Physical activity improves strength, balance and endurance in adults aged 40–65 years: a systematic review

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Question: Can physical activity in adults aged 40–65 years enhance strength and balance and prevent falls? **Design**: Systematic review with meta-analysis of randomised clinical trials. **Participants**: Healthy adults aged 40–65 years. **Intervention**: Programs that involved the performance of any physical activity in community settings and workplaces. **Outcome measures**: Strength, balance, endurance, and falls rate. **Results**: Twenty-three eligible trials were identified and 17 of these were pooled in the meta-analyses. The meta-analysis of strength outcomes found a moderate effect of physical activity on strength (SMD = 0.54, 95% CI 0.38 to 0.70). Larger effects were observed from programs that specifically targeted strength (SMD = 0.68, 95% CI 0.49 to 0.87), when compared to those that did not (SMD = 0.32, 95% CI 0.09 to 0.55). This difference was statistically significant (effect of strength in meta-regression p = 0.045). Physical activity also had a moderate effect on both balance (SMD = 0.52, 95% CI 0.24 to 0.79) and endurance (SMD = 0.73, 95% CI 0.50 to 0.96). No trials reported effects of physical activity on falls soon after receiving the intervention. A statistically non-significant effect on falls 15 years after receiving a physical activity intervention was found in one trial (RR = 0.82, 95% CI 0.53 to 1.26). **Conclusions**: This review found that muscle strength, balance, and endurance can be improved by physical activity in people aged 40–65 years. There were bigger effects on muscle strength from programs that used resistance exercises, indicating the need to include a resistance training component if strength enhancement is the goal. **[Ferreira ML, Sherrington C, Smith K, Carswell P, Bell R, Bell M, Nascimento DP, Máximo Pereira LS, Vardon P (2012) Physical activity improves strength, balance and endurance in adults aged 40–65 years: a systematic review. *Journal of Physiotherapy* 58: 145–156]**

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The prevention of falls and mobility-related disability among older people is an urgent public health challenge around the world. Falls and fractures already have a major impact on older individuals, their carers, health services, and the community. One-third of people aged 65 years and over fall once or more annually (Lord et al 1993). Up to half of people identified by a simple screening tool to be at an increased risk of falling will fall in the subsequent 12 months (Lord et al 2005). Falls can result in injuries, loss of confidence, and subsequent reduction in activity levels, independence, and community participation. In addition, falls are associated with a threefold increase in the risk of being admitted to a residential aged care facility after adjusting for other risk factors (Tinetti and Williams 1997).

The impact of falls on the community will grow substantially in the near future due to the increased proportion of older people in the population. It is estimated that, between 2010 and 2050, the number of people aged 60 years and older will increase by 56% in most developed countries (Strong et al 2005). For example, the proportion of Australians aged 65 years or over is predicted to increase from 13% in 2010 to 23% by 2050 (Commonwealth of Australia 2010), of whom approximately 2 million will be older than 80 years of age (Perls 2009). Large increases in numbers of older people are also predicted for most developing countries (Perls 2009). Accordingly, additional efforts to reduce falls in the risk age group are suggested prior to this ‘demographic shift’ at which time investment in prevention will become more difficult due to the costs of treatment of fall-related injuries (Moller 2003).

Many epidemiological studies have identified risk factors for falls (Lord et al 2006). In particular, reduced balance and mobility (Ganz et al 2007) and muscle weakness (Moreland et al 2004) have been shown to be important risk factors for falls. As both balance and strength deteriorate with age due to a combination of physiological ageing, chronic diseases, and inactivity (Lord and Ward 1994), physical activity has been considered an important strategy in the prevention of falls in older people. Systematic reviews of randomised clinical trials have confirmed that physical activity programs are an effective single fall prevention strategy in the older population (Gillespie et al 2009, Sherrington et al 2008).

What is already known on this topic: Falls increase with age and can have important sequelae. Physical activity programs are an effective single fall prevention strategy in the older population, but implementation during middle age may be a useful strategy.

What this study adds: Physical activity can improve strength, balance, and endurance in people aged 40–65, but the effect on falls remains unclear. Greater effects on strength occur with programs that use resistance exercises.

As strength, balance, and endurance deteriorate after the age of 40, it is possible that physical activity in 'middle-aged' adults could prevent falls in later years by improving performance on risk factors such as muscle strength, balance, and endurance (Toraman and Yildirim 2010). In order to investigate this hypothesis we sought to establish the effects of physical activity programs on risk factors for falls and falls in adults aged between 40 and 65 years living independently in the community. Therefore we systematically reviewed the literature to answer the following questions:

1. Do physical activity programs improve muscle strength, balance, and endurance in adults between 40 and 65 years old?
2. Do physical activity programs reduce falls in adults between 40 and 65 years old?

In this review, we used the definition of physical activity recommended by the American College of Sports Medicine: *body movement that is produced by the contraction of skeletal muscles and that increases energy expenditure* (Garber et al 2011), which includes, but is not restricted to, structured and planned exercise programs.

Box 1. Inclusion criteria.

Design
- Randomised or quasi-randomised controlled trial

Participants
- Adults between 40 and 65 years old
- No specific pathology
- No recent surgery

Intervention
- Physical activity program in community or workplace
- Intended to develop the body or part of the body
- Intended to improve health

Outcome measures
- Strength
- Balance
- Endurance
- Falls

Comparisons
- Physical activity program versus nothing/sham

Method

Design

A protocol defining the aims and methods of this systematic review with meta-analysis was written before conducting the review. Reporting was guided by the PRISMA statement (Moher et al 2009).

