Department of Health

Falls and fractures

Exercise Training to Prevent Falls

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Key Messages

Exercise to prevent falls should be evidence based and individually tailored

- Not all types of exercise prevents falls
- Exercise prescription will differ depending on the individuals history of falls, medical condition and functional capacity
- Exercise to prevent first falls could involve tai-chi and other balance and strength training activities
- Exercise to manage falls should include dynamic balance, strength and functional floor activities. It should also aim to include bone loading, power, flexibility, postural and gait training, supported endurance work and tasks to improve visual, vestibular and sensory input
- Exercise to manage falls can be home or group based and should be delivered by specialist trained professionals
- If the person has a history of falls, exercise should retrain or maintain the ability to get up from the floor to avoid a 'long lie'.

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Introduction

Research over the past 3 decades has advanced our understanding of common risk factors predisposing to falling and has provided important insights for the prevention of falls, including specific strength and balance training (NICE 2004; Skelton & Todd 2004; Chang *et al.* 2004; Gillespie *et al.* 2005; Campbell & Robertson 2006). Risk factors for falls have been classified into two types: intrinsic and extrinsic factors (Skelton & Todd 2004). Both are affected by exposure to risk. Intrinsic risk factors include poor balance and strength (Lord *et al.* 1992; Tinetti *et al.* 1988). Extrinsic factors are social and physical factors that relate to the external environment and include obstacles, slippery surfaces, poor lighting and poor footwear. There comes a time when a change in a person's intrinsic risk factors means they are no longer able to cope with the extrinsic risk factors they have managed before (Skelton & Todd 2004; Skelton & Dinan 1999). We all 'trip' and 'slip' but can normally right ourselves relatively easily and safely; at some point there are losses in the ability to correct this challenge to our balance mechanisms (intrinsic) because of declining balance, co-ordination or strength.

Whilst it is acknowledged that some risk factors are not modifiable with exercise (i.e. age, gender, chronic medical conditions, non-correctable vision problems), others, such as physical activity, environment and the effects of medication, can be positively influenced through appropriate education and intervention (NICE 2004; Skelton & Dinan 1999; Close 2005). Modifiable risk factors, with the use of specific exercise, include poor balance and fear of falling, low strength and power, poor gait and functional ability, depression, urinary urgency and incontinence, postural hypotension, depression and arthritic pain (Skelton 2001).

Many older people do not injure themselves in a fall, but have great difficulty getting up again after the fall and may stay on the floor for some time (a 'long lie') (Tinetti *et al.* 1993). Some of the difficulty of rising from the floor may be due to shock or injury, or a fear of further damage to the body by trying to move, but for many lack of physical fitness is an important cause (Skelton & Dinan 1999). Indeed, many older adults attended by the Ambulance Services are not taken into hospital, they were simply unable to get up from the floor (Halter *et al.* 2000).

Recent reviews and guidelines suggest multi-disciplinary falls assessment and intervention, including exercise, should be considered *alongside* osteoporosis diagnosis and management to reduce the number of falls and fall-related injuries (NICE 2004; Skelton & Todd 2004; DoH 2001; DoH 2007).

Ageing, decreasing fitness and effects on balance

Physical fitness is especially important in old age, in order to cope with everyday tasks and any unforeseen demands such as hills, uneven ground, trips etc., on the ageing body (Dinan 2001; Skelton 2001; Young & Dinan 2000). Reduced sensory input (seen with increasing age and compounded by medications, oedema, arthritis etc.) exacerbates the inefficiency of the musculo-skeletal system (Skelton 2001).

Comparisons of fallers versus non-fallers have shown several muscle groups in the lower limb to be weaker, including quadriceps, hip and ankle strength (Whipple *et al.,* 1987; Skelton *et al.* 2002). Lower limb power (the speed with which a person can use their muscles) is also weaker in fallers and shows more asymmetry between limbs (Skelton *et al.* 2002). It seems likely that lower limb muscle power (Skelton 2001) 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. Functional, mobility and balance deficits are also common in fallers (Lord *et al.* 1992; Tinetti *et al.* 1988). Balance is a complex automatic integration of several body systems. With age and inactivity these unconscious processes may not integrate as well or as quickly so that maintaining balance and preventing injurious falls may require ever increasing focus of attention and fatiguing effort. The "stops walking when talking" phenomena reflects this difficulty (Lundin-Olsson *et al.* 1997).

