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Different Resistance Exercise Interventions for Handgrip Strength in Apparently Healthy Adults: A Systematic Review

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Abstract

Background: Although handgrip strength is a biomarker for morbidity/mortality, there is lack of evidence on the effects of resistance training on handgrip strength in healthy adults of all ages. **Objective**: The aim of this systematic review was to assess the impact of resistance training on handgrip strength in healthy adults. **Methods**: Five databases/search engines were searched. Studies comparing different types of resistance exercise interventions versus a non-exercised control group on handgrip strength were included. The available data did not allow us to conduct the pre-planned meta-analyses; therefore, only descriptive statistics were performed to summarize the data. **Results**: Twenty studies (17 randomized and three non-randomized controlled trials) were included, most of which were conducted in older adults. Twelve studies reported no significant difference in the change in handgrip strength between the resistance training and control groups. Two studies showed increases in handgrip strength in the resistance training group compared with the control group. Other studies included results for multi-training groups or left/right hands and found increasing handgrip strength compared to controls, but only in one training group or one hand. Overall, the randomized and non-randomized clinical trials presented moderate risk of bias. **Conclusions**: Due to the lack of low risk-of-bias randomized controlled trials of young and middle-aged adults, different training protocols, and small sample sizes, the existing evidence appears insufficient to support resistance training for increasing handgrip strength in healthy adults. Future studies may seek to discern the optimal way to develop and employ resistance training to improve handgrip strength.

Keywords

Grip Strength, Strength Training, Biomarker, Healthy Adults

1. Introduction

Studies published over the last quarter century clearly show that better health (reduced morbidity and mortality) is associated with higher handgrip strength in adults [1] [2] [3] [4] [5]. Specifically, large-scale longitudinal studies published in the past two years have repeatedly reported inverse associations between handgrip strength and the risk of various diseases and accidents, such as heart diseases [6], diabetes [7] [8], cancer [9] [10], dementia [11] [12], and falls [13]. These associations remain even when adjusting for age, education level, body mass index, alcohol, tobacco, medical history, etc. If handgrip strength is a valid biomarker of health, we need to find out how best to increase this biomarker. This would allow studies to explore whether increasing that biomarker actually confers health benefits.

The debate about the possible factors of the causal association between handgrip strength and morbidity risks has not been well-studied. Some of these factors are difficult to assess because they are not always constant, especially over long-term follow-up. For example, several studies have discussed the impact of physical activity as a mediating factor between handgrip strength and morbidity/mortality [5] [14] [15] [16] [17]. However, although the association between handgrip strength and physical activity is evident in cross-sectional studies, it has not been confirmed in longitudinal studies [18]. Additionally, many types of physical activity (e.g., aerobic- or resistance-type training with upper body and/or lower body movements) may impact handgrip strength differently [19] [20]. Therefore, it is essential to investigate the interventional effects of different types of physical activity on handgrip strength.

A recent systematic review and meta-analysis reported statistically significant but small intervention effects (standardized mean difference: 0.28, $p < 0.001$) of different training types on handgrip strength in healthy community-dwelling older adults [19]. Other systematic reviews and meta-analyses reported on the impact of resistance training on handgrip strength, but the participants of these studies were older than 60 years [21] [22] [23] [24]. Therefore, investigating the effects of resistance training on handgrip strength in adults of all ages, including young adults, is warranted to understand the effects of physical activity on handgrip strength. Thus, this study investigated the impact of various types of resistance training interventions on handgrip strength in apparently healthy adults. Similar to the results for older adults, we hypothesized that although the impact of resistance training on handgrip strength would be statistically significant in younger adults, the impact of the intervention would be negligible.

2. Methods

We performed this systematic review according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement [25]. The study was pre-registered (February 5, 2023) in the International Prospective Register of Systematic Review (PROSPERO) (CRD42023394028).

2.1. Search Strategy

English-language searches of the electronic databases and search engines Medline (PubMed), Scopus, Web of Science, Cochrane Central Register of Controlled Trials (CENTRAL), and Google Scholar were conducted from inception to February 15, 2023, by two independent researchers (T.A. and R.V.). The reference lists of included studies were searched to locate any further relevant articles not found with the initial search.

Articles were retrieved from electronic databases and search engines combining the following terms: (handgrip strength OR grip strength OR physical function OR sarcopenia) AND (resistance training OR strength training OR home-based exercise OR power training OR elastic band) AND (healthy adults OR elderly OR older people OR community-dwelling). No filters were applied to the searched databases to prevent omitting irrelevant articles.

