

Effects of Different Exercise Interventions on Risk of Falls, Gait Ability, and Balance in Physically Frail Older Adults: A Systematic Review

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Abstract

The aim of this review was to recommend training strategies that improve the functional capacity in physically frail older adults based on scientific literature, focusing specially in supervised exercise programs that improved muscle strength, fall risk, balance, and gait ability. Scielo, Science Citation Index, MEDLINE, Scopus, Sport Discus, and ScienceDirect databases were searched from 1990 to 2012. Studies must have mentioned the effects of exercise training on at least one of the following four parameters: Incidence of falls, gait, balance, and lower-body strength. Twenty studies that investigated the effects of multi-component exercise training (10), resistance training (6), endurance training (1), and balance training (3) were included in the present revision. Ten trials investigated the effects of exercise on the incidence of falls in elderly with physical frailty. Seven of them have found a fewer falls incidence after physical training when compared with the control group. Eleven trials investigated the effects of exercise intervention on the gait ability. Six of them showed enhancements in the gait ability. Ten trials investigated the effects of exercise intervention on the balance performance and seven of them demonstrated enhanced balance. Thirteen trials investigated the effects of exercise intervention on the muscle strength and nine of them showed increases in the muscle strength. The multi-component exercise intervention composed by strength, endurance and balance training seems to be the best strategy to improve rate of falls, gait ability, balance, and strength performance in physically frail older adults.

Introduction

FRAILTY IS AN AGE-ASSOCIATED BIOLOGICAL SYNDROME characterized by decreases in the biological functional reserve and resistance to stressors due to changes in several physiological systems, which puts individuals at special risk for poor outcomes (disability, fall death, and hospitalization) from minor stressors.¹⁻⁴ Frailty encompasses changes that are associated with aging, life styles, chronic diseases, and the interactions among them.^{5,6} The prevalence of frailty in people older than 65 years is high (ranging from 7% to 16.3%), increases with age,⁷⁻⁹ and is the main risk factor for disability.^{10,11} The diagnosis of frailty comprises several domains, including physical impairments (*e.g.*, low gait speed, fatigue, and low grip strength), weight loss, and low physical activity.⁷ One of the main pathophysiological issues underlying the frailty syndrome is the loss of muscle mass that is induced by biological aging (*i.e.*, sarcopenia). Sarcopenia is exacerbated by decreased physical activity, causing a decline

in overall function that leads to frailty.^{12,13} In addition, other diseases, such as malnutrition, immobility, anemia, obesity, cancer, and cardiovascular disease, can accelerate the morbidity and mortality that are induced by the frailty syndrome.¹⁰

Poor health, disability, and dependency do not have to be inevitable consequences of aging. Indeed, older adults who practice healthy lifestyles, avoid sedentariness, participate in physical exercise (*e.g.*, walking, strength training, or self-adjusted physical activity), use clinical preventive services, and continue to engage with family and friends are more likely to remain healthy, live independently, and incur fewer health-related costs.¹⁴

The benefits of physical exercise in improving the functional capacity of frail, older adults have been the focus of considerable recent research.¹⁵⁻¹⁷ Exercise programs tailored to this population have been demonstrated to be effective. These interventions, such as resistance training, balance training, endurance training, coordination training,

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multi-component exercises (*i.e.*, simultaneous strength, endurance, and balance training), and Tai Chi, have yielded beneficial effects on certain functional parameters in frail, elderly subjects. However, multi-component exercise programs that include resistance training appear to result in greater overall enhancements because this type of intervention stimulates several components of physical health, such as strength, cardiorespiratory fitness, and balance.^{16–18}

Some studies observed an impaired physical function of subjects who were not necessarily defined as frail subjects, but presented severe functional declines such as lower limb weakness, poor balance, and physical impairments induced by recent history of injurious falls.^{9,12,15,17} Thus, there is a need to define exercise prescription strategies to improve the functional capacity in elderly who are overall physically frail.

In addition to reducing the loss of muscle strength and mass, exercise interventions should focus on reducing the number of falls and improving balance and gait ability. To optimize the physical training prescription and meet these goals in subjects with physical frailty, the most effective type of exercise program should be identified by considering the optimal combination of intensity, volume, and frequency of weekly training that would promote neuromuscular and cardiovascular adaptations and thus result in improved functional capacity in the frail elderly. Furthermore, because muscle power is an important predictor of functional capacity, strategies to develop skeletal muscle power in this population must be discussed. Although descriptive and systematic reviews have been written on the effects of exercise interventions on physical outcomes in frail subjects or elderly with impaired mobility,^{10,19–21} none of these previous reviews analyzed the effects of different exercise interventions on specific functional outcomes, such as balance, gait ability, and the risk of falls in elderly with physical frailty.