Sarcopenia and Power

The maintenance of physical performance as we age is important not only to prevent a fall but in the event of a fall, to have the functional capability to get up from the floor, and in the long term, repair from injury and regain confidence and independence. Ageing is associated with loss of muscle mass (sarcopenia) with a corresponding reduction in maximal muscle strength (Skelton & Beyer 2003). Sarcopenia occurs even in fit, athletic elderly adults who continue to lose lean mass and muscle mass despite retaining functional status. However, some age related changes that were once thought to result solely from ageing are now known to be the result of disuse and are therefore potentially reversible.

Muscle power may be even more important than maximal strength in older people. The ability to develop high force rapidly contributes to successful performance in activities such as rising from a chair, climbing stairs or regaining balance after tripping to avoid an impending fall. While cross-sectional data suggest that healthy women in their seventies retain 40-50% of the handgrip strength found in young adults they may retain as little as 26% of the power (Skelton & Beyer 2003). In 65-84 year old individuals, isometric strength showed a decline of approximately 1.5% per year while the loss in power was approximately 3.5% per year (Skelton *et al.* 1994). The decline in power is steeper than force because it is magnified by the loss of velocity due to the selective loss of type II fibres, and this is also consistent with the greater percentage loss of isokinetic torque at high speed with ageing.

While greater strength is found among the physically more active it is known that a few weeks of immobilisation or disuse has a detrimental effect on muscle mass, muscle strength and power even in young people (Appell 1990). The decrease in muscle strength is greatest during the first week of immobilisation, 3-4% per day, and up to a 40% decrease in isokinetic muscle strength after 3 weeks of immobilisation (Appell, 1990). One of the main causes for this is the reduction of gravitational effect on the muscles. Especially vulnerable to immobilisation and inactivity are the anti-gravity muscles of the lower extremities and the faster type 2 muscle fibres, those that keep us upright!

Studies have shown that muscle strength can be improved by progressive high-intensity resistance training (using therabands), even in the oldest old (Skelton *et al*. 1995; Skelton 2001). Muscle power is also improved within 12 weeks (3 x per wk) with progressive high resistance strength training (Skelton *et al,* 1995). Some studies of low-intensity strength training have resulted in increased muscle strength in nursing home residents, frail elderly and elderly with co-morbidity (McMurdo & Rennie 1994).

Functional Ability

Muscle weakness is one of the underlying mechanisms of poor function and it is documented that muscle strength correlates with several measures of functional status (Skelton *et al.*, 1994). It would thus be reasonable to assume that an increase in muscle strength would lead to an improvement in function. However, improvements in strength do not always translate into improvements in daily functioning in all older people (Skelton *et al*. 1995). Combining strength training with more functional training have resulted in more functional gains both in non-frail elderly (Skelton & McLaughlin 1996) and frail elderly (Hauer *et al.*, 2001).

Balance

One cross-sectional study shows close positive association with the amount of physical activity reported and postural stability in postmenopausal women (Brooke-Wavell *et al*. 1998). The period of life during which physical and sporting activities are practised seems also to be of importance (Perrin *et al*. 1999). However, static balance can be improved within 8 weeks in older people with co-morbidity (Skelton and McLaughlin, 1996) and sway and dynamic balance improved with gait and strength training (Skelton & Dinan 1999; Skelton 2001).

Falls and physical activity levels

Physical activity is important, not only as we age, but over the life span (Young & Dinan 2000). Age-adjusted risk of hip fractures is up to 40% lower in the most active compared with the least active adults (Gregg *et al.* 2000). Indeed, epidemiological studies have shown that a lifetime's history of regular physical activity can reduce the risk of hip fracture by up to 50% and much of this benefit is thought to result from a reduction in falls (Law *et al.* 1991). A lack of vigorous exercise in the preceding 2 weeks has been associated with increased risk of wrist fracture (Ivers *et al.* 2002). Wrist fractures become less common (and hip fractures more common) in the very old, because of slower reaction times and inability to extend an arm in time to break the fall (Skelton & Dinan 1999).

