Biological Research For Nursing
2022, Vol. 0(0) 1–19

DOI: 10.1177/10998004221120945
journals.sagepub.com/home/brn
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A Systematic Review and Meta-Analysis of Resistance Training on Quality of Life, Depression, Muscle Strength, and Functional Exercise Capacity in Older Adults Aged 60 Years or More

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Abstract

Background: Aging is generally associated with numerous metabolic and physical changes that augment susceptibility to several chronic conditions, disability, and diminished quality of life.

Objective: The purpose of this meta-analysis was to investigate the efficacy of resistance training on quality of life, depression, muscle strength, and functional exercise capacity in older adults (≥60 years).

Data sources: A systematic search was conducted in PubMed, MEDLINE, Cochrane, Google Scholar, and Scopus up to December 20, 2021.

Results: 21 studies (N = 1610) were included. Resistance training significantly improved physical functioning (standard mean differences (SMD), 0.31; p = 0.02), mental health (SMD, 0.44; p = 0.001), bodily pain (SMD, −0.52; p = 0.004), general health (SMD, 0.43; p = 0.002), social functioning (SMD, 0.25; p = 0.006), and mental component score (SMD, 0.51; p = 0.001) subscales. Moreover, depression (SMD, −1.13; p = 0.01), upper-limb muscle strength (mean difference (MD), 15.26 kg; p = 0.002), lower-limb muscle strength (MD, 48.46 kg; p = 0.02), and handgrip muscle strength (MD, 1.35 kg; p = 0.003) significantly improved following resistance training. No benefits were found for vitality, physical component score, total score of quality of life, and the 6-min walk distance.

Conclusion: Preliminary evidence reveals that resistance training can be effective for improving most domains of quality of life, upper- and lower-limb muscle strength, handgrip strength, and depression in aged people. More proof is hence needed to draw solid conclusions.

Keywords

randomized controlled trials, psychological health, exercise, elderly, performance

Introduction

Population aging is a global phenomenon. Aging is usually associated with numerous metabolic and physical changes that augment susceptibility to several chronic conditions, disability, and diminished quality of life (Franceschi et al., 2018). In addition, muscular weakness has a critical role in the pathogenesis of frailty and functional impairment that happens with advancing age and causes a number of ailments. In those aged 50 to 70, there is a decline of roughly 30% in muscle strength (Larsson et al., 2019; Palla et al., 2021; Peterson et al., 2010). Furthermore, older adults accounted for approximately 50% of the prevalence of disability (Rathnayake et al., 2022).

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Unfortunately, no drug or drug combination can counteract the functional decrement caused by aging in the predictable future (Izquierdo et al., 2020). Nevertheless, organized physical activity is able to attenuate physical and cognitive deterioration in the aged population (Brasure et al., 2018; Falck et al., 2019; García-Hermoso et al., 2020). In particular, there is high-certainty evidence supporting higher levels of physical activity are accompanied by better quality of life (Groessl et al., 2019; Marquez et al., 2020; Puciato et al., 2017; Ramalho et al., 2015; Rugbeer et al., 2017).

The recent World Health Organization approaches on physical activity and inactive lifestyle recommended that aged individuals accomplish at least 150 or 75 min per week moderate intensity aerobic exercise or high intensity aerobic exercise training, respectively, or a combination of them, also regular resistance training (Bull et al., 2020). Yet, Keadle et al. (2016) found that just 27%–44% of older adults complete international aerobic physical activity recommendations, and only 18%–22% engage in strengthening workouts on two or more days in a week. Consequently, there is a need to elevate physical activity schedules particularly targeted for the elderly.

Resistance training programs are effective to attenuate aging-induced functional reduction (Fragala et al., 2019; Valenzuela Ruiz et al., 2019), with enhancements apprised in aged adults for mobility and muscle strength, quality of life dimensions, functional independence (Di Lorito et al., 2021; Fragala et al., 2019; Grgic et al., 2020; Mañas et al., 2021; Pucci et al., 2021; Socha et al., 2016). Aged individuals can achieve other health advantages in addition to boosted muscle mass and strength by engaging in resistance training (Westcott, 2012). Researchers have demonstrated that resistance exercise regimens can benefit bone mineral density (Huovinen et al., 2016), body composition (Wanderley et al., 2015), and symptoms of frailty (Nagai et al., 2018). Moreover, resistance exercise program may ameliorate psychosocial health outcomes like depression (Cassilhas et al., 2007; Sparrow et al., 2011), anxiety (Ferreira et al., 2018), and fatigue (Schmidt et al., 2012).

A recent meta-analysis on resistance training alone effect on quality of life was conducted (Hart & Buck, 2019), but only included investigations prior to December 2017. It also had some trials with resistance training accompanied by other interventions; finally, it only focused on quality of life. In this regard, additional randomized controlled trials have since been published, and this argues in favor of carrying out an updated meta-analysis. Moreover, to our knowledge there is no systematic review and meta-analysis on the effect of resistance training on quality-of-life dimensions, depression, and muscle strength in older adults. As the individual studies in this area tend to have low sample sizes and might absent sufficient power to distinguish small but clinically significant alterations, such an analysis is ideal for assessing resistance training interventions. Thus, this systematic review and meta-analysis aimed to assess the impact of resistance training on quality of life, depression, muscle strength, and functional exercise capacity among older adults aged 60 years and over.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guideline for completing meta-analyses of intervention investigations was adhered to in our review (Page et al., 2021). A systematic literature search was performed by one investigator (VS) to identify and assess research of resistance training in elderly. Five electronic databases comprising PubMed, MEDLINE, Cochrane, Google Scholar, and Scopus were searched from inception to December 20, 2021. The search strategies were developed through a combination of medical subject heading (Mesh) terms and text words. The following Mesh terms and free words were used when searching: “resistance training” OR “resistance” AND “training” OR “resistance training” AND “quality of life” OR “quality” AND “life” OR “quality of life” AND “aged” OR “aged” OR “elderly” OR “elderlies” OR “elderlys”, OR “strength” AND (“training” OR “strength training” AND “quality of life” OR “quality” AND “life” OR “quality of life” AND “aged”) AND (“power training”, “psychological” OR “power” AND “psychological” OR “psychological power” OR “power” OR “powered” OR “powers” OR “powering”) AND (“w8lifter” OR “w8lifters” OR “w8lifting” AND “mental health” OR “mental” AND “health” OR “mental health” OR “psychological” AND “health” OR “psychological health”). Reference lists of studies found were also manually analyzed for additional studies.

Two authors independently screened titles and abstracts of potential papers. The full text was retrieved if there was uncertainty about the eligibility of an investigation. Two independent authors read full texts and judged eligibility criteria via an electronic screening form. Papers were separately screened in two stages: screening title and abstracts and screening of full-text articles by two authors (ShKK and VS) by the eligibility criteria. Discrepancies concerning the research eligibility were fixed through discussion and, when required, with the help of a third author (ZSM).

Inclusion and Exclusion Criteria

Type of Studies. Randomized controlled trials (RCTs) and control trials were included in the current review. Review articles, conference abstracts and study protocols were excluded. The full-text articles must have examined research outcomes from a randomized controlled pretest-posttest design. Single group studies, studies with active control group, and studies with between-group posttest only results were omitted.

Type of Participants. Studies with men and women aged 60 years and older were included in our systematic review and meta-analysis.

Type of Interventions. Randomized controlled trials and control trials involving resistance training (at least 4r weeks of intervention) aimed to improve health-related quality-of-life, depression, muscle strength, and functional exercise capacity (measured by the 6-min walk distance). Resistance training was defined as any regimented program that worked for large muscle groups by using either concentric, eccentric, or isometric muscle actions.

Publications. English language manuscripts published in specialized English journals.