Identification and selection of trials

We conducted a computerised search of MEDLINE, CINAHL, LILACS, and EMBASE using optimised search strategies from earliest record to February 2010. These search strategies are outlined in Appendix 1 (see the eAddenda for Appendix 1).

Reference lists of systematic review and clinical guidelines (eg, ACSM) as well as specialised websites (eg, Lifestyle Medicine, National Institutes of Health) were also hand searched. Searches were not restricted by language. Two reviewers (MF and DN) independently assessed study eligibility using the criteria shown in Box 1. The same investigators also independently extracted information about trial quality and outcome data using standardised data extraction forms. Disagreements were resolved by discussion.

Assessment of characteristics of trials

Quality: The quality of included trials was assessed by extracting information about whether the study design incorporated concealed allocation of participants to groups and blinding of outcome assessors.

Participants: Trials involving adult participants with a mean age between 40 and 65 years were included. Trials of post-surgical rehabilitation or involving participants with a specific pathology were excluded. The age, gender, and number of participants were extracted to describe the trials. The recruitment method was also extracted.

Intervention: The experimental intervention was required to be a program that involved the performance of any physical activity in community settings and workplaces as defined by the ACSM (Garber et al 2011). Active forms of water-based exercises were eligible, but passive forms (eg, bathing in hot mineral waters, underwater massage) were not eligible. Trials were only included if they compared a physical activity program to a no-intervention control condition, irrespective of the duration of the physical activity program. Trials where physical activity was combined with other interventions were only included if the control group excluded physical activity. The content of the physical activity program was recorded to describe the trials. This included the setting (workplace, general community), the presence and intensity of different physical activity program components (primarily addressing strength, balance, endurance, or a combination), adherence to the program, and the overall dose of physical activity. Trials of strength training were also coded according to the extent of strength training delivered. They were coded as specifically targeting strength if they used weights or another form of resistance, and if training was at a moderate to high intensity (ie, using a weight so heavy that only 8 to 12 repetitions could be done without resting).

Outcomes measures: Trials were required to have measured at least one of the outcomes shown in Box 1. Because some tests involve more than one of these outcomes (eg, strength and balance), outcome measures in the included trials were classified as being primarily measures of strength, balance, or endurance. A broad view of balance was taken because performance of many tasks requires control of excursions of the body's centre of mass. We were guided by the well-accepted definition of balance from Winter (1995) as the ability to maintain the body's centre of mass within manageable limits of the base of support, in maintaining a standing or sitting position, or in walking or moving (Winter 1995). Therefore tests such as the Timed Up and Go and figure-8 run were classified as balance tests. Tests of walking longer distances (eg, 800 m) were classified as endurance tests. We also sought to extract data on fall rates from included studies.

Outcome data were extracted as endpoint or change over time (ie, pre-intervention mean subtracted from post-intervention mean). When trials provided data for multiple physical activity groups, comparison groups, or measures of balance or strength, original data were extracted and then combined as suggested by the Cochrane Collaboration handbook (Higgins and Green 2011). The measures used to record outcomes and timing of measurement were recorded to describe the trials.

Data analysis

Information about setting, physical activity program components, program dose, and adherence was summarised descriptively.

To establish physical activity effect sizes, ie, the difference in means of the treatment and control groups (Herbert 2000), we conducted meta-analyses. Between trial heterogeneity was identified using I^2 statistics. An I^2 of more than 75% may represent considerable heterogeneity, an I^2 of 50–75% may represent substantial heterogeneity, and an I^2 of less than 40%, not important heterogeneity (Higgins and Green 2011).

As the aim of the review was to provide a broad answer about the impact of physical activity to guide health policy, diverse interventions were pooled in meta-analyses. Random effects meta-analyses were conducted separately according to outcome (ie, strength, balance, and endurance). Outcomes were measured on different scales, and therefore standardised mean differences (using Hedges' g) and 95% confidence intervals were calculated. The standardised mean differences were calculated by dividing the raw result by the standard deviation of the post-test score for the 14 trials for which this value was available. For the remaining three trials, the post-test standard deviation was estimated from the standard deviation of the change between initial and final assessment scores assuming a 0.6 correlation between pre and post scores.

Meta-regression was also undertaken to assess whether there was a bigger effect on strength outcomes of programs that specifically challenged strength. Meta-regression was not possible for any other outcomes due to the relatively small number of trials for those outcomes (ie, six) (Sterne et al 2001).

Results

Flow of studies through the review

The search strategy identified 2198 studies (excluding duplicates). After screening, 23 eligible randomised trials were included in this review (Asikainen et al 2006, Bemben et al 2000, Bergstrom et al 2007, Bravo et al 1996, de Jong et al 2006, Fu et al 2009, Garcia-Lopez et al 2007, Heinonen et al 1998, Janzen et al 2006, King et al 1991, Klentrou et al 2007, Levinger et al 2007, Lindheim et al 1994, Maiorana et al 2001, Mitchell et al 1998, Pereira et al 1998, Sallinen et al 2007, Shirazi et al 2007, Sillanpaa et al 2009, Singh et al 2009, Stefanick et al 1998, Teoman et al 2004, Uusi-Rasi et al 2003). Figure 1 presents the flow of studies through the review.