This review will focus on supervised exercise programs that improved muscle strength, balance, and gait ability and decreased the risk of falls. In addition to these effects of training, the present review will identify other characteristics of the exercise programs, such as the volume, intensity, and weekly frequency, as well as possible injuries and side effects. Training strategies to improve the functional capacity of elderly individuals with physical frailty will then be recommended based on the scientific literature.

Literature Search

Definition of terms

The most frequent frailty definition is focused on the evaluation of five domains, which are assessed by five criteria (one per each domain): Weight loss, exhaustion, leisure time activity, gait speed, and grip strength.^{1–8} Along with studies investigating frail and pre-frail subjects, in the present review, we searched for studies that classified their subjects as “physically frail older adults,” basing its classification in the physical performance domains of frailty syndrome, such as gait speed, grip strength, and exhaustion. In addition, we also searched for studies on elderly who were aged 70 years and older and presented severe declines in the physical function, such as lower limb weakness, poor balance, slow reaction time, and physical performance impairments induced by recent history of injurious falls.

Search strategy

The Scielo, Science Citation Index, MEDLINE, Scopus, Sport Discus, and ScienceDirect databases were searched from February to September, 2012, for published articles based on original scientific investigations during the period from 1990 to 2012. The search terms included various combinations of the following keywords: ‘resistance training in frail’, ‘endurance training in frail’, ‘exercise training in elderly’, ‘multi-component exercise interventions’, ‘muscle power in elderly’, ‘muscle strength in elderly’, ‘combined resistance and aerobic training’, and ‘muscle quality’. The names of authors who were cited in some of the studies were also used in the searches. This systematic review is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement.²²

Criteria for study consideration

The search criteria were as follows: (1) The studies must have been published in English, peer-reviewed, scholarly journals; (2) dissertations, theses, and conference proceedings were excluded; (3) the studies must have mentioned the effects of exercise training programs on at least one of the following four functional parameters in the frail elderly, elderly with physical frailty, and elderly with severe functional declines—incidence of falls, gait, balance, and lower-body strength; and (4) detailed information about the exercise interventions and the control group must have been provided. The control group must be a no physical activity group (maintenance of the habitual lifestyle) or home-based low-level recreational exercise intervention with only stretching and relaxation exercises. Exceptions were done in the studies comparing two different exercise interventions. Data on exercise interventions that were associated with hormonal treatments, drug therapy, or other supplements were excluded. Thus, only the results of the exercise interventions alone were considered and are described in this review.

Inclusion of studies

From the preliminary search, 79 manuscripts had their title read and 27 were selected for a second analysis, which included the reading of the abstracts. Twenty original randomized controlled trials that investigated the effects of exercise interventions in elderly with physical frailty were included in the review (Fig. 1); the interventions included strength training, endurance training, balance training, and multi-component exercises. Ten of these studies investigated the effects of multi-component exercise interventions,^{15,17,23–29} six studies investigated the effects of resistance training,^{30–35} one study investigated the effects of endurance training combined with yoga,³⁶ and three studies investigated the effects of a Tai Chi intervention, which was considered to be a balance training intervention.^{37–39}

Assessment of risk of bias

Risk of bias was evaluated according to the PRISMA recommendation.²² Study quality assessment included adequate sequence generation, allocation concealment, blinding of outcomes assessors, use of intention-to-treat analysis, and description of losses and exclusions. Studies without clear descriptions of an adequate sequence generation or how the

allocation list was concealed were considered not to have fulfilled these criteria. Quality assessment was independently performed by 2 unblinded reviewers, and disagreements were solved by consensus or by a third reviewer. Among the included studies, 45% presented adequate sequence generation (9 of 20),^{15,17,24,28,33,35,36,38,40} 60% reported allocation concealment (12 of 20),^{15,17,24,26,32–36,38–40} 80% had blinded assessment of outcomes (16 of 20),^{15,17,23–26,31–40} 100% described losses to follow-up and exclusions (20 of 20),^{15,17,23–40} and 70% used the intention-to-treat principle for statistical analyses (14 of 20).^{15,17,23–26,28,30,33–36,39,40}

Subject characteristics

The sample size of the studies that were included in the present review was 171.8 ± 196.6 subjects (ranging from 9¹⁶ to 684 subjects³⁸). The mean \pm standard deviation (SD) of the subjects' ages was 78.2 ± 5.3 (ranging from 70 ± 2 ¹⁶ to 90 ± 2 ³⁵). In seven of the 20 included studies, the subjects were defined as frail, pre-frail, and mild-to-moderate frail.^{27–29,31–33,36} From these studies, six presented criteria for classification of frailty consistent with the literature.^{27,29,31–33,36} Five studies classified their subjects as elderly with physical frailty using criteria consistent with the literature.^{23–26,30} Six studies investigated elderly aged 70 and older presenting recent history of injurious falls, transition for frailty, and recent illness-induced functional decline.^{17,34,37–40} Finally, one study investigated sarcopenic women presenting poor strength and gait ability levels based on literature criteria,¹⁵ and one study investigated elderly aged 90 and older.³⁵

Physical outcomes measurements

Among the included studies, the gait ability was assessed by the 6-meter walk test and the Timed Up and Go test. The balance performance was assessed by the tandem and semi-tandem tests, Berg balance scale, one leg stand test, and clinical test of sensory interaction and balance. The strength measurements were done using the one repetition maximum test (1RM) and isokinetic and isometric dynamometry. Data on incidence of falls were assessed using validated questionnaires.

