EXERCISE FOR NONAGENARIANS: A SYSTEMATIC REVIEW

ABSTRACT

Background: Physical exercise has been identified as a health promotion strategy for the oldest old. However, scientific evidence regarding the benefits of exercise on nonagenarians is scarce. This systematic review aimed to evaluate the characteristics and methodological quality of investigations that have examined the effects of physical exercise on nonagenarians.

Methods: A systematic review and evidence synthesis were conducted. MEDLINE/PubMed, CINAHL, Scopus, SPORTDiscuss, and the Cochrane Library were systematically searched up to November 2018. Investigations were included if they tested the effects of an exercise intervention on people 90 years of age or older. The methodological quality of the randomized controlled trials was evaluated using the PEDro scale. Quality appraisal tools developed by the National Heart, Lung and Blood Institute were used to evaluate the uncontrolled and observational investigations.

Results: Three randomized controlled trials, one retrospective study, two case reports, and one single subject A-B design met the eligibility criteria. The methodological quality scores obtained from the scales ranged from poor to good. Most interventions were based on muscular strengthening, balance exercises, or a combination of both. No adverse effects were registered. In general, exercise showed a significant impact on muscular strength, while mixed effects were found regarding gait and balance. Pooled analyses indicated that interventions had significant improvements in global lower-body functioning (SMD = 0.47; 95% CI = 0.04, 0.90; $p < .01$).

Conclusions: Exercise is a feasible therapy for nonagenarians, which can lead to improvements in physical functioning. Future research should focus on the effects of aerobic interventions, as well as the impact that exercise has on the cognitive functioning of nonagenarians.

Keywords: aging, oldest old, exercise, physical activity, physical functioning.

INTRODUCTION

Physical exercise has been recognized as an important health strategy to promote successful aging, since it can further enhance the functioning of older adults who are already characterized as aging normally.[1] Maintenance of physical functioning and independence is a key attribute of successful aging.[2,3] Given that physical independence is typically associated with higher levels of physical fitness, older people are encouraged to regularly participate in physical exercise training programs. This strategy can help older adults continue to be independent until the end of their lifespan.[4]

When it comes to prescribing physical exercise for older age, nonagenarians are often overlooked and represent a population of significant interest. In comparison with older people of younger age, nonagenarians tend to participate in reduced levels of physical activity, which leads to poorer functional independence.[5] Thus, it seems that the performance of physical exercise is especially important in this age group.[6]

Exercise prescription for the oldest old needs to be carefully tailored and individualized with the specific objectives of the person or group in mind.[7] In relation to this, it is important to note that although there are numerous studies that have described the characteristics and effects of exercise training programs on older adults, most studies have been conducted on people under 90 years old. Consequently, scientific evidence directly investigating the effects of exercise prescription on nonagenarians is scarce.

In light of this limitation, it is important to identify the basic exercise prescription guidelines for people over 90 years old by scrutinizing the key studies that have provided evidence on the effects of exercise training among nonagenarians. This can be achieved by conducting systematic reviews that synthesize and summarize the scientific evidence on this topic. Thus, the purpose of this study was to conduct a systematic review to identify the characteristics and methodological quality of investigations that have examined the effects of physical exercise on nonagenarian cohorts. It is anticipated that the obtained findings will provide information of relevance that will allow clinicians and researchers to establish basic guidelines for effective physical exercise intervention and prescription in this population.

METHODS

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The selected search strategy and methods of analysis were registered in the PROSPERO database (ref: CRD42018112642).

Search Strategy

Five electronic databases (MEDLINE/PubMed, CINAHL, Scopus, SPORTDiscuss, and the Cochrane Library) were searched systematically from their inception until June 2018. A secondary search was performed in November 2018 to update the initial search. The following search terms, Boolean operators, and combinations were used: “nonagenarians” OR “centenarians” OR “oldest old” AND “exercise” OR “physical activity”.

Eligibility Criteria

Intervention studies that provided information regarding the effects of exercise on people 90 years of age or older were considered eligible. Although randomized controlled trials (RCTs) provide the highest quality of scientific evidence, the search also included non-RCT designs, due to the following reasons. Firstly, if the number of RCTs analyzing non-pharmacological therapies is scarce, it is advisable to include non-RCTs to gain a better overview of the available evidence.[8,9] Secondly, when reviewing the feasibility of novel therapies, non-RCTs are useful to inform safety, potential adverse effects, and response rates,[10] which are of special interest in frail and older populations.

