Effects of physical exercise on physical function in older adults in residential care: a systematic review and network meta-analysis of randomised controlled trials

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Summary

Background Physical exercise is effective at attenuating ageing-related physical decline in general, but evidence of its benefits for older adults in residential care, who often have functional dependency, multimorbidity, and polypharmacy, is inconclusive. We aimed to establish the effects of exercise interventions on the physical function of this population.

Methods For this systematic review and network meta-analysis, we searched PubMed, Web of Science, Cochrane Library, Rehabilitation & Sports Medicine Source, and SPORTDiscus to identify randomised controlled trials assessing the effects of exercise interventions (*vs* usual care) on physical function (ie, functional independence, physical performance, and other related measures, such as muscle strength, balance, or flexibility) in adults aged 60 years or older living in residential care. Relevant studies published in English or Spanish up to Jan 12, 2023, were included in the systematic review. The quality of studies was assessed using the Tool for the Assessment of Study Quality and Reporting in Exercise (TESTEX) score. A network meta-analysis was performed for physical function-related outcomes reported in at least ten studies, with subanalyses for specific intervention (ie, exercise type, training volume, and study duration) and participant (eg, having cognitive impairment or dementia, pre-frail or frail status, and being functionally dependent) characteristics. The study protocol was registered on PROSPERO (CRD42021247809).

Findings 147 studies (11 609 participants, with mean ages ranging from 67 years [SD 9] to 92 years [2]) were included in the systematic review, and were rated as having overall good quality (median TESTEX score 9 [range 3–14]). In the meta-analysis (including 105 studies, n=7759 participants), exercise interventions were associated with significantly improved overall physical function, with a standardised mean difference [SMD] of 0·13 (95% credible interval [CrI] 0·04–0·21), which was confirmed in all analysed subpopulations. The strongest association was observed with 110–225 min per week of exercise, and the greatest improvements were observed with 170 min per week (SMD 0·36 [95% CrI 0·20–0·52]). No significant differences were found between exercise types. Subanalyses showed significant improvements for almost all analysed physical function-related outcomes (Barthel index, five-times sit-to-stand test, 30-s sit-to-stand test, knee extension, hand grip strength, bicep curl strength, Short Physical Performance Battery, 6-min walking test, walking speed, Berg balance scale, and sit-and-reach test). Large heterogeneity was found between and within studies in terms of population and intervention characteristics.

Interpretation Exercise interventions are associated with improved physical function in older adults in residential care, and should, therefore, be routinely promoted in long-term care facilities.

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For the Spanish translation of the abstract see Online for appendix 1

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Introduction

The ageing of the global population presents important medical and socioeconomic challenges.[1] According to WHO, healthy ageing is largely determined by the ability to preserve intrinsic capacity, defined as the sum of all the individual's physical and mental capacities.[1,2] Preservation of physical function is therefore a core element of healthy ageing, and different outcomes related to physical function (eg, functional independence for activities of daily living or physical performance) have been shown to be inversely associated with the risk of major health outcomes such as hospitalisation, institutionalisation, or mortality in older adults.[3–5] Although no pharmacological therapy exists to counteract ageing-induced physical decline in older adults,[6] meta-analytic evidence[7–9] supports the effectiveness of physical exercise interventions (ie, physical activity that is planned, structured, and repetitive) to improve physical function or attenuate ageing-related physical decline in older adults.[10,11]

An increasing proportion of older adults (who are often affected by functional dependency, multimorbidity,

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Research in context

Evidence before this study

Physical exercise is effective in attenuating ageing-related physical decline in general, but meta-analytical evidence of its effects for older adults in residential care, who often have functional dependency, multimorbidity, and polypharmacy, is scarce. Previous meta-analyses have reported beneficial effects of exercise interventions on specific physical function outcomes in older adults in residential care, but several important physical function outcomes have not been meta-analysed and the potential moderator effect of intervention (eg, exercise type, duration, or frequency) and participant (eg, cognitive or functional status) characteristics also remains unknown. To fill these research gaps, we performed a network meta-analysis of randomised controlled trials or cluster randomised controlled trials conducted in older adults in residential care that assessed the effects of a supervised physical exercise programme (*vs* usual care) on at least one physical function-related measure. We searched PubMed, Web of Science, Cochrane Library, Rehabilitation & Sports Medicine Source, and SPORTDiscus from inception until Jan 12, 2023, using terms related to the population of interest (eg, "nursing home", "institutionalized", "care home", "long-term care", "resident", or "assisted living") along with terms related to the intervention ("exercise", "physical activity", "physical therapy", or "training") and the outcomes of interest (eg, "function", "physical", "performance", "capacity", "strength", or "mobility", among others). Articles published in English or Spanish were included.

Added value of this study

To our knowledge, this is the largest systematic review and meta-analysis on the effect of exercise interventions in older adults in residential care and provides strong evidence of a beneficial effect of exercise interventions on the physical function of this population, which was confirmed in subpopulations with different cognitive and functional status. Benefits in several physical function-related outcomes were observed, including improvements in measures of functional independence, muscle strength or power, physical performance, balance, and flexibility. The largest benefits were observed with around 3 h of exercise training per week, with no consistent differences between exercise types.

