured exercise programmes with frailer older people do not always improve strength, balance, walking ability or reduce falls[41,75].

The studies that *did not* show benefit to *strength* in frailer older people included ones which provided exercises for people to do at home, without supervision or much support, or weight bearing only exercise (did not progress to PRT), or ankle weights that did not progress past 1.5kg[41]. The studies which *did not* show improvements in balance included ones which either did not challenge balance specifically, exercises were just in standing without challenging balance or did not include standing exercises at all[41,75].

Two reviews suggests that the effects on bone and muscle of PRT and multimodal (strength and balance) programmes are enhanced with protein and some multi-nutrient supplements[76,77]. However, if the individuals are well-nourished then nutritional supplements often did not confer additional benefit to PRT or multimodal exercise[7].

Beaudart's review (2017) showed in fact that the effective exercise interventions (a mix of PRT and multimodal supervised programmes) were between 3-6 months in duration, 2-3 times per week, for between 45-60 minutes and were progressive in nature, aiming at 65-80% 1RM[7] (Table 3). Two studies in nursing home residents, with a much lower duration (4-8 weeks) but a similar frequency or time, did not show significant improvements in strength[7]. Silva et al. (2017) also recommend PRT and multimodal exercise is supervised and continues for at least 6 months with sessions lasting around 60 minutes performed 3 or more times per week, for effectiveness on cognition, physical functioning, and psychological wellbeing in frailer older people[78]. Some argue that exercise in extreme frailty should be treated like a 'drug' with the same accountability in terms of exercise dose, duration, delivery method and supervision as delaying positive outcomes in this population with a short future lifespan is unethical[79,80]. Studies which have looked at outcomes of *supervised* multimodal exercise on outcomes comparing sarcopenic and non-sarcopenic older people have not shown differences in adverse events[81]. There are, as yet, few studies

which have examined MBSBA in patients in *hospital settings*, but functional exercise, involving transfer training (sit to stands) and balance activities, in a subacute hospital setting showed a reduction in falls within the hospital setting[82].

The importance of making PRT a long term lifestyle change is seen in a longitudinal study examining PRT exercise (mean age of 72.5 years) over a 5-year period[83]. The first group performed PRT (80% 1RM) throughout the entire 5 years and the second group stopped after 2 years. Both groups significantly improved muscle strength at the end of two years, but at the 5 year follow-up those that had stopped at 2 years had lost strength whereas those that continued got stronger[83].

Obese older adults who have very low muscle strength have poorer bone health and balance[84] so care must be taken in progression of balance work to avoid falls. A review considering the effectiveness of nutrition and exercise on body composition and muscle strength in sarcopenic obese older people found few studies, but one PRT intervention (supervised high-speed circuit resistance training) significantly improved strength and physical function[85].

Interventions aimed at increasing mobility in *cognitively impaired* or *chair/bed bound individuals* may actually serve to increase risk of falls if not suitably adapted and tailored. In these vulnerable older adults, sit to stand transfers could be seen as small bouts of low energy demand functional training that are achievable for older adults that are not able to engage in exercise programmes requiring a greater energy cost. A recent study looking at breaking up sedentary behaviour in residents from sheltered housing involved residents standing approximately once an hour to break up prolonged sitting and showed improvements in Timed Up and Go (balance) and 30s chair rise (strength) over a 10 week period[86], without an increased risk of falls. From a public health perspective, reducing sedentary behaviour and engaging in regular sit to stands may be a more feasible and less challenging approach to increase strength and balance in *frailer* older adults than taking part in more strenuous activities in order to promote health[86,87].

Involvement in MBSBA that are not supervised or structured exercise

Involvement in less structured or unsupervised MBSBA (such as sports or untailored group activities) reduces in advanced ages[88]. Whilst there is a plethora of evidence for structured MBSBA exercise programmes, there are almost no studies of unstructured or unsupervised MBSBA in frailer older people. There may be a limit at which people become *too frail* to benefit from balance exercise[22]. In terms of Tai Chi for balance (static and dynamic) improvements, active older people and those in transition to frailty *benefited* more than *older frail* individuals[89]. In one large RCT comparing the effects of a functional walking programme with Tai Chi in care home residents on falls risk found the risk of becoming a faller in the exercise groups increased significantly in the subgroup of participants who were classified as being frail (hazard ratio [HR]=2.95). For participants who were classified as being pre-frail, the risk of becoming a faller decreased with the effect becoming significant after 11 weeks of training (HR=0.39)[90]. For the frailer older adult, a chair based yoga programme was reported to be effective in improving mobility and reducing the fear of falling[91].

