

## Review

# Exercise and Sports Science Australia Position Statement on exercise and falls prevention in older people

Anne Tiedemann<sup>a,b,\*</sup>, Catherine Sherrington<sup>a,b</sup>, Jacqueline C.T. Close<sup>b,c</sup>, Stephen R. Lord<sup>b</sup>

<sup>a</sup> Musculoskeletal Division, The George Institute for Global Health, University of Sydney, Australia

<sup>b</sup> Falls and Balance Research Group, Neuroscience Research Australia, University of New South Wales, Australia

<sup>c</sup> Prince of Wales Hospital Clinical School, University of New South Wales, Australia

Received 16 December 2010; received in revised form 4 April 2011; accepted 7 April 2011

## Abstract

Falls affect a significant number of older Australians and present a major challenge to health care providers and health systems. The purpose of this statement is to inform and guide exercise practitioners and health professionals in the safe and effective prescription of exercise for older community-dwelling people with the goal of preventing falls. Falls in older people are not random events but can be predicted by assessing a number of risk factors. Of particular importance are lower limb muscle strength, gait and balance, all of which can be improved with appropriate exercise. There is now extensive evidence to demonstrate that many falls are preventable, with exercise playing a crucial role in prevention. Research evidence has identified that programs which include exercises that challenge balance are more effective in preventing falls than those which do not challenge balance. It is important for exercise to be progressively challenging, ongoing and of sufficient dose to maximise its benefits in reducing falls. Other (non-exercise) interventions are necessary for certain people with complex medical conditions or recent hospitalisation and risk factors relating to vision and the use of psychotropic medications. Qualified exercise professionals are well placed to implement the research evidence and to prescribe and supervise specific exercise aimed at preventing falls in both healthy older community-dwelling people and those with co-morbidities.

© 2011 Sports Medicine Australia. Published by Elsevier Ltd. All rights reserved.

**Keywords:** Accidental falls; Aged; Exercise; Postural balance

## 1. Background

Population ageing and the increased tendency to fall with age, present a major challenge to health care providers and health systems as well as for older people and their carers. Falls affect a significant number of older Australians, with over one-third of community dwelling people aged 65 years and older falling one or more times every year.<sup>1</sup> Falls can also result in disability, loss of mobility, reduced quality of life and fear of falling.<sup>2</sup> The rate of falling is even higher in residents of aged care facilities and in hospital patients.<sup>3</sup> Fall rates and the risk of multiple falls also increase significantly with age.<sup>4</sup> Most falls result in only minor injuries, however

more serious consequences can include hip fracture, permanent disability, institutionalisation and death.<sup>5</sup> Among older people, falls account for 14% of emergency admissions and are the leading cause of the injury-related deaths.<sup>2</sup> With the proportion of the Australian population aged 65 years and older expected to increase substantially in the years to come, this is a public health issue that demands attention.<sup>6</sup>

Studies undertaken in Sweden,<sup>7</sup> the United States<sup>8</sup> and the United Kingdom<sup>9</sup> have drawn attention to the significant direct health care costs required for the treatment of fall-related injury. Furthermore, Australian data estimate the economic cost of fall related injury to be more than double the cost attributed to road trauma each year.<sup>6</sup> Studies have reported that the cost of medical care needed to treat a single injurious fall can average between \$1600<sup>10</sup> and \$5688<sup>11</sup> (amounts in Australian dollars, calculated in year 2000 and 1999 respectively). These costs, while significant,

\* Corresponding author at: The George Institute for Global Health, PO Box M201, Missenden Rd, NSW 2050, Australia.

E-mail address: [atiedemann@georgeinstitute.org.au](mailto:atiedemann@georgeinstitute.org.au) (A. Tiedemann).

do not account for the substantial psychosocial and opportunity costs also associated with falls.

Falls defined as “unexpected events in which the participant comes to rest on the ground, floor, or lower level”<sup>12</sup> are not random events and many can be predicted by assessing a number of risk factors.<sup>13</sup> Some of these risk factors (e.g. reduced muscle strength and impaired balance and gait) can be improved with exercise,<sup>14</sup> whereas others (e.g. poor vision, psychoactive medication use) require different, complementary intervention approaches.