Implications of all the available evidence

Physical exercise interventions are associated with improvements in the physical function of older adults in residential care and should, therefore, be routinely promoted in long-term care facilities.

and polypharmacy) reside in long-term residential care facilities,[12] where they typically spend most of their time sitting or lying down, and rarely exercise (once per week or less in most cases), which potentially accelerates their physical decline.[13,14] Although a heterogeneous population group, older adults in residential care commonly undergo a rapid impairment of physical function[15] and more than half lose the ability to independently perform at least one activity of daily living within the first 2 years of admission to a long-term care facility.[16] Exercise interventions could therefore be beneficial to improve the physical function of older adults in residential care,[17] and specific exercise guidelines are available for this population segment.[18]

However, meta-analytical evidence on the effects of exercise intervention on the physical function of older adults in residential care is scarce. A meta-analysis by Crocker and colleagues[19] showed that exercise interventions can improve residents' functional ability (as determined by the Barthel index), but only non-significant or small benefits were found for other important outcomes (eg, performance on the timed up-and-go test and walking speed);[19] and importantly, several major physical capacity indicators, such as muscle strength, flexibility, and balance, were not specifically analysed. Another meta-analysis including 17 randomised controlled trials[20] reported a beneficial effect of specific exercise categories, such as resistance and multicomponent training, on some physical function outcomes (ie, Short Physical Performance Battery, timed up-and-go test, and 30-s sit-to-stand test) in residents of nursing homes, with no differences between exercise types.[20] However, the authors did not assess the effect of muscle resistance (strength) training alone because it was often combined with other stimuli, such as balance or flexibility, and only a small number of studies was available for the assessment of differences between exercise categories.

The comparative effect of different exercise types (eg, endurance or balance) on the physical function of older adults in residential care remains unknown, and some important physical function outcomes have not yet been meta-analysed. Moreover, potential effect modifiers, such as the characteristics of the intervention (eg, duration or training volume) or of the participants (eg, differences in the participants' setting, or in their cognitive or functional status) have not been assessed in this population. Numerous randomised controlled trials supporting the benefits of different exercise interventions on different markers of physical function in older adults in residential care have been published but, to our knowledge, their results have not been meta-analysed. A network meta-analysis might be helpful in this regard, to combine direct (ie, studies that did head-to-head intervention comparisons) and indirect (ie, those cases in which no previous randomised controlled trial has directly compared the effect of two specific interventions) evidence, assessing all the existing exercise interventions in the same network to ascertain which is the most effective.

In this systematic review and network meta-analysis of randomised controlled trials, we aimed to assess the effects of exercise interventions on the physical function of older adults in residential care. We also assessed potential moderator effects, including characteristics of the interventions (ie, exercise type, programme duration, and training volume) and of the participants (ie, setting, functional status, and cognitive status).

Methods

Search strategy and selection criteria

Relevant articles in English or Spanish were identified by title and abstract in the electronic databases PubMed, Web of Science, Cochrane Library, Rehabilitation & Sports Medicine Source, and SPORTDiscus, using terms related to the population of interest (eg, "nursing home", "institutionalized", "care home", "long-term care", "resident", or "assisted living") along with others related to the intervention ("exercise", "physical activity", "physical therapy", or "training") and the outcomes of interest (eg, "function", "physical", "performance", "capacity", "strength", or "mobility", among others). An example of the search strategy is shown in appendix 2 (p 3). An initial systematic search was conducted for articles published from database inception up to Sept 23, 2021, and was subsequently updated to Jan 12, 2023. The electronic search was supplemented with a manual review of reference lists from relevant publications to locate additional publications. Grey literature (eg, abstracts, conference proceedings, or editorials) was excluded.

Three authors (FM-P, GS-L, and JSM) independently performed the systematic search, and disagreements were resolved through discussion with a fourth author (PLV). Citations were first retrieved and preliminarily screened by title and abstract, and the full text of studies that met the inclusion criteria was assessed. Each author provided a separate list with the studies selected at each stage, as well as with those to be finally included in the review.

Studies were included if they met all of the following criteria: randomised controlled trial or cluster randomised controlled trial design; the study population comprised older adults (individually aged 60 years or older, or with a mean age of at least 65 years) living in long-term care facilities (eg, nursing home, care home, or assisted living); the study assessed an intervention group enrolled in a supervised physical exercise programme and a comparator (control) group performing no or minimal physical exercise (ie, usual care); and it assessed at least one self-reported or performance-based physical function measure (eg, functional ability [the ability to independently perform activities of daily living], physical performance [objectively measured whole-body function related to locomotion],[21] or other related outcomes, such as muscle strength, balance, or flexibility). No specific criterion regarding the minimum duration of the programmes was set, but studies analysing the acute effect of physical exercise were excluded, as were those including non-supervised exercise programmes or physical activity recommendations. Only programmes including voluntary physical exercises targeting peripheral muscles were included; interventions including only other types of interventions, such as respiratory muscle training or neuromuscular electrical stimulation, were excluded. Risk of falls was not considered as a physical function outcome. To isolate the effect of exercise on the different outcomes, we excluded studies combining voluntary physical exercise with other types of interventions (eg, multidomain interventions including medication and environmental changes, or other interventions such as occupational therapy, cognitive, nutritional, or psychological interventions, surface neuromuscular stimulation, or whole-body vibration) that were not applied in the control group, unless the study design allowed for the isolation of the effects of exercise (eg, exercise plus vibration in one group *vs* vibration alone in the other group).