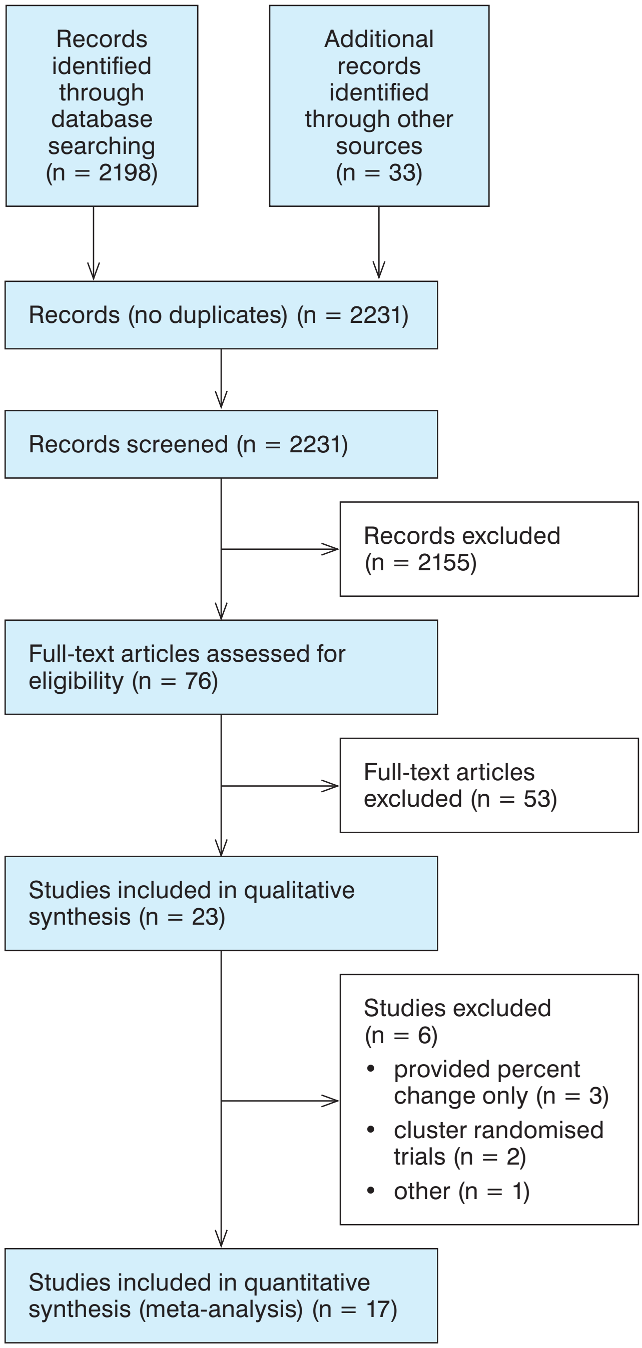

Figure 1. Identification and selection of studies for the review.

Characteristics of included trials

The 23 included trials involved a total of 2550 participants. Table 1 summarises the features of the included trials. Table 2 presents the characteristics of participants, interventions, and adherence to the intervention.

Quality: Three trials performed concealed allocation (de Jong et al 2006, Fu et al 2009, King et al 1991) and two trials used blinded assessment of outcomes (Fu et al 2009, Uusi-Rasi et al 2003). This information is also presented in Table 2.

Participants: The majority of trials recruited postmenopausal women. The mean age of participants in the included studies ranged from 41 to 60 years of age.

Intervention: Most trials included a strength component, followed by a combination of the strength and endurance components. Three trials included a combination of all three physical activity components (ie, strength, balance, and endurance). Included trials were heterogeneous regarding the total prescribed physical activity hours and adherence.

Outcome measures: Lower limb strength was measured in 13 trials, endurance was measured in 7 trials, and balance in 6 trials. No studies reported effects of physical activity on falls soon after receiving the intervention program. One study reported longer-term (15 year) effects of physical activity on falls.

Effects of physical activity on strength, balance and endurance

We were able to pool data from 17 of the included trials in the meta-analyses. The data used in the meta-analyses are shown in Table 3.

The meta-analysis of strength outcomes included 13 trials (17 comparisons, as 4 trials had more than one group) and found a moderate effect of physical activity on muscle strength, with a standardised difference in means (SMD) of 0.54 (95% CI 0.38 to 0.70, $p < 0.001$, random effects meta-analysis, $I^2 = 12\%$). There was a bigger effect on strength in the trials in which the programs targeted strength specifically (by using weights with a moderate to high intensity, ie, using a weight so heavy that only 8–12 repetitions could be done without resting). The pooled effect from the 7 programs that did not target strength specifically was 0.32 (95% CI 0.09 to 0.55) whereas the pooled effect from the 10 programs that did specifically target strength was 0.68 (95% CI 0.49 to 0.87). This difference was statistically significant (effect of strength in meta-regression, $p = 0.045$) (Figure 2).

The meta-analysis of balance outcomes included six trials and found a moderate effect of physical activity on balance (SMD = 0.52, 95% CI 0.24 to 0.79, random effects meta-analysis, $I^2 = 51\%$) (Figure 3).

The meta-analysis of endurance outcomes included six trials (8 comparisons, as one trial had three groups) and found a moderate effect of physical activity on endurance (SMD = 0.73, 95% CI 0.50 to 0.96, $p < 0.001$, random effects meta-analysis, $I^2 = 65\%$) (Figure 4).

Only one trial (Pereira et al 1998) reported on the effects of a physical activity program on long-term falls. Pereira et al 1998 showed a non-significant decrease in the occurrence of falls over the last 12 months (RR 0.82, 95% CI 0.53 to 1.26). Of those who received a walking program 15 years earlier, 27% percent reported falling in the year prior to follow-up, whereas 33% of the control group reported falling in the past year. The rate of women reporting more than one fall over the last 12 months was also lower in the walking group (23%) when compared to controls (30%) but this difference was not statistically significant (RR 0.76, 95% CI 0.48 to 1.23).