One study where care staff encouraged repetitive activity (not always supervised) of daily living tasks to try to improve strength and function (eg. repetitive activities included bed mobility, sitting to standing, and transfers to various surfaces and heights, taking longer routes to the lounge and outside walking routes). The study showed a short-term improvement in mobility not sustained beyond 3 months. However, 57% of the intervention group had falls compared to 42% of the control group[92].

It is well known that muscle function declines whilst frailer older people are in hospital, mostly due to effects of immobilistion on people who are close to thresholds of strength needed to remain independent. Up to 60% of older patients experience functional decline after hospitalisation[93]. *Frailer* older people (those who require a walker), those who report *unsteadiness* at hospital admission, and those with *cognitive impairment* are significantly more likely to suffer functional decline whilst in hospital[94,95]. Early mobilization following hip fracture surgery reduces medical complications and mortality, but may increase the risk of falling, because mobilisation in patients following hip fracture is a highly balance challenging activity for this population[2]. Yet a number of recent studies have shown that early standing and moving activity and sustained upright time reduces fear of falling and improves walking speed and timed up and go (falls risk) on discharge[96], and reduces length of stay[81]. There were few adverse events during the interventions so with support and supervision, balance challenging movements during mobilization and transfers appear safe and efficacious.

In patients following hospital discharge, a recent meta-analysis of MBSBA exercise interventions showed a pooled effect of 1.16 (95% CI 0.88-1.52) on falls, suggesting that these patients, who may be particularly deconditioned after discharge, are most at risk of increased falls with exposure to more risky movements without supervision[32]. Indeed, one study looking at home-based MBSBA exercises (based on OEP) given to older people who had recently been discharged from hospital (70% had fallen in previous year) showed an increase in falls compared to no exercise programme, although mobility outcomes were significantly better[97]. There were few adverse events as a result of the MBSBA, including low back, knee and calf pain and exacerbation of hernia symptoms. Pre-existing conditions (mainly musculoskeletal) limited progression of the exercises[97].

MBSBA in older adults with cognitive impairment

Dementia is a syndrome that impairs brain function and cognition and as severity of dementia increases over time,

the person with dementia often has increased difficulties with many important functions, including gait impairments, problems with postural control, reduced participation in physical activity and activities such as shopping[98]. However, even in mild cognitive impairment there are deficits in balance, gait and movement co-ordination[99,100]. These factors may partially explain the higher risk of falls and hip fractures in people with dementia compared with their peers without dementia[101]. Indeed, up to 50-80% of people living with dementia fall every year[102,103]. Therefore, it is important that strength and balance activities are maintained or increased to help reduce the impact of the dementia over time.

A review of the effectiveness of structured PRT and multimodal exercise programmes on strength, balance and mobility in people with cognitive impairment and dementia showed significant improvements in strength (30s chair rise and handgrip strength)[9]. This review showed also that balance (Berg balance scale, Functional Reach, Tinetti) was improved with multimodal exercise, Tai Chi, resistance and functional training[9]. Poorer physical function was a determinant of better response to exercise training, but cognitive performance did not have an impact. In almost all of the reviewed trials, the exercise training was conducted under the supervision of either the caregiver or professional staff. Most studies reported no adverse events. Those that did tended to be musculoskeletal pain, which was reduced after modification of the exercise or which eased over time. The authors concluded that people with various levels of cognitive impairment can benefit from supervised multimodal exercise for about 60 minutes a day, 2 to 3 days a week to improve physical function[9].

A recent review of exercise interventions on falls in people with dementia found that most exercise programmes concentrated on strength, balance, and mobility, and were established and supervised by physiotherapists, occupational therapists, or trained assistants[104]. In two of the studies, carers were actively involved in monitoring and encouraging participation between therapist visits. Exercises included climbing stairs, balance and transfer training, resistance work, dual tasking, and outdoor activities and equipment included gym equipment, ankle/hand weights, balls, and balance pillows[104]. Only one study reported exercise related adverse events (dizziness and muscle strain while exercising) but a number of studies reported that participants could not exercise without supervision for safety reasons. The reviews meta-analysis showed a significant reduction in falls rate and number of fallers with structured exercise programmes[104], confirmed in a more recent meta-analysis (pooled effect 0.55; 95% CI 0.37-0.83)[32].