Type of Outcome Measures. The primary outcome was health-related quality-of-life, which it was measured using the SF-36/12/8 assessment, WHOQOL-BREF questionnaire, WHOQOL-OLD, or menopause-specific quality-of-life questionnaire. The secondary outcome measures were depression (measured by the Geriatric Depression Scale (GDS)), muscle strength (including upper and lower body strength and handgrip strength) and the 6-min walk distance.

Data Extraction

The characteristics and intervention outcomes of each included article were independently extracted by two investigators (ShKK and VS) according to the PRISMA statement (Page et al., 2021) using a standardized electronic data extraction form. The data extracted from each included study were as follows: first author, year of publication, country, data on subject characteristics (sample size, sex of participants, mean age), the population features, intervention duration, outcome measures, mean and standard deviation (SD) of continuous outcomes at baseline, post-intervention and/or changes between baseline and post-intervention.

Analyses and Meta-Analyses

We completed meta-analysis by Review Manager 5.3 (The Nordic Cochrane Centre, Copenhagen, Denmark) when more than two studies reported on the same outcome. Both random-effects model and fixed-effects model was used, using the method described by DerSimonian and Laird.

Where a trial contained more than one intervention group and a control group, we separately labeled each intervention group and adjusted the sample size of the control group in accordance with the number of intervention groups. The effect size of each outcome was summarized by calculating the mean difference (MD) or standardized mean difference (SMD) and 95% confidence interval (CI). The data of extracted outcomes were completed by the change in the mean and SD values. The pre-intervention mean was subtracted from the post-intervention mean, and the change SD was calculated using for study group participant numbers in conjunction with group p values or 95% CI where the change in mean and SD was not reported. In studies that reported standard error of the mean (SEM) data instead of the SD, this value was converted to SD (Higgins et al., 2003). To evaluate the heterogeneity among the studies, the I^2 statistic was used, with values >50% showing substantial heterogeneity (Higgins, 2011). To discover heterogeneity within main effects analyses of the physical functioning subscale (the subscale reported in most studies), subgroup analyses were applied to evaluate the effect of health status of participants and type of resistance training. Moreover, a mixed-effect model of meta-regression was conducted using the Comprehensive Meta-Analysis (CMA) V3 software, including intervention duration and gender of the mentioned subscale. Meta-analysis was performed using forest plots and statistical significance was set at $p < .05$.

Assessment of Publication Bias

We examined publication bias through funnel-plot inspection (Higgins & Green, 2005). A scatter plot of intervention impacts of included studies against a measure of the study's sample size is provided in Funnel plots. In RevMan 5.3, this is the standard error (SE). In the absence of bias, the plot should resemble an inverted symmetrical funnel. As it has been reported, visual inspection of funnel plots provides a generic and accepted way of evaluating publication bias in meta-analysis (Higgins & Green, 2005). Funnel plots were created applying RevMan 5.3.

Study Quality Assessment

Study quality was judged by the Physiotherapy Evidence Database (PEDro) scale, which has been revealed to be a valid measure of the methodological quality of RCTs (Elkins et al., 2010) and has acceptable inter-rater reliability (Moseley et al., 2002). Only those investigations scoring ≥5 on the PEDro scale, a value considered to be of moderate to high quality (Moseley et al., 2002), were considered for analysis. The study quality was independently evaluated by two authors (ShKK and VS). Third researcher was consulted if discrepancies occurred.

Results

Literature Search

A total of 1171 records were retrieved from database and other sources, of which 524 records were duplicates. A further 609 were then eliminated following screening of titles and abstracts. We excluded 17 studies with reasons: 12 did not included a control group, four applied resistance training plus other types of interventions, and one included an active control group. Finally, a total of 21 investigations comprising 1610 subjects with valid outcome data met the inclusion criteria. The PRISMA flow diagram of the studies included in our review is shown in Figure 1.

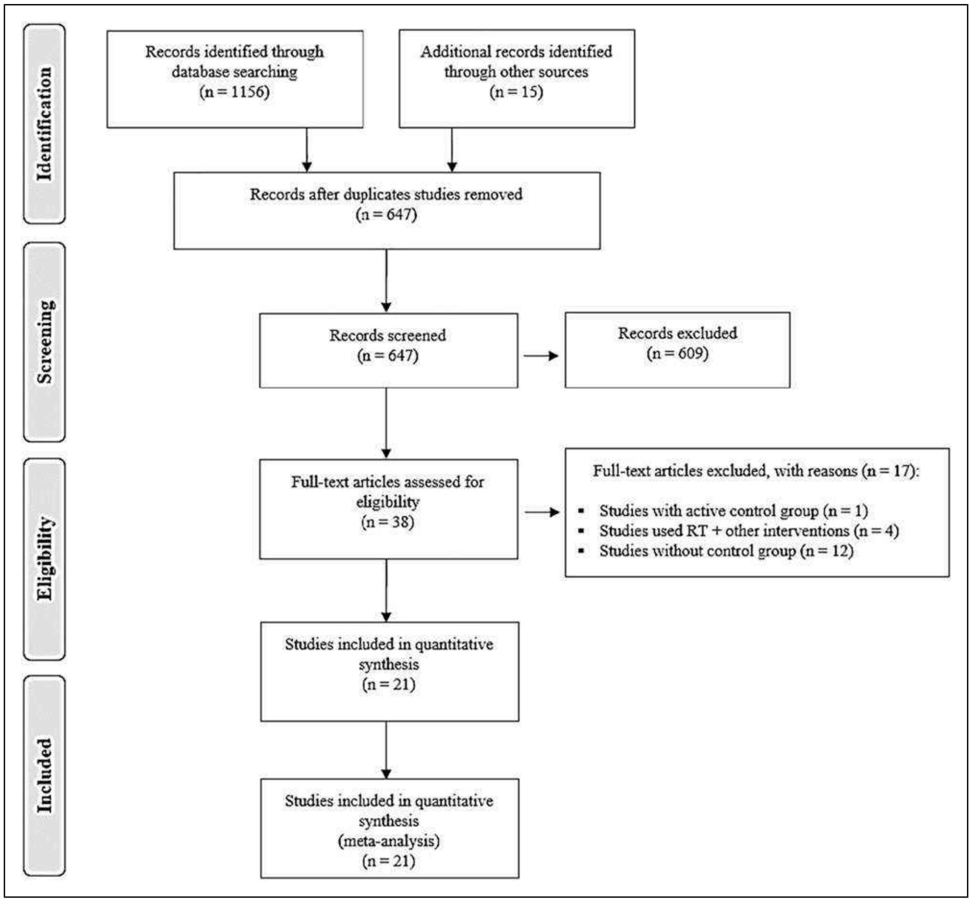

Figure 1. PRISMA flow diagram.

Cohort Characteristics

All 21 studies reported from this review were randomized controlled trials and controlled trials published in English between 2003 and 2021. Details of included studies are presented in Table 1. Studies were conducted in the USA (4), Brazil (4), Norway (2), Spain (2), Portugal (2), Taiwan (1), Sweden (1), Korea (1), Finland (1), Japan (1), New Zealand (1), and Poland (1). Sample sizes ranged from 24 (Ha & Sung, 2021) to 226 (Latham et al., 2003), with a total of 1610 participants across the 21 trials, 876 (54%) participants in the intervention group and 734 (46%) in the control group. Thirteen studies recruited both males and females (Brovold et al., 2012; Chang & Chiu, 2020; Ha & Sung, 2021; Kekäläinen et al., 2018; Kimura et al., 2010; Latham et al., 2003; Lincoln et al., 2011; Mangione et al., 2010; Marcos-Pardo et al., 2019; McDermott et al., 2009; Sylliaas et al., 2011; Wanderley et al., 2015; Winters-Stone et al., 2016), seven studies exclusively recruited female subjects (Ericson et al., 2018; Pirauá et al., 2021; Pucci et al., 2021; Ramirez-Campillo et al., 2018; Socha et al., 2016; Teixeira et al., 2010; Vasconcelos et al., 2016) and one study recruited only male participants (Cassilhas et al., 2007). Intervention length ranged from 4 to 32 weeks.