Effects of Exercise Programs on Different Physical Outcomes in Elderly with Physical Frailty

Incidence of falls

Ten studies investigated the effects of exercise interventions on the incidence of falls in elderly with physical frailty. Seven of the studies found a lower incidence of falls after the physical training period^{23,26,28,35,37,38,40} compared with the control group, and three studies did not demonstrate any difference.^{17,33,39} Four of the studies that showed a reduced incidence of falls used multi-component exercise programs in their intervention,^{23,26,28,40} one study used only resistance exercises,³⁵ and two studies used Tai Chi exercises.^{37,38} The mean decrease in the incidence of falls ranged from 22% to 58%. Among the three trials that did not reveal a significant effect, in the study of Latham et al.,³³ the subjects participated in a home-based resistance exercise program using 60–80% of the individuals' 1RM with ankle cuffs, with no balance exercises included in the exercise intervention. In the study of Freiburger et al.,¹⁷ the subjects participated in a

multi-component exercise intervention; the authors justified their results based on the study's limitations, such as the statistical power calculation, which was based on the Timed Up and Go test data and may have prevented the results from reaching statistical significance. In the study by Wolf et al.,³⁹ the incidence of falls was compared between the Tai Chi and wellness education interventions. In this study, the incidence of falls was reduced in both groups after 48 weeks; however, the authors stated that their study had the power to detect a 50% reduction in the rate of falls, which did not occur in their study.

Gait ability

Eleven trials investigated the effects of exercise interventions on the gait ability in elderly with physical frailty. Six studies revealed enhancements in the subjects' gaits after the physical training period,^{15,17,23,30,32,36} whereas five studies demonstrated no improvement.^{26,33–35,38} Three of the studies that demonstrated improvements in their subjects' gaits used multi-component exercise programs,^{15,17,23} two studies used only resistance exercises,^{32,35} and one study used endurance training combined with yoga.³⁶ The mean improvement in gait ranged from 4% to 50%. Among the six studies that did not reveal a significant effect, the study of Barnett et al.,²⁶ used a 1-year, home-based exercise intervention; the authors justified the absence of changes in gait based on the emphasis on balance-related exercises and a low-frequency exercise program. Specific exercises for improving gait were not used in the studies of Latham et al.,³³ Sullivan et al.,³⁴ Serra-Rexach et al.,³⁵ (resistance training intervention), Hagedorn and Holm,²⁹ (resistance training and balance interventions), and Taylor et al.³⁸ (Tai Chi intervention).

Balance

Ten studies investigated the effects of exercise interventions on balance in elderly with physical frailty. Eight of the investigations revealed enhanced balance after the physical training period,^{17,23–26,29,39,40} whereas two studies did not demonstrate any improvement.^{28,33} Seven of the studies that revealed enhancements in balance used multi-component exercise programs that included balance training,^{17,23–26,29,40} and one study included Tai Chi exercises.³⁹ The mean improvement in balance ranged from 5% to 80%. Of the two research groups that did not determine a significant effect, Lord et al.²⁸ suggested that their exercise interventions were of insufficient intensity to produce gains in this domain; indeed, they mentioned in the intervention description that most of the utilized exercises emphasized social interaction and enjoyment.²⁸ As previously mentioned, the study of Latham et al.³³ did not include any balance exercises in the intervention.

Muscle strength

Thirteen studies investigated the effects of exercise interventions on lower-body muscle strength in elderly with physical frailty. Nine studies revealed increased muscle strength after the physical training period,^{23,24,29–32,34,35,40} whereas four studies did not identify any improvement.^{15,26,28,33} Five of the studies that demonstrated enhanced strength used resistance exercise programs,^{30–32,34,35}

and four studies used multi-component exercise interventions.^{23,24,29,40} The mean increase in strength ranged from 6% to 60%. Of the four studies that did not reveal a significant effect on muscle strength, Latham et al.³³ and Barnett et al.²⁶ used home-based exercise interventions, which may not have provided sufficient stimuli for facilitating strength gains. In the exercise intervention of Lord et al.,²⁸ it appears that only weight-bearing exercises were performed, and no details were provided regarding the exercise intensity used. In the study of Kim et al.,¹⁵ the subjects performed gait and balance and strength exercise with ankle-weight cuffs from 0.50 kg to 1.50 kg and resistance bands, which may not have provided sufficient stimuli for facilitating strength gains.