Over the past 25 years there has been an extensive amount of research conducted into the problem of increased susceptibility to falling in older age. The published literature provides a good understanding of the size of the problem, the factors that increase a person’s risk of falling and the consequences of falls. There have also been many randomised controlled trials (RCTs), Cochrane reviews and other systematic reviews conducted to explore the effectiveness of a range of fall prevention strategies. This statement has utilised this high quality evidence to provide guidance on effective exercise prescription for the prevention of falls in older community-dwelling people.

## 2. Role of exercise for prevention of falls

The definitions of exercise and physical activity used in the American College of Sports Medicine (ACSM) Position Stand on Exercise and Physical Activity for Older Adults were used in this paper.<sup>15</sup> *Physical activity* refers to body movement that is produced by the contraction of skeletal muscles and that increases energy expenditure. *Exercise* refers to planned, structured, and repetitive movement to improve or maintain one or more components of physical fitness.

It is known that the function of the sensorimotor systems that are involved in the maintenance of postural control decline with age,<sup>16</sup> leading to an increased risk of falling. Of particular importance is muscle strength and power in the lower limbs, reaction time and balance, all of which can be improved with appropriate exercise.<sup>14,17</sup>

It is now clear from RCTs that exercise as a single intervention can prevent falls in community dwellers.<sup>18,19</sup> Exercise can prevent falls when delivered to the general community<sup>20</sup> as well as to those at high risk of falls.<sup>21</sup> The recent Cochrane review of interventions to prevent falls in community dwelling older people concluded that exercise interventions can reduce the risk and rate of falls in older people by between 17% and 34%, depending on the type of program and measures used to assess effectiveness.<sup>18</sup>

The role of physical activity (as opposed to exercise programs) in fall prevention is less clear. It is known that more active people have fewer falls<sup>22</sup> and that this relationship persists after adjustment for other variables which are associated

with falls. However, there is no evidence that simply providing advice with regard to being more active is an effective fall prevention strategy.

## 3. Other interventions to prevent falls

Several other single interventions have been found to prevent falls, including home safety interventions in high risk people, psychoactive medication reduction, cataract surgery,<sup>18</sup> the use of single lens rather than bi-, tri- or multifocal glasses for outdoor mobility<sup>23</sup> and the insertion of cardiac pacemakers for the small proportion of people who experience blackouts and are diagnosed with the cardio-inhibitory form of carotid sinus hypersensitivity.<sup>18</sup> Multifactorial interventions include individual assessment and different combinations of the single interventions mentioned above, often including exercise. There is evidence that multifactorial interventions can reduce the rate of falls but due to their multidimensional nature, the specific factors which are most effective are yet to be conclusively determined.<sup>18</sup>

The impact on the rate of falls of multiple and single interventions is similar<sup>24</sup> and exercise as a single intervention appears to be a more cost-effective approach to falls prevention.<sup>25</sup> Therefore, in the absence of contraindications, we suggest that exercise should be considered a core fall prevention strategy for older people. Those with other risk factors should be referred for appropriate care. This article focuses on the prescription and implementation of exercise programs aimed at preventing falls and does not have the scope to describe non-exercise interventions.

## 4. Guidelines for exercise and physical activity in older people

It is widely acknowledged that physical activity has wide ranging benefits for the health and well-being of people of all ages. Physical activity can reduce the risk of developing certain diseases and can play a role in the management and control of many chronic medical conditions such as arthritis, diabetes, heart and respiratory conditions<sup>26</sup> and can slow the decline in mobility in cognitively impaired older people.<sup>27</sup>

The ACSM and the American Heart Association (AHA) physical activity recommendation statement for older adults applies to all adults aged 65 years and over, and to adults aged 50–64 years with clinically significant chronic conditions or functional limitations that affect movement ability, fitness, or physical activity.<sup>26</sup> A summary of the recommendations are included in Table 1.