Quality-of-Life Assessment

Fourteen studies (19 arms) evaluated physical functioning subscale, 11 studies (16 arms) evaluated mental health subscale, nine studies (11 arms) measured vitality subscale, eight studies measured social functioning, bodily pain, and general health subscales, seven investigations (8 arms) assessed physical component score, six investigations (7 arms) assessed mental component score, and two studies (3 arms) investigated total score quality-of-life.

Secondary Outcomes Assessment

The 6-min walk distance and depression were assessed in 5 (6 arms) and 4 (8 arms) studies, respectively. Also, upper body and lower body strength were evaluated in three studies (6 arms), and handgrip strength was measured as an outcome in two studies (6 arms).

Meta-Analysis

Change in Quality-of-Life Subscales

Fourteen studies (19 arms) providing a total of 943 participants (exercise = 514 and control = 429) reported physical

Table 1. Details of Included Studies.

Study; country	Subjects INT/CON	Gender	Age, mean (*SD*), yearr	Population	INT description: frequency and duration	Outcome (s)
Brovold et al. (2012); Norway	53/55	Both	**INT**: 79.0 (6.5) **CON**: 79.0 (6.9)	Acute problem	Participants recommend 10–12 repetition and 2–3 sets of each resistance exercise. The amount of resistance and number of repetitions was individually tailored by the physical therapist. The ankle weights were progressed in weight as soon as a participant could perform more than 14 repetitions of an exercise. Participants completed five exercises in each session. The duration of intervention was 12 weeks	BP, GH, MH, PF, SF, VT, 6 MWD
Cassilhas et al. (2007); Brazil	39/23	Male	**INT**: 68.7 (4.5) **CON**: 67.0 (5.6)	Healthy	Training consisted of three 1-h sessions per week. The groups were submitted to a brief 10-min warm-up on the cycloergometer followed by stretching exercises. Loads were 50% of 1-RM for the EMODERATE group and 80% of 1-RM for the EHIGH group for 24 weeks	PF, BP, GH, VT, MH, chest press, leg press, depression
Chang & Chiu (2020); taiwan	63/60	Both	**INT**: 80.0 (6.7) **CON**: 80.7 (8.4)	SO	The RT intervention involved chair muscle strength training by using a grip ball or 2–5-pound sandbags on wrist or ankle joints. Daily 50-min-long sessions were administered two times per week for 3 months. The 50-min interventional program included three parts: Warm-up, sitting muscle RT, and relaxation	PCS, MCS, depression
Ericson 2017; Sweden	14/18	Female	**INT**: 68.0 (2.0) **CON**: 68.0 (1.0)	Healthy	The exercises performed in the gym were: squats, leg extensions, leg presses, seated rows and pull-downs, squat jumps, and core stability exercises. Each training session included a 10-minute warm-up together and ended with 5 minutes of core stability exercises and seven squat jumps and finally, 5 minutes of stretching exercises. Participants performed three sets per exercise, with 2 minutes' rest between sets and 3 minutes between exercises. The duration intervention was 24 weeks	PCS, MCS
Ha & Sung (2021); Korea	12/12	Both	**INT**: 74.2 (5.7) **CON**: 73.8 (5.8)	Healthy	Participants applied scapular strengthening exercise using elastic band exercise. Each session lasted 40 min, five times a week, for a total 4 weeks	PF, VT, MH, SF, BP, GH
Kekäläinen et al. (2018); Finland	81/23	Both	**INT**: 68.5 (2.9) **CON**: 68.3 (2.3)	Healthy	Each training session lasted for 1 hr, and consisted of a 10-min warm-up and 8–9 exercises for different muscle groups. Months 1–3: All three training groups trained twice a week, to become familiar with RT methods, and to build capacity for subsequent high-load training. The focus was on local muscular endurance using low loads. Months 4–9: The training groups split into different training frequencies in which they were randomized: For RT1, this represented a reduced and for RT3 an increased training frequency. All training groups followed identical two-session training programs: Completing one cycle took 2 weeks for RT1, 1 week for RT2, and RT3 completed three cycles in 2 weeks. Training during months 4–9 was progressively periodized RT, focused on muscle hypertrophy and maximum strength. 9 months	Depression, PF, MH, SF

(continued)

Table 1. (continued)

Study; country	Subjects INT/CON	Gender	Age, mean (*SD*), yearr	Population	INT description: frequency and duration	Outcome (s)
Kimura et al. (2010); Japan	65/54	Both	**INT**: 73.6 (4.7) **CON**: 75.2 (6.3)	Healthy	The program comprised a 3-month facility-based program using progressive resistance training. Participants were asked to train twice weekly for 1.5 hr each session for a total of 24 training sessions. The first phase was designed to condition physical functions through low-intensity exercise with high repetition. In this phase, participants learned proper forms, speed control, and a breathing technique. The second phase began at 60% of 1 RM, defined as the maximum weight that could be lifted through a full range of motion with proper form. Evaluation of 1 RM was performed on the first day of the second phase. Weight was adjusted accordingly to ensure that the intensity was moderate to high. Resistance was increased if the participant was able to effortlessly complete 3 sets of 10 repetitions. A rest of approximately 2 min, sometimes more, was provided between sets of machine training	PF, BP, GH, VT, SF, MH
Latham et al. (2003); New Zealand	112/114	Both	**INT**: 80.0 (7.3) **CON**: 80.0 (6.4)	Frail	The resistance exercise intervention consisted of a quadriceps exercise program using adjustable ankle cuff weights undertaken three times per week for 10 weeks. The aim was for patients to exercise at a high intensity by midway through the program. This was defined as exercising at 60%–80% of the patient's 1RM	PCS
Lincoln et al. (2011); USA	29/29	Both	**INT**: 66.0 (7.9) **CON**: 66.6 (7.4)	T2D	Participants exercised three times per week under supervision for 16 weeks. Each session lasted approximately 45 min and included warm-up, resistance training, and cool-down exercises	Depression, MCS
Mangione et al. (2010); USA	14/12	Both	**INT**: 79.6 (5.9) **CON**: 82.0 (6.0)	Healthy	Sessions occurred twice a week for 10 weeks for 20 total sessions, a frequency of visits found to be sufficient for change that was established in previous work. Each session lasted approximately 30–40 min. The exercise intensity was an eight (8RM), and volume was three sets of eight repetitions. Intensity was reevaluated every 2 weeks, and the resistance was increased if the participant was able to complete eight repetitions at the higher load in good form	PF, 6 MWD
Marcos-Pardo et al. (2019); Spain	24/21	Both	**INT**: 69.0 (3.2) **CON**: 70.0 (4.1)	Healthy	Participants performed the sets with moderate-intensity (8–12 repetitions) in each exercise. The load was increased during the 12 weeks from 60% 1-RM to high-intensity 80% 1-RM. The training load was increased when the individual could perform more than the prescribed number of repetitions (12 repetitions) followed the OMNI-RES scale and a hard effort perception level. Rest between sets was 1–2 min	Chest press, leg press, total score of QoL

(continued)

Table 1. (continued)