This systematic review and meta-analysis was reported according to PRISMA guidelines.[22,23] The study protocol was registered on PROSPERO (CRD42021247809) and is available online. Deviations from the original protocol, with reasons, are explained in appendix 2 (pp 1–2).

For the **study protocol** see https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=247809

See **Online** for appendix 2

Data analysis

Three authors (FM-P, GS-L, and JSM) independently extracted the following data from each study: number of participants, characteristics of the participants and interventions, main outcomes, outcome assessment methods, and main results (summary estimates). Disagreements were resolved by a fourth author (PLV). When outcome assessment was done at several timepoints during the intervention, the longest follow-up was used for analyses, with the exception of eventual post-intervention assessments after a detraining period. If needed, data from figures were extracted using specific software (WebPlotDigitizer version 4.5). Data from the studies were either directly extracted as mean and SD at baseline and post-intervention, or estimated (as reported elsewhere[24,25]) in those reporting the results as intervention effects or other measures of dispersion, such as standard error, 95% CI, median, or range. We contacted the first, last, and corresponding author of all the studies that did not report the required data (authors of 22 studies were contacted, of whom authors of four studies responded).

For **WebPlotDigitizer software** see https://automeris.io/WebPlotDigitizer

The Tool for the Assessment of Study Quality and Reporting in Exercise (TESTEX) scale, a 15-point scale including five points for study quality and ten points for reporting that has been specifically designed and shown to be reliable for exercise training studies,[26] was used to assess the methodological quality of the included studies. The quality of the studies was classified according to their total TESTEX score as high (≥12 points; maximum 15 points), good (7–11 points), or low (≤6 points). Four authors (BR-B, GS-L, JSM, and SL-O) independently scored the studies, and disagreements were resolved through discussion with a fifth author (PLV).

After the systematic search, the number of studies and available effect sizes contained sufficient information to perform a meta-analysis. We did a network meta-analysis (instead of a pairwise meta-analysis), which enables the comparison of exercise types using both direct and indirect (ie, even if no previous study has directly compared the effect of the exercise categories) evidence, thereby increasing the precision of the estimate compared with using only direct evidence.

The overall effectiveness of the exercise interventions versus usual care was estimated using standardised mean difference (SMD; Hedges' *g*) as an effect measure (an SMD of 0 to 0·2 was considered to be a trivial effect, >0·2 to 0·5 a small effect, >0·5 to 0·8 a medium effect, and >0·8 a large effect). Only the outcomes assessed in at least ten different intervention groups were meta-analysed to avoid the shortcomings of meta-analysing a small number of studies.[24,27] When studies reported results for a given outcome using the same units (eg, kg or m), relative effects were computed as absolute mean differences. In studies reporting a given outcome in overlapping populations (cohorts), only the largest one was included in the analysis. Bayesian hierarchical random-effects meta-analysis models were applied to obtain the posterior distribution of the estimates, with their uncertainty reported as a 95% credible interval (CrI).[24] In addition, we conducted meta-regression and subgroup analyses to investigate the marginal effects (ie, the effect of a variable across studies on average) of the intervention (ie, exercise type, training volume, and total duration of the intervention) and population (eg, setting and cognitive or functional status) characteristics. Specifically, subanalyses were conducted on studies that exclusively comprised nursing home residents, individuals with cognitive impairment (eg, mild cognitive impairment, Alzheimer's disease, or other dementias), individuals with dependence in activities of daily living, or individuals with pre-frailty or frailty. Cumulative ranking probabilities (including the analysis of the surface under the cumulative ranking curve) were also calculated to identify the most effective exercise intervention.

Several meta-analytic models were tested and compared using model fit parameters. The natural spline function presented the best fit and was therefore used to predict meta-regression results. Information about the standardisation process and meta-analytic model implementation (ie, prior knowledge, Markov chain Monte Carlo methods, and convergence analysis) is provided in appendix 2 (pp 4–5).

Fixed-effects and random-effects network meta-analysis models were conducted for overall (ie, exercise) and intervention-specific (ie, different exercise types) levels for each physical function-related outcome (with effect measures reported as absolute mean differences). Model selection was performed by comparing model fit parameters (deviance information criterion, total residual deviance, and number of parameters; appendix 2 pp 4–5). Key assumptions for network meta-analysis were tested, indicating consistency in our data and transitivity.[28] As additional analyses, Egger's test was used to assess small-study effects and the I^2 statistic was used to assess inconsistency between studies. All analyses were done with the statistical software R 4.2.1, with the packages brms for hierarchical meta-analysis, marginaleffects for network meta-analysis models, and ggplot2 for plotting.

Role of the funding source

There was no funding source for this study.

Results

Of the 10 835 records identified in our initial search, 4713 duplicates were removed and 5871 were excluded during screening (figure 1). 251 full-text reports were retrieved and assessed for eligibility, of which 147 randomised controlled trials were included in the systematic review, with 12 059 participants in total (n=11 609 after removal of duplicate participants, because some studies shared part of the same sample). The included studies and their characteristics are shown in appendix 2 (pp 6–41).