One study, in community dwelling older people with Alzheimer's disease showed that the effect of structured strength and balance exercise (2 x pw for 1 year) on fall reduction was more potent in people with advanced dementia due to their inherent high fall rate[105]. However, in those with mild dementia, the decline in physical function was still slower than that seen in the control group who did not take part in the structured programme. Another study, in residents of care homes, found a falls prevention exercise programme maintained ability to ambulate and increased step height and gait speed (falls not measured) irrespective of cognitive impairment[106]. It certainly appears that strength and balance programmes are still effective and recommendations on frequency and intensity remain the same as for those without cognitive impairment, however, supervision and support becomes increasingly important as the dementia progresses.

Involvement in MBSBA that are not supervised or structured exercise

Unfortunately there are few studies on unsupervised exercise or on physical activities that might improve strength or balance in people with dementia. Many reviews have *walking* within multimodal interventions that included structured exercise but not as walking alone, for example[9,105,107]. Yoga is feasible in people with cognitive impairment (in smaller groups) and in some, but not all studies, there have been improvements in verbal and visual memory, executive function and verbal fluency[108]. The effects of yoga on mental health, particularly depression, anxiety, sleep, quality of life and self-efficacy are also shown in a number of studies[108].

Safety and efficacy of MBSBA in people with other health conditions

Adults with knee and hip osteoarthritis

MBSBA exercise that is adequately dosed (e.g. frequency, intensity) and progressive in nature demonstrated the greatest improvements in patient outcomes for pain reduction and mobility. Few adverse events are reported apart from occasional flare-ups of pain if the progression of strength training is too fast[109]. As many older adults have arthritis, a review on Tai Chi and osteoarthritis showed a reduction in pain, stiffness and improvements in physical function[110] and Tai Chi is now a conditional recommendation of the American College of Rheumatology for osteoarthritis of the hand, hip, and knee[111].

Adults with diagnosed neurological diseases

Even in those under the age of 55, if they have diagnosed neurological disease, 50% will fall each year due to impaired strength and balance[112]. Many people, on diagnosis of disease, start avoiding activity; particularly diseases which affect stability and balance. People with Parkinson's disease undertaking multimodal exercise sessions (which include strength, balance and aerobic activities) improve strength, balance, safety with mobility, fatigue, depression and quality of life without adverse events (e.g.[113]). Evidence suggests that a minimum of 8 weeks of structured exercise MBSBA can have positive effects that persist for 3-12 months after treatment completion[114]. Sustained strength training, Tai Chi or dance therapy lasting at least 12 weeks can produce long-term beneficial effects[114]. In Parkinson's disease, MBSBA

exercise interventions reduced falls rate (pooled effect 0.47; 95% CI 0.30-0.73) in a recent meta-analysis[32]. Improvements in static balance, lower limb strength and sway in patients with Parkinson's disease follow yoga programmes[115]. A systematic review of respiratory muscle training (most commonly using resistance based devices) for people with multiple sclerosis showed positive effects with no serious adverse effects[116].

Adults with stroke and heart disease

There is evidence that both muscle strength and muscle power are reduced after stroke (e.g.[117]). There is also evidence that strength training improves muscle strength after stroke[118-120]. Just as the UK physical activity guidelines, a number of other stroke and chronic disease guidelines recommend strength training 2 days per week[120-122]. The other key risk for stroke survivors undertaking exercise is from falls and fractures. In their review of circuit class therapy to improve mobility after stroke, English et al. (2010) found two studies reporting adverse events (i.e. falls) during therapy. None of the falls were serious but the risk of falls from participation in exercise should be carefully evaluated and session design measures (e.g. adaptations to pace, transitions between exercises and direction changes etc.) introduced to minimise this risk for stroke survivors[120,123]. In stroke patients, MBSBA exercise interventions did not significantly decrease falls rate (pooled effect 0.74; 95% CI 0.42-1.32) in a recent meta-analysis[32].