Fear of falling is the most commonly reported anxiety among older people (Skelton & Todd 2004) and falls and fear of falling are associated with increased anxiety and depression, decreased mobility, reduced social contact, higher medication use, and increased dependence on medical and social services and informal carers (Yardley & Smith 2003). Fear of falling can also cause older people to limit their movement, not just in terms of habitual activity but also in their normal body movements. This unwillingness to move can lead to poor compliance with exercise interventions and even avoidance of a particular activity that led to a past fall. Fear of personal injury is often cited as a reason for people not taking part in regular indoor and outdoor physical activity (Skelton 2001). Fear of falling and falls self efficacy can be improved with regular exercise (Skelton & Todd 2004).

However, there may be a U-shaped relationship between the amount of physical activity and the number of falls, with a higher incidence of falls in both the least active and the most active (Gregg *et al* 2000). Nursing home residents have a higher incidence of falls than independently living older people and spend up to 90% of their time either sitting or lying down. Falls in independent older people take place during periods of maximal activity (Gregg *et al* 2000) and yet fallers are likely to be less active than their non-falling counterparts (Lord *et al*. 1992). Some people can fall whilst rambling, others just transferring from their chair to standing. This will, of course, mean that different exercise interventions will be required for people of different physical functions (Skelton & Dinan 1999).

Exercise and physical activity that prevents falls

Despite the considerable evidence that exercise is a key component of a multi-factorial fall prevention intervention, some exercise-only interventions have shown little or no effect on falls risk despite improvements in known risk factors (eg. strength) (Gillespie et al. 2009; Chang et al. 2004; Skelton & Dinan 1999). It appears that individualised exercise interventions with balance training at the core of the programme are most effective for those at risk of falls, including those with significant risk of fracture. Multiple-component group exercise reduced rate of falls and risk of falling (rate ratio (RaR) 0.78, 95%CI 0.71 to 0.86; risk ratio (RR) 0.83, 95%CI 0.72 to 0.97), as did Tai Chi (RaR 0.63, 95%CI 0.52 to 0.78; RR 0.65, 95%CI 0.51 to 0.82), and individually prescribed multiple-component home-based exercise (RaR 0.66, 95%CI 0.53 to 0.82; RR 0.77, 95%CI 0.61 to 0.97) (Gillespie et al. 2009).

For preventing the first fall

In over 65s, with poor strength and balance, modified Tai Chi appears effective as a preventative group exercise to prevent the first fall (Wolf *et al.* 1996). Modified Tai Chi over a 48 week period, however, was not beneficial to reducing falls in an older (70+) group with signs of frailty (Wolf *et al.* 2003). It seems if Tai Chi has to be significantly modified to allow those with poor balance to participate (eg. seated versions or versions without weight transfer) then Tai Chi loses its ability to improve balance and falls risk.

In Fallers and those at highest risk

In New Zealand, a targeted *home* exercise program (OTAGO), to women aged over 80, a population at high risk of falls, was taught to participants in their own homes by a physiotherapist and compared to social visits as a control (for review see Campbell & Robertson 2006; other references in the section on Physiotherapy). 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 visited each intervention participant four times over the first two months following on with regular telephone contact. The exercise group had a significantly lower rate of falls. This exercise approach, now called the Otago Exercise Programme has been further investigated in four RCTs (Campbell & Robertson 2006).

In Australia, a 15 week *group*-based exercise programme had a more significant effect on falls risk than a vision check or home safety check (Day *et al.* 2002). The effect was even more impressive in the same research group's next trial lasting one year (Lord *et al*. 2003). Those aged over 65 years, with impairments in lower limb strength, poor balance or slow reaction time, had a 40% lower rate of falls than those not taking part in a group-based exercise and home exercise plan lasting one year.

In the UK, independent living frequent fallers halved their risk of falls (IRR 0.46, 95% CI 0.34 to 0.63) with 9 months of weekly *group* balance and strength exercises, led by a postural stability exercise instructor, combined with twice weekly *home* exercises (Skelton *et al.* 2005). 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. The exercise was individually tailored in both type and intensity, with most exercises in weight-bearing positions, reducing upper limb support. Specific examples of exercises include single side steps, double sidesteps, flamingo swings, sit to stand and squats.