Initially, all files were extracted from databases in either RIS format (Scopus, Web of Science, CENTRAL, and Google Scholar) or nbib format (Medline). The files were then uploaded into Rayyan software, where the titles and abstracts of identified articles were checked for relevance. Subsequently, the reviewers independently reviewed the full text of potentially eligible papers. Any disagreements between the reviewers on inclusion were resolved by a consensus between both researchers (T.A. and R.B.V.). After that, all files selected for inclusion were retrieved from Rayyan software and uploaded into Mendeley software, which was used as a reference management tool to write the first draft of this manuscript.

2.2. Inclusion and Exclusion Criteria: Participants, Interventions, Comparators, Outcomes, and Study Design

The PICOS (population, intervention, comparison, outcome, and study design) framework [25] was used to guide this systematic review. *Population:* Healthy individuals (≥18 years) with and without sarcopenia (low handgrip strength, slow walking speed, and low muscle mass). *Intervention* (*exposure*): Different types of resistance training interventions with any session duration (e.g., 30 minutes, 45 minutes), and any weekly frequency (e.g., number of days per week). *Comparison*: Non-intervention control group. A group of individuals who were not exposed to any exercise or active intervention. *Outcome*: Changes in handgrip strength. *Study design*: Any randomized or non-randomized clinical trials comparing different types of resistance exercise intervention versus a non-intervention control group on handgrip strength. Studies enrolling individuals with obesity and/or chronic diseases (e.g., heart disease, diabetes, cancer, chronic lung disease, stroke, Alzheimer, chronic kidney disease) were excluded from this review.

Randomized clinical trials were included in the review if they met the following selection criteria: 1) a research question on the effects of a resistance training intervention, 2) adults or older adult participants without chronic disease (e.g., heart disease, diabetes, cancer, chronic lung disease, stroke, Alzheimer, chronic kidney disease), 3) compared the resistance training intervention with a non-intervention control group, 4) reported at least one outcome related to handgrip strength, and 5) written in English language. Studies were excluded based on the following file types: abstracts, study protocols, conference papers, books, book sections, theses, opinion articles, observational studies, letters to editor, and reviews. Furthermore, studies that used combined interventions (e.g., resistance training plus any other type of intervention [drug, nutritional supplement…]) were excluded from this systematic review. To address our main purpose, studies applying only handgrip strength training were excluded from this review. Comparison groups and study types were not included in the search strategy but were used as inclusion criteria.

2.3. Data Extraction

The following study characteristics were extracted: authors, publication year, study design, participants' characteristics (sample size, age, sex, and health status), changes in handgrip strength, device used to test handgrip strength, and characteristics of the exercise intervention program (type and intensity of exercise program, exercise frequency, and duration of intervention program). These data were extracted manually and independently by two researchers (T.A. and R.V.), with disagreements resolved by consensus between both researchers. All data were typed into an excel spreadsheet file and later manually transferred to a word file. When the data reported in the articles were insufficient, additional information was requested from the corresponding authors.

2.4. Risk of Bias Assessment

Two authors (R.V. and S.D.) independently assessed the risk of bias in randomized and non-randomized included studies using version 2 of the Cochrane risk-of-bias tool for randomized trials (RoB 2) [26] and the Risk of Bias In Non-randomized Studies of Interventions (ROBINS-I) [27], respectively. RoB 2 assess randomized trials in the following aspects: 1) bias arising from the randomization process, 2) bias due to deviations from the intended interventions, 3) bias due to missing outcome data, 4) bias in the measurement of the outcome, and 5) bias in the selection of the reported results. The overall risk of bias was expressed as "low risk of bias" if all domains were rated as low risk, "some concerns" if some concern was raised in at least one domain but not rated as high risk in any other, or "high risk of bias" if at least one domain was rated as high risk or has several domains with some concerns [26]. ROBINS-I assess non-randomized trials in the following aspects: a) bias due to confounding, b) bias in selection of participants into the study, c) bias in classification of interventions, d) bias due to deviations from intended interventions, e) bias due to missing data, f) bias in measurement of outcomes, g) bias in selection of the reported result [27]. Traffic light and weighted summary risk-of-bias plots for randomized and non-randomized included studies were produced by the online Risk of bias (robvis) tool (https://mcguinlu.shinyapps.io/robvis/). Any discrepancies were resolved through discussion between both researchers (R.V. and S.D.).