Adults with cancer

A Cochrane review looking at the effects of exercise on patients undergoing active cancer treatment found that exercise may have beneficial effects on quality of life, physical functioning and fatigue[124]. Positive effects of exercise interventions (most had resistance training at their core, with some adding walking, cycling and other activities), are more pronounced with moderate- or vigorous-intensity versus mild-intensity exercise programmes. There were few adverse events reported, mostly fatigue or musculoskeletal injury and none serious (such as lymphedema).

Are there any trends on injury from MBSBA with increased age?

This section covers an exploration of the literature on potential injuries and adverse events from MBSBA and strength and balance structured exercise programmes. Most evidence found was in the reporting of adverse events from structured exercise programmes as few reports on MBSBA gave any information on injuries.

Musculoskeletal Injury risk from strengthening activities

Overuse injuries appear to be the most prevalent musculo-skeletal injuries caused by exercise in older participants[16]. Ensuring a safe load on joints, bones and other support structures, through biomechanically sound positions, correct alignment and technique can reduce the risk of exacerbating an existing joint condition, such as arthritis. A series of systematic reviews of associations between physical fitness and chances of musculoskeletal injury risk found that poor hamstring or ankle flexibility, ankle and knee flexion strength, lower limb power and poor single leg balance performance were all risk factors for future musculoskeletal injury following exercise[125,126]. Although this review was in younger adults undertaking more extreme levels of strength and aerobic training, the risks for injury remain the same for older adults or those not used to strength or balance activities, particularly frailer older adults. This review highlights the need for adaptations and progressions in intensity meeting the needs of the participants. Cadore et al. (2013) did a review of adverse events in the structured PRT exercise programmes for frailer older people and found that 9/20 studies reported on adverse events and only 2 studies mentioned any. One mentioned that one individual got shoulder pain and another that the person dropped out for a medical reason related to the exercises[41], suggesting that in mostly supervised strength training, risks are minimal. In order to consider adverse events due to strength, balance or MBSBA interventions we conducted a search of all Cochrane Reviews that included MBSBA interventions in adults or older adults (Tables 4, 5 and 6). These highlight that strength training interventions for older people in the community or in residential settings, adults with hip or knee arthritis and adults with fibromyalgia have few adverse events, but mostly these interventions were supervised structured exercise and tailored to the individual (Table 4). Balance training interventions for older people in the community and residential settings, patients with chronic obstructive airways disease and those with low back pain also have few adverse events, but again these programmes were nearly always supervised and tailored (Table 5). Finally, in terms of MBSBA structured exercise, there were mostly few adverse events in older people living independently and in long term care, adults with chronic pain, post-menopausal women, individuals with vertebral fracture, hip fracture patients, stroke survivors and women with breast cancer (Table 6). Importantly, some fractures due to the interventions were seen in people with vertebral fractures and in frail patients following hip fracture, so there does appear to be a higher risk of injury with MBSBA activities in the frailest oldest adults and we therefore recommend that those that provide supervision and tailoring of programmes for these populations have training in safe exercise prescription.

We also reviewed the literature for injuries or adverse events within common unsupervised or untailored MBSBA.

Walking

Walking has many benefits to mental and physical health and is the most common activity reported in older people[38]. Higher intensity (moderate to vigorous)

Review Type/Name	Population	Strength Training	Adverse Events
Interventions for preventing falls[18]	Older people living in the community	Home-based high intensity quadriceps RT (10 wks) Progressive supervised high intensity RT (50min/session, 2x/wk for 13wks)	28 people had MSk injuries (eg. sore neck, bursitis of hip, strains)
Exercise interventions for fibromyalgia[149]	Adults with diagnosed fibromyalgia	Supervised progressive strength training (60-90min/session, 2x/wk for 21wks)	Exercise-induced pain or muscle soreness only reported at the initial phases of training
Strengthening exercises for knee osteoarthritis sufferers[150]	People with hip or knee osteoarthritis	60-80% of 1 RM high-RT vs 0-10% of 1 RM low-RT	5 people who were at the high intensity RT group experienced knee pain
Interventions for improving physical function[151]	Older people, resident in institutions or at home in the community	Progressive RT at moderate to high intensity by using exercise machines, free weights, or elastic bands	34 people reported pain (e.g. muscle, joint, lower back, knee) 2 experienced significant exacerbation of arthritic conditions

Key: RT = Resistance Training; MSk = Musculoskeletal, RM= Repetition maximum.

Table 4. Adverse events reported in Cochrane Reviews during or as a result of Strength Training.