Exercise to prevent falls could involve tai-chi and other dynamic balance exercises; chair exercises and floor work for strength, local muscular endurance, bone loading, power, flexibility, postural and gait training, supported endurance work and tasks to improve visual, vestibular and sensory input (Skelton & Dinan 1999).

A Falls Exercise Management Programme should retrain or maintain the ability to get up from the floor and to avoid a 'long lie' after a non-injurious fall. It should also practice other coping skills such as crawling and rolling, summoning help and keeping warm while on the floor (Skelton & Dinan 1999).

Cost effectiveness of exercise to prevent falls

There have only been a few research trials that have considered cost effectiveness of exercise interventions to prevent falls and even less on injurious falls (Gillespie et al. 2009).

Implementing the home based OEP (with appropriate home visits and telephone support by nurses trained in OEP delivery) for one and two years respectively cost $314 and $265 (1995 New Zealand dollars, implementation costs only) per fall prevented, and $457 and $426 per fall resulting in a moderate or serious injury prevented (Robertson et al. 2001a). This was repeated, with $NZ 1803 (£523 at

1998 prices) per fall prevented for delivering the programme and $NZ 155 per fall prevented when hospital costs averted were considered (Robertson 2001b).

In the first systematic review of exercise to reduce falls, three studies reported costs of the intervention ranging from US$891 to US$1,220 per intervention participant. One robust trial reported the cost effectiveness of a home-based multi-factorial intervention as US$1,947 per fall prevented, resulting in a cost-saving of US$12,392 in medical care. In all instances, costs were lower for the intervention groups than those not receiving the intervention (Gardner et al. 2000).

More recently, Tai Chi once a week for 15 weeks has been shown to cost $1683 per fall prevented (includes cost offset by charging individuals $44 per course) (Voukelatos 2007).

On a population, rather than an individual basis

On a population/public health basis, encouraging physical activity and the provision of exercise sessions as part of a wider campaign including literature, medication reviews and environmental changes has been shown to decrease fall related injuries (McClure *et al*. 2005). One large population approach trial, over 10 years, has seen a reduction in fracture rate by advocating increased physical activity and other lifestyle changes (McClure *et al*.2005).

Exercise and physical activity that prevents fractures

Exercise that can prevent fractures concentrates mainly on reducing falls, but there are examples of exercises that increase bone mineral density (BMD) but do not reduce the risk of falls, only fractures (Rutherford 1997; Omnabele-Pearson & Skelton 2007). For example, simple squeezing of a tennis ball for 30 seconds a day, has significant benefits in the non-injured forearm of women who had already sustained a Colle's fracture. A set of dynamic bone loading exercises for the distal forearm results in increased bone strength at the wrist. Total body calcium is improved in postmenopausal women training at a repetitive low force, as well as in those who train at a similar level with the addition of light weights attached to their wrists and ankles during the exercise classes. In postmenopausal women, Tai Chi exercise has been linked with a 3 to 4-fold slowing down in the rate of bone loss in both trabecular and cortical compartments of the distal tibia compared with a sedentary life style, as well as reducing future fall risk.

In patients with specific medical conditions

Even frail older patients with osteoporosis gain benefit from exercise. However, when working with these patients, exercise must be low-risk and low-impact for safety (Dinan 2001). For example, those with kyphosis/vertebral fractures should avoid unsupported forward flexion exercises such as abdominal curls and spinal flexion (Sinaki 1982; Omnabele-Pearson & Skelton 2007). These patients are likely to have reduced strength of the back extensor muscles and therefore must start with very low workloads and progress slowly. It is possible to reduce the incidence of future vertebral fractures with emphasis on back extensions. The overall emphasis should be on fall prevention. Several studies have shown good benefits of individualized exercise for osteoporosis patients, such as improved balance and strength after 20 weeks, reduced pain and improved muscle function after only 6 weeks (Omnabele-Pearson & Skelton 2007).

Patients with a history of Stroke and Parkinson's Disease can improve their balance and decrease their risk of falls (Gillespie *et al.* 2005). In patients with rheumatoid arthritis, a long-term high-intensity weight-bearing exercise programme has been associated with slowing down the rate of decrease in hip BMD, but not in lumbar spine BMD, which is another argument both for the effectiveness of exercise but also on the limitation of the extent of the benefits (for review see Omnabele-Pearson & Skelton 2007). There is also evidence that male heart transplant patients following a 6 month strength training programme have greater relative gains in BMD than age-matched controls.