Study; country	Subjects INT/CON	Gender	Age, mean (*SD*), yearr	Population	INT description: frequency and duration	Outcome (s)
McDermott et al. (2009); USA	46/48	Both	**INT**: 71.7 (8.7) **CON**: 68.5 (11.9)	PAD	Participants exercised three times a week for 24 weeks with a certified trainer. Participants performed three sets of eight repetitions of knee extension, leg press, and leg curl exercises using standard equipment. For each exercise, the 1 RM was measured at baseline and subsequently every 4 weeks. Participants began exercising at 50% of their 1 RM. Weights were increased over the first 5 weeks until participants were lifting 80% of their 1 RM. Weights were adjusted after each monthly 1 RM and as needed to achieve an exercise intensity of a rating of perceived exertion of 12–14. Participants also performed three sets of eight repetitions of squat and toe rise exercises	PF, 6 MWD
Pirauá et al. (2021); Brazil	22/14	Female	**INT**: 68.1 (3.9) **CON**: 67.5 (4.8)	Obese	Participants performed moderate-intensity strength exercise, thrice weekly during 24-weeks. A linear periodization was adopted and the prescription ranged from two to five sets of 7–12 repetitions, with 60-s to 150-s recovery interval between the sets and exercises, respectively	Total score of QoL, handgrip strength
Pucci et al. (2021); Portugal	14/14	Female	60–84	Healthy	A familiarization period of 2 weeks was applied in the devices before performing the 10-RM. During this period, the participants performed two sets of each exercise with a low load to learn how to reproduce the movement (70% of 10 RM). After this, the 10 RM tests were performed with the participants instructed to perform 10 repetitions with as great a load as possible. The sessions were held twice a week and lasted approximately 60 min, comprising: 10 min of warm-up, 40–45 min of resistance exercises and 5–10 min of stretching and warm-down, based on a previously conducted study 18. The warm-up took place in the equipment itself using a light load and performing the exercise with 10–15 repetitions	PF, BP, GH, VT, SF, MH, PCS
Ramirez-Campillo et al. (2018); Spain	35/17	Female	**INT**: 67.8 (5.4) **CON**: 66.5 (5.4)	Healthy	Training was undertaken three times per week for 12 weeks. Training consisted of a 10-min warm-up that included walking and mild stretching, resistance training exercises, medicine ball throwing, CMJs, abdominal crunches, and prone superman exercises, the aim of the last two was to target core and concluded with a cool-down. A combination of free weights and machine resistance training exercises was used. Training sessions for both groups lasted ~60 min and were separated by a minimum of 48 hr. Participants from both resistance training groups completed three sets (at 45%, 60%, and 75% of their baseline 1 RM) of each resistance training exercise, with eight repetitions for each set. The cluster-set group also completed eight repetitions per set but with an interest rest redistribution, such that after two consecutive repetitions, a rest of 30 s was allowed. All repetitions were completed using a concentric muscle action as fast as possible and an eccentric muscle action of 3 s. A metronome was used to assure control of movement speed during the eccentric portion of the resistance exercises	PF, MH

(continued)

Table 1. (continued)

Study; country	Subjects INT/CON	Gender	Age, mean (*SD*), yearr	Population	INT description: frequency and duration	Outcome (s)
Socha et al. (2016); Poland	13/19	Female	**INT**: 62.7 (6.8) **CON**: 62.4 (5.2)	PM	The internal resistance training included 25 repetitions (very low load). Strength exercises with the body's own resistance, dumbbells (1 kg on each side) and large exercise ball (35 min), two series of maximum 25 repetitions for each exercise; this stage comprised 12 exercise types for selected muscle groups; 3) stretching of main muscle groups used in the exercises (10 min), two series of 20 seconds for each side; included 9 types of exercise for selected muscle groups. The duration intervention was 8 weeks	PF, BP, GH, VT, SF, MH, PCS, MCS
Sylliaas et al. (2011); Norway	100/50	Both	**INT:** 82.1 (6.5) **CON:** 82.9 (5.8)	Hip fracture	Exercises during the 3-month phase (3–6 months after the fracture) were conducted by a physiotherapist using a combination of group and individual sessions. Exercise sessions lasted 45–60 min, depending on the participant's ability and tolerance. Initially, the participant performed three sets of 15 repetitions of each exercise at 70% of his or her 1-RM. The 1-RM measurements were repeated every third week and used to increase the exercise prescription progressively. After the first 3 weeks, the resistance was increased to 80% of the 1-RM, and every third week the number of repetitions was reduced from 12 to 10, while maintaining at least eight repetitions	PCS, MCS, 6 MWD
Teixeira et al. (2010); Brazil	43/42	Female	**INT:** 63.1 (4.5) **CON:** 62.8 (4.9)	OP	Strengthening exercises included leg extensions with a load up to 80% of 1-RM, following a protocol of 2 weeks of adjustment wearing 1–2 kg ankle weight, progressing for 50%, 60%, and 70% up to 80% of 1-RM. The protocol was applied twice a week during the 18-week treatment	BP, VT, GH, MH, SF, PF
Vasconcelos et al. (2016); Brazil	14/14	Female	**INT**: 72.0 (4.6) **CON:** 72.0 (3.6)	SO	Participants underwent a 10-week resistance exercise program, with 1-hr sessions twice a week. Each session consisted of a 5-minute walk for warm-up followed by stretching exercises and finally resistance exercises. Stretching exercises remained the same during the entire intervention period. They were performed for 60 s in each leg for posterior, anterior, lateral, and medial muscles of hips and knees	PF
Wanderley et al. (2015); Portugal	19/31	Both	**INT:** 67.3 (4.9) **CON:** 67.8 (5.5)	Healthy	Participants trained three times per week for 8 months. Each exercise session lasted approximately 50 min. Program consisted of a 10-min warm-up, nine exercises for different muscle groups, and a 10-min cool-down. Participants performed two sets of 12–15 reps at 50%–60% 1RM, or a RPE 4 to 6, for the first month. At the end of the first month, the 1RM was measured again and the load was increased to 80% 1RM. At this intensity, older adults performed two sets of 8–12 reps with a 2-min rest between each set. Every 2 months, the 1RM was measured to keep the training stimulus consistently at 80% 1RM. In addition, all participants had their RPE collected weekly. When an individual RPE was under the rating of seven for two consecutive sessions, the participant was instructed to increase the load so that he or she could perform two sets of 8–12 reps at an appropriate RPE.	PF, BP, GH, VT, SF, MH, PCS, MCS, 6 MWD, handgrip strength

(continued)

Table 1. (continued)

Study; country	Subjects INT/CON	Gender	Age, mean (*SD*), yearr	Population	INT description: frequency and duration	Outcome (s)
Winters-Stone et al. (2015); USA	64/64	Both	**INT:** 68.6 (6.6) **CON:** 71.3 (7.7)	PCS and spouses	Participants performed 8–15 repetitions of an exercise at intensities that progressed from 4 to 15% of body weight in a weighted vest for lower body exercises (ex. Chair rises, 90° squats, multi-directional lunges) and from a weight that could be lifted for 15-RM to a heavier weight that could be lifted 8-RM for upper body exercises (ex. rows, bench press, push-ups, triceps extension, shoulder raise) using free weights. Within a session, participants performed 8–10 different exercises, evenly split between upper and lower body training. A 5-min dynamic aerobic warm-up and 5–10 min stretching cool-down were performed at the beginning and end of each exercise session; 24 weeks	MH, PF, VT, chest press, leg press

Note. INT, intervention; CON, control; BP, bodily pain; GH, general health; MH, mental health; PF, physical functioning; SF, social functioning; VT, vitality; MCS, mental component score; PCS, physical component score; six MWD, 6 min walk test; T2D, type 2 diabetes; PM, postmenopausal; OP, osteoporosis; PAD, peripheral arterial disease; SO, sarcopenic obesity; RT, resistance training; 1RM, 1-repetition maximum.