The included studies recruited between 14 and 891 participants (median 56 [IQR 32–97]) with a mean age ranging from 67 years (SD 9) to 92 years (2). All participants were living in long-term care facilities (mostly nursing homes but also residential care homes), assisted living facilities, or congregate housing for older adults. Participant characteristics at baseline were highly heterogeneous across and within studies. Most studies included a mix of participants with multiple comorbidities. However, some studies focused on individuals with specific characteristics, such as frailty or pre-frailty (14 studies [9·5%]); cognitive impairment, including Alzheimer's disease and other dementias (31 studies [21·1%]); or functional dependence in at least one activity of daily living (12 studies [8·2%]). A small number of studies focused on participants who used a wheelchair (six studies [4·1%]) or with conditions such as sarcopenia (two studies [1·4%]), visual impairments (three studies [2·0%]), diabetes (one study [<1%]), or osteoporosis (one study [<1%]).

All exercise interventions were supervised by different members of staff, including sport science or kinesiology specialists, physical or occupational therapists, nurses or caregivers, certified instructors, researchers or research assistants, volunteers, or facility staff, although some studies did not report who supervised the intervention. Interventions lasted 4–96 weeks and included between one and seven sessions per week (session duration of 8–90 min). The chosen exercise type differed across studies, but most (83 studies [56·5%]) applied a multicomponent or combined intervention that included two or more different exercise categories, such as mobility (ie, joint movements), endurance (ie, aerobic activities, such as walking, pedalling, dancing, or exergames, or mind–body activities, such as tai chi or yoga), balance (eg, standing on one leg), and resistance (ie, isometric or dynamic strengthening exercises performed against an external load, such as an elastic band or free weights, or with the participant's own bodyweight). A smaller number of studies focused solely on one exercise type, such as muscle resistance (28 studies [19·0%]), endurance (34 studies [23·1%]), balance (eight studies [5·4%]), or flexibility (one study [<1%]). 21 studies (14·3%) compared more than one exercise type with the control intervention (usual care).

The interventions performed by the control groups were also heterogeneous and included social, musical, or cultural activities (eg, health education talks, watching videos, listening to music, playing instruments, reading, singing, or doing crosswords), or minimal doses of physical activities or exercises (eg, flexibility exercises or non-weight-bearing, low-intensity activities).

Overall, the quality of the included studies was good (median TESTEX score of 9 [IQR 7–11; range 3–14]; appendix 2 pp 42–48). 22 (14·9%) studies were deemed to be low quality, 97 (65·9%) were deemed to be good quality, and 28 (19·0%) were deemed to be high quality. All studies adequately described the inclusion criteria and most (96 [65·3%] studies) specified the randomisation method, although only 37 studies (25·1%) explained the allocation concealment method. 97 studies (65·9%) had intervention and control groups that were either similar at baseline or had differences that were not expected to affect the results (eg, the authors adjusted for these differences in their analyses). The assessor was masked to group assignment in 66 studies (44·9%). 84 studies (57·1%) assessed at least 85% of the initially included participants. 79 studies (53·7%) reported adverse events and 90 (61·2%) reported adherence rates, but only 66 studies (44·9%) performed intention-to-treat analyses. Almost all studies included between-group statistical comparisons for both primary (137 [93·2%] studies) and secondary (136 [92·5%]) outcomes and reported effect estimates along with variability measures (133 [90·5%]). 19 studies [12·9%) controlled the physical activity levels of the control group, and less than half of the studies specified intervention characteristics (ie, exercise volume and intensity) with the necessary detail (66 [44·9%]) or adjusted for gradual individual improvements in participant fitness to keep the relative training load constant (63 [42·9%]).

For the meta-analysis, 105 randomised controlled trials (n=7759 participants), with a median TESTEX score of 9 (IQR 7–11; range 4–14) were included in multilevel analyses (figure 1). Network geometry showed a robust network with 127 direct pairwise comparisons (appendix 2 p 49): 60 comparisons for multicomponent intervention versus usual care, 30 for endurance versus usual care, 22 for strength versus usual care, six for balance versus usual care, four for endurance versus multicomponent