What Is the Best Exercise Intervention to Reduce Falls and Disability and Improve Balance in Elderly with Physical Frailty?

Several studies have investigated the effects of various physical exercise programs on the functional capacity of elderly with physical frailty.^{16,24,26,30,32} Resistance training, endurance training, balance training, and combinations of these programs (*i.e.*, multi-component exercises) have yielded beneficial effects on certain functional parameters in frail elderly subjects. As expected, greater gains in strength have been achieved when resistance training was used in exercise programs.^{24,26,30} In addition, exercise programs (including resistance training) have also enhanced functional parameters, such as gait and balance, and reduced the risk of falls.^{17,23,41} Table 1 summarizes the methods applied and the results obtained in the studies that have investigated exercise interventions in elderly subjects with physical frailty.

Resistance training

Studies on resistance training in the elderly have shown that this type of exercise intervention can improve neuromuscular activity, muscle mass, strength, power, and functional capacity, as well as enhance cardiovascular function when prescribed in combination with aerobic training.^{42–47} Notwithstanding, a limited number of studies have investigated the effects of resistance training in the oldest-old and frail subjects. Fiatarone et al.³⁰ studied the adaptations induced by resistance training in 100 frail elderly men and women. The subjects underwent resistance training that consisted of 3 sets of 8 repetitions at 80% of 1RM, 3 times per week for 10 weeks. The results revealed that the resistance training groups improved their habitual gait velocities, stair-climbing abilities, and overall levels of physical activity. Moreover, resistance training significantly enhanced the leg muscle strength outcomes ($p < 0.001$). In a study by Serrarexach et al.,³⁵ 20 oldest-old subjects (90–97 years of age) underwent resistance training 3 times a week for 8 weeks, with 2–3 sets of 8–10 repetitions at 30% of 1RM in the initial phase of training, progressing to 70% of 1RM. The results demonstrated increases in the leg press strength (10.6 kg; $p < 0.05$), but no changes were observed in the speed during an 8-meter walking test, the time to complete a 4-step stair test, and the results of the Timed Up and Go test. Using a similar progression of intensity, Hennessey et al.,³¹ observed significant 1RM increases after 24 weeks of training in frail elderly individuals (71.3 ± 4.5 years of age). In this study, the participants performed 3 sets of 8 repetitions at 20% of 1RM,

progressing gradually to 95% of 1RM. In another study, Lustosa et al.³² observed significant improvements in the Timed Up and Go test, gait speed, and power at $180^\circ \cdot s^{-1}$ in pre-frail elderly subjects (72 ± 4 years of age) after 12 weeks of resistance training that was performed 3 times per week. In this study, a half-squat exercise was performed using the participants' body weights as resistance.

In a study of the effectiveness of different training intensities (% of 1RM) in frail elderly subjects (79.4 ± 7.4 years of age), Sullivan et al.³⁴ have shown greater strength increases in the training groups that underwent progressively the intensity of the resistance training (starting at 20% and progressing to 80% of 1RM) compared with the low-intensity training groups that underwent resistance training (at 20% of 1RM during the entire 12-week training period).

In a study investigating the efficacy of home-based resistance training, Latham et al.³³ assessed frail elderly men and women who were over 65 (79.1 ± 6.9) years of age. The subjects performed 10 weeks of home-based resistance training, with intensities between 60% and 80% of 1RM (3 sets of 8 repetitions). After the training period, no effects of the resistance training were detected regarding the incidence of falls, the timed walking test, the Timed Up and Go test, and the Berg balance test compared with the control group. In addition, no difference was observed in quadriceps strength between the resistance training group and the control group after the training period.

In summary, resistance training programs that are performed 3 times a week, with 3 sets of 8 to 12 repetitions and an intensity starting at 20%–30% and progressing to 80% of 1RM, may be well tolerated by frail subjects, resulting in positive effects on gait and gains in muscle strength. Table 2 summarizes the resistance training methods and the results obtained in the studies that investigated the adaptations induced by resistance training in frail elderly individuals. No injuries or side effects were mentioned in the studies that investigated the effects of strength training in frail elderly subjects.^{30–35} To optimize functional capacity, resistance training programs should include exercises in which the participants' body weights are used for resistance and in which usual daily activities are simulated (such as the "sit to stand" exercise). Furthermore, resistance exercises that are performed with a high speed of motion promote greater improvements in the functional task performance of healthy elderly individuals.^{48,49} Thus, the same benefits of high-speed strength training may be observed in frail elderly patients, and this possibility should be investigated in future studies.