Review Type/Name	Population	Balance Training	Adverse Events
Exercise for improving balance in older people[152]	People aged 60 or over living in the community or in institutional care	Mix of WBV, walking, cycling, general physical activity, 3D activity.	Few adverse events were reported but most studies did not monitor or report adverse events. Falls reported in multiple studies, but not more than the control groups.
Physical Rehabilitation[5]	Older people in long term care	WBV	1 person developed phobia 1 person groin pain 2 cases of lower limb tingling
Tai Chi for Chronic Obstructive Pulmonary Disease[153]	Patients with COPD	Tai Chi	No adverse events reported
Exercise for low back pain[154]	Adult participants aged 16 or older with acute, subacute or chronic non-specific LBP	Pilates	2 people reported minor shoulder pain 1 person reported knee pain

Key: 3D = 3-dimensional (eg. Tai chi, dance); WBV = Whole Body Vibration; LBP = low back pain; COPD = Chronic Obstructive Pulmonary Disease.

Table 5. Adverse events reported in Cochrane Reviews during or as a result of Balance Training.

walking is recommended for bone health and to prevent osteoporosis[127]. However, one study looking at the effect of 26 weeks of moderate- and high-intensity walking training on injury rates in older men and women found that leg and groin injuries occurred much more commonly in those that took part in the high-intensity group[128]. Another study evaluating the effectiveness of a walking programme supported by telephone coaching found that this programme did not prevent falls[129]. Indeed, an earlier trial in women who had sustained a wrist fracture, in which the risk of falls was increased from a brisk walking programme[34], and the meta-regression findings in Sherrington's review suggest walking should not be prescribed as a single fall prevention intervention and high-risk older people should not be told to walk briskly. The inclusion of individually prescribed walking in some successful interventions (such as the Otago Home Exercise Programme which looked at increasing duration rather than speed of walking), suggests that walking programmes may be carefully prescribed to older people in addition to other fall prevention exercises[32].

Review Type/Name	Population	Multimodal Training	Adverse Events
Physical Rehabilitation[5]	Older people in long term care	High Intensity Functional Exercise	1 person developed chest pain and another lost balance. Otherwise MSk injuries.
		Brisk walking with strength and balance stations around walk areas	5 falls during exercise sessions, one causing head injury.
		One to one sessions by physiotherapist (RT and balance)	More falls (and more serious falls) in intervention group, not during session but over course of study
Physical rehabilitation for chronic pain[155]	Adults (aged 18 years and over) reporting chronic non-cancer pain, including persistent (e.g. chronic back pain, fibromyalgia) and intermittent (e.g. migraine, dysmenorrhoea) pain, for at least three months	Any specified style of land-based exercise or physical activity such as one designed to improve strength, range of movement, balance, aerobic capacity, or a combination of any of the above	Most adverse events were increased soreness or muscle pain, which reportedly subsided after a few weeks of the intervention.
Exercise for improving balance in older people[152]	People aged 60 or over living in the community or in institutional care	Resistance and balance jump training	1 study reported 14 musculoskeletal injuries or symptoms
		Balance and strength training using free weights	1 study reported a fall in the session
		Standing strength and balance exercises using weight belt	1 study reported 22 people with soreness (lower back, hip and knee pain)
		Otago exercise programme	1 study reported 2 people with back pain.
Interventions for preventing osteoporosis[127]	Postmenopausal women	Training included walking, calisthenics and resisted strengthening	3 studies reported 75 falls in exercise vs 55 falls in control groups 11 studies reported 60 other events in exercise vs 5 in control groups (e.g. muscle soreness, joint pain, headache and itching)
Physical therapy for improving outcomes of osteoporotic vertebral fracture[3]	Individuals with vertebral fracture	Exercises included stretching, strengthening with weights and resistance bands and balance training	1 study reported 3 people having a fracture (rib/hip/metatarsal) , 1 study reported 1 person having irritation to tape 3 studies reported adverse effects possibly attributed to the exercise with 19 people reporting pain/ illness/injury, 4 fear of falling
Exercise for breast cancer sufferers[156]	Women who were diagnosed with breast cancer stages I, II, and III and who were undergoing adjuvant (including neoadjuvant) chemotherapy, radiotherapy, or a combination.	4 studies of aerobic and resistance training	1 participant with lymphedema 2 people with muscle soreness and 1 with musculoskeletal injury 9 people with musculoskeletal pain 1 person with knee discomfort
Physical therapy after hip fracture surgery[157]	Patients treated for a hip fracture at any stage during rehabilitation	weight bearing after surgery, and any other mobilisation strategies, such as exercises, physical training and muscle stimulation	1 study reported 3 adverse effects (1 rib fracture, 1 metatarsal fracture, 1 bruised ankle)
Physical training for stroke patients[119]	Adult stroke survivors who were considered suitable for fitness training	cardiorespiratory training or resistance training, or both (mixed training)	2 studies reported 40 falls in 158 participants allocated mixed training 7 exercising participants receiving suffered a cerebrovascular event and 1 a cardiovascular event