Adherence to physical activity in included trials

Adherence to the physical activity programs, presented in Table 2, was assessed in 12 of the 22 included trials (Asikainen et al 2006, Bemben et al 2000, Heinonen et al 1998, Janzen et al 2006, King et al 1991, Klentrou et al 2007, Levinger et al 2007, Mitchell et al 1998, Sallinen et al 2007, Shirazi et al 2007, Singh et al 2009, Uusi-Rasi et al 2003). In general, physical activity adherence (calculated as the percentage of completed physical activity hours, out of the prescribed hours) was greater than 80% (Asikainen et al 2006, Bemben et al 2000, Janzen et al 2006, Levinger et al 2007, Mitchell et al 1998, Sallinen et al 2007, Singh et al 2009), ranging from 48% (Shirazi et al 2007) to 96% (Levinger et al 2007).

Table 1. Summary of included trials.

Characteristic	Summary data from included trials
Total sample size, n	2550
Mean age of trial cohort *(yr)*, range	41 to 60
Physical activity component *(number of programs)*[a]	
strength	8
balance	1
endurance	8
strength and endurance	4
strength and balance	2
balance and endurance	4
strength, balance and endurance	3
Participant cohorts *(number of trials)*	
premenopausal women	1
perimenopausal women	1
postmenopausal women	11
healthy sedentary adults	4
healthy active adults	1
community dwellers	5
Gender of participants *(number of trials)*	
women	16
men	2
mixed	5
Total dose *(prescribed hours)*, range	12 to 260
Adherence *(%)*, range	48 to 96

[a] Five trials included multiple physical activity programs, yielding a total of 29 programs across the 23 trials.

Discussion

This systematic review found that strength, balance and endurance can clearly be improved by physical activity in people aged 40–65. The effect of physical activity on falls has not been well investigated in this age group. Most of the trials identified focused on strength and/or endurance training.

This review found a moderate effect of physical activity on muscle strength. The meta-analysis using the strength outcome included 13 trials (17 comparisons) and meta-regression revealed that there were greater effects on strength in trials that targeted strength specifically using resistance exercise ($p = 0.045$ for difference in effects in the meta-regression). There was a large effect (SMD = 0.68, 95% CI 0.49 to 0.87) on strength in the trials that targeted strength, and only a small effect (SMD = 0.32, 95% CI 0.09 to 0.55) in those that did not. Therefore, for greater effects on strength, it is suggested that programs target strength by specifically providing weights or other forms of resistance and aiming for an intensity and dose of strength training as

Table 2. Description of included trials (n = 23).

Trial	Age mean (SD) Exp	Age mean (SD) Con	Physical activity intervention	Program components	Setting (recruitment)	Total prescribed hours (adherence)	Concealed allocation to groups	Blinding of outcome measures
Asikainen 2006 n = 134	57.7 (4.3)	56.5 (4.2)	15 weeks of walking and resistance training, centre-based (2 × weekly) and home-based (3 or 8 additional sessions)	Strength and endurance	Postmenopausal women in Finland (via newspaper adverts)	11.5 (92%)	No	No
Bembem 2000 n = 35			6 months of centre-based resistance training 3 × weekly:	Strength	Postmenopausal women in USA (media adverts)	72 (87–93%)	No	No
	52.3 (1.4)	50.5 (2.0)	high-load, low repetition (80% 1RM, 8 reps)					
	52.3 (1.4)	51.9 (2.3)	low-load, high repetition (40% 1RM, 16 reps)					
Bergstrom 2007 n = 40	47 (2.1)	47 (2.7)	18 months of walking (3 fast 30-min weekly) and class with strengthening and aerobic (2 × 1 hour weekly)	Strength and endurance	Perimenopausal women in Finland (newspaper adverts)	180 (n/a)	No	No
Bravo 1996 n = 124	59.6 (5.8)	59.9 (6.6)	12 months of exercise classes (60 mins 3 × weekly) and bi-monthly educational seminars	Balance and strength	Postmenopausal osteopenic women in Canada (media adverts and local physicians)	156 (n/a)	No	No
de Jong 2006 n = 315 (cluster RCT)	59.6 (2.4)	58.8 (2.7)	15 weeks of weekly 60 min sessions of the 'Groningen active living model' (mixed recreational sport)	Balance and endurance	Sedentary adults in Netherlands (written invitation, home visit)	15 (n/a)	Yes	No
Fu 2009 n = 50	51.3 (5.3)	52.2 (5.6)	12 weeks of 2 × weekly 'balance strategy' training functional strength, flexibility, cardiovascular	Balance	Healthy Australian women (uni staff and health professionals)	24 (n/a)	Yes	Yes
Garcia-Lopez 2007 n = 32			21 weeks of 2 × weekly:	Strength Endurance	Healthy men in Finland	42 (n/a)	No	No
	53.6 (2.4)	53.3 (2.5)	endurance training (60–90 min)					
	54.9 (1.9)	53.3 (2.5)	strength training					
Heinonen 1998 n = 101			18 months of 4 × 50-min weekly centre and home based:	Balance Endurance	Sedentary women in Finland (mailout to random sample)	260 (66–80%)	No	No
	53.1 (0.9)	53.1 (0.8)	calisthenics					
	52.9 (0.9)	53.1 (0.8)	endurance training					