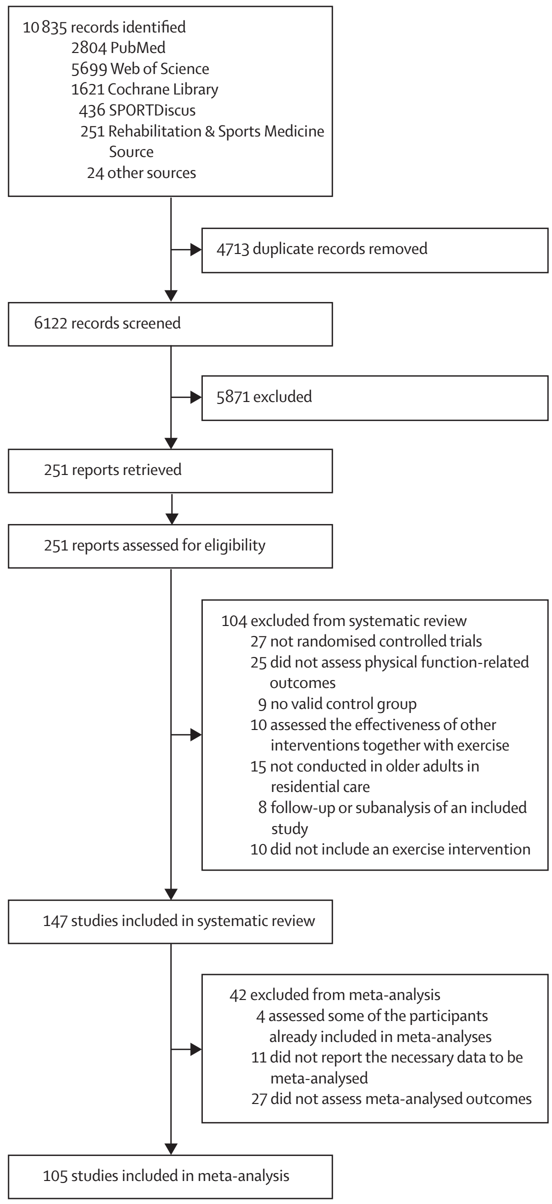

Figure 1: **Study selection**

intervention, three for multicomponent intervention versus strength, one for endurance versus balance, and one for strength versus endurance.

Overall multilevel analyses (ie, all possible exercise types and outcomes) showed that exercise interventions were associated with significantly improved overall physical function outcomes compared with usual care (105 studies; SMD 0·13 [95% CrI 0·04–0·21]; appendix 2 p 50), with no between-study heterogeneity (I^2=0%), but with signs of small-study effects (Egger's test p<0·0001).

Sensitivity analyses were done when possible in the most commonly analysed subpopulations. Significant

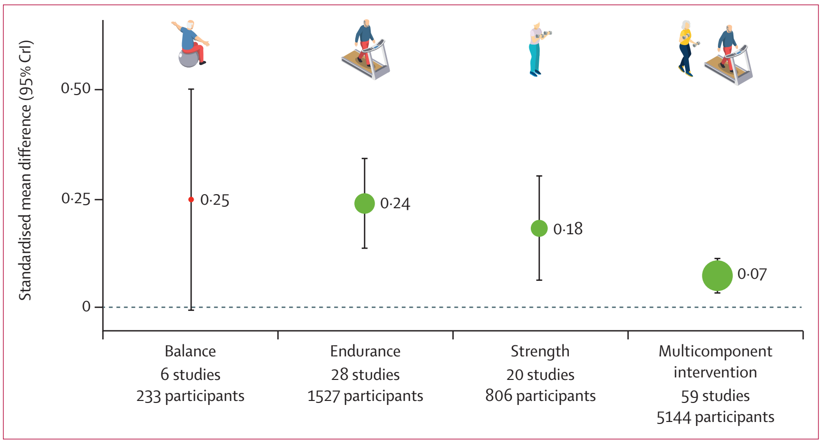

***Figure 2:* Effects of different exercise interventions on physical function**

Data are shown as standardised mean differences (*vs* usual care) with 95% CrIs. Circle sizes are proportional to the number of studies and participants included. CrI=credible interval.

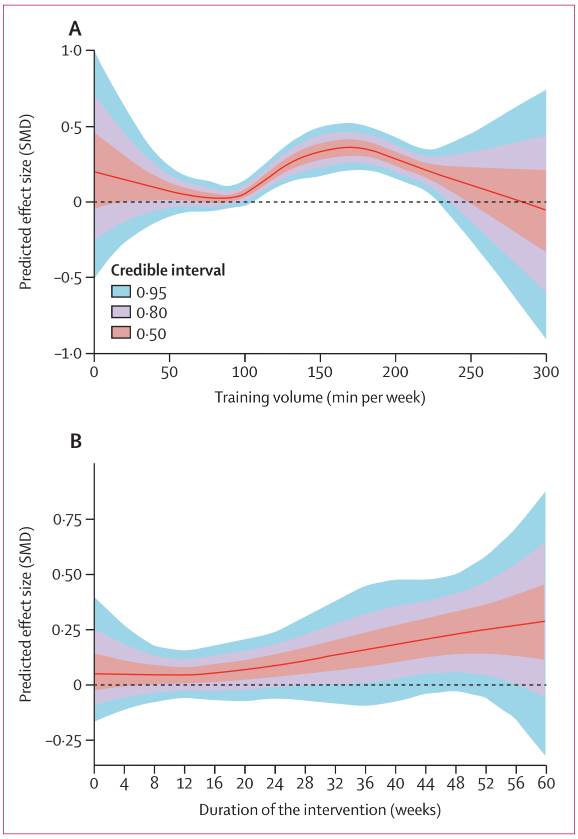

***Figure 3:* Effects of the volume (A) and duration (B) of exercise interventions on physical function**

Data are shown as SMD (*vs* usual care; red line) with credible intervals shown as shaded areas. SMD=standardised mean difference.

benefits were observed in studies specifically conducted in nursing homes (56 studies; SMD 0·07 [95% CrI 0·03–0·11]), and a moderate-to-large effect was observed in older adults with cognitive impairment (22 studies; 0·44 [0·19–0·70]), those with dependence in activities of daily living (ten studies; 0·40 [0·08–0·71]), and in those with pre-frailty or frailty (13 studies; 0·65 [0·49–0·82]).