2.5. Statistical Analysis

The available data did not allow us to conduct the pre-planned meta-analyses. Thus, only descriptive statistics were performed to summarize data, including the main participants' characteristics, interventions characteristics, handgrip measurements, and main results reported by the included studies.

3. Results

3.1. Included Studies

Twenty studies were included in this systematic review [28]-[47]. **Figure 1** presents the flow of papers through the study selection process. The included studies were published from 1995 [42] up to 2021 [34], in which six are randomized controlled trials [28] [34] [36] [40] [45] [47], ten are randomized trials [30] [31] [32] [33] [35] [37] [39] [42] [43] [46], one is cluster randomized controlled trial [29], and three are non-randomized trials [38] [41] [44] (**Table 1**).

3.2. Participant Characteristics

Participants' characteristics are summarised in **Table 1**. Most of the included studies (95%, n = 19) were conducted with older adults [28]-[42] [44] [45] [46] [47], while only one study was conducted with young adults [43]. Almost half (45%, n = 9) of the included studies clearly stated that were conducted with healthy individuals [30] [31] [32] [33] [36] [37] [39] [42] [43], the remaining studies were conducted with older adults without experience in resistance training [38] [40] [45], older women with cognitive impairment [35], prefrail and frail older adults [44], sedentary older men [34], community-dwelling older adults receiving home care [29], community-dwelling and independent older adults [47], sarcopenic and recreationally active older adults [46], postmenopausal women [28], and older inner-city African American women [41].

The number of participants in each study varied from 22 [41] to 419 [37]. Eight studies examined exclusively women [28] [33] [35] [36] [38] [39] [41] [42], one exclusively men [34], whilst 11 studies assessed men and women [29] [30]