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Study or Subgroup	Intervention Mean	Intervention SD	Intervention Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Brovold 2012	6	15.6	53	6.5	11.47	55	6.8%	-0.04 [-0.41, 0.34]
Cassilhas 2007; HI	3.25	2.87	20	1.95	2.6	12	4.9%	0.46 [-0.27, 1.18]
Cassilhas 2007; MOI	3.94	2.87	19	1.95	2.6	11	4.7%	0.70 [-0.07, 1.46]
Ha 2021	5.83	8.21	12	2.08	14.37	12	4.5%	0.31 [-0.50, 1.12]
Kekäläinen 2018; RT1	0.3	1.7	26	0.1	1.9	7	4.4%	0.11 [-0.72, 0.95]
Kekäläinen 2018; RT2	0.4	1.57	27	0.1	1.9	8	4.6%	0.18 [-0.61, 0.97]
Kekäläinen 2018; RT3	0.3	1.97	28	0.1	1.9	8	4.6%	0.10 [-0.69, 0.89]
Kimura 2010	1.1	6.19	65	1.2	4.71	54	6.9%	-0.02 [-0.38, 0.34]
Mangione 2010	0.3	17.7	14	2.9	14.4	12	4.7%	-0.15 [-0.93, 0.62]
McDermott 2009	10	27.6	46	1.7	18.23	48	6.6%	0.35 [-0.05, 0.76]
Pucci 2021	3.57	22.4	14	9.29	23.68	14	4.8%	-0.24 [-0.98, 0.50]
Ramirez-Campillo 2018; CSG	0.5	0.7	15	0	0.92	8	4.2%	0.62 [-0.26, 1.50]
Ramirez-Campillo 2018; TSG	0.7	0.89	20	0	0.92	9	4.5%	0.76 [-0.06, 1.57]
Socha 2016	3.14	10.46	13	3.3	18.97	19	5.0%	-0.01 [-0.72, 0.70]
Teixeira 2010	56.39	29.99	43	-0.48	35.82	42	6.1%	1.71 [1.21, 2.21]
Vasconcelos 2016	-1	22	16	6	22.5	15	5.0%	-0.31 [-1.02, 0.40]
Wanderley 2015	-0.4	2.2	19	-3.2	1.7	31	5.3%	1.45 [0.81, 2.09]
Winters-Stone 2016; (1)	0.9	9.13	32	1.1	8.25	32	6.2%	-0.02 [-0.51, 0.47]
Winters-Stone 2016; (2)	1.2	7.85	32	1	8.8	32	6.2%	0.02 [-0.47, 0.51]
Total (95% CI)			**514**			**429**	**100.0%**	**0.31 [0.05, 0.57]**

Heterogeneity: Tau² = 0.22; Chi² = 62.02, df = 18 (P < 0.00001); I² = 71%
Test for overall effect: Z = 2.36 (P = 0.02)

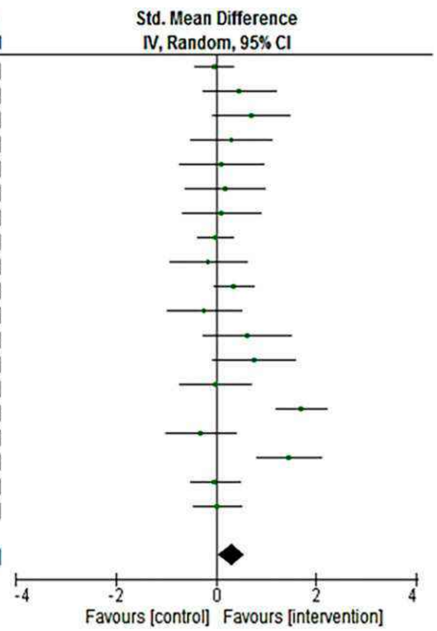

Figure 2. Forest plot for the subscale of physical functioning. HI, high intensity; MOI, moderate intensity; RT1-3, resistance training one, two or three times a week; CSG, cluster-set group; TSG, traditional-set group.

unctioning as an outcome measure (Brovold et al., 2012; Cassilhas et al., 2007; Ha & Sung, 2021; Kekäläinen et al., 2018; Kimura et al., 2010; Mangione et al., 2010; McDermott et al., 2009; Pucci et al., 2021; Ramirez-Campillo et al., 2018; Socha et al., 2016; Teixeira et al., 2010; Vasconcelos et al., 2016; Wanderley et al., 2015; Winters-Stone et al., 2016). Pooled results revealed that resistance training had a significant impact on physical functioning subscale (SMD: 0.31, 95% CI [0.05–0.57]; p = 0.02; Figure 2). Subgroup analyses by participants' health status revealed a significant improvement of physical functioning for healthy participants (SMD: 0.31, 95% CI [0.04–0.57]; p = 0.02; 12 arms), but not in non-healthy participants (SMD: 0.30, 95% CI [−0.27–0.87]; p = 0.30; five arms. In addition, subgroup analysis by types of resistance training revealed a significant improvement for only free w8s and machine resistance (SMD: 0.69, 95% CI [0.09–1.29]; p = 0.02; two arms), but not for isolated free w8s (SMD: 0.07; 95% CI [−0.13–0.28]; p = 0.47; eight arms), isolated machine resistance (SMD: 0.45, 95% CI [−0.13–1.03]; p = 0.13; seven arms), elastic bands (SMD: 0.31; 95% CI [−0.50–1.12]; p = 0.45; one study), and dumbbells (SMD: −0.01, 95% CI [−0.72–0.70]; p = 0.98; one study).

We also performed a meta-regression analysis to examine the variation in resistance training effect based on intervention duration and gender. The meta-regression analysis revealed that both intervention duration and gender were not significant sources of heterogeneity for physical functioning changes (Q = 3.80, p = 0.0513 for intervention duration and Q = 1.26, p = 0.5319 for gender; Figure 3).

Eleven studies (13 arms) reported mental health subscale (Brovold et al., 2012; Cassilhas et al., 2007; Ha & Sung, 2021; Kekäläinen et al., 2018; Kimura et al., 2010; Pucci et al., 2021; Ramirez-Campillo et al., 2018; Socha et al., 2016; Teixeira et al., 2010; Wanderley et al., 2015; Winters-Stone et al., 2016) that included a combined total of 792 participants. We combined the results using the random-effects model and revealed a significant improvement in mental health subscale after resistance training (SMD: 0.44; 95% CI, 0.17–0.71; p = 0.001; I^2 = 66%, p < 0.0001; Figure 4A).

The effect of resistance training on the bodily pain subscale was reported in eight studies, nonetheless, owing to subgroups, nine intervention groups were analyzed. Figure 4B reveals the SMD change in bodily pain with resistance training. The change in bodily pain was significantly lower in the resistance training groups (SMD, −0.52; 95% CI, −0.87 to −0.16; p = 0.004).

Figure 5A shows the results for general health subscale. Statistically significant improvements were found for general health after resistance training (SMD, 0.43; 95% CI, 0.16–0.70; p = 0.002; nine intervention arms).

Eight studies reported the effects of resistance training on social functioning, nevertheless, 10 data collections were evaluated owing to subgroups in the studies. Figure 5B illustrates the SMD in the social functioning. Social functioning improved significantly after resistance training (SMD, 0.25; 95% CI, 0.07–0.42; p = 0.006).

Six studies (7 arms) with a total of 445 participants (exercise = 238 and control = 207) reported mental component score as an outcome measure (Chang & Chiu, 2020; Ericson et al., 2018; Lincoln et al., 2011; Socha et al., 2016; Sylliaas et al., 2011;