Investigations were excluded if: (a) the exercise group included people under 90 years old, unless separate data were available for the nonagenarian subgroup; (b) the intervention was based on the performance of a single exercise training session; (c) the full-text of the study was not available; or (d) the study was not written in English or Spanish.

Study Selection

Two researchers independently screened the titles and abstracts of the identified studies for eligibility, and discrepancies were resolved by consensus with a third researcher. Once an agreement had been reached, a full-text copy of all potentially relevant studies was obtained. Full-text articles were initially sought from journal websites or ordered through the university’s interlibrary loan system. If it was not available, then an email was sent to the corresponding author. If it was unclear whether the study met the selection criteria, advice was sought from a third researcher and an agreement was reached.

Data Extraction

Information on participants' characteristics, exercise program, adverse events, attrition rates, and outcomes were extracted from the records by one researcher and validated by a second investigator. Missing data were obtained from the corresponding author, whenever possible.

Quality Appraisal

Studies were evaluated using two quality appraisal tools. The methodological quality of the selected randomized controlled trials (RCTs) was directly retrieved from the Physiotherapy Evidence Database (PEDro). The quality appraisal of RCTs not rated in the PEDro was independently performed by two researchers, with discrepancies in ratings arbitrated by a third researcher. The suggested cut-off scores to categorize studies by quality were excellent (9-10), good (6-8), fair (4-5), and poor (≤3).[11]

The methodological quality of the non-controlled studies was assessed by two researchers independently using the Quality Assessment Tool for Before-After Studies with No Control Group.[12] This tool includes 12 criteria for evaluating the internal validity of a research design. Researchers must evaluate the quality of each study's design ("good", "fair", or "poor") in accordance with how much risk of bias they detect. In case of disagreement, advice was sought from a third researcher. Similarly, the 14-item Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies[12] was used to assess the methodological quality of the retrospective investigations. After independently reviewing the methodological quality of the selected studies, Cohen's kappa coefficient was calculated to evaluate overall agreement between reviewers.

Evidence Synthesis

Data were analyzed using Stata Software version 15.1.[13] When at least two studies reported pre- and post-treatment data on homogeneous outcome measures, within group analyses were presented in forest plots.[14] The standardized mean differences (SMD) and their 95% confidence interval (CI) were calculated to assess the change in the exercise groups comparing pre-treatment versus post-treatment results for each selected variable. If heterogeneity between outcome measures prevented pooling of effect size data, a descriptive analysis was reported.

To obtain the pooled effects, a fixed effect model and a random-effects model were performed, selecting the most adequate model for each analysis according to the heterogeneity level, according to DerSimonian and Laird (random-effects model if $I^2 > 30\%$).[15] SMDs were considered significant when their 95% CIs excluded zero, while pooled SMD values were interpreted according to Cohen,[16] whereby effects were considered small (0.2), medium (0.5), and large (0.8). Positive effect sizes were indicative of the exercise intervention having a positive post-treatment effect on the specified outcome measure. Authors were contacted if additional information was required for effect size calculations.

RESULTS

From an initial 460 records, a total of seven studies were included in the systematic review (see Figure 1). The methodological designs of the included studies comprised of three RCTs, one retrospective study, two case reports, and one single subject A-B design. Notably, RCTs by Serra-Rexach et al.[17] and Ruiz et al.[18] reported the same trial and participant data.

[Insert Figure 1]

Figure 1. Flowchart of screening process.

Characteristics of Included Studies

Full information regarding the participants' characteristics, intervention programs, feasibility outcomes (adherence, attrition, and adverse effects), and main findings from each study are summarized in Table 1.

[Insert Table 1]

Participants

Participants in the included studies were nonagenarians who were described as frail institutionalized,[19] community dwelling,[20] nursing home residents,[17,21] living with family,[22] and independent.[23]

Interventions

Three studies conducted a mixed muscular strength program, with the addition of either balance and gait [19,21] training or aerobic exercise.[17] Two studies focused primarily on balance training,[22,23] while one study exclusively focused on muscular strengthening.[20] The duration of the interventions ranged from six days[21] to 36 weeks.[22] Sessions lasted for a duration of 40 to 60 minutes, and frequency was between two and six sessions per week.