In relation to preventing falls, the ACSM/AHA guidelines are brief and state that *To reduce risk of injury from falls, community-dwelling older adults with substantial risk of falls (e.g. with frequent falls or mobility problems) should perform exercises that maintain or improve balance.*<sup>26</sup> However, as there is also evidence that appropriate exercise can

Table 1

Summary of the ACSM/AHA physical activity recommendations for all adults aged 65+ years and adults age 50–64 years with clinically significant chronic conditions and/or functional limitations.<sup>26</sup>

Older adults should:

1. Do moderately intense aerobic exercise, 30 min a day, 5 days a week

Or

- Do vigorously intense aerobic exercise, 20 min a day, 3 days a week

And

2. Do 8–10 strength-training exercises, 10–15 repetitions of each exercise 2–3 times per week

And

3. If you are at risk of falling, perform balance exercises

And

4. Have a physical activity plan<sup>a</sup>

<sup>a</sup> Older adults should have a plan of how, when and where each activity will be performed.

prevent falls in the general population rather than only in high risk groups<sup>19</sup> we suggest that all older adults should be encouraged to undertake balance training. More detail in relation to prescription of balance exercises is provided in the ACSM position stand on exercise and physical activity for older adults.<sup>15</sup>

The Australian National Physical Activity Guidelines are less definitive and do not include a specific recommendation for exercise to prevent falls in older people (available at: <http://www.health.gov.au/internet/main/publishing.nsf/content/phd-physical-rec-older-guidelines>). Similarly the 2010 physical activity recommendations for older Australians<sup>28</sup> provide general advice regarding the need for all older Australians to be physically active regardless of age, weight, health problems or abilities. Therefore, we suggest that exercise practitioners in Australia refer to the more detailed ACSM recommendations when prescribing exercise for older adults.

The findings of a meta-analysis and meta-regression of 44 randomised controlled trials indicated that the optimal exercise program for preventing falls is one that contains the following three elements: exercises that provide a high challenge to balance, exercise of a high dose, and no walking program. This combination of factors resulted in a significant 42% reduction in the rate of falls (adjusted pooled rate ratio = 0.58, 95% confidence interval 0.48–0.69).

The reason for the apparent lesser effect of exercise on fall rates when walking programs are included may be due to: (a) increased exposure to risk with walking, (b) walking taking time away from high level balance training or (c) confounding of the results as walking programs were more likely to be prescribed in high risk populations (e.g. in residential care) and the beneficial effects of exercise in this population are less marked. Although walking appears not to be the best fall prevention strategy there are other benefits of walking programs for older people.<sup>26,29</sup> We therefore suggest that walking training be included in a program as long as it is not at the expense of balance training. However, high risk

individuals should not be prescribed brisk walking programs due to the increased risk of falls with this activity.<sup>30</sup> The Otago Exercise Programme<sup>31</sup> is a home based strength and balance training program involving intensity progression with the use of ankle cuff weights. It is effective in preventing falls and includes the prescription of a walking program if the exercise provider considers the individual participant to be safely able to undertake such a program. We suggest that this approach be used for participants in fall prevention exercise programs.

The ACSM position stand on resistance training for healthy adults also contains important guidelines for the modification of resistance exercise for the safe and effective prescription of these programs for older people.<sup>32</sup> These modifications relate to the rate of progression, exercise intensity and the mode and frequency of exercise shown to produce optimal results.

Although the falls prevention literature emphasises the importance of balance training for preventing falls,<sup>19</sup> it is possible that strength training plays a role as strength declines steadily after the age of 40.<sup>33</sup> Furthermore, lower limb muscle strength has been identified as an important risk factor for falls.<sup>34</sup> Strength training may be most important for very deconditioned individuals, for whom increased strength is likely to result in improved function. However once a threshold level of strength is obtained, further improvements in strength may not correspond to further improvements in function. Further research is needed to establish the direct benefits of strength training alone on risk of falls in older people.<sup>18</sup>

## 5. Exercise prescription – recommendations

There is now clear evidence that exercise is beneficial for the prevention of falls in older people.<sup>18</sup> Exercise programs which include exercises that challenge balance are more effective in preventing falls than programs which do not challenge balance.<sup>19</sup> These programs include: exercises conducted while standing in which participants aim to (a) stand with their feet closer together or on one leg, (b) minimise use of their hands to assist balance and (c) practice controlled movements of the body's centre of mass.

