SYSTEMATIC REVIEW

Multi-modal exercise programs for older adults

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Abstract

Background: various modalities of exercise have been demonstrated to improve physical function and quality of life in older adults. Current guidelines stress the importance of multi-modal exercise for this cohort, including strengthening exercises, cardiovascular, flexibility and balance training. There is a lack of evidence, however, that simultaneously prescribed doses and intensities of strength, aerobic, and balance training in older adults are both feasible and capable of eliciting changes in physical function and quality of life.

Methods: a comprehensive, systematic database search for manuscripts was performed. Two reviewers independently assessed studies for potential inclusion. Physical and functional performance outcomes were extracted. The relative effect sizes (ES) were calculated with 95% confidence intervals.

Results: fifteen studies were included totalling 2,149 subjects; the mean cohort age ranging from 67 ± 8 to 84 ± 3 years. A low mean relative ES for strength was seen across the reviewed studies. Only six of the eleven studies that included balance measurements found a significant improvement in balance compared to controls. Aerobic fitness was seldom measured or reported. Five out of the six studies investigating fall rates showed a significant reduction. Functional and quality of life measures generally did not improve with exercise.

Conclusion: multi-modal exercise has a positive effect on falls prevention. The limited data available suggests that multi-modal exercise has a small effect on physical, functional and quality of life outcomes. Future research should include robustly designed trials that involve multi-modal exercise at individually prescribed intensities based on doses found to be effective in single-modality studies.

Keywords: exercise, older adults, systematic review, elderly

Introduction

The number of people over 60 years of age is projected to double in the next 20 years [1], hence, reducing age-related disability is an essential public health goal. Declining physical function is associated with institutionalisation, morbidity and mortality [2]. Various modalities of exercise have been demonstrated to improve physical function and quality of life in older adults. Current guidelines stress the importance of multi-modal exercise for this cohort, including strengthening exercises, cardiovascular, flexibility and balance training [3, 4]. Recommended doses have been established, or theorised, for each of these three modalities. There is a lack of evidence, however, that simultaneously prescribed doses and intensities of strength, aerobic, and balance training at levels known to produce physiological adaptation in older adults are both feasible and capable of eliciting changes in physical functioning and quality of life.

The purpose of this paper is to systematically review all health outcomes to concurrent strength, aerobic, and balance training in older adults to assess the current level of evidence regarding the feasibility and efficacy of current guidelines.

Methods

Criteria for study inclusion/exclusion

Design

Only randomised controlled trials were considered for inclusion.

Subjects

Studies that involved adult cohorts with a mean age ≥60 years were included. Studies with younger cohorts or that had a single clinical diagnosis as an entry criteria (e.g. stroke, multiple sclerosis, Down syndrome) were not considered.
This increases the external validity of the review as studies that were selected commonly excluded such conditions.

Interventions
The study exercise intervention must have been multi-modal, comprised of at least the three modalities of strength/resistance training, aerobic/cardiovascular endurance training, and balance/stability training, and may or may not have included flexibility exercises. The rationale for the selective inclusion of strength, aerobic, and balance training was that they are the modalities that are the best studied and have been demonstrated to have positive effects on health outcomes when prescribed in isolation. In contrast, the health benefits of stretching or specific flexibility exercises had not been well established and such exercises are commonly used as a ‘sham’ or placebo activity.

The resistance training was required to be progressive in nature (progressive resistance training), defined as involving an increase in load across the training period but was not required to be of any specific intensity. Aerobic training could include any exercise involving movement of large muscle groups for a period of time including walking, cycling and rowing. Balance/stability training included any training that sought increases in the subject’s ability to maintain balance in the face of a threat to stability and may have included specific balance exercises or Tai Chi. The three modes of training had to be conducted concurrently.

Only full articles limited to the English language were considered.

Search strategy
A comprehensive, systematic database search for manuscripts was performed on 20 December 2006 using MEDLINE, PreMEDLINE, AMED, CDSR, DARE, CCTR, CINAHL and SPORTDiscus databases from 1966 to December 2006. First, four categorical searches were conducted using the following keywords: (i) ‘balance’ or ‘stability’, (ii) ‘endurance’, ‘aerobic’, ‘stamina’ or ‘cardiovascular’, (iii) ‘strength’, ‘resistance’ or ‘weight’, (iv) ‘multi-modal exercise’ or ‘multimodal exercise’. Second, searches 1–3 were combined and duplicate results were removed. All titles were manually searched for potential inclusion in the review. Reference lists of articles retrieved, review articles and position stands were examined for further relevant references.