Adherence, Attrition, and Adverse Events

Adherence to the exercise sessions was reported in four studies[17-20] and ranged from 57%[20] to >90%.[19] Attrition rate was also reported in four studies.[17,19-21] Finally, two studies reported the presence of adverse events. In one study,[20] a participant reported an episode of cardiovascular symptoms and another reported transient muscle soreness. In the second study,[17] a participant suffered transient lower back pain at the start of training, while other participants complained of mild muscle pain associated with leg press exercises. No other major or minor adverse events were reported.

Quality Appraisal

The methodological quality of the studies included in the systematic review is outlined in Table 2. The methodological quality of the RCTs was good.[17-19] Single-subject and case report designs ranged from moderate[20,22] to poor quality.[23] The methodological quality of the retrospective study was moderate.[21] The inter-rater agreement (Cohen's kappa) between reviewers was 0.80.

[Insert Table 2]

Primary Outcomes

Gait

Six studies analyzed the effects of the interventions on gait-related outcomes.[17,19-23] There was a statistically significant difference between pre- and post-treatment intervention outcomes in five studies,[19-23] whereas the Serra-Rexach et al.[17] did not report a difference.

Muscular strength

Out of the four studies that assessed the effects of an exercise intervention on muscular strength parameters[17,19,20,22], two found significant changes in this outcome. Significant improvements were reported in the muscular strength of participants' upper and lower-body after a twice-weekly, 12-week multicomponent exercise program composed of muscle power training (8-10 repetitions, 40-60% of the one-repetition maximum) combined with balance and gait retraining.[19] In addition, an 8-week intervention focused on lower limb strength exercises of light to moderate intensity contributed to a significant improvement in participants' lower-body muscular strength.[17]

Balance

Four studies included balance as an outcome measure,[19,21-23] with significant improvements reported in two of them. On the one hand, the multicomponent exercise intervention used by Cadore et al.[19] resulted in significantly increased balance. On the other hand, Torpilliesi et al.[21] demonstrated that participants undergoing a standardized rehabilitation treatment comprised of strengthening exercises, transfers, postural and gait training, and adaptive equipment training (40-min sessions twice a day from

Monday to Friday, and one session on Saturday), had a significantly enhanced balance between on admission and at discharge after hip fractures surgery.

Fall incidence

The effects of the intervention on fall incidence was analyzed in two studies.[17,19] After 12 weeks of multicomponent exercise, this parameter not only experienced a significant reduction in the intervention group, but was also significantly lower in the intervention group compared with the control group.[19] Similarly, over their study period (intervention + detraining), Serra-Rexach et al.[17] reported that the number of falls per participant was 1.2 times significantly lower in the intervention than in the control group.

Functional independence

Two studies[19,21] analyzed the impact of the interventions on outcomes related to the functional independence of the participants, with both reporting significant improvements in this parameter.

Other outcomes

Exercise did not have a significant impact on cognition and related serum biochemical markers.[18] The effects of exercise on sensation in the toes, speed reaction, exercise capacity, range of motion, and perceived quality of life was examined in one study.[22] An improvement was observed in all parameters except for sensation in the toes, although no significance analysis was performed due to the nature of the study design.

Evidence Synthesis

Data from a total of 37 participants across the three RCTs with pre- and post-treatment data were pooled in the analysis. Adequate effect size data was available for five outcome measures: gait speed, Timed Up and Go (TUG) test, 30-second Chair Stand (30SCS) test, one-repetition maximum (1RM) leg press, and hand grip strength. The information provided in the studies by Gaub et al.[22] and Silsupadol et al.[23] were not included in the analysis, since an effect size could not be calculated using data from less than three cases. The pooled analysis included all the outcome measurements related to lower-body functioning, which were reported as the SMD for each variable and the pooled estimates. Full analyses can be found in Figure 2.

When assessing the impact of exercise programs on the lower-body physical functioning of nonagenarians, the pooled analyses of the interventions showed significant improvements in the 30SCS (SMD = 0.74; 95% CI = 0.03, 1.44; $p < .05$) and in 1RM leg press (SMD = 1.51; 95% CI = -0.84, 3.86; $p < .01$), but not in the gait speed (SMD = 0.35; 95% CI = -0.11, 0.81; $p = .137$) or the TUG test (SMD = -0.02; 95% CI = -0.48, 0.44; $p = .935$). The overall pooled results showed a significant improvement in global lower-body functioning (SMD = 0.47; 95% CI = 0.04, 0.90; $p < .01$).