The initial level of balance exercise difficulty needs to be tailored to the capabilities of the individual and with consideration of safety. Once the older person has mastered a balance task in a stable manner without the need for upper limb support, the task should be progressed to increase the challenge to balance. Methods to increase the intensity and effectiveness of balance challenging exercises over time include (a) using progressively difficult postures with a gradual reduction in the base of support (e.g. two-legged stand, semi-tandem stand, tandem stand, one-legged stand), (b) using dynamic movements that perturb the centre of gravity (e.g. tandem walk, circle turns, leaning and reaching activities, stepping over obstacles), (c) specific resistance training for postural muscle groups (e.g. heel stands, toe stands, hip abduction with added weights to increase intensity, unsupported sit to

Table 2

Balance challenging exercises suitable for prescription to older people and methods to progress exercise intensity.

| Baseline exercise                | Progression                                                                                                                                                                                                                       |
|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Graded reaching in standing      | Narrower foot placement<br>Reaching further and in different directions<br>Reaching down to a stool or the floor<br>Reaching for heavier objects<br>Standing on a softer surface, e.g. foam rubber mat<br>Stepping while reaching |
| Stepping in different directions | Longer or faster steps<br>Step over obstacle<br>Pivot on non-stepping foot                                                                                                                                                        |
| Walking practice                 | Decrease base of support, e.g. tandem walk<br>Increase step length and speed<br>Walking on different surfaces<br>Walking in different directions<br>Walk around and over obstacles<br>Heel and toe walking                        |
| Sit to stand                     | Don't use hands to push off<br>Lower chair height<br>Softer chair                                                                                                                                                                 |
| Heel raises                      | Add weight (vest or belt)<br>Decrease hand support<br>Hold raise for longer<br>One leg at a time<br>Add weight (vest or belt)                                                                                                     |
| Step Ups-forward and lateral     | Decrease hand support<br>Increase step height<br>Add weight (vest or belt)                                                                                                                                                        |
| Half squats sliding down a wall  | Decrease hand support<br>Hold the squat for longer<br>Move a short distance away from the wall<br>Add weight (vest or belt)<br>One leg at a time                                                                                  |

stand practice), and/or (d) reducing sensory input (e.g. standing with eyes closed, standing/walking on an unstable surface such as foam mats).<sup>15</sup> Further challenge can be provided by the use of dual tasks, such as combining a memory task with a gait training exercise or a hand-eye co-ordination activity with a balance task. Some examples of exercises which challenge balance and are appropriate for older people to perform are included in Table 2. Information is also included about methods for progression of exercise intensity over time.

Balance is defined as the ability to maintain the projection of the body's centre of mass within manageable limits of the base of support, as in standing or sitting, or in transit to a new base of support, as in walking.<sup>35</sup> Therefore balance involves anticipatory and ongoing postural adjustments and is thus a co-ordination task. Activities such as aerobics, tennis, yoga and dancing have not been evaluated for their effectiveness in preventing falls but as they require co-ordination practice they are likely to be beneficial in maintaining balance abilities for middle aged people and more able older people. For older people with poorer postural control, these activities may increase risk of falling so individually prescribed exercises which safely challenge balance (such as those in the Otago Exercise Programme,<sup>31</sup>

<http://www.acc.co.nz/otagoexerciseprogramme>) should be prescribed.

There are also bigger effects of exercise on falls from programs which include a higher dose of exercise (e.g. a dose of more than 50 h of exercise, typically 2 × 1 hour sessions per week for 6 months). It is likely that exercise needs to be ongoing to have a lasting effect on fall rates. Therefore programs should offer ongoing exercise, or encourage people to undertake ongoing exercise at the end of a short-term formal program as recommended by the ACSM.<sup>26</sup>

In summary, falls can be prevented by a range of exercise programs which target balance and provide ongoing exercise. These include: the Otago Programme of home-based balance and strength training,<sup>31</sup> group based-Tai Chi<sup>36</sup> and other group-based balance and strengthening exercise.<sup>37</sup> Programs should be designed according to the needs of the target population to ensure they provide exercise that is challenging yet safe.