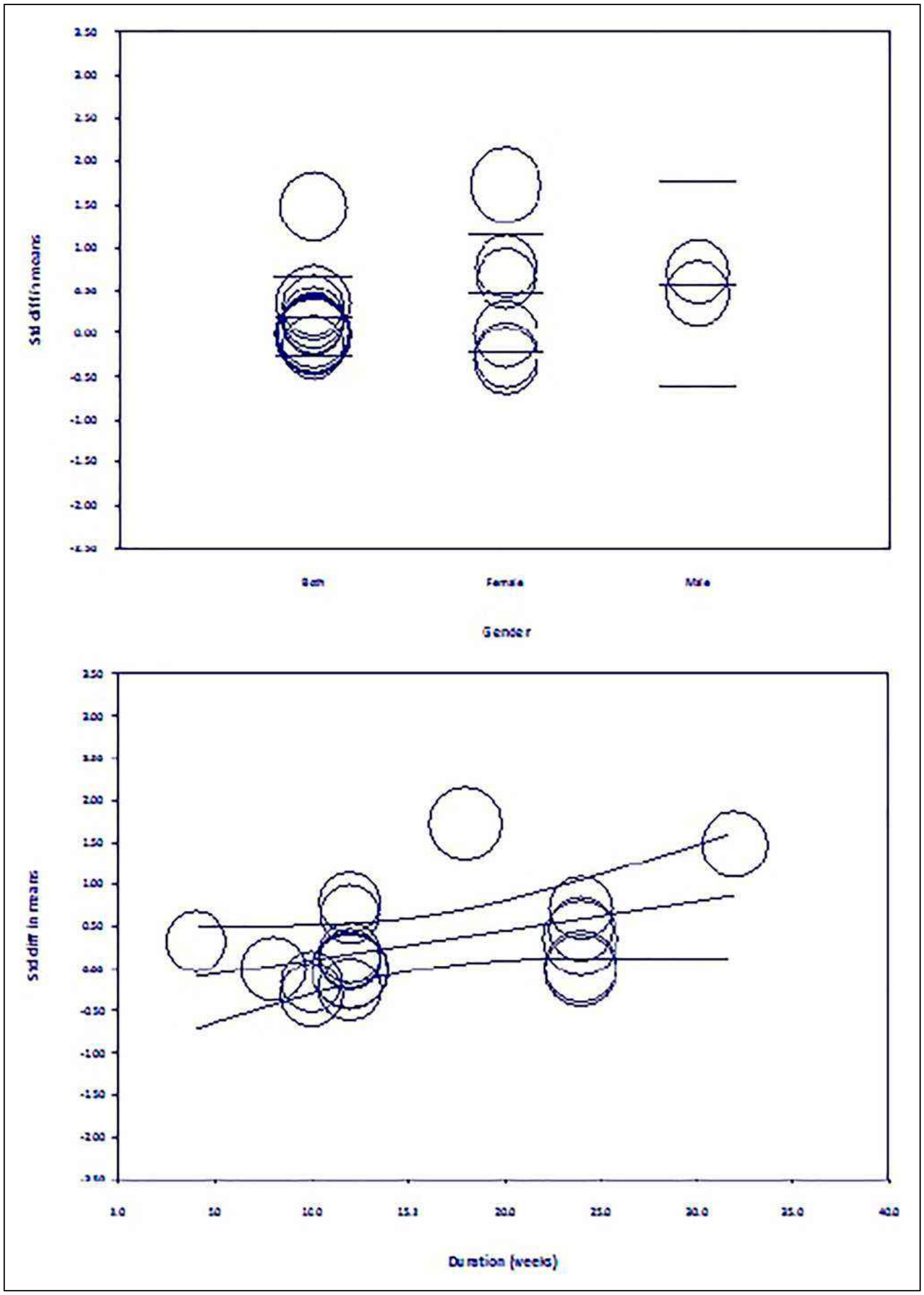

Figure 3. Regression of standard difference in means on Gender and duration (weeks) of physical functioning.

Wanderley et al., 2015). Pooled results demonstrated that resistance training had a significant effect on mental component score (SMD: 0.51; 95% CI, 0.20–0.82; p = 0.001; Figure 5C).

Meta-analysis of the effect of resistance exercise intervention revealed a non-significant alteration in vitality (SMD, 0.13; 95% CI, −0.15–0.41; p = 0.37, I^2 = 65%; 11 intervention arms) subscale, as well as in total score of quality-of-life (SMD, 0.25; 95% CI, −0.19–0.69; p = 0.27, I^2 = 0%; three intervention arms) and physical component score (SMD, −0.02; 95% CI, −0.17–0.14; p = 0.84, I^2 = 0%; eight intervention arms) (see Supplementary Figures S1–S3).

Change in Depression

Four studies (8 arms) providing a total of 347 participants reported depression alterations as an outcome measure. The

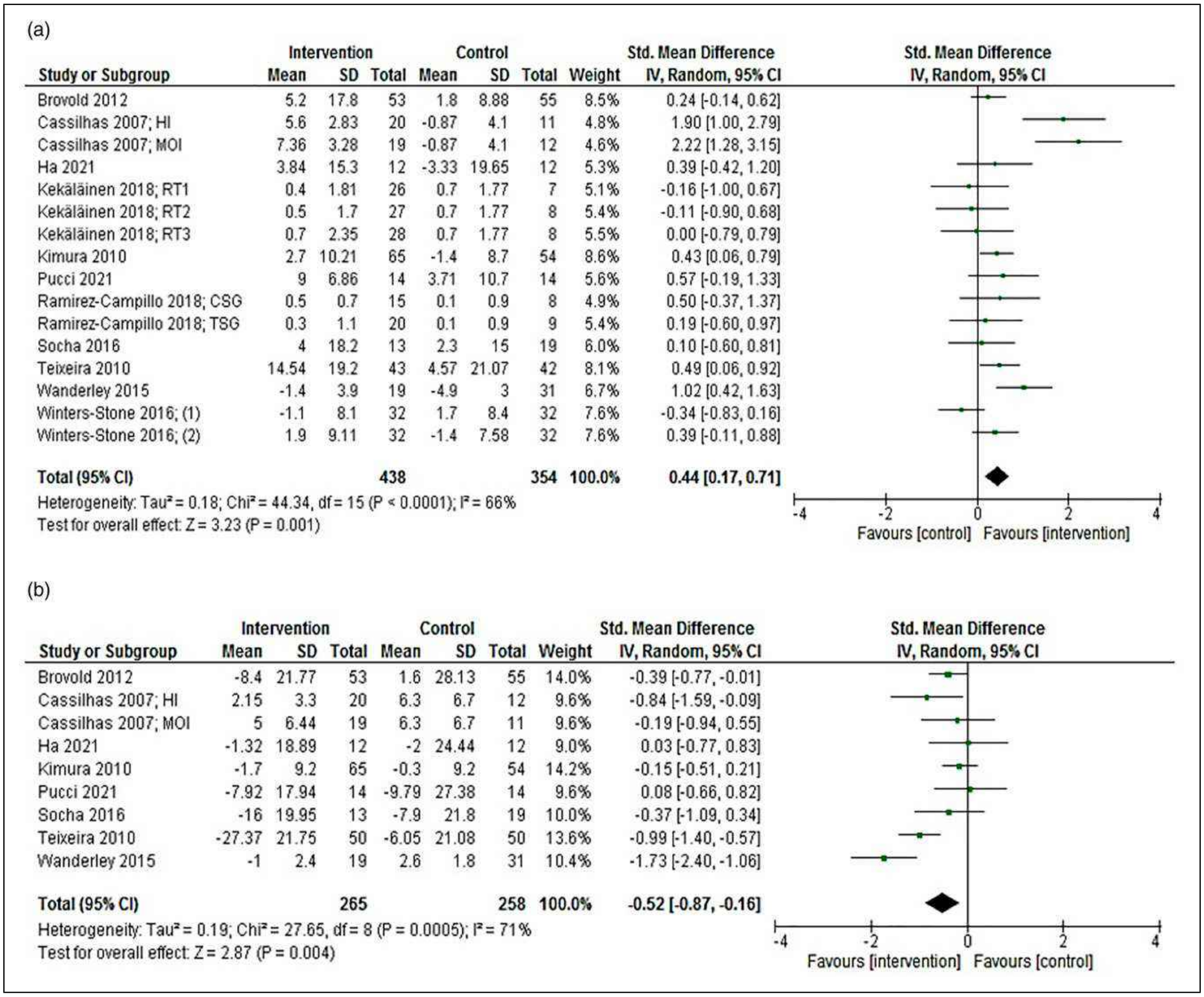

Figure 4. Forest plot for the subscale of mental health (A) and bodily pain (B). HI, high intensity; MOI, moderate intensity; RT1-3, resistance training one, two or three times a week; CSG, cluster-set group; TSG, traditional-set group.

results were combined employing the random-effects model and showed a significant reduction in depression following resistance training programs (SMD, −1.13; 95% CI, −2.01 to −0.24; p = 0.01). The heterogeneity was high among studies included for this comparison (I^2 = 91%, $p < 0.00001$; Figure 6).