Is all exercise good for all fallers?

There are, however, as many trials of exercise that have been unsuccessful at reducing falls as have been effective (Gillespie *et al.* 2009). The Cochrane review (Gillespie *et al.* 2005) did a meta-analysis of 9 trials that did not individualise/ adapt the exercise programme or progress the balance challenges and did not show a significant reduction in the number of fallers (RR: 0.89, 95%CI 0.78 to 1.01). A more recent review by Sherrington et al (2008) showed that The greatest relative effects of exercise on fall rates (RR=0.58, 95% CI=0.48-0.69) were seen in programs that included a combination of a higher total dose of exercise (>50 hours over the trial period) and challenging balance exercises (exercises conducted while standing in which people aimed to stand with their feet closer together or on one leg, minimize use of their hands to assist, and practice controlled movements of the center of mass) and *did not include a walking program*.

These findings underline the value of a tailored approach rather than those based on a "one size fits all" methodology. One long term (ten-year) follow-up of regular walkers showed the importance of specificity: 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 (Pereira *et al.* 1988). Indeed, one walking intervention in patients with previous colles fracture increased the risk of falls and fractures compared to not walking (Ebrahim *et al.* 1997).

There are special concerns when increasing physical activity and exercise in older people who have poor balance. It is likely that, in some individuals, preparatory strength and flexibility training is needed before balance challenging exercise commences. For those who have balance deficits, less demanding options maybe necessary initially, particularly if they are exercising at home unsupervised.

Many local areas are promoting Tai Chi as preventative falls exercise but are incorrectly then "prescribing" it to people who have already had a fall. A frail older person will find this level of unadapted Tai Chi class too demanding and may well be at risk of a fall during the class, especially as many classes do not align with current exercise warm-up guidelines or adapt the moves appropriately for older people. Tai Chi teachers should have additional training in with working with older people and moves should be adapted and progressed gradually before introducing more demanding moves (Skelton & Dinan, 1999).

There may be a limit at which people become too frail to benefit from balance exercise. There is also evidence to suggest that risk factors for falls differ in the institutionalised in a non-linear pattern, those who cannot rise from a chair being at lowest risk of falls and those who can stand but not walk steadily at the highest risk (Skelton & Todd 2004). Therefore exercise interventions aimed at increasing mobility in cognitively impaired or chair/bed bound residents may actually serve to increase risk of falls if not suitably adapted and tailored.

Specialist professional training is likely to improve effectiveness and reduce likelihood of inappropriate exercise (Dinan 2001; Craig *et al* 2000). Therefore an assessment of the functional capacity of the individual should lead to appropriate referral to specialist professionals (Skelton & Dinan 1999; Craig *et al* 2000). See the next two sections for further information.

Reducing the risk of falling during exercise

The foremost worry for any health professional working with older people with postural instability is that the person may fall whilst exercising. It is recommended that people with a history of injurious falls are referred to specialists such as Physiotherapists, Occupational Therapists or experienced Exercise Instructors qualified in working with older people with a history of falls (Dinan, 2001). Failure to assess or account for an individual's condition in a structured exercise class puts them at unnecessary risk. The wearing of hip protectors during exercise could potentially reduce the risk as they are known to be effective in the prevention of fractures when the person is compliant (Skelton & Todd 2004; Gillespie *et al*. 2005). Moreover, the wearing of protectors appears to improve confidence in the person and the instructor (Skelton & Dinan, 1999).

Exercise Referral Routes

Effective exercise can reduce the risk of a fall, help avoid a 'long lie' and can maintain threshold levels of strength and power necessary to remain independent. The National Service Framework for Older People [4] acknowledges the evidence that targeted exercise can help in the prevention and management of falls and in rehabilitation after the event. Guidelines for best practice have been clearly laid out for a range of multidisciplinary professionals involved in the provision of physical activity for older people with a high risk of falls. Yet, despite all this knowledge, there is still scant evidence based community provision for people at high risk of falls.