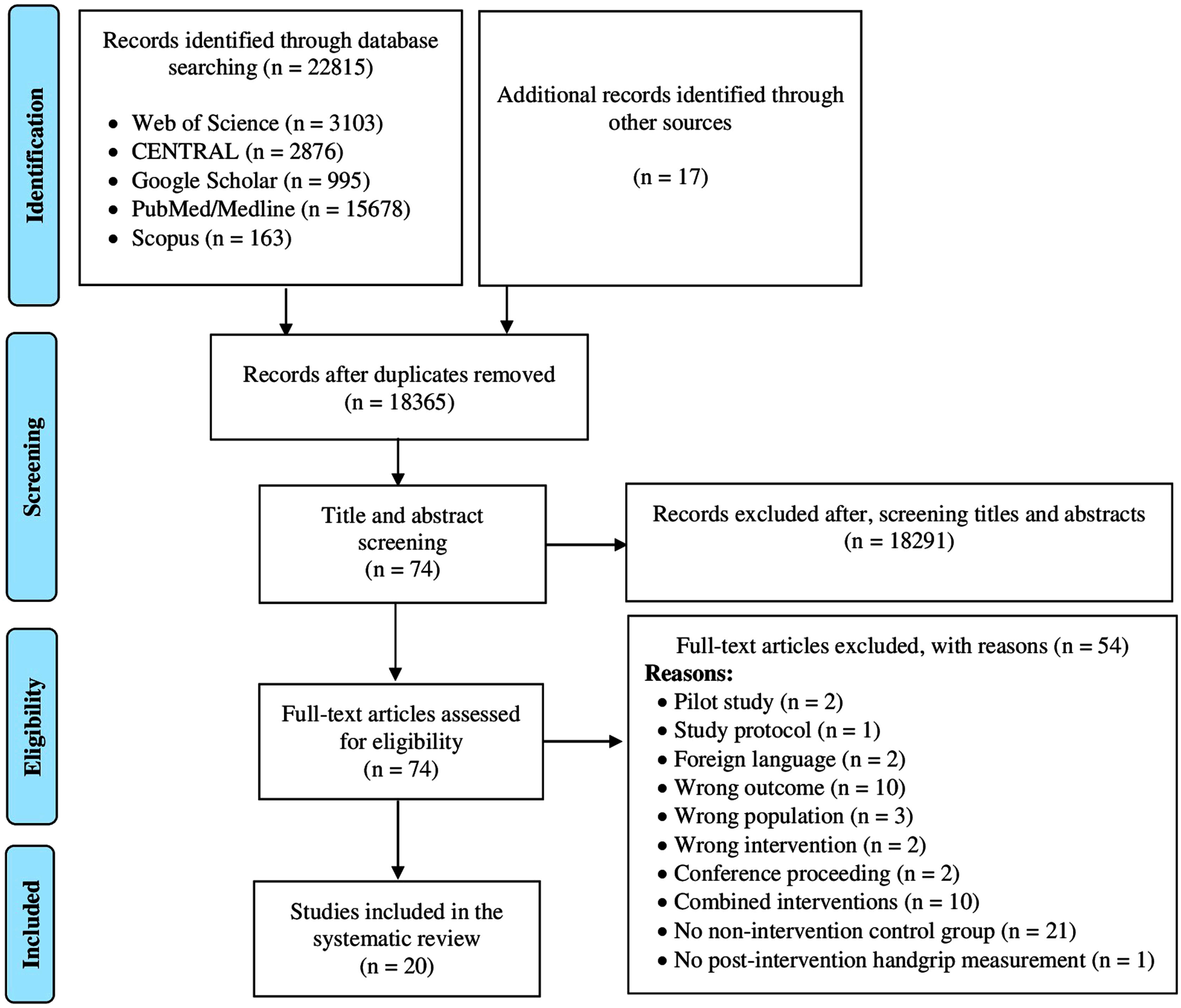

Figure 1. Flowchart of the study selection process.

[31] [32] [37] [40] [43] [44] [45] [46] [47].

3.3. Intervention Characteristics

Resistance training programmes are summarised in **Table 2**. Most of the studies (70%, n = 14) applied one resistance training intervention [29] [31] [32] [33] [35] [38] [39] [41]-[47], five studies (25%) applied two different resistance training interventions [28] [30] [34] [36] [37], and the remaining study applied four different resistance training interventions [40]. Resistance training protocols were composed of heavy or moderate intensity or slow eccentric/concentric resistance exercises with rubber bands, elastic band, water canes and/or own body weight [29] [31] [37] [45] [46], whole-body resistance exercises [39] [44], home-based resistance exercises [42] [43], functional-task exercises [28] [36], suspension resistance exercises [33] [34], chair-based elastic resistance exercises [35] [41], traditional moderate/high-intensity resistance exercises [32] [47],

Table 1. Characteristics of the participants of the included studies (n = 20).

Study	Study design	Sex (n)	Age (years)[a]	Body mass (kg)[a]	Height (cm)[a]	BMI (kg/m²)[a]	Health status
Aragão-Santos *et al.* (2020)	Randomized controlled trial	EBFT: 13F TSBFT: 15F CON: 11F	EBFT: 65.2 (4.3) TSBFT: 66.0 (5.2) CON: 66.1 (4.1)	EBFT: 67.4 (12.9) TSBFT: 69.8 (13.5) CON: 70.4 (9.5)	EBFT: 153.9 (6.2) TSBFT: 151.7 (4.8) CON: 154.3 (3.3)	EBFT: 28.47 (5.22) TSBFT: 30.31 (5.65) CON: 29.54 (3.62)	Postmenopausal women
Bårdstu *et al.* (2020)	Cluster randomized controlled trial	RT: 42F/22M CON: 22F/21M	RT: 86.5 [80 - 90] CON: 86.0 [80 - 90] (median & IQR)	RT: 66.5 [55.5 - 79.5] CON: 70.4 [62.4 - 80.2] (median & IQR)	RT: 160 (9) CON: 164 (9)	RT: 25.1 [23.6 - 28.1] CON: 27.0 [23.7 - 30.3] (median & IQR)	Community-dwelling older adults receiving home care
Bezerra *et al.* (2018)	Randomized trial	MJ: 7F/4M MJ+SJ: 5F/6M CON: 4F/4M	MJ: 63.2 (5.7) MJ + SJ: 64.6 (4.8) CON: 65.0 (6.0)	MJ: 76.7 (13.9) MJ + SJ: 76.1 (18.0) CON: 68.4 (12.4)	MJ: 1.69 (0.86) m MJ+SJ: 1.66 (0.11) m CON: 1.65 (0.71) m	Not reported	Untrained healthy aging adults
Bunout *et al.* (2004)	Randomized trial	SE: 21F/10M SN: 16F/12M NE: 12F/4M NN: 17F/16M	SE: 74.0 (3.6) SN: 74.7 (3.8) NE: 74.4 (3.27) NN: 73.7 (3.6)	SE: 66.2 ± 11.9 SN: 61.9 ± 11.2 NE: 62.2 ± 10.11 NN: 68.7 ± 12	SE: 155.7 ± 9.1 SN: 153.8 ± 9.1 NE: 151.5 ± 8.76 NN: 154.1 ± 10.3	27.4 (4.6) Reported total sample value	Healthy, non-institutionalized older adults
Bunout *et al.* (2005)	Randomized trial	RT: 94F/17M CON: 92F/38M	RT-F: 75.1 (4.5) RT-M: 74.6 (5.8) CON-F: 74.8 (4.6) CON-M: 75.2 (4.4)	RT-F: 60.4 (10.0) RT-M: 71.2 (11.8) CON-F: 59.3 (9.7) CON-M: 68.3 (10.4)	RT-F: 147.5 (6.2) RT-M: 165.2 (5.6) CON-F: 146.8 (6.1) CON-M: 162.3 (6.6)	Not reported	Healthy Chilean older adults
Campa *et al.* (2021)	Randomized controlled trial	36M	67.4 (5.1)	76.6 (10.7)	1.68 (0.72) m	27.1 (3.3)	Sedentary older men
Campa *et al.* (2018)	Randomized trial	RT: 15F CON: 15F	RT: 66.5 (4.3) CON: 65.6 (5.2)	RT: 72.7 (12.1) CON: 77.1 (7.1)	RT: 158.7 (4.7) CON: 155.3 (10.2)	RT: 28.8 (4.6) CON: 32.4 (5.6)	Healthy older women