Table 2. Description of included trials (n = 23) *continued*

Trial	Age mean (SD)		Physical activity intervention	Program components	Setting (recruitment)	Total prescribed hours (adherence)	Concealed allocation to groups	Blinding of outcome measures
	Exp	Con						
Janzen 2006 n = 50			26 weeks of 3 × weekly centre-based:	Strength	Post-menopausal women in Canada (newspapers ads and posters)	78 (n/a)	No	No
	55.8 (8.2)	58.8 (6.7)	bilateral training					
	54.8 (6.5)	58.8 (6.7)	unilateral training					
King 1991 n = 357	n/a	n/a	12 months of 3 × weekly 60 min endurance training:	Endurance	Sedentary men and women in US (random phone calls/citywide promotion)		Yes	No
			higher-intensity home-based (73–88% max HR)			156 (52.6 ± 29.8%)		
			lower-intensity home-based (60–73% max HR) 5 × 30 min			39 (78.7% ± 33.9)		
			higher-intensity group-based exercise training			30 (88% ± 8.3 to 96% ± 6.5)		
Klentrou 2007 n = 16	52.7 (4.1)	53.4 (5.6)	12 weeks of 3 × weekly 65-min multi-modal exercise classes using weighted vests	Balance, endurance and strength	Postmenopausal women in Canada	39 (78.7 ± 33.9%)	No	No
Levinger 2007 n = 49	51.2 (6.2)	50.5 (6.9)	10 weeks of 3 × weekly 60 min centre-based resistance training	Strength	Untrained people in Australia	30 (88 ± 8.3% to 96 ± 6.5%)	No	No
Lindheim 1994 n = 101	50 (1.3)	48.6 (1)	6 months of 3 × weekly 30 min treadmill walking and stationary cycling	Endurance	Sedentary post-menopausal women in USA	39 (n/a)	No	No
Maiorana 2001 n = 19	47 (2)	47 (2)	8 weeks of 3 × weekly 1-hour centre-based circuit training with aerobic and resistance exercise	Endurance and strength	Healthy people in Australia	24 (n/a)	No	No
Mitchell 1998 n = 30	59 (6)	63 (5)	12 weeks of approx 40 min 2 × weekly group exercise (aerobic weight-bearing exercise) and one home exercise session (eg, 20-min brisk walk)	Balance and endurance	Postmenopausal osteoporotic women in Scotland	20 (87%)	No	No
Pereira 1998 n = 196	57.8 (4.3)	57.2 (4.0)	Walking program preceded by an 8-week training period	Endurance	Postmenopausal women in the USA	7 miles per week (57% compliers)	No	No
Sallinen 2006 n = 43	57.9 (6.6)	58.2 (6.1)	21 weeks of 2 × weekly strength training	Strength	Healthy physical active men in Finland	42 (n/a)	No	No

Table 2. Description of included trials (n = 23) *continued*

Trial	Age mean (SD)		Physical activity intervention	Program components	Setting (recruitment)	Total prescribed hours (adherence)	Concealed allocation to groups	Blinding of outcome measures
	Exp	Con						
Shirazi 2007 n = 116 (cluster RCT)	53.5 (7.9)	52.8 (8.8)	12 weeks of home-based exercise with education based on 'stage of change', muscle strength, balance exercises plus walking 30 min daily	Balance, endurance and strength	Women in Iran	42 (47.5%)	No	No
Sillanpaa 2009 n = 62	51.7 (6.9)	50.8 (7.9)	21 weeks of 60–90 min 2 × weekly endurance training, strength training or combined strength and endurance training	Endurance and strength	Women in Finland recruited by newspapers adverts	53 (n/a)	No	No
Singh 2009 n = 58	40.8 (1.3)	41.6 (1.2)	9 months of centre-based strength training (15 weeks supervised 50-min 2 × weekly then 24 weeks unsupervised)	Strength	Premenopausal women in USA recruited from University staff and students	65 (89-92%)	No	No
Stefanick 1998 n = 377	n/a	n/a	12 months of aerobic exercises in one-hour sessions 3 × weekly for 6 weeks then monthly sessions plus centre or home based session of 16 km brisk walking or jogging each week; dietary recommendations	Endurance	Postmenopausal women and men with high cholesterol in the USA	233 (n/a)	No	No
Teoman 2004 n = 81	51 (4.0)	51 (4.2)	6 weeks of 30-50 min 3 × weekly endurance, strength, flexibility and balance exercise classes	Balance, endurance and strength	Postmenopausal women on HRT in Turkey	12 (n/a)	No	No
Uusi-Rasi 2003 n = 164	53 (2.8)	54.2 (2.4)	12 months of 60-min 3 × weekly jumping and callisthenic classes	Balance and strength	Postmenopausal women in Finland recruited by mailout to random sample	156 (53%)	No	Yes

Exp = physical activity group, Con = control group, n/a: not available

Table 3. Data used in meta-analyses.