[Insert Figure 2]

Figure 2. Forest plot displaying the fixed effect (I+V) and random-effects (D+L) meta-analysis of exercise intervention effects on lower-body physical function of nonagenarians. Squares represent the effect size estimate (SMD) and horizontal lines represent the confidence intervals (CI) for each study. The diamonds represent the effect

size estimates for subgroups and the overall effect. The vertical line represents the null hypothesis (SMD = 0). The vertical dotted line represents the overall mean difference from all studies. A positive SMD is indicative of post-intervention improvement in lower-body physical function.

Two RCTs[17,19] reported no significant differences between pre- and post-treatment hand grip strength. This persisted even when effect sizes were pooled, with a pooled SMD = 0.07 (95% CI = -0.43, 0.57); $I^2 = 0.0\%$; $p = .78$, indicating that exercise did not significantly improve hand grip strength (kg) in nonagenarians.

DISCUSSION

This study aimed to perform a systematically search the current literature, identifying key characteristics and scrutinizing the methodological quality of investigations that have examined the effects of physical exercise on nonagenarians. To achieve this objective with the maximum accuracy, we opted to include all experimental study designs rather than only focusing on RCTs. Thus, the spectrum of the results was broader, and in this sense, the data and conclusions drawn from this review can provide greater clarity around the issues at hand.

Despite the small number of investigations that were analyzed in this review, most included studies displayed acceptable methodological quality. This indicates that although the existing scientific evidence is scarce, valuable information is still available to allow clinicians and researchers to determine if this population can safely and effectively take part in exercise programs specifically designed for those regarded as the oldest age group.

Interestingly, the completion rates reported from the studies was generally high and only two individuals, representing around 1% of the total sample included in the review, reported adverse events. Therefore, it can be speculated that people over 90 years can safely perform some types of physical exercise. Related to this, a second aspect of crucial interest is the potential benefits that this age group can gain from participating in these exercise interventions. Significant improvements were found in gait, muscular strength, balance, and fall incidence. These variables are strongly related to functional independence, which is typically poorer in nonagenarians than other age groups.[24] It is important to note, however, that these significant effects were not reported in all the studies that included these variables as outcome measures. For instance, only half of the investigations that tested the effects of exercise on muscular strength and/or balance reported significant improvements. Therefore, more research is needed before reliable conclusions can be drawn.

In the present systematic review, when more than two studies analyzed the same outcome measure, within group analyses were calculated with a weighted mean difference (95% CI) and presented as a forest plot. This allowed independent results from several studies to be combined on a standardized scale of measurement, accounting for the variation in sample size and dispersion in effect sizes. Thus, rather than examining findings individually, similar studies were pooled together so that more precise conclusions can be made about the results and heterogeneity can be evaluated across a diverse range of nonagenarian cohorts.

The pooled results of two RCTs[17,19] and one single subject A-B design[20] demonstrated a significant improvement in lower-body functioning, validating the results of the individual studies. These findings are of importance, since lower-body functioning is a significant factor in the prevention of falling and maintenance of independent gait[25,26]. Therefore, it is conceivable that physical exercise could be used to maintain lower-body mobility and reduce the natural decline of physical functioning typically associated with aging. This highlights the need for further experimental research.

Another finding of this review is the lack of scientific evidence regarding the effects of aerobic training programs on nonagenarians, since only one of the selected studies included aerobic exercise as part of a combined intervention modality. This is a remarkable fact that should be considered in future studies, given that this exercise modality has been shown to have a positive impact on important age-related health factors, including fall risk and cognitive decline[27,28].

Similarly, although exercise has been shown to improve cognition in older adults due to several neurophysiological responses (i.e. increase of peripheral brain-derived neurotrophic factor [BDNF], greater production of insulin-like growth factor, or exercise-induced synaptogenesis, among others)[28], only one of the studies included in this review tested cognitive functioning as an outcome measure. The absence of significant effects observed in this research were explained based on a lack of a stimulating effect of resistance training on basal BDNF.

In summary, the findings of this review indicate that exercise, particularly interventions integrating a combination of muscular resistance and balance/gait-related tasks, is a feasible therapy for nonagenarians, which can reduce the impact of the natural process of deterioration associated with aging. This information is of particular interest for health professionals who want to prescribe physical exercise to older people and researchers who wish to further the understanding of exercise as an intervention against age-related deterioration in nonagenarians.