At the intervention-specific level, no consistent differences were found between exercise types, with the exception of a small beneficial effect of endurance training over multicomponent training (SMD 0·17 [95% CrI 0·06–0·27]; appendix 2 p 51), with all exercise types providing significant benefits compared with usual care (figure 2). The largest effect size was observed for balance exercise, although with a large degree of imprecision. The most consistent benefits were found with endurance exercise compared with other single-exercise categories (ie, balance or strength), and ranking analyses showed endurance exercise to be the most likely to be effective (appendix 2 p 52).

The most consistent beneficial effects were observed with 110 min (SMD 0·12 [95% CrI 0·03–0·22]) to 225 min (0·19 [0·03–0·34]) of exercise per week, and the largest benefits were observed with 170 min per week (0·36 [0·20–0·52]; figure 3A), although the association between effect estimate and the duration of the intervention (in weeks) had a high degree of imprecision (figure 3B).

A summary of the pooled results for each specific physical function-related outcome is shown in the table and in figure 4. Significant benefits were found (based on studies that were, on average, of good quality) for all meta-analysed outcomes with the exception of timed up-and-go: Barthel index, five-times sit-to-stand test, 30-s sit-to-stand test, isometric knee extension, hand grip strength, bicep curl strength, Short Physical Performance Battery, 6-min walking test, walking speed, Berg balance scale, and sit-and-reach test. No significant differences were found between the analysed exercise types (appendix 2 p 53).

Discussion

The findings of this systematic review and meta-analysis of randomised controlled trials show that exercise interventions enhance physical function in older adults in residential care regardless of their functional or cognitive status, including by improving functional independence for activities of daily living (ie, higher scores in the Barthel index), as well as in different measures of muscle strength, physical performance, balance, and flexibility.

Although the benefits of physical exercise on the physical function of older adults in general have been widely proven,[10,11] debates are ongoing regarding its benefits for older adults in residential care. Previous meta-analyses that included both older adults living in the community and those living in institutions showed beneficial effects of exercise,[7,8] but no subanalyses focusing on adults living in institutions were conducted. In a systematic review (with no meta-analysis) including 49 randomised controlled trials, Forster and colleagues[17] concluded that exercise interventions can be successful at improving functional independence in activities of daily living and other physical performance indicators (muscle strength, flexibility, or balance) in older people in long-term care. However, meta-analytical evidence on the effects of exercise intervention on physical function in older adults in residential care is scarce.[17,19,20,29] Crocker and colleagues[19] reported a non-significant trend for a beneficial effect of exercise in the timed up-and-go test (p=0·05, average improvement of 5 s; no improvement was found in the present meta-analysis) and walking speed (p=0·1, average increase of 0·03 m/s; an increase of 0·14 m/s was found in the present study). However, the authors did not meta-analyse other outcomes, such as muscle strength, balance, or the Short Physical Performance Battery,[19] in which physical exercise can induce significant benefits (as shown here). In a 2022 systematic review and meta-analysis by Pinheiro and colleagues,[20] benefits of specific exercise interventions, such as resistance and multicomponent training, were reported for the Short Physical Performance Battery (improvement of 1·2–2·0 points), the 30-s sit-to-stand test (three repetitions) and the timed up-and-go test (–4 s).

The changes induced by exercise interventions in the present meta-analysis are small overall, but they are likely to be of clinical relevance. Of note, the improvement observed for the Barthel index in the present meta-analysis (4·5 points) is larger than the minimum clinically important difference reported in geriatric patients (mean age 80 years) undergoing rehabilitation (3·1 points).[30] The improvements observed in the present meta-analysis for other outcomes, such as the 6-min walking test (38 m), walking speed (0·14 m/s), or Short Physical Performance Battery (0·8 points), are also greater than what is considered a meaningful change in older adults (approximately 20 m, 0·05 m/s, and 0·5 points, respectively).[31] For example, the benefits observed in the present meta-analysis are greater than or close to the improvements that have been associated with improved physical function, better health perception, or a reduced mortality risk in different cohorts of older adults,[32] such as 0·8 more points in the Short Physical Performance Battery,[33] 18 m in the 6-min walking test,[34] two more repetitions in the 30-s sit-to-stand test,[35] or an increase in walking speed of 0·03–0·05 m/s.[33] Similarly, in the present study we observed that, on average, exercise interventions increase hand grip strength by 3·6 kg compared with usual care, and meta-analytical evidence shows that each increase of 1·0 kg in this test is associated with a 30% reduction in cardiovascular risk and a 9% reduction in all-cause mortality risk in older adults (>65 years).[36] Of note, several outcomes assessed in the present meta-analysis are commonly used as indicators of major medical conditions in older adults—particularly sarcopenia, which is highly prevalent in nursing home residents, affecting about one-third of this population.[37] In fact, a 2019 European consensus report recommends the use of muscle strength (eg, hand grip strength or sit to stand) and physical performance (eg, walking speed, Short Physical Performance Battery, or timed up-and-go) tests for the diagnosis of sarcopenia.[21] Therefore, the improvements found here support the potential of exercise interventions as a preventive strategy against this prevalent condition. Moreover, impairments in functional ability, strength, or physical performance have been associated with an increased risk of falls, dementia, or mortality among older adults, and particularly nursing home residents,[38–41] which further reinforces the relevance of our findings. However, we did not assess the sustainability of exercise benefits once programmes were completed, and evidence suggests that these benefits partly disappear after short detraining periods (3–6 months).[42,43] Therefore, long-term maintenance of exercise programmes should be recommended.