It is a major challenge is to ensure a continuum of exercise and physical activity provision and to bridge the current gap between the Hospital-based rehabilitation setting (therapy led work done on an individual or very small group basis) and the much more active community based 'senior' exercise classes (up to 25 older people in a group). Where does the therapist refer their patient after they leave the 6-8 week provision that might be found at a falls clinic? In order for the exercise to be effective we know that the person must continue the balance challenges for up to a year for a valuable reduction in risk of falls and fall related injuries. The Department of Health funded the development and pilot of a specialist exercise qualification and training for health and exercise professionals to help address this need – The Postural Stability Instructor. This training was piloted in Merton, Sutton and Wandsworth Falls and Injury Prevention Exercise Service piloted this training and is cited as a model of good practice in the National Service Framework (DoH 2001). The Postural Stability Instructor is a specialist trained instructor trained to L4 (S)NVQ. The Otago home exercise leader is also trained to deliver and support home based exercise that is evidence based. It is important to provide a choice of exercise opportunities to ensure individual need and preference are met as this is more likely to improve uptake and adherence. Effectiveness will be determined by how receptive the patient is to the recommendation and by how capable they are of carrying it out independently, safely and effectively (Dinan 2001). Referral to an exercise-prescription scheme is appropriate if the patient is likely to need motivation, supervision, monitoring, and help in choosing the right type of activity for a specific health outcome(s) (Craig *et al* 2000). Exercise referral is effective with older people (Dinan et al. 2006). Recent research suggests that older people will be more receptive and more likely to undertake an exercise intervention if the information provided discusses the wider benefits of exercise to their quality

of life and maintenance of independence and autonomy than just to prevent falls (Skelton & Todd 2004).

For older adults who are at increased risk of falls but who have not yet fallen, there are many community exercise programmes that may be appropriate, including Tai Chi as well as activities such as dancing and bowls. The Register of Exercise Professionals also has a directory of instructors.

Conclusion

There is strong evidence that physical activity across the life span is important in preserving adequate to good skeletal health and in preventing fractures. Exercise, even at advanced ages and in people of varying physical activities, can improve balance, strength and other risk factors for falls and injury. The evidence for the promotion and provision of safe, effective, exercise to prevent falls is strong. Unlike UK cardiac rehabilitation, where there is a referral pathway from Phase 3 to Phase 4 in most primary care trusts, equivalent provision of such exercise opportunities for those with a history of falls is still inadequate. A recent British Geriatric Society Survey on Falls Services provision in the UK was disappointing, only 69% suggesting a formal exercise programme was part of the service (Ali *et al* 2004). Of even more concern was the response that 41% of exercise programmes reported no strength or balance training, the two key components of a successful exercise programme for fallers (Ali *et al.* 2004). The Geriatrician or the Physiotherapist is in a powerful position to increase awareness of evidence based interventions (Close & McMurdo 2003; Close *et al.* 2005) and ensure that the patient who falls and who would benefit from appropriate exercise receives the most effective long term support for managing their risk.

Hyperlinks

www.laterlifetraining.co.uk
(for falls prevention exercise training courses and a directory of classes)

http://www.taichifinder.co.uk/
(for finding Tai Chi classes)

http://www.exerciseregister.org/
(for Register of Exercise Professionals)

References

1. Ali A, Morris RO, Skelton DA, Masud T. Falls Services in the UK – A Survey of UK Geriatricians. 5th National Conference on Falls and Postural Stability. Manchester, 2004.
2. Appell HJ. Muscular atrophy following immobilisation. A review. *Sports Med*. 1990; 10, 42-58
3. Brooke-Wavell K; Athersmith LE; Jones PR; Masud T. (1998) Brisk walking and postural stability: A cross-sectional study in postmenopausal women. Gerontology 44(5), 288-92
4. Campbell AJ, Robertson MC. Implementation of multifactorial interventions for fall and fracture prevention. *Age Ageing*. 2006 Sep;35 Suppl 2:ii60-ii64.
5. Chang JT, Morton SC, Rubenstein LZ, et al. Interventions for the prevention of falls in older adults: systematic review and meta-analysis of randomised clinical trials. *Brit Med J* 2004; 328: 680-7.
6. Close JCT, McMurdo MET. Falls and bone health services for older people. *Age Ageing* 2003;32:494-496.
7. Close JCT, Lord SR, Menz HB, Sherrington C. What is the role of falls? *Best Practice & Research Clinical Rheumatology* 2005;19(6):913-935.
8. Craig A, Dinan S, Smith A, Taylor A, Webborn N. NHS: Exercise Referral Systems: A National Quality Assurance Framework. Department of Health. The Stationary Office, 2000.
9. Day L, Fildes B, Gordon I, et al. Randomised factorial trial of falls prevention among older people living in their own homes. *Brit Med J* 2002; 325: 128-32
10. Department of Health. *National Service Framework for Older People: Modern Standards and Service Models.* London, Her Majesty's Stationary Office, 2001.
11. Department of Health. *A Recipe for Health – Not a Single Ingredient.* London, Her Majesty's Stationary Office, 2007.
12. Dinan SD. *Exercise for vulnerable older patients.* In: (Eds) Young A, Harries M. Physical Activity for Patients: An exercise prescription. London: Royal College of Physicians, 2001.