Trials	Comparison	Outcome	Std diff in means (Hedges's g)	Std Err	Strength component
Asikainen 2006	Walking and resistance training v usual activities	Endurance	1.12	0.20	Yes
Asikainen 2006	Walking and resistance training v usual activities	Strength	0.40	0.18	Yes
Bemben 2000	Hi load low rep v control	Strength	1.17	0.60	Yes
Bemben 2000	Hi rep, low load v control	Strength	0.84	0.60	Yes
Bravo 1996	Exercise classes v usual activities	Balance	0.54	0.18	Yes
Bravo 1996	Exercise classes v usual activities	Endurance	0.81	0.19	Yes
Fu 2009	Balance, strength, cardiovascular training v usual activities	Balance	0.59	0.30	No
Fu 2009	Balance, strength, cardiovascular training v usual activities	Strength	0.87	0.31	No
Garcia-Lopez 2007	Endurance v control	Strength	0.19	0.55	No
Garcia-Lopez 2007	Strength v control	Strength	0.85	0.57	Yes
Heinonen 1998	Calisthenics v control	Strength	0.06	0.33	No
Heinonen 1998	Endurance v control	Strength	0.50	0.34	No
Janzen 2006	Bilateral training v control	Strength	0.74	0.39	Yes
Janzen 2006	Unilateral training v control	Strength	0.61	0.40	Yes
King 1991	High intensity group v control	Endurance	0.55	0.23	No
King 1991	High intensity home v control	Endurance	0.42	0.23	No
King 1991	Low intensity home v control	Endurance	0.39	0.23	No
Klentrou 2007	Multi-modal exercise v usual activities	Strength	0.24	0.48	No
Levinger 2007	Resistance training v usual activities	Balance	0.52	0.27	Yes
Levinger 2007	Resistance training v usual activities	Strength	0.85	0.28	Yes
Lindheim 1994	Walking v usual activities	Endurance	0.31	0.20	No
Maiorana 2001	Circuit training v usual activities	Strength	0.59	0.32	Yes
Mitchell 1998	Group aerobic v usual activities	Balance	0.51	0.36	No
Mitchell 1998	Group aerobic v usual activities	Strength	0.63	0.37	No
Singh 2009	Strength training v usual activities	Strength	1.06	0.29	Yes
Stefanick 1998	Aerobic training v usual activities	Endurance	0.90	0.11	No
Teoman 2004	Endurance, strength, flexibility and balance v usual activities	Balance	0.99	0.23	Yes
Teoman 2004	Endurance, strength, flexibility and balance v usual activities	Endurance	1.26	0.24	Yes
Teoman 2004	Endurance, strength, flexibility and balance v usual activities	Strength	0.68	0.23	Yes
Uusi-Rasi 2003	Jumping exercises v usual activities	Balance	0.11	0.16	No
Uusi-Rasi 2003	Jumping exercises v usual activities	Strength	0.12	0.16	No

SD = standard deviation, Bilat = bilateral, Hi load = high load, Low rep = low repetition

for instance suggested by the ACSM guidelines for healthy adults, ie, 8–10 strength-training exercises, with 8–12 repetitions of each exercise twice a week at an intensity where only 8–12 repetitions can be done without resting (Haskell et al 2007).

This review found a moderate effect of physical activity on balance but only six studies had tested this outcome. Trials in older people suggest that physical activity which includes a high challenge to balance leads to a greater reduction in falls than physical activity that does not provide such a challenge to balance (Sherrington et al 2008). This review does not provide clear evidence on the best way to improve balance in middle-aged people. Yet as previous work has pointed to the importance of 'specificity' in training, ie, people get better at what they practise, it seems likely that the best way to improve balance would be with exercises which involve challenges to balance such as tennis, dancing, tai chi, exercise to music, and running. The current ACSM guideline for adults aged under 65 does not

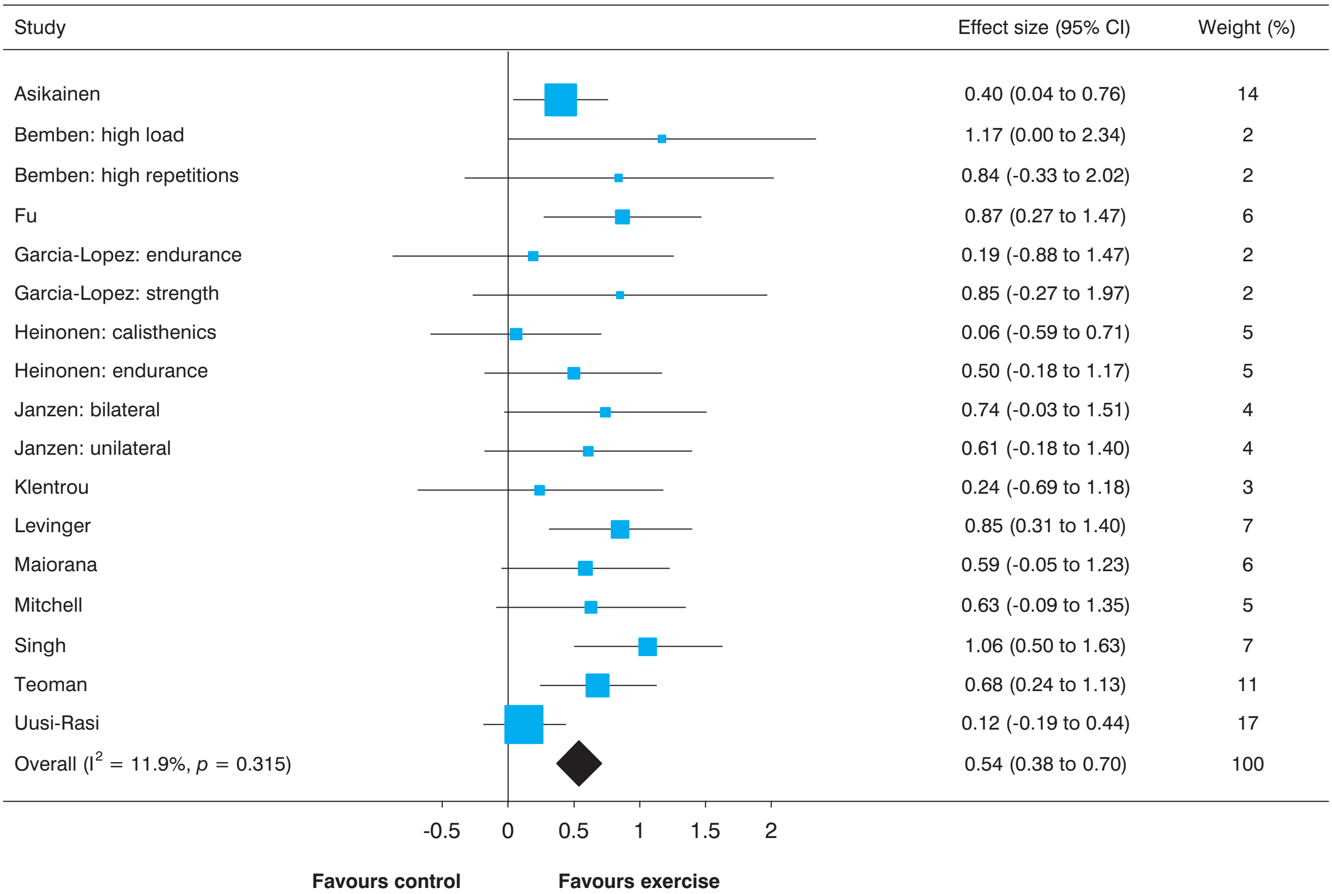

Figure 2. Effect size (95% CI) of physical activity on strength by pooling data from 13 studies (n = 537).