Quality assessment
Once studies were collected based on a minimum quality threshold, defined as having met all inclusion criteria, a more detailed assessment of the study quality was conducted. The quality of the studies retrieved was assessed according to a modified Delphi list.

Data extraction and synthesis
Two reviewers independently assessed studies for potential inclusion. Outcomes for physical or functional performance as well as health and quality-of-life outcomes were extracted.

Statistical analysis
Due to the heterogeneity of exercise prescriptions, outcomes assessed and measurement tools used, a systematic and critical review was conducted rather than a meta-analytic approach.

An effect size (ES) over the intervention time (standardised mean response) for each of the groups was calculated using the equation:

\[ ES = \frac{\text{Mean}_{\text{POST}} - \text{Mean}_{\text{PRE}}}{\text{SD}_{\text{PRE}}} \]

The relative ES as a difference between the control and the intervention group ES is presented:

\[ ES_{\text{RELATIVE}} = ES_{\text{INTERVENTION}} - ES_{\text{CONTROL}} \]

Ninety five percent confidence intervals for the relative ES were calculated. This method accounts for differences in baseline values between the groups as well as changes over time seen in both the control and intervention groups.

Results

Study inclusion/exclusion
The process of study inclusion/exclusion at each step is presented in Figure 1. The search strategy yielded 1,925 papers, of which 110 were identified as potentially relevant and were retained for criterion and quality assessment. Fifteen papers satisfied all inclusion criteria and threshold of quality and were included in the review. Of the 95 papers excluded, the most common reason for exclusion was the training intervention not meeting selection criteria (n = 40). Other reasons for exclusion were the paper being a review (n = 29), and not being an RCT (n = 13).

Study quality
An assessment of the study quality according to a modified Delphi list is presented in Table 1. In general, all included studies specified their inclusion criteria, randomly assigned groups, reported standard deviations or confidence intervals, and reported baseline characteristics. Seven studies reported percent exercise attendance and only two studies reported compliance with exercise progression. The occurrence of adverse events was reported in only nine of the 15 studies and the outcome results were incompletely reported in four of the studies. No study reported the coefficient of variation for all outcome measures. Half of the studies reported power calculations in their methodology.

Cohorts
In general, the study cohorts were relatively healthy independent living older adults with a number of stable chronic conditions, commonly hypertension, arthritis and diabetes. The majority (10/15) of the included studies did not select participants based on any functional or mobility limitation. A summary description of each of the study cohorts is shown in Table 2.
Multi-modal exercise for older adults

were of female cohorts [10, 16, 18, 20, 21, 23, 24], six were of mixed cohorts [11, 13–15, 17, 19, 22] and one study included males only [12]. In total, the 15 studies consisted of 2,149 subjects with the mean cohort age ranging from 67 ± 8 to 84 ± 3 years of age. Thirteen studies recruited their subjects from the general community, one study recruited from a retirement village [23] and one from a long-term care facility [11]. Five of the studies listed some degree of functional impairment/limitation as an inclusion criteria [12–15, 20]. Exclusion criteria commonly included cardiovascular disease [10–12, 14–17, 20, 23], patients taking medications affecting bone mineral density (BMD) [10, 13, 16, 23], and some minimum cognitive or psychological function measure [12–23].

Interventions

Table 3 (available online at http://ageing.oxfordjournals.org) shows a summary of all reviewed studies demonstrating the heterogeneity in methods and exercise interventions between studies. Five studies administered home-based interventions [15, 18, 19, 21, 22] while the other studies had interventions that were directly supervised centre-based programs in either a class format [11, 12, 14, 16] or in small groups [10, 13, 23]. Two studies had a combination of home- and centre-based exercise [17, 20]. The intervention duration was on average, 8.8 (±3.6) months ranging from 3 to 12 months. While all studies included the three modalities specified as the review inclusion criteria, the delivery of modalities varied between studies.