Despite the overall beneficial effects of physical exercise for older adults in residential care, controversy persists regarding the most effective exercise type. In the present meta-analysis, we observed no consistent differences between exercise categories (with the exception of balance training alone, but with large imprecision); some were more or less effective on the basis of the different outcomes. This result is consistent with the meta-analysis by Pinheiro and colleagues,[20] in which no differences were found between resistance and multicomponent training. Thus, given that no consistent differences seem to exist between interventions, our results highlight the

	Interventions (participants), n	Relative effect (95% CrI)	Quality of studies, median TESTEX score (range)
Overall			
Physical function, SMD	105 (7759)	0·13 (0·04 to 0·21)	9 (4–14)
Muscle strength			
Isometric knee extension, N	16 (743)	10·0 (8·5 to 11·5)	10 (8–13)
Hand grip strength, kg	26 (1512)	3·60 (3·22 to 3·96)	10 (5–14)
Bicep curl strength, repetitions in 30 s	18 (1079)	3·0 (2·7 to 3·4)	9 (5–12)
Five-times sit-to-stand test, s	16 (780)	–1·9 (–2·5 to –1·4)	10 (6–14)
30-s sit-to-stand test, repetitions	18 (1117)	2·5 (2·2 to 2·9)	10 (5–14)
Physical performance			
3-m timed up-and-go test, s	47 (3061)	0·0 (–0·1 to 0·0)	10 (5–14)
Short Physical Performance Battery, score, 0–12	15 (1362)	0·76 (0·52 to 1·01)	11 (6–14)
6-min walking test, m	19 (991)	37·7 (30·4 to 44·9)	9 (5–14)
Walking speed, m/s	26 (1623)	0·14 (0·12 to 0·16)	10 (4–14)
Balance			
Berg balance scale, score, 0–56	22 (1681)	2·0 (1·6 to 2·4)	11 (7–14)
Flexibility			
Sit-and-reach test, cm	19 (1315)	2·1 (1·3 to 2·8)	8 (5–12)
Functional independence			
Barthel index, score, 0–100	20 (1890)	4·5 (3·6 to 5·5)	10 (7–14)

Relative effect represents the estimated effect of exercise interventions compared with usual care, and are presented as either SMDs or absolute mean differences. CrI=credible interval. SMD=standardised mean difference. TESTEX=Tool for the Assessment of Study Quality and Reporting in Exercise.

Table: **Summary of pooled results for the effects of exercise interventions compared with usual care**

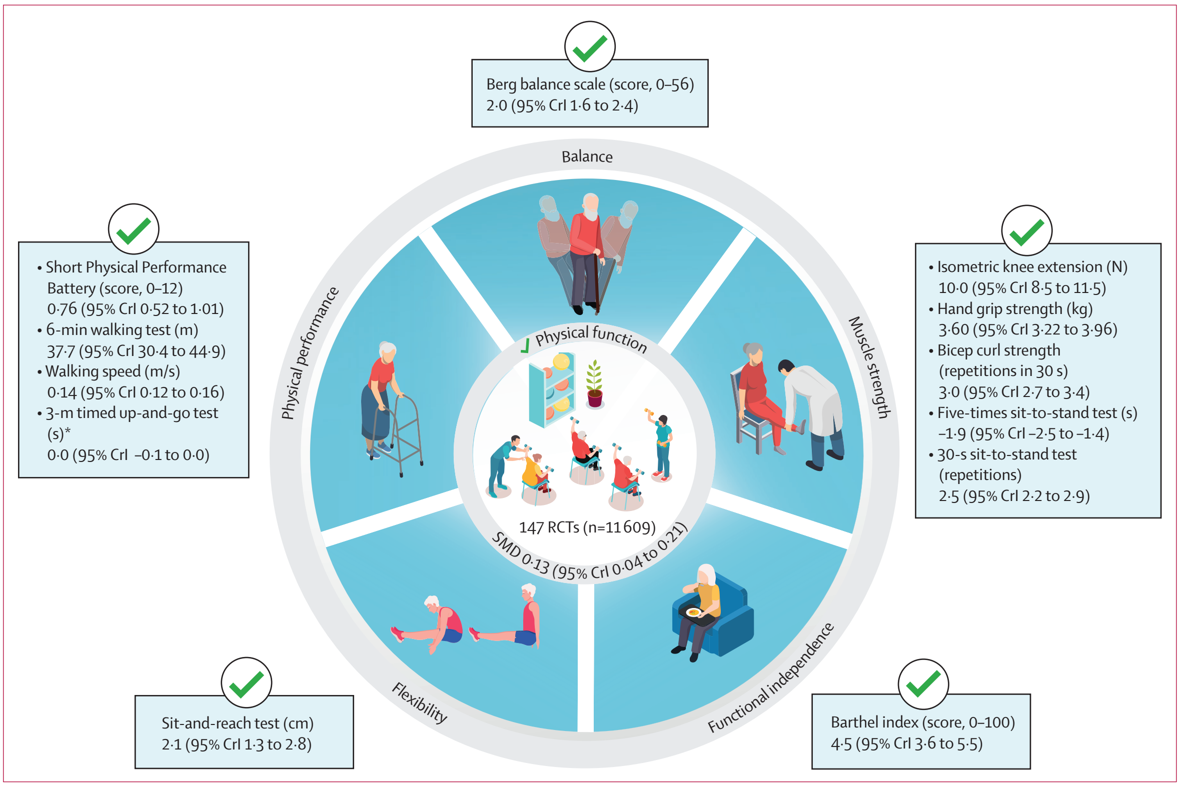

Figure 4: **Summary of study findings**
Data are presented as SMDs or absolute mean differences, with 95% CrIs. CrI=credible interval. RCT=randomised controlled trial. SMD=standardised mean difference. *Results for the 3-m timed up-and-go test did not reach statistical significance.