## 6. Special considerations

The ACSM states that “virtually all sedentary individuals can begin a moderate exercise program safely”. Regarding pre-exercise screening and medical clearance for older adults, the ACSM recommends that: (1) if an older person wanting to begin *moderate* exercise is apparently healthy, medical screening is not necessary, and (2) if an older person wanting to begin *vigorous* exercise is apparently healthy, medical screening is recommended. Additionally, people with known cardiac, pulmonary, or metabolic diseases or other factors which increase the risk of adverse effects should also undergo medical screening before beginning an exercise program. Cessation of exercise and medical review of the older person is recommended if they experience chest pain, shortness of breath or dizziness during physical activity.<sup>38</sup>

Older adults who are highly de-conditioned or functionally limited should start with low intensity and duration physical activity. Progression of activity should take into account the individual tolerance and preference of the older person.<sup>15</sup>

People aged 85 years and over and those with chronic disease, such as Parkinson's disease and previous stroke or functional limitations, are at a substantially increased risk of falls. Although there may be a lesser relative effect from exercise participation in high risk groups,<sup>19</sup> the absolute number of falls prevented is likely to be greater. However, exercise programs must be prescribed carefully to ensure they do not cause the falls they are attempting to prevent. There is evidence that falls can be prevented in people at increased risk of falls through well-designed exercise programs.<sup>21,37</sup> Further research is needed, however to determine the optimal approach for preventing falls in people with specific medical conditions as discussed in the “gaps in evidence” section later in this paper.

Transport and access to venues are important considerations when delivering group programs to older populations. A

“circuit” design where participants take turns at completing more challenging exercises with more supervision may be of use.<sup>39</sup> In addition, the use of more than one exercise class leader should be considered and differing levels of functional ability may require the modification of exercise protocols to suit individual needs. Many hospitals and health services are already offering physiotherapy-led exercise for people at a high risk of falls.<sup>39</sup> As these usually safely challenge balance they are likely to assist in reducing fall risk.

For people with certain medical conditions, special precautions may be required to ensure safe and effective exercise participation. For example, people with osteoarthritis may require analgesia,<sup>40</sup> people with asthma<sup>41</sup> and heart disease/angina<sup>42</sup> may require the use of medication and people with diabetes may require additional carbohydrate prior to or during exercise.<sup>43</sup>

Exercise guidelines recommend an extended cool down period after physical activity for older people to reduce the chance of hypotension, syncope (fainting) or arrhythmias during the post-exercise recovery period. Dehydration is also more likely to occur in older people taking diuretics, so fluid intake is recommended before, during and after exercise.<sup>44</sup>

## 7. Adherence with exercise programs

Despite the evidence promoting its benefits, a major limitation of physical activity and exercise as a public health intervention is low rates of participation. In the year 2000 only 57% of the Australian adult population was reported to be participating in the recommended minimum level of physical activity per week.<sup>45</sup> In addition, of the people who commence exercise programs, around half dropout within 6–12 months,<sup>46</sup> and those who dropout are likely to be those most in need of regular exercise.<sup>47</sup>

A recent systematic review of facilitators and barriers to participation in falls prevention interventions by older people<sup>48</sup> identified several factors associated with increased exercise participation. These included high exercise self-efficacy, past exercise history, good general health and functional independence. Improved adherence was associated with frequent, moderate duration activity, program accessibility and convenience, emphasis on social aspects, strong leadership and individually tailored exercise. Consideration of these factors may maximise uptake and participation in exercise programs by older people. Furthermore it has been demonstrated that programs with a positive health message and goal are likely to result in higher levels of acceptance from older people than those with “falls prevention” as the sole aim.<sup>49</sup>

## 8. Gaps in evidence

Research gaps exist regarding the effects of dance, organised activities (bowls, golf, etc.), walking and strength

training as single fall prevention interventions. There are also few direct comparisons of different exercise interventions. It has not been demonstrated prospectively whether mid-life exercise can prevent falls in older age. Similarly more research is needed to definitively determine whether exercise can prevent fall-related fractures in an appropriately designed and powered randomised controlled trial.<sup>50</sup> There have also been few large-scale trials of exercise in residential care and hospital settings.<sup>3,51</sup> The relative benefit of exercise as a single intervention versus multiple interventions also requires further investigation.