Strength/resistance training

The frequency of training was most commonly (12/15 studies) 3 days per week, with one study training twice per week [16], and one study training once per week [14]. One study had three exercise groups training one, two and three days per week for all modalities [24]. Although the resistance training was delivered in a progressive fashion in all reviewed papers, the intensity was not always specified. Four studies [10, 13, 15, 23] reported strength training intensities at or above 65% 1RM, one at 7 on the 10-point Borg scale [25], and two up to 16 on the 20-point Borg scale [17, 20]. Four studies reported prescribing training at a 'moderate' intensity [18, 19, 21, 22]. Exercises were primarily performed using resistive
bands, ankle weights, hand weights and body weight (11/15 studies) with three studies [10, 13, 23] prescribing machine-based training. Six studies [13, 15, 16, 20, 23, 24] performed both upper-body and lower-body exercises, seven studies [10, 12, 17–19, 21, 22] performed lower-body exercises only, and two studies [11, 14] did not specify the muscle groups targeted or the exercises performed.

Balance training

Balance training was most commonly prescribed (11/15 studies) 3 days per week, with two studies training twice per week [12, 16], and one study training once per week [14]. All studies prescribed both static and dynamic balance exercises. An intensity level was specified in only one study [15] as being 7 on the 10-point Borg scale [25]. Five of the reviewed studies stated that the balance training was progressive in nature [10, 12, 13, 15, 16].

Aerobic training

Aerobic exercise was prescribed 3 days per week in most studies (8/15 studies) with three studies prescribing 2 days per week [16, 18, 19] of activity, two studies training once per week [14, 20], and one study not specifying frequency and instead prescribing an accumulation of activity over a week [15]. Intensity was not reported in the majority of studies (9/15 studies). Three studies prescribed intensities of 13 to 16 on the 20-point Borg scale [17, 20, 24], one set an intensity of 70% maximum heart rate [10], one study at or below 70% heart rate reserve [12], and one study at 65–70% VO2PEAK [13]. All studies included walking as a modality; one study also included cycling ergometer training [12], and one study included both cycling and rowing ergometer training [13]. Duration of exercise ranged from approximately 8.3 min [12], up to 45 min [23] per session.

Control group

Control groups are described in Table 2 (available online at http://ageing.oxfordjournals.org). Most commonly, the control groups received no treatment or advice [12, 18, 19, 22–24]. In two studies the control group performed low intensity ‘sham’ or flexibility exercises [10, 11, 20]. Three studies provided the control group with some form of education [14, 15, 17]; one study used an attention control in the form of a nurse visit [21]; one study advised the control group to increase physical activity to 120 min per week of walking [13], while another advised the control group to not increase physical activity levels for 12 months [16].

Outcomes

Primary and secondary outcomes are presented in Table 3 (available online at http://ageing.oxfordjournals.org).

Strength outcomes

Strength measurement methods varied between studies with four studies using maximal isometric contractions [11, 14, 16, 21], four studies using hand-grip strength [11, 15, 16, 24], two studies using isokinetic dynamometry [12, 13], and four studies using 1 RM testing [10, 11, 15, 23]. Five studies did not record any strength measures [17–20, 22] and one study did not report pre- or post-intervention values [21] but stated there were no group differences. Only one study found a significantly greater increase in strength in the intervention group compared to controls across all-strength measures [13]; while four studies [10–12, 16] found an increase in some measures of strength but not in others. Four studies reported no significantly greater improvements in strength in the exercise group relative to controls [14, 15, 23, 24]. Relative ESs for strength measures ranged from −0.08 [12] to 1.67 [10], with a mean of 0.41 across all study strength measures.

Balance outcomes

Eleven of the fifteen studies reviewed included a measure of balance. The most common measure used was single-leg stance time which was measured in six studies [12, 13, 15–17, 21], with the Berg balance scale measured in three studies [11, 13, 16], and units of sway measured in three studies [10, 14, 23]. One study included the POMI balance scale [12], one study measured a tandem-walk time [15] and one study measured functional reach [24]. Six of the eleven studies that included balance measurements found a significant improvement in balance as a result of the intervention when compared to the controls [11, 14, 15, 21, 23, 24]. Relative ESs for balance measures ranged from 0.22 [16] to 1.41 [23].