Limitations

There are several limitations that need to be considered to accurately interpret the data shown here. First, the samples were small in all included studies and authors did not report whether the requisite of 80% power for the selected sample size was met, which may have increased the chance of type II errors. Second, despite the benefits of including a mixture of methodological designs in the one review (as previously mentioned), the results extracted from high quality research designs such as RCTs were not directly comparable to those of studies with no control groups or case-report studies. Related to this, only pre- and post-treatment data from the exercise groups were included in the quantitative analysis. This was due to the low number of studies incorporating comparable control groups. Finally, there are certain methodological limitations inherent to the review design, such as language restrictions, possible publication bias, or not having reviewed grey literature.

CONCLUSION

Exercise is a feasible therapy for nonagenarians that can lead to improved physical functioning and subjective well-being. Future research should focus on the effects of aerobic interventions, as well as on the impact that exercise has on the cognitive level of this population.

FUNDING

This research did not receive any grants from funding agencies in the public, commercial, or not-for-profit sectors.

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Table 1

Characteristics of the studies included in this review.

AUTHORS	STUDY DESIGN	PARTICIPANTS	INTERVENTION	VARIABLES	RESULTS
Cadore et al[19]	**RCT**	**Sample:** n = 39 pre, 24 post (70.83% women) **Distribution (mean age ± SD; sex):** IG: n = 11 (93.4 ± 3.2 y) CG: n = 13 (90.1 ± 1.1 y) **Living status:** Institutionalized	**Duration: 12 weeks** **IG**: Balance exercises + upper and lower body resistance exercises. 40 min sessions with 8-10 repetitions for exercise performed at 40-60% 1RM and high velocity of motion, in 2 non-consecutive days/week. **CG**: Mobility and stretching exercises, 30 min/day and 4 days/week.	• Gait velocity (m/s) • Gait velocity verbal task (m/s) • Gait velocity arithmetic task (m/s) • TUG • TUG verbal task • TUG arithmetic task • Raise from a chair • Balance • Barthel Index Deterioration • Hand grip (N) • Hip flexion strength (N) • Knee extension strength (N) • Upper-body 1RM (kg) • Lower-body 1RM (kg) • Maximal power at 30% 1RM (W) • Maximal power at 60% 1RM (W) • Falls incidence • Cognitive score (arithmetic) • Cognitive score (verbal) • Cognitive score (TUG arithmetic) • Cognitive score (TUG verbal)	**Recruitment:** 82.05% (32 out of 39) **Completion rate:** IG: 68.75% (11 out of 16) CG: 81.25% (13 out of 16) **Adherence:** >90% in all the sample **Adverse effects:** NR **Significant differences (p<0.05):** Intragroup (pre vs post) ↑ TUG: IG ↑ TUG verbal task: IG ↑ Raise from a chair: IG ↑ Gait velocity: CG ↑ Gait velocity arithmetic task (m/s): CG ↑ Gait velocity verbal task (m/s): CG ↑ Hand grip (N): CG ↑ Hip flexion strength (N): IG ↑ Knee extension strength (N): IG, CG ↑ Upper-body 1RM (kg): IG ↑ Lower-body 1RM (kg): IG ↑ Maximal power at 30% 1RM (W): IG ↑ Maximal power at 60% 1RM (W): IG ↓ Falls incidence: IG Intergroup (pre): NR Intergroup (post): Lower falls incidence: IG < CG Less time in TUG verbal task: IG < CG Lower Barthel Index deterioration: IG < CG Higher hip flexion strength (N): IG > CG Higher knee extension strength (N): IG > CG