Trials have not specifically investigated the role of exercise in people from culturally and linguistically diverse backgrounds or indigenous people. However, if offered in a culturally sensitive manner, exercise should also be able to prevent falls in these groups. An ongoing project in Sydney is currently evaluating the implementation of the Stepping On Program<sup>52</sup> which has been adapted for people from a range of ethnic backgrounds. Similarly, trials of exercise in the cognitively impaired population have not had falls outcomes, but people with a mild cognitive impairment would be expected to benefit from carefully prescribed and monitored exercise programs where safety is thoroughly considered. Finally, further research is needed to determine the effectiveness of falls prevention exercise interventions targeting people with specific medical conditions such as Parkinson’s disease<sup>53</sup> and stroke<sup>54</sup> as there is currently limited evidence on the best approach for these groups of people.

## 9. Summary

Falls can result in long term disability and impaired quality of life for older people. They also present a major burden to health care providers, health systems and to the wider community. Encouragingly though, there is now extensive evidence to demonstrate that many falls are preventable and that exercise is an effective intervention.

Qualified exercise professionals are well placed to implement the research evidence and to prescribe and supervise specific exercise aimed at preventing falls in both healthy older people and those with co-morbidities. More active people experience fewer falls but it does not appear that we can prevent falls by simply encouraging older people to be more active. Specific balance challenging exercise needs to be undertaken on a regular basis for a sustained period of time for a significant reduction in falls to occur. Through this targeted approach the public health burden of falls and related injury may be reduced.

## Practical implications

- Exercise has been established as an effective way of preventing falls in older community-dwelling people.

- Programs which include exercises that challenge balance are more effective in preventing falls than those which do not challenge balance.
- Exercise should be progressively challenging, ongoing and of sufficient dose to maximise its benefits in reducing falls.

## Acknowledgments

Dr Tiedemann is funded by a National Health and Medical Research Council Australian Research Training Fellowship. Professor Lord and Associate Professor Sherrington are supported by Australian National Health and Medical Research Council Fellowships. The funders had no role in study design or execution or in manuscript preparation.