Endurance training

Aging is associated with a decline in the cardiorespiratory capacity that is primarily associated with a decrease in the maximal heart output caused by a reduced maximum stroke volume and heart rate and changes in the oxygen arterio-venous difference.⁵⁰ To counteract these phenomena, endurance training induces central and peripheral adaptations that enhance the maximal oxygen uptake (VO_{2max}) and the ability of skeletal muscle to generate energy via oxidative metabolism.^{27,51–53} However, elderly subjects with severe functional declines may not be able to perform endurance training to recover some of their neuromuscular capacity.

TABLE 1. EFFECTS OF DIFFERENT TYPES OF EXERCISE INTERVENTION ON RATE OF FALLS, GAIT ABILITY, BALANCE, CARDIORESPIRATORY, AND STRENGTH PERFORMANCE

<i>Authors</i>	<i>N, age</i>	<i>Intervention</i>	<i>Primary results</i>
Fiatarone et al. ³⁰	100, 87	RT vs. RT+SUP: 3x/wk, 10 wk	↑ Strength outcomes (26%–215%); ↑ gait speed (9%–15%).
Wolf et al. ³⁷	200, 70	BT composed by Tai-Chi exercises, 2/wk, 15 wk.	↓ Rate of falls (47%).
Lord et al. ²⁸	551, 79	MCEP:RT+ET+BT, 2/wk, 48 wk	↓ Rate of falls (22%).
Hauer et al. ²³	57, 82	MCEP:RT+BT, 3/wk, 12 wk	↑ Strength (75%); ↓ rate of falls (25%).
Kenny et al. ³⁶	99, 76	Yoga+chair aerobics with and with no DHEA SUP, 2/wk, 24 wk	↑ TUG test (4%); ↑ strength only in the SUP group.
Binder et al. ²⁴	115, 83	MCEP: ET+RT+BT+COOT, 3/wk, 36 wk.	↑ Strength outcomes; ↑ balance; ↑ VO _{2max} ; ↑ physical performance score.
King et al. ²⁵	155, 77	MCEP: ET+RT+BT+FT, 1-3/wk, 48 wk.	↑ Balance (35%).
Latham et al. ³³	243, 79	Home-based RT, 3/wk, 10 wk.	No changes in strength, falls, balance and gait speed.
Barnett et al. ²⁶	163, 75	MCEP: BAL+TAI+ET+BVRT, 1 yr, 37 supervised sessions.	No changes in strength, reaction time and walking speed. ↑ Balance (6%–15%); ↓ Rate falls: EG vs. CG (36%).
Ehsani et al. ²⁷	46, 82	MCEP: ET+RT, 3/wk, 24 wk.	↑ VO _{2max}
Wolf et al. ³⁹	286, 81	BT composed by Tai-Chi exercises, 2/wk, 48 wk vs. active control with low level RT+ET, with no BT.	No difference between groups in the incidence of falls.
Sullivan et al. ³⁴	29, 79	RT: high vs. low intensity, with or with no megestrol acetate SUP, 12 wk.	↑ Strength (23%) only in the RT at high intensity.
Hagedorn and Holm ²⁹	27, 81	MCEP: RT+BT with and with no visual computer feedback 2/wk, 12 wk,	↑ Strength (19%); ↑ Overall balance scores (80%); ↑ 6-min walk test (8%).
Lustosa et al. ³²	48, 72	BVRT: 3x/wk, 10 wk,	↑ Gait speed (10%); ↑ strength outcomes (6%).
Serra-Rexach et al. ³⁵	40, 92	RT, 3/wk, 10 wk.	↑ Strength (10.6kg); ↓ falls (1.2 fewer).
Freiberger et al. ¹⁷	197, 76	3 MCEP: ST+BT vs. ET+ST+BT vs. ST+BT+falls risk education. 2/wk, 16 wk.	↑ Gait speed in ST+BT and ET+ST+BT. No changes in the number of falls.
Kim et al. ¹⁵	115, 79	MCEP vs. MCEP+SUP: 2x/wk, 12 wk. MCEP=BT+ET+BVRT.	↑ Strength (6%); ↑ gait speed (12%–17%).
Clemson et al. ⁴⁰	317, 83	MCEP:RT+BT, 3/wk, 12 wk	↓ Rate of falls (31%); ↑ balance
Henessey et al. ³¹	31, 71	RT vs. RT+GH SUP: 3/wk, 10 wk	↑ Strength (~50%).
Taylor et al. ³⁸	684, 74	BT composed by TAI, 1/ wk vs. 2/wk, 20 wk.	↓ Rate of falls (58%).

RT, Resistance training; ET, endurance training; BT, balance training; BVRT, body weight resistance training; MCEP, multicomponent exercise program; TAI, Tai-Chi exercises; FT, flexibility training; COOT, coordination training; SUP, supplementation; GH, growth hormone; DHEA, dehydroepiandrosterone; wk, weeks; ↑, increase; ↓, reduction.