13. Dinan S, Lenihan P, Tenn T, Iliffe S Is the promotion of physical activity in vulnerable, older people feasible and effective in general practice? 2006; 56(531): 791-3.

14. Ebrahim S, Thompson PW, Baskaran V, Evans K. Randomized placebo-controlled trial of brisk walking in the prevention of postmenopausal osteoporosis. *Age Ageing* 1997; 26: 253-260.

15. Gillespie LD, et al. *Interventions for preventing falls in elderly people*. The Cochrane Database of Systematic Reviews 2005, Issue 5.

16. Gillespie LD, Robertson MC, Gillespie WJ, Lamb SE, Gates S, Cumming RG, Rowe BH. *Interventions for preventing falls in older people living in the community*. Cochrane Database of Systematic Reviews 2009, Issue 2. Art.No.: CD007146. DOI: 10.1002/14651858.CD007146.pub2.

17. Gregg EW, Pereira MA, Caspersen CJ. Physical activity, falls, and fractures among older adults: a review of the epidemiologic evidence. *J Am Geriatr Soc* 2000; 48:883-93.

18. Halter M, Close J, Elrick A, Brain G, Swift C. *Falls in older population: A pilot study to assess those individuals who are attended by the London Ambulance Service as a result of a fall but are not conveyed to an Accident and Emergency Department*. London Ambulance Service NHS Trust, 2000.

19. Hauer, K., Rost, B., Rutschle, K., *et al*. Exercise training for rehabilitation and secondary prevention of falls in geriatric patients with a history of injurious falls. *J.Am.Geriatr.Soc*. 2001; 49, 10-20.

20. Ivers RQ, Cumming RG, Mitchell P, et al. Risk factors for fractures of the wrist, shoulder and ankle: the Blue Mountains Eye Study. *Osteoporos Int* 2002; 13:513-8.

21. Law MR, Wald NJ, Meade TW. Strategies for prevention of osteoporosis and hip fracture. *Brit Med J* 1991; 303:453-9.

22. Lord SR, McLean D, Strathers G. Physiological factors associated with injurious falls in older people living in the community. *Gerontol* 1992;38:338-46.

23. Lord SR, Castell S, Corcoran J, et al. The effect of group exercise on physical functioning and falls in frail older people living in retirement villages: a randomized, controlled trial. *J Am Geriatr Soc* 2003; 51: 1685-92.

24. Lundin-Olsson L, Nyberg L, Gustafson Y. "Stops walking when talking" as a predictor of falls in elderly people. *Lancet* 1997; 349:617

25. NICE 21 Falls Guideline. Falls: the assessment and prevention of falls in older people. National Institute of Clinical Evidence, London. 2004.

26. McClure R, Turner C, Peel N, Spinks A, Eakin E, Hughes K. *Population-based interventions for the prevention of fall-related injuries in older people.* The Cochrane Database of Systematic Reviews 2005, Issue 1.

27. McMurdo ME, Rennie LM. Improvements in quadriceps strength with regular seated exercise in the institutionalized elderly. *Arch.Phys.Med.Rehabil*. 1994; 75, 600-603.

28. Omnabele-Pearson G, Skelton DA. *Exercise and Bone Health*. In: Lanham-New S, O'Neill T, Morris R, Skelton D, Sutcliffe A (eds). Managing Osteoporosis. Oxford: Clinical Publishing, 2007; pp 151–168

29. Pereira MA, Kriska AM, Day RD. A randomised walking trial in postmenopausal women: Effects on physical activity and health 10 years later. *Arch Int Med* 1998; 158: 1695-1701.