## References

1. Lord SR, Ward JA, Williams P, et al. Physiological factors associated with falls in older community-dwelling women. *J Am Geriatr Soc* 1994;**42**(10):1110–1117.
2. Lord SR, Sherrington C, Menz HB, et al. *Falls in older people: risk factors and strategies for prevention*. 2nd ed. Cambridge: Cambridge University Press; 2006.
3. Cameron ID, Murray GR, Gillespie LD, et al. Interventions for preventing falls in older people in nursing care facilities and hospitals. *Cochrane Database Syst Rev* 2010;(1), doi:10.1002/14651858CD005465pub2 [Art. No.: CD005465].
4. Sattin RW. Falls among older persons: a public health perspective. *Annu Rev Public Health* 1992;**13**:489–508.
5. Campbell AJ, Borrie MJ, Spears GF, et al. Circumstances and consequences of falls experienced by a community population 70 years and over during a prospective study. *Age Ageing* 1990;**19**(2):136–141.
6. Moller J. *Changing resource demands related to fall injury in an ageing population*. NSW Health, Injury Prevention Policy Unit; 2000.
7. Sjogren H, Bjornstig U. Unintentional injuries among elderly people: incidence, causes, severity, and costs. *Acc Anal Prev* 1989;**21**(3):233–242.
8. Carroll N, Slattum P, Cox F. The cost of falls among the community-dwelling elderly. *J Manage Care Pharm* 2005;**11**:307–316.
9. Scuffham P, Chaplin S, Legood R. Incidence and cost of unintentional falls in older people in the United Kingdom. *J Epidemiol Community Health* 2003;**57**:740–744.
10. Tiedemann AC, Murray SM, Munro B, et al. Hospital and non-hospital costs for fall-related injury in community-dwelling older people. *NSW Public Health Bull* 2008;**19**(9–10):161–165.
11. Potter-Forbes M, Aisbelt C. *Injury costs! A valuation of the burden of injury in New South Wales in 1998–1999*. Sydney: NSW Injury Risk Management Research Centre, University of New South Wales; 2003.
12. Lamb SE, Jorstad-Stein EC, Hauer K, et al. Prevention of Falls Network Europe and Outcomes Consensus Group. Development of a common outcome data set for fall injury prevention trials: the Prevention of Falls Network Europe consensus. *J Am Geriatr Soc* 2005;**53**:1618–1622.
13. Ganz DA, Bao Y, Shekelle PG, et al. Will my patient fall? *JAMA* 2007;**297**:77–86.
14. Howe TE, Rochester L, Jackson A, et al. Exercise for improving balance in older people. *Cochrane Database of Systematic Reviews*. The Cochrane Library The Cochrane Collaboration. *Cochrane Database Syst Rev* 2007;(4), doi:10.1002/14651858. CD004963.pub 2 [Art. No.: CD004963].
15. Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, et al. ACSM position stand on exercise and physical activity for older adults. *Med Sci Sports Exerc* 2009;**41**:1510–1530.
16. Lord SR, Ward JA. Age-associated differences in sensori-motor function and balance in community dwelling women. *Age Ageing* 1994;**23**(6):452–460.
17. Liu C-J, Latham N. Progressive resistance strength training for improving physical function in older adults. *Cochrane Database Syst Rev* 2009;(3), doi:10.1002/14651858.CD002759.pub2 [Art. No.: CD002759].
18. Gillespie LD, Robertson MC, Gillespie WJ, et al. Interventions for preventing falls in older people living in the community. *Cochrane Database Syst Rev* 2009;(2), doi:10.1002/14651858.CD007146.pub2 [Art. No.: CD007146].
19. Sherrington C, Whitney JC, Lord SR, et al. Effective exercise for the prevention of falls: a systematic review and meta-analysis. *J Am Geriatr Soc* 2008;**56**:2234–2243.
20. Woo J, Hong A, Lau E, et al. A randomised controlled trial of Tai Chi and resistance exercise on bone health, muscle strength and balance in community-living elderly people. *Age Ageing* 2007;**36**(3):262–268.
21. Skelton D, Dinan S, Campbell M, et al. Tailored group exercise (Falls Management Exercise – FaME) reduces falls in community-dwelling older frequent fallers (an RCT). *Age Ageing* 2005;**34**(6):636–639.
22. Heesch KC, Byles JE, Brown WJ. Prospective association between physical activity and falls in community-dwelling older women. *Epidemiol Community Health* 2008;**62**:421–426.
23. Haran MJ, Cameron ID, Ivers RQ, et al. Effect on falls of providing single lens distance vision glasses to multifocal glasses wearers: VISIBLE randomised controlled trial. *BMJ* 2010;**340**:c2265.
24. Campbell AJ, Robertson MC. Rethinking individual and community fall prevention strategies: a meta-regression comparing single and multifactorial interventions. *Age Ageing* 2007;**36**(6):656–662.
25. Davis JC, Robertson MC, Ashe MC, et al. Does a home-based strength and balance programme in people aged  $\geq 80$  years provide the best value for money to prevent falls? A systematic review of economic evaluations of falls prevention interventions. *Br J Sport Med* 2010;**44**(2):80–89.
26. Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc* 2007;**39**:1435–1445.
27. Littbrand H, Lundin-Olsson L, Gustafson Y, et al. The effect of a high-intensity functional exercise program on activities of daily living: a randomized controlled trial in residential care facilities. *J Am Geriatr Soc* 2009;**57**:1741–1749.
28. Sims J, Hill K, Hunt S, et al. Physical activity recommendations for older Australians. *Australas J Ageing* 2010;**29**:81–87.
29. Murphy MH, Nevill AM, Murtagh EM, et al. The effect of walking on fitness, fatness and resting blood pressure: a meta-analysis of randomised, controlled trials. *Prev Med* 2007;**44**:377–385.
30. Ebrahim S, Thompson PW, Baskaran V, et al. Randomized placebo-controlled trial of brisk walking in the prevention of postmenopausal osteoporosis. *Age Ageing* 1997;**26**:253–260.
31. Robertson MC, Campbell AJ, Gardner MM, et al. Preventing injuries in older people by preventing falls: a meta-analysis of individual-level data. *J Am Geriatr Soc* 2002;**50**:905–911.
32. Ratamess NA, Alvar BA, Evetoch TK, et al. American College of Sports Medicine position stand on Progression Models in Resistance Training for Healthy Adults. *Med Sci Sports Exerc* 2009:687–708.
33. Kallman DA, Plato CC, Tobin JD. The role of muscle loss in the age-related decline of grip strength: cross-sectional and longitudinal perspectives. *J Gerontol* 1990;**45**:M82–M88.
34. Moreland JD, Richardson JA, Goldsmith CH, et al. Muscle weakness and falls in older adults: a systematic review and meta-analysis. *J Am Geriatr Soc* 2004;**52**:1121–1129.
35. Winter DA. *A.B.C. (Anatomy, Biomechanics and Control) of balance during standing and walking*. Ontario: Waterloo Biomechanics; 1995.
36. Li F, Harmer P, Fisher KJ, et al. Tai Chi and fall reductions in older adults: a randomized controlled trial. *J Gerontol A: Biol* 2005;**60**:187–194.