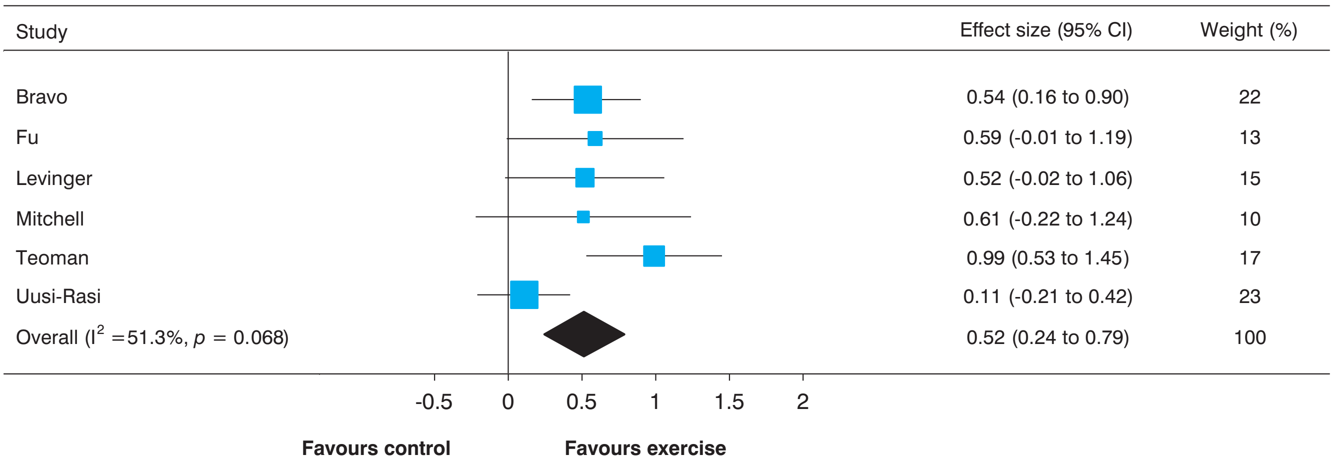

Figure 3. Effect size (95% CI) of physical activity on balance by pooling data from 6 studies (n = 406).

mention balance training, whereas the guideline for those over 65 does recommend balance training for those at risk of falls (Haskell et al 2007). The present review provides evidence that balance can be improved in people under 65 and previous work has shown the importance of balance as a risk factor for falls and that balance deteriorates with age. We therefore, suggest that a recommendation that all people undertake physical activities that challenge balance be considered for inclusion in future guidelines.

The meta-analysis found a moderate effect of physical activity on endurance (usually measured by walking distance). Endurance has not been clearly identified as a risk factor for falls but it is linked to frailty (Fried and Guralnik 1997) in older adults and is important in maintaining reserve capacity of the cardiovascular system which also deteriorates with increasing age in order to maintain the ability to perform activities of daily living. Again the ACSM guidelines about endurance training are supported by this analysis (Haskell et al 2007).

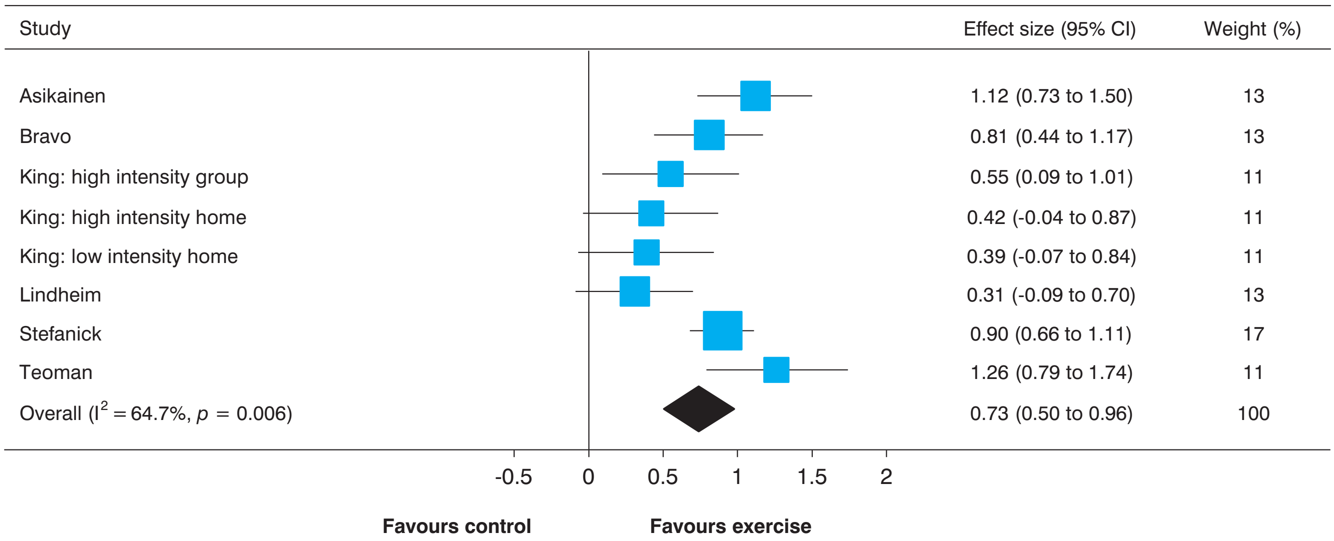

Figure 4. Effect size (95% CI) of physical activity on endurance by pooling data from 6 studies (n = 357).