Indeed, it has been demonstrated that power and strength levels are positively associated with the cardiorespiratory capacity in elderly subjects.^{54,55} Thus, endurance interventions in frail elderly individuals have previously included endurance training within multi-component exercise programs.^{15–17,28,29}

Endurance exercises for the elderly include walking with changes in pace and direction,^{15,17,26} treadmill walking,^{16,29} step-ups, stair climbing, and stationary cycling.¹⁶ The en-

durance exercises may start with a duration of 5–10 min in the first weeks of training, progressing to 15–30 min for the remainder of the program.^{17,28,29} Ehsani et al.²⁷ investigated the effect of endurance exercise sessions in frail octogenarians, starting with 20 min and progressing to 60 min of walking at an intensity of 70%–75% of the maximal heart rate. However, in this study, the endurance training was performed after two previous phases of training, namely 1 month of physical therapy and 1 month of strength

TABLE 2. TRAINING CHARACTERISTICS OF SYSTEMATIC RESISTANCE TRAINING PROGRAMS APPLIED IN FRAIL ELDERLY

Authors	Weekly frequency (times per week)	Volume (sets x repetitions)	Intensity (% of 1RM)	Adverse effects
Fiatarone et al. ³⁰	3	3 × 8	80% of 1RM	No adverse effects mentioned.
Hauer et al. ²³	3	3 × 10	70%–90% of 1RM	No adverse effects mentioned.
Binder et al. ²⁴	3	1: 1–2 × 6–8 2: 3 × 8–12	1: 65% of 1RM 2: 85%–100% of initial 1RM	1 subject dropped out for medical reasons related to study.
Sullivan et al. ³⁴	2	3 × 8	10%–20% vs. 20%–80% of 1RM	No adverse effects mentioned.
Hagedorn and Holm ²⁹	2	3 × 10–15RM	Not mentioned, repetitions until failure	No adverse effects mentioned.
Villareal et al. ¹⁶	3	1–3 × 8–12	65%–80% of 1RM	1 subject related shoulder pain.
Serra-Rexach et al. ³⁵	3	2–3 sets of 8–10 repetitions	30% progressing to 70% of 1RM	No adverse effects mentioned.
Henessey et al. ³¹	3	3 × 8	20% progressing to 90% of 1RM	No adverse effects mentioned.
Izquierdo et al. ¹⁸	2	1–3 × 8–10	40% progressing to 60% of 1RM	No adverse effects mentioned.

1RM, maximum repetitions.

training. This exercise intervention resulted in a 12.5% increase in the VO_{2max}.²⁷ Thus, it may be necessary to strengthen the neuromuscular system before initiating endurance training to achieve these cardiovascular adaptations. Other methods for controlling the exercise intensity may be

the use of the rate-of-perceived-exertion scale¹⁵ (*i.e.*, Borg scale),⁵⁶ in which intensities of 12–14 appear to be well tolerated.

Aerobic capacity is an important component of physical fitness, and endurance training should be part of the exercise