Continued

Chupel *et al.* (2017)	Randomized trial	RT: 16F CON: 17F	RT: 83.50 (5.13) CON: 82.12 (6.41)	RT: 66.26 (16.35) CON: 67.45 (14.57)	RT: 150.4 (0.08) CON: 150.8 (0.06)	RT: 29.27 (7.10) CON: 29.67 (5.98)	Older women with mild cognitive impairment
de Vreede *et al.* (2005)	Randomized controlled trial	RT: 34F FT: 33F CON: 31F	RT: 74.8 (4.0) FT: 74.7 (3.5) CON: 73.0 (3.2)	RT: 70.7 (12.1) FT: 69.4 (9.0) CON: 71.3 (11.4)	RT: 1.62 (0.08) m FT: 1.63 (0.06) m CON: 1.62 (0.06) m	Not reported	Community-dwelling healthy older women
Gylling *et al.* (2020)	Randomized trial	HRT: 143FM MRT: 144FM CON: 132FM	62 - 70 Reported total sample value	75.5 (14.3)[c] Reported total sample value	Not reported	25.8 (4.1)[c] Reported total sample value	Independently healthy and chronically diseased men and women
Pereira *et al.* (2012)	Non-randomized trial	RT: 28F CON: 28F	RT: 62.5 (5.4) CON: 62.2 (4.3)	RT: 68.2 (11.2) CON: 66.2 (10.9)	RT: 1.55 (0.06) CON: 1.57 (0.06)	RT: 28.2 (4.0) CON: 27.0 (3.2)	Older women without experience in resistance training
Rhodes *et al.* (2000)	Randomized trial	RT: 22F CON: 22F	RT: 68.8 (3.2) CON: 68.2 (3.5)	RT: 68.4 (12.0) CON: 61.7 (12.9)	RT: 160.9 (5.5) CON: 159.3 (4.5)	Not reported	Healthy sedentary older women
Richardson *et al.* (2019)	Randomized controlled trial	HVLL1: 5F/5M HVLL2: 5F/5M LVHL1: 5F/5M LVHL2: 5F/5M CON: 5F/5M	HVLL1: 66 (5) HVLL2: 67 (6) LVHL1: 67 (4) LVHL2: 66 (6) CON: 65 (5)	HVLL1: 80.0 (16.9) HVLL2: 83.2 (13.5) LVHL1: 76.3 (11.8) LVHL2: 73.0 (13.4) CON: 71.4 (12.7)	HVLL1: 168.7 (7.4) HVLL2: 173.3 (9.7) LVHL1: 167.2 (11.1) LVHL2: 166.8 (8.9) CON: 170.4 (9.5)	HVLL1: 28 (5) HVLL2: 28 (5) LVHL1: 28 (5) LVHL2: 26 (4) CON: 24 (3)	Moderately-highly active, but resistance exercise naïve older adults
Rogers *et al.* (2002)	Non-randomized trial	RT: 16F CON: 6F	RT: 74.8 (8.8) CON: 74.7 (4.5)	Not reported	Not reported	RT: 24.4 (1.9) CON: 24.1 (2.3)	Older African American women