Key: RT = Resistance Training; MSk = Musculoskeletal.

Table 6. Adverse events reported in other Cochrane Reviews during or as a result of Multimodal Strength and Balance Exercise Training.

Cycling

In one large study from the Netherlands, looking at what activities that over 65s (mean age of 80 yrs) were doing prior to their falls injury hospitalization (N=5880), 14% of all injuries were cycling related[130]. However, cycling (which constitutes a balance challenge) is far less common as an activity in the UK (<1% of all 'transportation') than in the Netherlands (27%)[131]. The US also has low cycling prevalence, but also found facial traumas and fractures common in men and women who had been cycling at the point of injury[132]. A greater proportion of men than women sustained bicycle-associated fractures (35.7% vs 14.9%; P=3.1056×10-170), while more women than men sustained fractures associated with gardening (15.5% vs 6.1%; P=2.1029×10-97), outdoor activities (14.6% vs 7.7%; P=4.3156×10-50), and gym exercise (7.7% vs 1.3%; P=3.0281×10-114).

Tai Chi

There are more than 500 studies and 120 systematic reviews to assess the benefits of Tai Chi for 25 different conditions as well as for general health and fitness[133]. There is now plethora of evidence to support its role in 5 conditions: preventing falls in older adults in the community (and reducing fear of falling), osteoarthritis, Parkinson disease, chronic obstructive pulmonary disease, and cognitive functioning. Tai Chi is also one of the safest forms of exercise as evidenced by systematic review of 153 trials[134]. Only 50 included reported adverse events and the most common adverse events were minor and primarily musculoskeletal, such as mild knee and back pain; no intervention-related serious adverse events were reported.

Dance

There are many forms of dance movement, from tea-dances to ballroom dancing, folk, line and creative dance and perhaps some forms have greater effects on strength and balance than others. In a review of dance interventions in older adults health, there were improvements in strength (82% of studies), balance (80% of studies) and cognitive ability (80% of studies)[135]. Six studies used ballroom, 5 used contemporary, 4 used cultural, 1 used pop, and 2 used jazz. Most studies did not report on dropouts or adverse events[135]. In a ballroom dance programme (including foxtrot, waltz, rumba, swing, samba and bolero) in nursing home residents, 27% reported muscle discomfort, 10% cramp and 7% dizziness, which disappeared a few weeks into the intervention[136].

Pilates

The Pilates method of exercise is practiced on a mat or Pilates apparatus (body conditioning equipment) in private lessons or small groups. Systematic reviews show strong evidence for improvements in balance, and moderate (conflicting) evidence for improvements in muscle strength (mostly trunk and abdominal strength) in healthy older people[137,138]. Few studies report on dropouts or adverse events and there is a lack of robust trial methodologies to assess if these changes in strength and balance are unbiased[139].

Yoga

A recent systematic review suggests that yoga interventions resulted in small improvements in balance (static balance, sway, Berg balance) and medium improvements in physical mobility (gait speed, chair rise test, flexibility) in people aged 60+ years, but it is not known if these translate into prevention of falls or changes in strength[140]. There are some yoga positions and moves that have been recommended to be avoided in those with vertebral fractures[12,141].

Whole body vibration

Several RCTs of a long-term regimen (6 months) of whole-body vibration (WBV) exercise on muscular performance in the legs have shown improved strength and power in older people, including one with nursing home residents[142]. The addition of WBV to exercise programmes has been shown to increase strength and power more than exercise programmes without vibration[143]. A recent review of WBV showed that six studies did not report adverse events of the interventions, but in four studies, WBV training was associated with transient and mild adverse effects such as erythema, oedema, headache, knee pain without objective clinical signs, and itching of the legs or soreness during the first sessions, none of them were considered serious[60].