Changes in Muscle Strength

Table 2 demonstrates the results for upper body strength, lower body strength, and handgrip strength. Statistically significant increases were found for upper body strength (MD, 15.26 kg; 95% CI, 5.51–25.00; p = 0.002; six arms), lower body strength (MD, 48.46 kg; 95% CI, 6.53–90.39; p = 0.02; six arms), and handgrip strength (MD, 1.35 kg; 95% CI, 0.47–2.24; p = 0.003; two arms) after resistance training.

Six-Min Walk Distance (in Meters)

Resistance exercise interventions were associated with a non-significant improvement in 6-min walk distance (MD, 20.59; 95% CI, −9.38–50.56; p = 0.18; I^2 = 80%; five studies; Supplementary Figure S4).

Quality Assessment

The quality assessment of included investigations is presented in Supplementary Table S1. Overall, scores ranged from five to nine out of a maximum of 11 points (average was 7.5).

Publication Bias

Funnel plots including Egger regression tests ($p > 0.05$ for all) for the different analyses did not suggest publication bias, nor

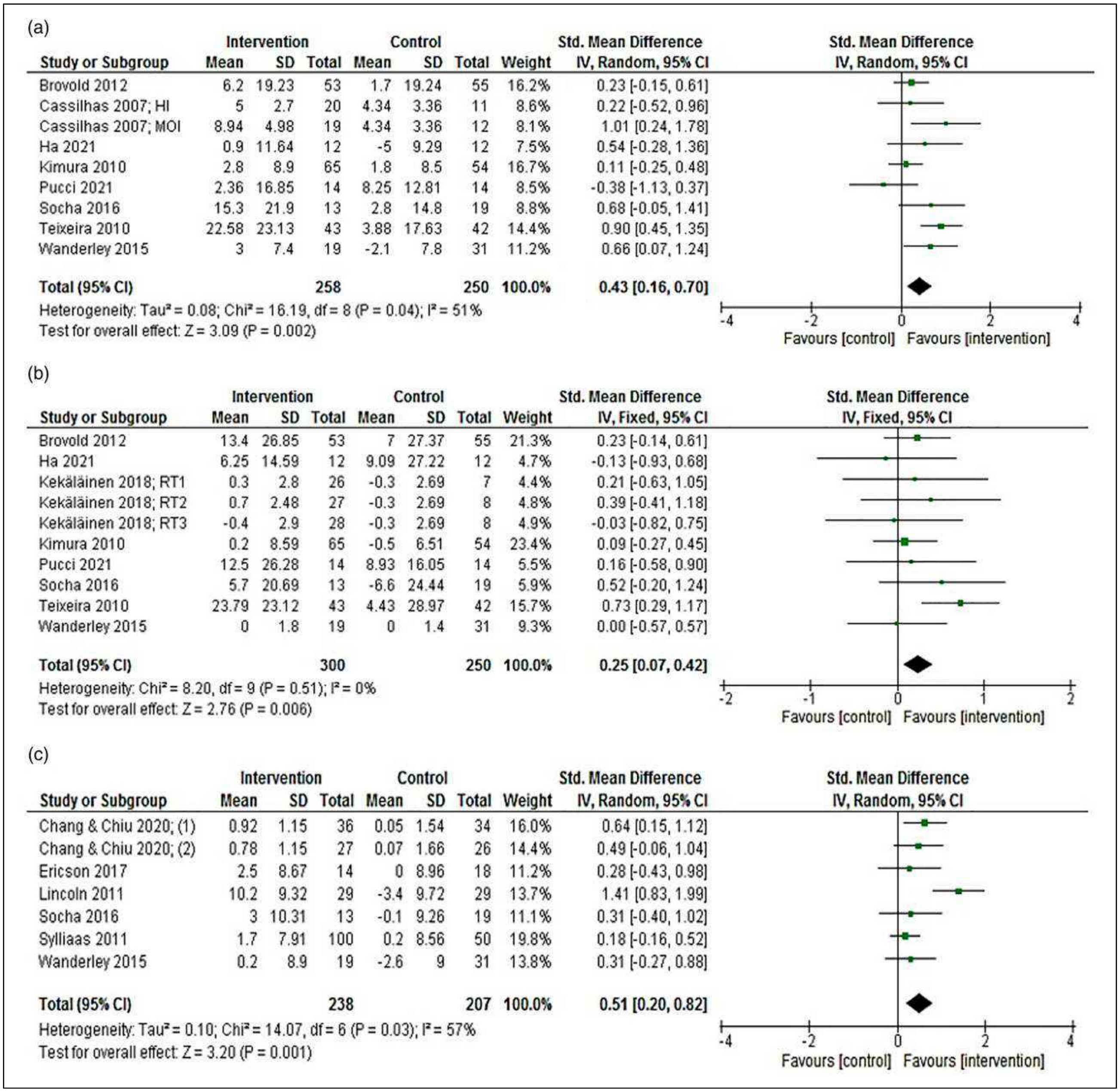

Figure 5. Forest plot for the subscale of general health (A), social functioning (B), and mental component score (C). HI, high intensity; MOI, moderate intensity; RT1-3, resistance training one, two or three times a week.

did Duval and Tweedie's trim and fill computation change the results (see Supplementary Figures S7–S15).

Discussion

This systematic review and meta-analysis aimed to update previous pooled analyses, by evidence on outcome measures relating to quality-of-life, depression, and muscle strength attributed to resistance training among the elderly. Our results demonstrate that resistance training significantly increase physical functioning, mental health, general health and social functioning subscales and mental component score. Furthermore, this meta-analysis demonstrates that resistance training significantly reduces the bodily pain subscale of quality-of-life as well as depression compared to the control condition. Finally, it is evident that upper body strength, lower body strength, and handgrip strength significantly increased following resistance training. Nevertheless, there were not significant improvements in vitality subscale, overall quality-of-life, physical component score, and 6-min walk distance.

Diverse studies that address changes in aging quality-of-life related to different resistance training modalities were

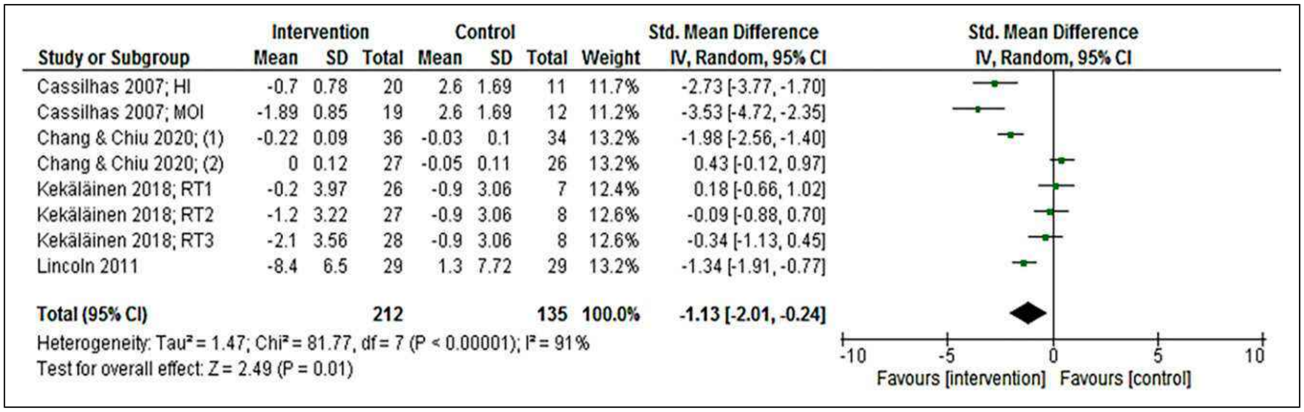

Figure 6. Forest plot for depression. HI, high intensity; MOI, moderate intensity; RT1-3, resistance training one, two or three times a week.

Table 2. Pooled estimates of muscle strength.