Aerobic fitness outcomes

Aerobic fitness was infrequently measured or reported in the reviewed studies. Three studies [12, 15, 21] recorded a 6 min walk distance, and one study [13] recorded a VO2PEAK measured using a treadmill protocol. Only one of the three studies using a 6 min walk protocol reported an increase in distance for the intervention group significantly different from the control group [12], with the other two studies reporting no significant difference. The study which measured VO2PEAK reported a significant improvement in the intervention group and a decline in performance in the control group.

Functional and physiological outcomes

Six studies assessed the incidence of falls in the intervention group compared to the control group [14, 18–22]. In all but one of these studies [22] the incidence of falling was reduced with exercise. Habitual gait velocity [11, 14, 17, 21], and maximal gait velocity [11, 13–16] were also commonly
assessed. Only two of the studies that measured gait velocity found an increase in maximal [16] and habitual walking velocity [17] in the intervention group significantly greater than the control group. Two studies measured BMD [16, 23], with one of the studies [23] reporting an increase in BMD at the femoral neck but not at the lumbar spine in the exercise group, the other study finding no significant changes. A chair-stand test was administered in five studies [12–14, 21, 24], with one study [13] reporting a significant improvement in the intervention group.

Psychological and quality-of-life outcomes

Four studies reviewed included SF-36 quality-of-life outcomes [12–15], and one study included a GDS score for depressive symptom outcomes [15]. One study found the exercisers rated their global health better than the controls at post-test but without significant differences in the subscales of the SF-36 [12]. One study reported a greater improvement on the 'change in health' subscale of the SF-36 in the exercise group [13]. Two studies [14, 15] observed no group differences in quality-of-life measures and no study reported a group difference in depressive symptoms following multi-modal exercise.

Adherence

Adherence data are presented in Table 1 (available online at http://ageing.oxfordjournals.org). Eight of the 15 studies reported compliance in terms of attendance [10–19, 22]. The mean attendance rate was 78.2% of sessions, ranging from a median of 62% in a community-based class program [14]; to a mean of 100% in a centre-based trial [13] that required the completion of the designated number of sessions before progression to the next phase of training. One of the home-based studies reported an attendance rate of 82% [15]. Only one study reported compliance with the prescribed exercise intensity for resistance training, with the final training loads progressing to two to four times the initial training loads after 6 months [15]. One study reported compliance of aerobic exercise volume with a mean of 138 min per week [17].

Adverse events

Adverse events are presented in Table 1 (available online at http://ageing.oxfordjournals.org). Of the nine studies that reported adverse events, four reported that no events occurred [11, 12, 16, 20]; two reported a fall during the exercise training [15, 18] and one reported two falls [19], all resulting in only minor injuries. One study reported a subject experiencing pain with exercise [19], and one study reported two shoulder injuries/worsening of existing shoulder injury [13], all three injuries resulting in a discontinuation of the exercise intervention. One study reported a range of instances of events both related and unrelated to the intervention, reporting the intervention and control groups as having similar rates of adverse events [17].

Discussion

Although current exercise guidelines [3, 4] stress the importance of multi-modal exercise for older adults, there is a lack of evidence that simultaneously prescribed doses and intensities of strength, aerobic and balance training in older adults are both feasible and capable of eliciting changes in physical function and quality of life.

This paper identified the available literature regarding the effect of multi-modal (strength, aerobic and balance) exercise for older adults. Overall, this review suggests that multi-modal exercise has a positive effect on falls prevention. The limited data available suggests that multi-modal exercise may have a smaller effect on physical and functional outcomes than single-modality exercise training. Future directions for research should include robustly designed RCTs [26] that involve multi-modal exercise at individually prescribed intensities based on doses found to be effective in single-modality studies.

A low mean relative effect size for strength, 0.41, was seen across the reviewed studies. A recent meta-analysis has reported a mean effect size as 0.68 across studies of strength training in older adults [6]. Previous studies using single modal strength training in older cohorts have reported changes in strength much larger than those in the present review [6, 27]. The ESs for the centre-based non-class style programs tended to be higher than in the class-based or home-based interventions. It is not known if the prescribed intensities or volumes of training were adhered to in the studies reviewed, as only one study reported information on initial and final training loads.