Serra-Rexach et al[17]	**RCT**	**Sample:** n = 40 pre, 38 post **Distribution (mean age ± SD; sex):** IG: n = 19 (92 ± 2 y; 78.94% women) CG: n = 19 (92 ± 2 y; 78.94% women) **Living status:** Nursing home residents	**Duration: 8 weeks** **IG**: 45-50 min sessions composed of aerobic exercise (5-15 min) performed at 12-13 on Borg RPE Scale followed by 2-3 sets of upper and lower-body resistance exercises performing 8-10 repetitions, 1-2 min of rest in between, and 1 set of minor muscle groups, progressing from 30% 1RM at the start of the program to the 70% 1RM at the end (weekly load increase of 5% 1RM), performed 3 non-consecutive days/week + 5 days/week of mobility exercises. **CG**: Mobility exercises in 40-45 min sessions 5 days/week.	• 1RM leg press (kg) • Hand grip strength (kg) (dynamometer) • 8-m walk test • 4-step stairs test • TUG • Number of falls	**Recruitment:** 61.53% (40 out of 65) **Completion rate:** IG: 95% (19 out of 20) CG: 95% (19 out of 20) **Adherence:** 74 ± 6% IG **Adverse effects:** One patient suffered transient lower back pain at the start of a training program. Some patients complained of mild muscle pain associated with the leg press exercises. **Significant differences (p<0.05):** Intragroup (pre vs post) ↑ 1RM Leg press (kg): IG Intergroup (pre): NR Intergroup (post): Higher 1 RM Leg press (kg)): IG > CG Lower number of falls: IG < CG
Ruiz et al[18]	**RCT**	**Sample:** n = 40 **Distribution (mean age ± SD; sex):** IG: n = 20 (92.3 ± 2.3 y; 80% women) CG: n = 20 (92.1± 2.3 y; 80% women) **Living status:** Nursing home residents	**Duration: 8 weeks** **IG**: 45-50 min sessions composed of aerobic exercise (5-15 min) performed at 10-12 on Borg RPE Scale followed by 2-3 sets of lower-body resistance exercises performing 8-10 repetitions, 1-2 min of rest in between, and 1 set of minor muscle groups of both upper and lower-body, progressing from 30% 1RM at the start of the program to the 70% 1RM at the end (weekly load increase of 5% 1RM), performed 3 non-consecutive days/week + 5 days/week of mobility exercises. **CG**: Mobility exercises 5 days/week.	• Angiotensin-converting enzyme (ng/ml) • Soluble amyloid precursor protein (ng/ml) • Brain-derived neural factor (pg/ml) • Epidermal growth factor (pg/ml) • Tumor necrosis factor alpha (pg/ml)	**Recruitment:** CD **Completion rate:** IG: 100% CG: 100% **Adherence:** 74 ± 6% IG **Adverse effects:** NR **Significant differences (p<0.05):** Not found

Torpilliesi et al[21]	**Retrospective study**	**Sample:** n = 76 pre, 71 post **Distribution (mean age ± SD; sex):** IG: n = 71 (93.2 ± 2.5 y; 84.2% women) **Living status:** Outpatients	**Duration: 6 days, between admission and discharge following hip fracture surgery** Rehabilitation program composed of strengthening, transfers, postural and gait training, performed in 2 sessions per day of 40-min from Monday to Friday and 1 session on Saturday. Interruptions of no more than 1 minute were allowed when the patient needed to rest.	• Barthel Index • Tinetti Score • Gait ability (% of patients in grades 1, 2, 3 and 4)	**Recruitment:** CD **Completion rate: 93.42% (**71 out of 78) **Adherence:** NR **Adverse effects:** NR **Significant differences (p<0.05):** Intragroup (pre vs post) ↑ Barthel Index ↑ Transferring subitem of Barthel Index ↑ Walking subitem of Barthel Index ↑ Tinetti Score ↑ Gait ability
Idland et al20	**Single subject A-B**	**Sample:** n = 8 pre, 6 post **Distribution (mean age ± SD; sex):** IG: n = 6 (91.33 ± 1.36 y; 100% women) **Living status:** Community dwelling	**Duration: 12 weeks** 45-60 min resistance training sessions of the upper and lower-body main muscle groups, 4 exercises performed for 8-12 RM, quickly in the concentric and slower in the eccentric phase of the contraction, for 2-3 sets, 2 days/week.	• TUG (s) • Comfortable walking speed test in 6 meters (s) • 30-s-chair stands	**Recruitment:** 8 of 27 (29.62%) **Completion rate:** 75% (6 out of 8) **Adherence:** 57-96% **Adverse effects:** One participant reported an episode of cardiac arrhythmia and another reported transient muscle soreness. **Significant differences (p<0.05):** Not analysed **Trends towards improvement** All of the participants improved in the TUG. Four of six improved in the 30-s-chair stands.
Silsupadol et al[23]	**Case report**	**Sample:** n = 2 **Distribution (age; sex):** Patient 1: 90y; female Patient 2: 93y; female **Living status:** Independent	**Duration: 4 weeks** **Patient 2:** 45 min sessions of dual task balance training under a fixed-priority instructional set, 3 days/week. **Patient 3:** 45 min sessions of dual task balance training under a variable-priority instructional set, 3 days/week.	• TUG (s) under single-task condition • TUG (s) under dual-task condition • Berg Balance Scale • Dynamic Gait Index • Activities-specific Balance Confidence Scale • Number of counted backward by “threes” over 5 trials performer simultaneously with narrow walking. • Number of counted backward by “threes” over 5 trials performer simultaneously with an obstacle crossing.	**Recruitment:** CD **Completion rate:** 100% **Adherence:** NR **Adverse effects:** NR **Significant differences (p<0.05):** Not analysed **Trends towards improvement** Both improved in the Berg Balance Scale. Both improved the Activities-specific Balance Confidence Scale. Both improved in the TUG in single and dual task conditions. Both improved in the Dynamic Gait Index.