30. Perrin PP, Gauchard GC, Perrot C, Jeandel C. Effects of physical and sporting activities on balance control in elderly people. *Brit. J. Sports Med* 1999; 33:121-126

31. Rutherford OM. Bone density and physical activity. *Proceed Nutr Soc* 1997; 56: 967-975

32. Sherrington C, Whitney JC, Lord SR, Herbert RD, Cumming RG, Close JC. Effective exercise for the prevention of falls: a systematic review and meta-analysis. *J Am Geriatr Soc*. 2008;56(12):2234-43.

33. Sinaki M. Postmenopausal spinal osteoporosis: physical therapy and rehabilitation principles. Mayo Clin Proc 1982; 57:699-703.

34. Skelton DA, Greig CA, Davies JM, Young A. Strength, power and related functional ability of healthy people aged 65-89 years. *Age Ageing* 1994; 23:371-377

35. Skelton DA, Young A, Greig CA, Malbut KE. Effects of resistance training on strength, power and selected functional abilities of women aged 75 and over. *Journal American Geriatric Society* 1995; 43:1081-1087

36. Skelton DA, McLaughlin AW. Training Functional ability in old age. *Physiotherapy* 1996; 82, 159-167.

37. Skelton DA, Dinan SM. Exercise for falls management: Rationale for an exercise programme to reduce postural instability. *Physiotherapy: Theory and Practice*. 1999; 15: 105-120.

38. Skelton DA. Effects of physical activity on postural stability. *Age Ageing* 2001; 30(Suppl 4), 33-39

39. Skelton DA, Kennedy J, Rutherford OM. Asymmetry in Muscle Strength And Explosive Power Amongst Community Dwelling Frequent Fallers And Non-Fallers Aged Over 65. *Age Ageing* 2002; 31:119-125

40. Skelton DA, Beyer N. Exercise and Injury Prevention in Older People. *Scandinavian Journal of Medicine and Sports Science.* 2003; 13: 1-9

41. Skelton DA, Todd C. *What are the main risk factors for falls amongst older people and what are the most effective interventions to prevent these falls? How should interventions to prevent falls be implemented?.* WHO, Denmark. 2004.

42. Skelton DA, Dinan S, Campbell M, Rutherford O. Tailored group exercise (Falls Management Exercise - FaME) reduces falls in community-dwelling older frequent fallers (an RCT). *Age Ageing* 2005 34;6:636-639

43. Tinetti M, Speechley M, Ginter S Risk factors for falls among elderly persons living in the community. *N Eng J Med* 1988; 319:1701-1707

44. Tinetti ME, Lui WL, Claus EB. Predictors and prognosis of inability to get up after falls among older persons. *J Am Med Assoc* 1993; 269:65-70

45. Voukelatos A, Cumming RG, Lord SR, Rissel C. A randomized, controlled trial of tai chi for the prevention of falls: the Central Sydney tai chi trial. *J Am Geriatr Soc*. 2007 Aug;55(8):1185-91.

46. Whipple, R. H., Wolfson, L. I., & Amerman, P. M. (1987). The relationship of knee and ankle weakness to falls in nursing home residents: an isokinetic study. *J.Am.Geriatr.Soc*. 35 , 13-20.

47. Wolf SL, Barnhart HX, Kutner NG, McNeeley E, Coogler C, Xu T. Reducing frailty and falls in older persons: an investigation of tai chi and computerised balance training. *J Am Geriat Soc* 1996;44:489-97.

48. Wolf SL, Sattin RW et al. Intense Tai Chi exercise training and fall occurrences in older, transitionally frail adults: A randomized, controlled trial. *J Am Ger Soc* 2003;51(12):1693-1701

49. Yardley L, Smith H. A prospective study of the relationship between feared consequences of falling and avoidance of activity in community-living older people. *Gerontologist* 2003; 42: 17-23.

50. Young, A. & Dinan, S. M. (2000). *Active in later life.* In ABC of sports medicine. pp. 51-55. British Medical Journal Books, Cambridge, UK.

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