possibility of using the form of exercise that best suits the resources, needs, and preferences of older adults in residential care, because any exercise type or combination provides greater benefits than usual care. However, according to a taskforce report published by experts in geriatrics and exercise science, multicomponent training comprising strengthening, endurance, and balance or coordination exercises might be the most recommendable option for older adults in residential care.[18] Our meta-regression analysis also showed a non-significant trend for a positive association between intervention duration and the obtained benefits, although the low number of available effect sizes for medium-term and, particularly, long-term interventions might have potentially biased our results. Moreover, the most consistent beneficial effects were observed with 110–225 min per week of exercise, with an optimal dose of 170 min per week. Of note, none of the included studies reported exercise volumes of more than 240 min per week, which might partially confound our results (ie, we cannot know whether greater exercise volumes would result in larger benefits). In this regard, previous evidence supports a positive association between training volume (eg, min per week or time under tension) and exercise-induced benefits, particularly for strength training,[44,45] but controversy remains regarding the dose–response relationship of other exercise types such as balance[46] or endurance training.[47,48] Finally, other important intervention characteristics that have been previously shown to moderate exercise benefits, such as exercise intensity,[48,49] could not be analysed, partly because most studies did not report intervention characteristics (eg, exercises included, intensity, work-to-rest ratio, session duration, or progression) with sufficient detail—a common issue in this field of research.[50,51] More evidence is needed to establish how specific intervention characteristics moderate exercise effects.

An important limitation of our meta-analysis is the large heterogeneity in participant characteristics found both between and within studies (eg, functional independence, frailty and cognitive status, or other medical conditions), which might have potentially confounded the effects of exercise interventions. For example, the included studies were done in different settings, including not only nursing homes, but also assisted living facilities or care homes, with the respective populations usually differing in terms of individual abilities and organisational designs or service provision. However, to partly reduce this confounding factor, we performed sensitivity analyses when possible, which showed that exercise benefits are also observed when solely including studies performed in nursing homes (which is likely to be the setting associated with the highest level of dependence). In addition, those willing to participate in exercise trials might be the healthier or more proactive residents in a particular setting, which represents an additional potential source of bias. Although most studies combined participants with heterogeneous conditions, our sensitivity analyses indicate that exercise benefits occur in older adults in residential care with different cognitive and functional status (with even larger benefits observed in individuals with cognitive impairment or in those with functional dependence, pre-frailty, or frailty), and previous meta-analytical evidence supports the beneficial effects of exercise in older adults with disease,[9] or in those with dementia[52] or frailty.[53]

Some further limitations of the present study must be acknowledged: we focused on studies published in Spanish and English only, and we did not include unpublished studies, which might be considered a potential bias (although only one completed but unpublished trial was found; appendix 2 p 54). However, these types of studies usually represent a small proportion of the available evidence and rarely affect the results and conclusions of systematic reviews and meta-analyses.[54] Regarding the analyses, several outcomes (eg, Katz index, functional reach test, Tinetti assessment, or back scratch test) were not meta-analysed due to the decision to meta-analyse only those outcomes assessed in at least ten different intervention groups.[24,27] Several relevant outcomes assessed by a large number of studies and many participants were meta-analysed, which is expected to result in a robust effect estimate. Nonetheless, although we meta-analysed the outcomes that were most commonly assessed in the included randomised controlled trials—including those with relevance for daily life, such as functional independence or physical performance—these outcomes do not necessarily represent the outcomes with the largest relevance to older adults in residential care. Finally, data from some studies could not be obtained despite attempts to contact the authors and, therefore, these studies could not be included in the quantitative analyses, which is another potential source of bias.

In summary, exercise interventions are effective in improving physical function outcomes in older adults in residential care. Although more evidence is needed to establish the most effective intervention characteristics (including exercise type, training volume, and intensity), the most consistent benefits seem to be attained with around 3 h of exercise per week, with no significant differences between exercise types. Exercise interventions should, therefore, be routinely promoted in long-term care facilities.

Contributors

PLV, GS-L, and JSM conceptualised the study. PLV and AL supervised the study. PLV, GS-L, JSM, FM-P, SL-O, BR-B, DJ-P, and AS-L curated the data. PLV, DG-G, and BdPC analysed the data. AC-G and DG-G produced the figures. PLV wrote the original draft of the manuscript. All authors contributed to the writing and revision of the manuscript. PLV, JSM, and GS-L have accessed and verified all the underlying data. All authors confirm that they had full access to all the data in the study and accept responsibility for the decision to submit for publication.

Declaration of interests

We declare no competing interests.

Data sharing

The datasets analysed for this study are available upon reasonable request by email to the corresponding author.

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