Gaub et al[22]	**Case report**	**Sample:** A 101 year-old woman.
		
		Living status: Family-dwelling
			Duration: 36 weeks
			
			12 weeks of balance and flexibility intervention, 36 sessions, 60 min 3 days/week including balance, speed of reaction and flexibility exercises.
			
			24 weeks of seated strengthening exercises in group classes, in 30-min sessions, 3 days/week.
				• Functional status (Physical Performance Tests)
				  ○ Book lift
				  ○ Don/Doff lab coat
				  ○ Pick up nickel
				  ○ 500 foot walk
				  ○ Satir climb-1 flight
				  ○ Chair rise
				  ○ Stairs of flights
				  ○ 360 degree turn
				  ○ Standing balance
				• Berg Balance Scale
				• Sensation of the toes
				• Speed of reaction
				• Exercise capacity (6 min walking test)
				• Gait speed in 15m
				• Range of motion of the ankle, knee and hip
				• Perceived quality of life (SF-36)
				• Knee extension strength (isokinetic hand-held dynamometry)
				• Knee flexion strength (isokinetic hand-held dynamometry)
					Recruitment: NA
					Completion rate: NA
					Adherence: NR
					Adverse effects: NR
					Significant differences ($p<0.05$): Not analysed
					Trends towards improvement
					After 12 weeks:
					↑ Score in the physical performance test (better ability to climb a flight of stairs, control a 360 degree turn and balance in standing.
					↑ Berg Balance Scale score (global).
					↑ Speed of reaction, but minimal change.
					↑ Distance in 6-Min walking test.
					↓ Time to walk 15m.
					↓ self-perceived quality of life.
					After 24 weeks:
					↓ score in the physical performance test.
					
					↓ Berg Balance Scale score (standing balance).
					↑ Berg Balance Scale score (sit to stand transition).
					↓ Distance in 6-Min walking test.
					↑ Time to walk 15m.
					↑ Perceived quality of life.
					↑ Knee flexion/extension strength measures.
					After 36 weeks:
					↓ score in the physical performance test, without reaching the pre-intervention score.
					↓ Distance in 6-Min walking test, without reaching the pre-intervention score.
					↑ Time to walk 15m.

Note. CD = cannot determined; CG = control group; IG = intervention group; NA = not applicable; NR = not reported; RCT = randomized controlled trial; RPE = rating of perceived exertion; SF-36 = Short-Form Health Survey; TUG = Timed Up and Go.

Table 2

Quality Assessment

PEDro scale	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**			
Cadore et al[19]	Y*	Y	Y	Y	N	N	Y	N	N	Y	Y	6/10			
Ruiz et al[18]	Y*	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10			
Serra-Rexach et al[17]	Y*	Y	Y	Y	N	N	Y	Y	Y	N	Y	7/10			
NHLBI Pre-Post Tool	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**		
Gaub et al[22]	Y	NR	N	CD	N	Y	Y	Y	Y	Y	N	NA*	6/11		
Idland et al[20]	Y	Y	Y	N	N	Y	Y	N	Y	Y	Y	NA*	8/11		
Silsupadol et al.[23]	Y	NR	N	CD	N	CD	Y	N	Y	Y	N	NA*	4/11		
NHLBI Observational Cohort Tool	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**Total**
Torpillesi et al[21]	Y	Y	Y	N	N	Y	N	N	Y	N	N	CD	Y	Y	7/14

Note. Y = yes; N = no; NR = not reported; CD = cannot determine; NA = not applicable. PEDro scale scores are interpreted as excellent (9-10), good (6-8), fair (4-5) or poor (≤3). NHLBI tools do not have specific cut-off scores, but are tentatively interpreted as poor, fair or good.