Practical resources and information for those working with a range of older adults

Practical resources for interpreting the strength and balance guidelines for the 'Actives', 'Those in transition' and 'Frailer older people' have been produced[144]. Those in transition will be moving from good health to poor health, from being fit to being unfit and from independence to dependence. This will include people who have been diagnosed with osteoporosis as nearly three quarters may start avoiding activity through fear of future fractures and lack of knowledge of benefits of MBSBA[145,146]. Those who are frail are 'operationalised' in the SSEHS interpretation documents as those who are identified as being frail (clinically diagnosed) or have very low physical or cognitive function, perhaps as a result of chronic disease such as arthritis, dementia or advanced old age itself. Many frailer, older people will be in supported living settings and residential care[144]. Even vulnerable older patients can exercise safely, provided that the exercise programme is appropriately designed and adapted to their needs[16]. Examples are ensuring a cautious pre-training load in strength training, with isometric (muscle does not change length) work in the initial stages to minimise joint tension[147] and also cautious

Type of Sport, Physical Activity or Exercise	Considerations			
	Adults (>50 yrs)	Osteoporosis (OP) *	OP with vertebral fractures*	Frailer Older People /Significant cognitive impairment
Running				
Resistance training				
Aerobics, circuit training				
Ball Games				
Racquet Sports				
Golf				
Yoga, Pilates				
Tai Chi				
Dance				
Cycling				

** all people with diagnosed OP should understand safe lifting of weights (technique and spine sparing movement)[12].*

not recommended-potential fracture risk (from a fall or propulsive high resistance activity) even if have a history of the activity §based on recommendations with information on case reports or adverse events with some of these activities. Discussion with physiotherapist for spine sparing tips if practiced in activity[12].

not recommended if inexperienced to the activity (OP or frailer older people), without advice on spine-sparing techniques, and avoidance of repetitive (even if slow), weighted or rapid end range flexion or extension of the spine (for those with osteoporosis). Emphasis should be placed on slower more controlled movements. Frailer older people (or those with high falls risk or multiple comorbid conditions affecting balance or strength) should be supervised by a physiotherapist or exercise instructor that has had specific training on adapting and tailoring exercise prescription for those with osteoporosis §based on recommendations[12].

no considerations if have good strength and balance (low risk of injury) or are practiced in this activity (history of participation). Focus on good technique important[12].

Table 7. MBSBA and recommendations for engagement in people with Osteoporosis, with and without Verterbral fractures, and Frailer Older People or those with Dementia.

progression to isotonic (muscle remains to be in a relatively constant tension while its length changes) work[148]. However, when utilising isometric (static) work to achieve a targeted strength gain in specific muscle groups, by ensuring a moderate workload and limiting each contraction to 3-4 seconds avoids the risk of rapid rises in systolic and diastolic blood pressure associated with prolonged high intensity isometric work[148]. Emphasis on control throughout the range of movement, careful monitoring, progression in very small increments and patient feedback is necessary prior to adding multiple repetitions or further sets[16]. Exercise practitioners must be aware that with vulnerable, older patients, just using body weight is often a sufficient training stimulus in the early stages. Muscular soreness that inhibits the performance of everyday activities may prove such a negative experience that it prohibits participation temporarily or permanently[16]. Total duration of activity and frequency of exercise sessions can play a role in musculoskeletal injuries. Shorter bouts of resistance training performed more frequently, even several times a day, may reduce injuries compared to longer bouts performed only twice per week. Leaving a day's rest between PRT bouts in longer sessions allows recovery time and reduces significant muscle discomfort[13].

Discussion

Progressive resistance training offers numerous benefits beyond improvements in muscle strength alone for older individuals, frailer older individuals and those who have suffered fractures or are at risk of fracture. Several reviews have demonstrated improvements in balance, functional mobility, falls risk reduction and fall prevention. Age is no barrier to PRT, however, as there is potential for increased injury in certain people, if someone has arthritis, is frail or has poor cognition, it is recommended that PRT is supervised, by someone who is trained to adapt and tailor activity, to ensure safe progression of intensity and a reduced risk of injury. Particularly in terms of muscle strength, it is vital that we all remember that as soon as the training stops, muscle strength will decline and the person will revert to deconditioning and

potentially recross a threshold level of strength needed to help prevent a trip or stay independently mobile. Embedding an understanding of safe lifting techniques both in exercise sessions and in daily life is as important as making sure they do the required repetitions. For some, with memory problems, this means repetition and rehearsal are important and on the whole, that group exercise is more effective than home based partially or not supervised.