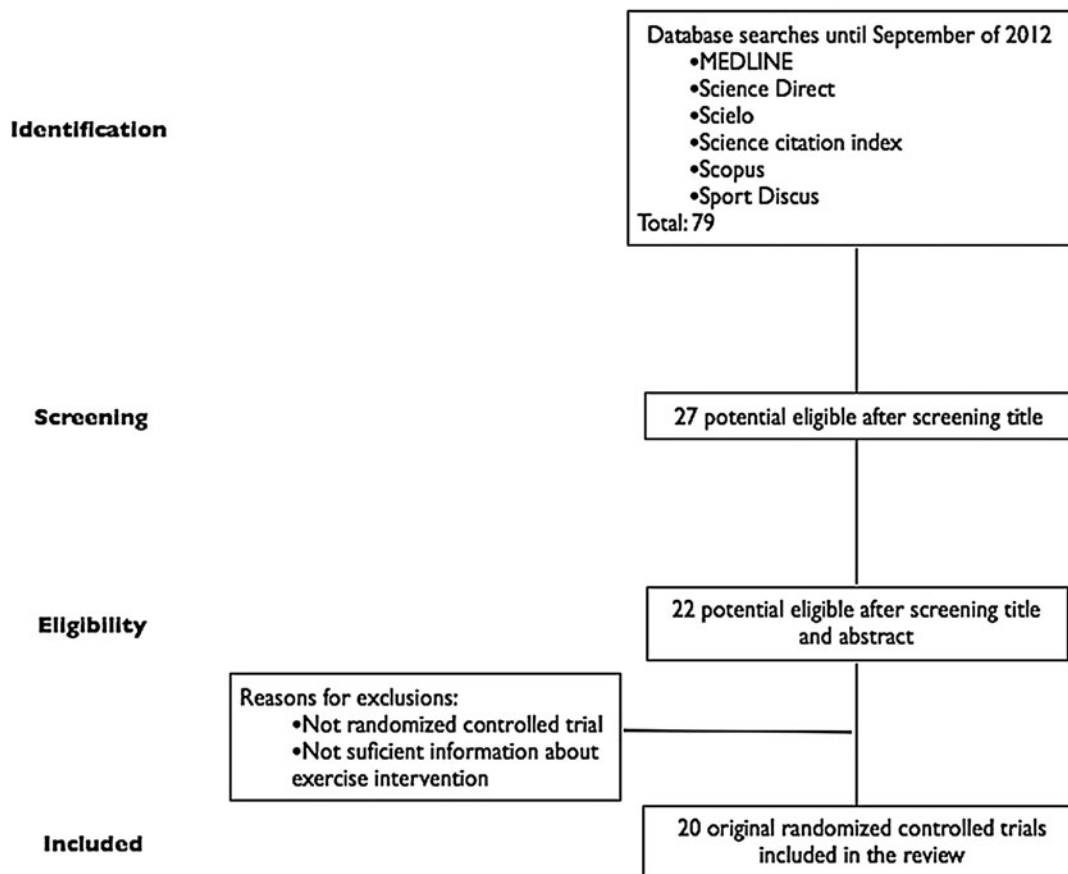


FIG. 1. Search process.

routine for frail elderly individuals. Although no studies have compared the effectiveness of various endurance training programs (*i.e.*, different intensities and volumes), this type of exercise should follow the basic principles of training, with the intensity and duration progressively increased based on the capacity of each participant.

Balance training

Balance training is another type of exercise intervention that is aimed at preventing falls.^{16,29} It is difficult to assess the effect of balance training alone on the risk of falls and on balance outcomes because this type of intervention is conventionally included in multi-component exercise programs.^{16,26,28}

Balance training generally includes exercises, such as tandem foot standing, multi-directional weight lifts, heel-toe walking, line walking, stepping practice, standing on one leg, catching/throwing a ball, altering the base of support, weight transfers (from one leg to the other), and modified Tai Chi exercises.^{15,26,28} Studies have demonstrated that Tai Chi is an effective fall-prevention intervention.^{37,38,57} In an investigation of the effects of intense Tai Chi interventions, Wolf et al.³⁷ determined that 15 weeks of Tai Chi reduced the occurrence of falls in elderly subjects. Likewise, in a recent study by Taylor et al.³⁸ both Tai Chi and home-based multi-component exercise programs were found to reduce the risk of falls (58%) in community-residing older adults (74.5 ± 6.5 years).

For the above-mentioned balance exercises, the training should progress from easy to more difficult exercises, with the physiological intensity of training increasing over time.²³ However, the effects of balance training on the risk of falls should be carefully analyzed because the effectiveness of this intervention has been demonstrated only when it is combined with other components of physical fitness, such as strength and endurance training.

Multi-component exercise programs

Multi-component exercise programs appear to be the most effective interventions for improving the overall health status of frail elderly individuals.^{15,16,26,28} This statement is supported by the literature, in which positive effects on functional capacity are more often observed when more than one physical-conditioning component (*i.e.*, strength, endurance, or balance) comprises the exercise intervention,^{15,16,26,28} compared with only one type of exercise.^{35,38} Along with the evidence provided, it is reasonable to suggest that different kinds of stimulus, such as to improve muscle strength and mass, cardiovascular function, gait ability, and balance, and promote a greater increase in independence and in the ability to perform daily activities. It is well known that the resistance exercise programs are recommended to improve neuromuscular function,^{44,45,47} endurance exercise programs are recommended to enhance cardiovascular function,⁴⁶ and balance training stimulates improvements on balance performance.²⁹ Thus, multi-component exercise programs could be composed with more emphasis in one these three types of exercise interventions, according to a specific goal (*i.e.*, strength and muscle mass in sarcopenic elderly).

Lord et al.²⁸ found that 12 weeks of an intervention that included aerobics, slow-to-moderate-paced walking, and flexibility, balance and weight-bearing exercises resulted in 22% fewer falls in frail elderly individuals compared with

control subjects. In addition, there were small increases in the reaction time over a 6-min walking distance. Similar results were observed by Barnett et al.,²⁶ who demonstrated that 1 year of a home-based multi-component exercise program (composed of functional, strength, balance, and aerobic exercises) resulted in 40% fewer falls in an exercise intervention group of elderly with physical frailty compared with a control group. Recently, Clemson et al.⁴⁰ investigated the effects of 12 months of an exercise intervention that consisted of balance and strength exercises performed with ankle cuff weights by elderly participants with recent history of injurious falls. These authors demonstrated a reduction in the rate of falls (31%) and greater strength and balance performance in the exercise groups after the intervention period. In another study, Izquierdo et al.¹⁸ observed that 12 weeks of progressive resistance training (8–10 repetitions at 40%–60% of 1RM) by using resistance-variable machines (Exercycle, S.L. [BH Group], Vitoria, Spain) combined with balance exercises yielded positive effects on the incidence and risk of falls and on the muscle strength, dual-task performance, gait, and balance in very elderly institutionalized and frail patients.