Variables	No of arms	MD (95% CI)	*p*-value	P-heterogeneity	I^2 (%)
Upper body strength (kg)	6	15.26 (5.51, 25.00)	0.002	<0.00001	98
Lower body strength (kg)	6	48.46 (6.53, 90.39)	0.02	<0.00001	100
Handgrip strength (kg)	2	1.35 (0.47, 2.24)	0.003	0.64	0

analyzed within the present review. In somehow interventions varied in terms of the previously revealed remaining FITT-principles (frequency, intensity, time, and type). It seems that various outcomes regarding impacts on quality-of-life and psychological health were illustrated by the included studies.

Aging, as previously stated (Hoogendijk et al., 2019; Khan et al., 2017), negatively affects people in different ways, and therefore requires wide-ranging studies to make general statements concerning exercise training influences on specific factors, such as loss of muscle mass, depression, and quality-of-life. The factors restricted in the present meta-analysis have been investigated for resistance training-induced changes according to the resistance exercise interventions of identified investigations. Nevertheless, investigations intervention regimes were very heterogeneous and thus made the comparability of the results more challenging.

The overall analysis demonstrates that resistance training compared with the control group significantly improved some subscales of quality-of-life such as physical functioning, mental health, bodily pain, general health, social functioning and mental component score. However, the sub dimension of vitality as well as physical component score were remained unchanged following resistance training. Evidence regarding the effect of general physical activity on quality-of-life suggested that there was larger correlation among physical activity and the psychological and physical scales (Bize et al., 2007; Pucci et al., 2021). In accordance with our findings, in a systematic review and meta-analysis, resistance training revealed the greatest impact on mental health scale of older individuals (Hart & Buck, 2019), indicating that the workouts accomplished enhanced the self-esteem and body image of aged individuals, enhancing their perception of this subscale. However, the findings of another meta-analysis concerning the relationship between resistance training and quality-of-life remain controvertible (Raymond et al., 2013).

These benefits of resistance training may be caused by an amelioration in functional restriction, social isolation, and emotional matters such as anxiety and depression, resulting in a reduced quality-of-life in older adults. Based on the literature, our findings support the results that an exercise intervention regimen contributes to ameliorate cognitive-behavioral, socio-psychological, and medical health (Chung, 2008; Conradsson et al., 2010), as in our study, not only some subscales of quality-of-life improved after resistance training but also depression significantly reduced. Nevertheless, as the heterogeneity was moderate to high in some outcomes, caution must be considered when interpreting the findings.

Our results demonstrate that vitality scores did not alter significantly after resistance training interventions and this conflicts with recent meta-analysis findings (Hart & Buck, 2019). This subscale of quality-of-life estimates energy and fatigue levels, with low values indicating the person feels exhausted and worn out most of the time, and high values meaning that they feel energetic (Ware & Sherbourne, 1992). Albeit this subscale comprises issues that appear to be affected by the practice of exercise training; this relationship is still unclear in the literature. In this regard, a review discovered that existing proof remains contradictory (Vagetti, 2012).

It is argued that the lack of positive results in other quality-of-life domains is not related to the ineffectiveness of the resistance training intervention, but rather, is explained by the fact that the sample investigated in some included studies was composed of healthy and active older adults who had a good quality-of-life at the beginning of the intervention, such as the study by Pucci et al. (2021). Researchers observed that regular engagement in the exercise training programs was correlated with better quality-of-life in the subscale of mental health in retirees (Pimenta et al., 2008). Furthermore, a systematic review and meta-analysis of exercise training and quality-of-life in the aging populations reported that the proof confirms a consistent relationship between exercise workouts and mental health subscale (Vagetti et al., 2012). This dimension is correlated with issues linked to four subscales comprising anxiety, depression, loss of emotional control, and psychological well-being. In the included studies, the fact that aged people were starting a new exercise training regimen and had a new objective in life with a twice- or thrice-weekly commitment, with greater social engagement, ascertained to be useful for the mental health of aged individuals in the resistance exercise (Ware & Sherbourne, 1992).

Our findings reveal a healthy, significant correlation between resistance training and upper and lower body strength enhancement among the elderly. These results are compatible with the findings of Peterson et al., 2010, who reported that resistance training had a meaningful impact on both upper and lower body strength in adults ≥50 years (Peterson et al., 2010). Interestingly, the examined effect size for both upper (15.26 kg) and lower (48.46 kg) body strength in our meta-analysis was large compared with effects for the Peterson and colleagues (9.83 kg and 31.63 kg, respectively). Moreover, a systematic review of meta-analyses by Di Lorito et al. (2021) found that resistance exercise supported by nutritional supplementation considerably improved muscle strength; therefore, they concluded that resistance training might improve general physical performance measures. From a health perspective, the value of resistance training for inhibition or handling of age-induced reductions in muscle function is confirmed by these results, which may in turn act as a protective approach versus incapacity. On the one hand, regarding the outsized reduction in strength that happens among inactive persons after the fifth decade of life (Kirk et al., 2021; Koivunen et al., 2021; Palla et al., 2021; Vandervoort & McComas, 1986), and on the other hand, considering the next contribution of strength deficit to disability and movement impairment (Rantanen et al., 1999; Rathnayake et al., 2022), these results bear clinical importance.

Present published resistance advice is significantly varied for young and middle-aged healthy individuals (Kraemer et al., 2002; American College of Sports Medicine, 2009), than those for the aging populations (American College of Sports Medicine, 1998; Pollock et al., 1998). Although most of the published intervention research and next suggestions for younger adults have included recommendations of periodization to promote improved strength adaptation, no such advice has been approved for elderly people. As most of the investigations in this review followed basic ACSM recommendations (American College of Sports Medicine, 1998; Pollock et al., 1998), the only requisite "progression" in the prescription of training was the absolute training load. Nevertheless, only boosting workout load during the time might not be adequate beyond a particular point, in view of the fact that this illustrates an unavoidable reliance on the same relative intensity. Despite the fact that the current study's findings affirm that resistance workout is significantly efficacious for improving some of the dimensions of quality-of-life and psychological health, as well as for boosting muscle strength, additional investigation is required that explores interventions with hierarchical resistance workout prescription modalities and varying volume dosage strategies in healthy aged populations.

The most important strength of this study is that we pooled all included investigations in our analysis and compared the efficiency of resistance training on quality-of-life, depression, muscle strength, and aerobic capacity in people aged ≥60 years. Furthermore, our study was focused specifically on resistance training-based interventions. Nevertheless, we acknowledge that there are some limitations to these findings. First, there are a relatively small number of included studies. Second, some included investigations have small sample sizes, which tended to weaken the quality of individual study as may be underpowered. Moreover, because of the high heterogeneity among assessment methods, a number of our results were shown as standardized mean differences, which prevents us from drawing more robust conclusions. Finally, in some investigations, accurate p values or 95% CIs, within or between groups, were unavailable, default p values were employed, and this may have introduced errors.

Conclusions

This systematic review displays that resistance training-based interventions may have some benefits on quality-of-life, depression, and muscle strength among older adults, as demonstrated by improved some sub-domains of quality-of-life and muscle strength (both upper- and lower-body strength), and decreased depression and bodily pain. The resistance training regimens are feasible for many health centers as well as for the nursing field using included resources in the current research to improve some of the subscales of the quality-of-life, psychological health, and boosting muscle strength for the aged population. Further long-term and high-quality investigation is required to confirm these findings.

Author Contributions

S.K.K. contributed to conception contributed to acquisition drafted manuscript gave final approval agrees to be accountable for all aspects of work ensuring integrity and accuracy Z.S.M. contributed to conception and design contributed to interpretation critically revised manuscript gave final approval agrees to be accountable for all aspects of work ensuring integrity and accuracy V.S. contributed to conception contributed to acquisition, analysis, and interpretation drafted manuscript gave final approval agrees to be accountable for all aspects of work ensuring integrity and accuracy.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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Supplemental Material

Supplemental material for this article is available online.

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