*Not included in total score.

Figure 1. Flow chart

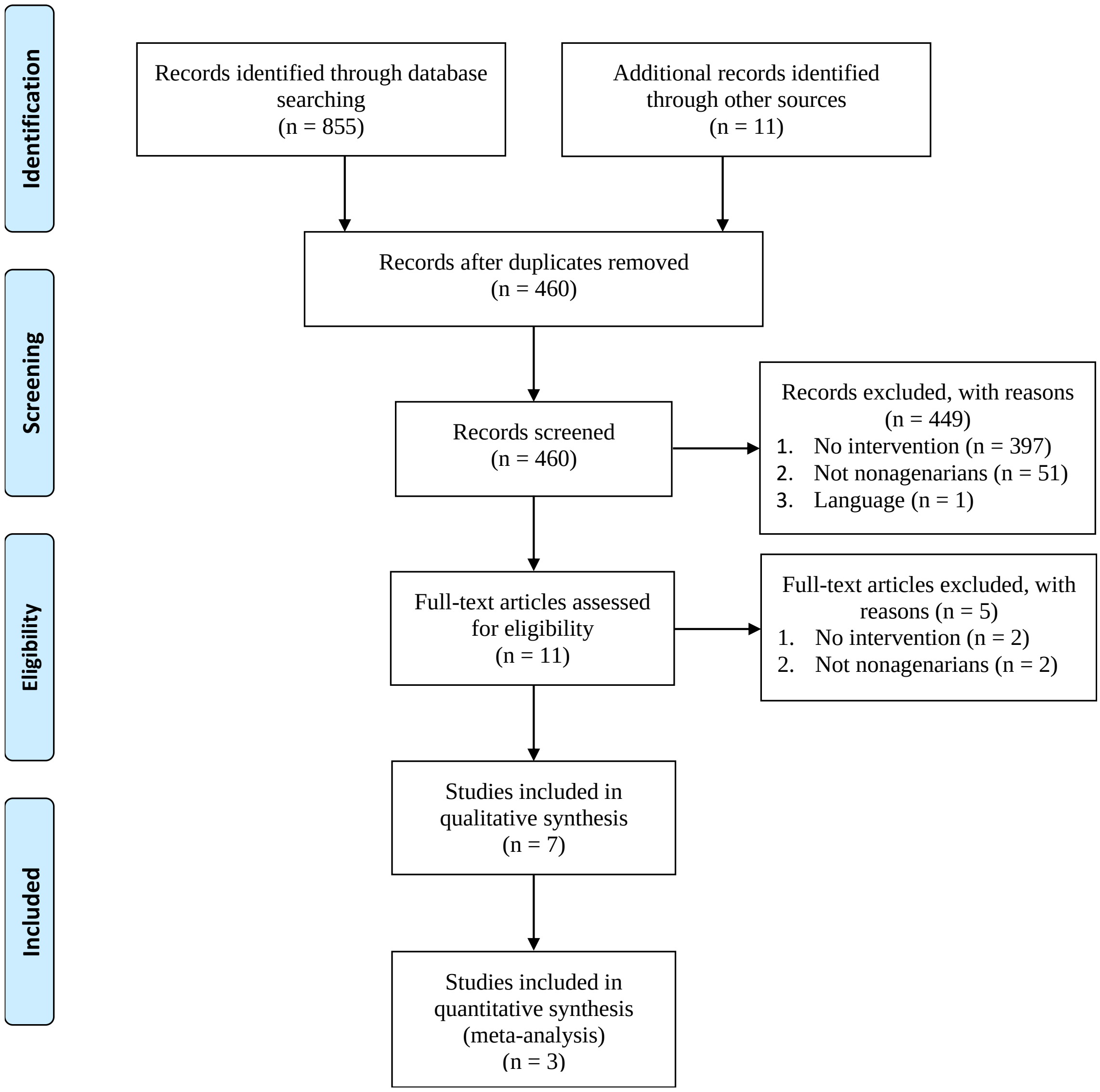

Figure 2. Results of meta-analysis