The above-mentioned results are important because they suggest that multi-component exercise interventions may reduce the incidence of falls and consequently prevent disability, morbidity, and death. Other studies have demonstrated the benefits of performing various types of exercises on the health and physical independence of frail elderly individuals.^{15,16,29} The physical outcomes that were improved in these studies include balance,²⁹ gait,¹⁵ muscle strength,^{16,24} and VO_{2peak} .²⁴

Some investigations have compared the effects of different multi-component exercise interventions. Binder et al.²⁴ observed greater enhancements in strength, VO_{2peak} , and other physical function tests (*i.e.*, the Physical Performance Test and Functional Status Questionnaire scores) in individuals who participated in an assisted exercise intervention program (strength, endurance, and balance) compared with those who participated in a home-based exercise program. In another study, Hagedorn and Holm²⁹ compared a combination of strength training with two different types of balance training—traditional training, which included standing on different surfaces with opened or closed eyes (TB), and balance training using a computer feedback system, which registered the position of the body (CB). The results of this study revealed that both groups of frail elderly individuals increased their muscle strength and physical endurance, with the CB group exhibiting a remarkable increase during the games that were used for training. A recent investigation by Freiberger et al.¹⁷ compared the effects of three different multi-component exercise programs on several physical outcomes in elderly with history of falls. The results revealed that the groups who performed balance exercises combined with strength training (with or without endurance training) exhibited greater improvements in walking speed and in the Timed Up and Go and Romberg tests than did a group that had received fall-risk education to address fall-related psychological aspects. However, the three intervention groups had better physical outcome scores than the control group after the intervention period.¹⁷

The above-mentioned results demonstrate the effectiveness of multi-component exercise programs in improving the physical fitness and health of frail elderly individuals. It should be noted, however, that the progression of training and the inclusion of different exercise stimuli should follow the

principles of physical fitness and should be slow and gradual, especially in frail participants. An interesting approach to increasing the training intensity was presented by Binder et al.²⁴ These authors used a training model with three blocks of 3 months, starting with exercises focused on flexibility, balance, reaction speed, and coordination in the first phase; switching to progressive resistance training in the second phase; and advancing to endurance training on treadmills, stationary bicycles, or rowing machines in the third phase.²⁴

Summary

A multi-component exercise intervention program that consists of strength, endurance, and balance training appears to be the best strategy for improving gait, balance, and strength, as well as reducing the rate of falls in elderly individuals and consequently maintaining their functional capacity during aging. Most of the studies demonstrating improvements in gait, balance, and fall risk have used multi-component exercise training as intervention in their subjects. However, the studies in which systematic resistance training was performed (either alone or as part of multi-component exercise programs) revealed greater strength gains in the elderly with physical frailty or severe functional declines. The absence of changes in the functional and strength outcomes that were measured in some of the investigations indicates that the exercise prescription must be carefully adapted to provide a sufficient stimulus for improving the functional capacity of frail subjects. In addition, the present review focused only on the physical function domains of the concepts of frailty and physical frailty. Thus, this systematic review is only able to recommend strategies to improve the physical function of physically frail individuals. On the basis of recent evidence, exercise strategies to improve neuromuscular and cardiovascular parameters and functional performance in frail elderly individuals should include the following:

- Resistance-training programs should be performed two to three times per week, with three sets of 8–12 repetitions at an intensity that starts at 20%–30% and progresses to 80% of 1RM.
 - To optimize the functional capacity of individuals, resistance training programs should include exercises in which daily activities are simulated, such as the sit-to-stand exercise.
 - Endurance training should include walking with changes in pace and direction, treadmill walking, step-ups, stair climbing, and stationary cycling. Endurance exercise may start at 5–10 min during the first weeks of training and progress to 15–30 min for the remainder of the program. The Rate of Perceived Exertion scale is an alternative method for prescribing the exercise intensity, and an intensity of 12–14 on the Borg scale⁵⁶ appears to be well tolerated.
 - Balance training should include several exercise stimuli, such as tandem foot standing, multi-directional weight lifts, heel-toe walking, line walking, stepping practice, standing on one leg, weight transfers (from one leg to the other), and modified Tai Chi exercises.
 - Multi-component training programs should include gradual increases in the volume, intensity, and complexity of the exercises, along with the simultaneous performance of resistance, endurance, and balance exercises.
- These recommendations, which are based on this systematic and narrative review, should be tested in new clinical trials that are specifically designed for such a purpose or in a formal meta-analysis.

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