37. Barnett A, Smith B, Lord SR, et al. Community-based group exercise improves balance and reduces falls in at-risk older people: a randomised controlled trial. *Age Ageing* 2003;**32**(4):407–414.
38. Gill TM, DiPietro L, Krumholz HM. Role of exercise stress testing and safety monitoring for older persons starting an exercise program. *JAMA* 2000;**284**:342–349.
39. Sherrington C, Pamphlett PI, Jacka JA, et al. Group exercise can improve participants' mobility in an outpatient rehabilitation setting: a randomized controlled trial. *Clin Rehabil* 2008;**22**:493–502.
40. American Geriatrics Society Panel on Exercise and Osteoarthritis. Exercise prescription for older adults with osteoarthritis pain: consensus practice recommendations. *J Am Geriatr Soc* 2001;**49**:808–823.
41. National Asthma Council of Australia. *Asthma management handbook*. Melbourne; 2006.
42. Briffa T, Maiorana A, Allan R, et al. On behalf of the Executive Working Group and National Forum Participants. *National Heart Foundation of Australia physical activity recommendations for people with cardiovascular disease*. Sydney (Australia): National Heart Foundation of Australia; 2006.
43. Sigal RJ, Kenny GP, Wasserman DH, et al. Physical activity/exercise and type 2 diabetes: a consensus statement from the American Diabetes Association. *Diabetes Care* 2006;**29**(6):1433–1438.
44. Fletcher GF, Balady GJ, Amsterdam EA, et al. Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. *Circulation* 2001;**104**(14):1694–1740.
45. Bauman A, Ford I, Armstrong T. *Trends in population levels of reported physical activity in Australia, 1997, 1999 and 2000*. Canberra: Australian Sports Commission; 2001.
46. Dishman RK. Compliance/adherence in health-related exercise. *Health Psychol* 1982;**1**(3):237–267.
47. Dishman RK, Sallis JF, Orenstein DR. The determinants of physical activity and exercise. *Public Health Rep* 1985;**100**(2):158–171.
48. Bunn F, Dickinson A, Barnett-Page E, et al. A systematic review of older people's perceptions of facilitators and barriers to participation in falls-prevention interventions. *Ageing Soc* 2008;**28**(04):449–472.
49. Yardley L, Donovan-Hall M, Francis K, et al. Older people's views of advice about falls prevention: a qualitative study. *Health Educ Res* 2006;**21**(4):508–517.
50. Karinkanta S, Piirtola M, Sievänen H, Uusi-Rasi K, Kannus P. Physical therapy approaches to reduce fall and fracture risk among older adults. *Nat Rev Endocrinol* 2010;**6**:396–407.
51. 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**(12):1685–1692.
52. Clemson L, Cumming RG, Kendig H, et al. The effectiveness of a community-based program for reducing the incidence of falls in the elderly: a randomized trial. *J Am Geriatr Soc* 2004;**52**(9):1487–1494.
53. Goodwin VA, Richards SH, Taylor RS, et al. The effectiveness of exercise interventions for people with Parkinson's disease: a systematic review and meta-analysis. *Mov Disord* 2008;**23**:631–640.
54. Batchelor F, Hill K, Mackintosh S, et al. What works in falls prevention after stroke?: a systematic review and meta-analysis. *Stroke* 2010;**41**:1715–1722.