In the studies we reviewed, the balance outcomes were varied with only six of the eleven studies that included balance measurements finding a significant improvement in balance compared to the controls. Studies prescribing balance training 3 days per week tended to have high ESs for the intervention group of 0.71 or higher. Previous studies have seen no association between improved balance and increased strength [10, 28] or aerobic fitness [10] following an exercise intervention suggesting that for improvements in balance to occur, specific balance training at sufficient volumes, that is 3 days per week or greater, may be required.

Aerobic fitness was seldom measured or reported in the reviewed studies, thus there is limited evidence on the efficacy of multi-modal exercise on improving this measure. The only study [13] to use a direct measure of VO₂ was able to find a significant effect of training on aerobic fitness. Although originally conceptualised as a proxy for aerobic fitness, recent use of the 6-min walk in geriatric cohorts has documented contributions of strength, balance, gait stability, health status, depression and body composition to 6-min walk performance [29, 30], making it a less-than-ideal measure of aerobic fitness in isolation, and may explain the inconsistencies found in the reviewed studies. The 6-min walk should, however, be expected to improve as a measure of overall function if a multi-modal intervention is successful in improving capacity across all three physiological
domains. Future studies should incorporate the 6-min walk to determine the relative contributions of changes in strength, balance and aerobic capacity to changes in performance.

Multi-modal exercise appears to be effective for falls prevention with five out of the six studies investigating fall rates finding a significant reduction associated with the intervention. The one study that found no effect of the exercise intervention [22] enrolled patients on psychotropic medication, rather than targeting those with other risk factors such as poor balance or fragility, where withdrawal of medication was most effective for falls reduction.

Functional measures and quality-of-life measures generally did not improve with multi-modal exercise. Gait velocity and chair-stand were infrequently shown to improve. Poorer performance in these two measures has been shown to be related to increased risk of morbidity, mortality and institutionalisation when used in the calculation of a Short Physical Performance Battery (SPPB) score [2]. A ceiling effect may have prevented further improvement in some functional measures for which subjects had little limitation at baseline. One study was able to demonstrate an improvement in the SPPB score after 12 months of training in subjects with a relatively low initial value [17].

The level of evidence is modest, with only a small number of studies investigating the effects of multi-modal exercise. Varied study methodologies resulted in a heterogeneity of outcomes. Few studies with robust interventions prescribing individually assessed intensities of each modality have been conducted, with the majority involving class- or home-based interventions. Further investigation is needed on the efficacy of simultaneous prescription of multi-modal training as a treatment for improving clinically relevant outcomes such as a reduction in disease risk factors, functional measures or activities of daily living. More evidence is needed to establish whether multi-modal exercise at adequate volumes and intensities is feasible in older populations. There is a need for future studies to document adverse events as well as attendance only. There is also a need for future studies to select cohorts matched to the outcome of interest, such as cohorts with functional impairments in studies with disability or performance outcomes.

This systematic review is limited, in that it did not include unpublished studies, studies not published in English or thesis dissertations. Additionally, the results of this review are not generalisable to clinical populations that were not included in the selected studies, such as patients with multiple sclerosis, Parkinson’s disease or in a rehabilitation program for heart disease or stroke.

The findings of our study may be clinically relevant when considering exercise prescription in a practical setting. Despite the modest level of evidence in multi-modal exercise, it may be seen as an effective treatment for preventing falls in older cohorts. In future clinical practice a staged prescriptive approach that prescribes the modality of exercise most targeted to the most urgent needs of the patient, followed by the introduction of other modalities, may allow greater

**Supplementary data**

Supplementary materials mentioned in the text are available online at http://ageing.oxfordjournals.org.

**Key points**

- A systematic review of the physiological and functional adaptations to concurrent resistance, aerobic and balance training in older adults was performed.
- The limited data available suggests that multi-modal exercise has a small effect on physical, functional and quality of life outcomes.
- Multi-modal exercise may be seen as an effective treatment for preventing falls in older cohorts.
- Further investigation is needed on the efficacy of simultaneous prescription of multi-modal training as a treatment for improving clinically relevant outcomes, and to establish whether multi-modal exercise at adequate volumes and intensities is feasible in older populations.

**Conflicts of interest declaration**

None.

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