The aim of this systematic review was to assess the effectiveness of being part of a physical activity program, rather than investigating the effectiveness of specific types of exercise. The ACSM defines physical activity as *body movement that is produced by the contraction of skeletal muscles and that increases energy expenditure* (Garber et al 2011) and goes on to affirm that *physical activity broadly encompasses exercise, sports, and physical activities.* We acknowledge that most trials included in this review centred on investigating the effectiveness of structured exercise, and that sub-grouping trials according to the type of exercise might yield different results, however this was outside the scope of our review. We also acknowledge the diversity of exercise programs assessed by the included trials would potentially introduce unwanted heterogeneity in our pooled analyses. However, a statistically significant level of heterogeneity ($p = 0.006$) was only observed in the pooled analysis of endurance. We recommend caution when interpreting these results.

We have based our conclusions about the size of effects of interventions on the widely used cut offs for clinical significance proposed by Cohen (1988), suggesting that standardised effect sizes of 0.2 should be considered small, those of 0.5 considered moderate, and those of 1.0 considered large (Cohen 1988). However, variations exist (Norman et al 2003), and by using different cut-offs we could have concluded differently. These benchmarks have been derived mainly from social science research; interpretations mainly reflect the opinions of researchers, rather than consumers (Ferreira et al 2012).

Many of the included trials were small and conducted in a research setting. The strength of a meta-analysis is that it can combine small trials that would not be individually powered to detect statistically significant effects of interventions. However the small size and research setting of many included trials means that it is difficult to draw conclusions about the feasibility of widespread implementation of these interventions in community settings.

The majority of the included trials did not appear to use blinded outcome assessment or concealed random allocation to groups. It is possible that this would increase the size of the effects seen. However, even if the true effect of physical activity intervention in this population is smaller than seen in the review we suggest that it still likely to be large enough to be useful.

No trials of the effectiveness of physical activity programs on short-term falls in middle-aged people were found. Although people in this age group do experience falls, which may be indicative of early problems with balance and strength, the overall incidence of falls is lower than in people aged 65 and older. Therefore very large sample sizes would be required to assess effects of physical activity on falls in this population. For example, if 10% of people aged 40–65 fell each year and physical activity reduced this to 8%, over 7500 participants would be required for a clinical trial to be large enough to establish that this difference was statistically significant.

This review found one trial that documented the effect of physical activity in people aged 40–65 on longer-term falls, suggesting a small, non-significant reduction of the risk of falls in people who exercised (Pereira et al 1998). Given that long-term falls was not one of the primary outcomes of the study by Pereira and colleagues, these findings should be interpreted with care, as the trial might have been underpowered to find a difference in the rate of long-term falls.

Recently, a trial (Lawton et al 2008) on the effectiveness of advice to increase physical activity levels was conducted among women aged 40–74. This trial found that, although effective in increasing the physical activity levels, advice to be more physically active only did not produce improvements in clinical or biological outcomes such as blood pressure, weight, levels of cholesterol, insulin, or blood glucose levels (Lawton et al 2008) and led to only a slight increase in the rate of short-term falls (32%) when compared to usual care (25%) (Lawton et al 2008). As the aim of the present review was to assess the effectiveness of physical activity programs, trials on advice to increase or promote physical activity such as the former, were not included. However the relationship between physical activity and falls needs further investigation.

Some information about the longer-term effects of physical activity can also be obtained from observational studies. There is a substantial risk of bias in such studies. It is likely that other factors (such as chronic disease, psychological factors) could be associated with both falls and physical activity and could confound any apparent protective effect of physical activity on falls. However, statistical techniques can be used to attempt to control for these factors. For example, an analysis of data from the prospective large-scale Australian Longitudinal Study on Women's Health study included over 8000 healthy women aged 70–75 and controlled for likely confounders. This analysis found that women who were more active experienced fewer falls and fall-related fractures (Heesch et al 2008). Women who were highly active were 36% less likely to have a fall in the subsequent three years (Heesch et al 2008). Similar analyses in large studies in other countries have found that highly active people are less likely to develop disability (Boyle et al 2007, Nusselder et al 2008).

The amount of physical activity required to prevent future falls is not clear from this review. However, as changes in muscle structure and muscular co-ordination (balance) are required, it is suggested that a more specific ACSM or World Health Organization guideline about strength and balance training be used to guide practice rather than a more general aim of increasing physical activity.

In conclusion, this review found that muscle strength, balance, and endurance can clearly be improved by physical activity in people aged 40–65. There were bigger effects on muscle strength from programs that specifically targeted strength using resistance exercises. These findings indicate the need to use resistance training if strength enhancement is the goal. There were insufficient trials in this review to enable investigation of different forms of physical activity on balance and endurance. One trial documented a small and non-significant effect of physical activity on long-term falls but trials have not documented an effect of physical activity in people aged 40–65 on short-term falls. Given the importance of strength and balance as risk factors for falls in older people, it is possible that future falls would be prevented by adoption and maintenance of physical activity programs by people aged 40–65. Such programs should include strength and balance components. ■

eAddenda: Appendix 1 available at jop.physiotherapy.asn.au

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