Balance activities have the inherent risk of a fall, but to effectively improve balance you have to challenge it. This means standing work and allowing a feeling of needing to work to stay upright (wobbliness). For someone who requires a walking aid or has severe dementia, this is often a difficult task and may well require more than one person as support. But if exercises are performed seated and there is no balance work, there is rarely any change in balance or indeed, falls risk. This is why it is important to have someone who is trained to work on balance in frailer individuals, whether this be because vertebral fractures have led to a forward flexed posture that makes any dynamic balance work more likely to lead to a forward fall, or whether someone with dementia needs constant prompting to keep their hands near a support.

The evidence is clear, a 'gentle' seated exercise session without moderate to high intensity PRT and balance work will not improve balance, nor strength, nor reduce falls. Where these outcomes are the priority, the risk of injury will increase, and therefore the training, knowledge and skills of the person delivering the intervention must also be to a higher level. We must consider the exercise history and participation experience that the person has. We know that people adhere to things they like and advice on safe continuation of the activity might be appropriate. Certainly those with mild to moderate dementia, those with osteoporosis and those transitioning to frailty but still active should be encouraged to continue the MBSBA activities they like but perhaps consider increasing the amount they do, or the range of activities they do to help them meet the guidelines of MBSBA activities at least twice a week.

Table 7 gives recommendations on considerations to taking part in strength and balance sport and recreational activities. This is based on the literature read for this review. No papers on frailer older people have given information on adverse events or injuries due to physical or activities, only on supervised and non-supervised exercise programmes that concentrate on strength and balance. Therefore the recommendations are sometimes based on actual case reports and adverse events, and sometimes extrapolating a recommendation from the literature on other similar activities. Generally, if a person has engaged in that activity previously and is practiced in technique and in skill levels, activities will not be unsafe unless their health or functional status has deteriorated to a point where staying upright (risk of falling) or contact sports or activities with a likelihood of a fall at speed require a decision on risk and weighing up the positives with the negatives of this particular activity to that person. For those frailer individuals at high risk of fracture who are previously sedentary or unfamiliar with a risky sport or activity, it is advisable not to start them but advice on where to start for the best benefits is appropriate.

Conclusion

In conclusion, for prevention of falls in people with a history in the last year, or frailer older adults, structured exercise programmes that incorporate progressive PRT and increasing balance challenge over time are safe and effective. These should be performed regularly, in a group, or at home, with supervision and support, over at least 6 months to ensure efficacy. The supervision and support should be offered by someone who is trained in delivery of an effective programmes (eg. Otago, FaME) so that the efficacy is more likely and there is not a risk of an ineffective programme being followed. For those in transition to frailty and have poor strength and balance, physical activities that are known to help maintain strength and balance (such as Tai Chi) are effective in preventing a decline in falls risk. For the very frail older adult, supervised structured exercise that has PRT, balance training and some endurance work, supervised and progressed by a trained person will have the quickest and most effective outcome and ensure safe technique and consideration of the multiple medical conditions and fatigue that these individuals may have. For people with osteoporosis who have a history of MBSBA activities, these can be continued and preferably increased in terms of frequency, duration and dose. For those with a high risk of fracture (poor balance, frailty, vertebral fractures) then supervised (by a person trained in osteoporosis exercise delivery) structured exercise programmes are most appropriate as a starting point. People with various levels of cognitive impairment can benefit from supervised strength and balance exercise for about 60 minutes a day, 2 to 3 days a week to improve physical function. Tai Chi and Yoga show evidence of efficacy and safety for those with mild to moderate cognitive impairment. Although there is little evidence of any MBSBA activities being inherently unsafe, for those who are frail, have vertebral fractures or have severe cognitive impairment it is appropriate to recommend supervised progressive strength and challenging balance exercise on a one to one or small group basis. For these individuals a form of MBSBA that is both safe and effective as rapidly as possible in terms of important outcomes for function, fracture prevention and mortality is vital.

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