Continued

Skelton *et al.* (1995)	Randomized trial	RT: 20F CON: 20F	RT: median 79.5 (range: 76 - 93) CON: median 79.5 (range: 75 - 90)	RT: 54.1 (9.1) CON: 61.5 (11.4)	RT: 1.54 (0.07) m CON: 1.57 (0.07) m	Not reported	Healthy older women
Thomas *et al.* (2008)	Randomized trial	RT: 9F[b] CON: 11F[b]	F: 24.6 (2.6) M: 25.9 (3.0)	F: 60.6 (7.5) M: 77.4 (10.1)	F: 168.2 (4.3) M: 180.9 (5.5)	Not reported	Young healthy adults
Tieland *et al.* (2015)	Non-randomized trial	RT: 41F/21M CON: 36F/29M	RT: 78.4 (8.1)[c] CON: 79.5 (7.9)[c]	RT: 78.5 (14.2)[c] CON: 74.0 (12.9)[c]	RT: 1.66 (0.08) m[c] CON: 1.66 (0.08) m[c]	Not reported	Prefrail and frail older adults
Tsuzuku *et al.* (2018)	Randomized controlled trial	RT: 17F/25M CON: 18F/26M	RT: 72.5 (2.1) CON: 73.2 (2.1)	RT: 57.2 (9.9) CON: 55.7 (9.6)	Not reported	RT: 23.2 (2.6) CON: 22.4 (2.4)	Older adults without experience in resistance training
Vezzoli *et al.* (2019)	Randomized trial	RT: 10F/10M CON: 9F/6M	RT: 73.0 (5.5) CON: 71.7 (3.4)	RT: 76.3 (16) CON: 69.8 (15.0)	RT: 1.65 (0.1) m CON: 1.62 (0.1) m	RT: 27.7 (4.4) CON: 26.6 (3.5)	Sarcopenic and recreationally active older adults
Wanderley *et al.* (2015)	Randomized controlled trial	AT: 18F/6M RT: 7F/12M CON: 24F/7M	AT: 70.0 (5.7) RT: 67.3 (4.9) CON: 67.8 (5.5)	AT: 65.6 (3.0) RT: 71.7 (3.5) CON: 71.6 (2.6)	Not reported	AT: 27.5 (0.9) RT: 28.9 (1.0) CON: 28.5 (0.8)	Community-dwelling and independent older adults

RT: resistance training. CON: control group. EBFT: element-based functional training. TSBFT: task-specific-based functional training. FT: function training. MJ: multi-joint resistance training. MJ+SJ: multi-plus single-joint resistance training. SE: supplemented and trained. SN: supplemented and non-trained. NE: non-supplemented and trained. NN: non-supplemented and non-trained. HVLL1: high-velocity, low-load once-weekly. LVHL1: low-velocity, high-load once-weekly. HVLL2: high-velocity, low-load twice-weekly. LVHL2: low-velocity, high-load twice-weekly. F: female. M: male. FM: female and male, m: meters. [a]Data presented as mean (standard deviation) or median [interquartile range] or amplitude (minimum – maximum). [b]Total sample size was 41 individuals (27 females and 14 males), but only females were enrolled in the interventions (resistance training [n = 15] or control group [12]). [c]Standard error was converted to standard deviation.

high-speed power exercises [38], high-velocity low-load and low-velocity high-load resistance exercise,40 and low volume multi-joint resistance exercises or a combination of multi- and single-joint resistance exercises [30].

Table 2. Characteristics of the resistance training interventions of the included studies (n = 20).

Study	Groups (n)	RT interventions	#weeks (#sessions)	Sets (repetitions)	Session duration	Rest interval	Supervision	Intensity control/ monitoring
Aragão-Santos *et al.* (2020)	EBFT: 13 TSBFT: 15 CON: 11	EBFT: 1 - 18 sessions composed by 8 exercises (squat in the smith, seated row, leg press 45˚, upright bench press, hamstring curl bilateral, lat pull-down, standing calf raises, and stiff) at RPE of 7 - 9. 18 - 36 sessions composed by 8 exercises (squat, seated row, knee extension, bench press, hamstring curl unilateral, seated row, leg press calf raises, and abdominal sit up) at RPE of 7 - 9. TSBFT: 1 - 18 sessions composed by 8 exercises (deadlift with kettlebell, suspension strap row, sit and stand up, push with elastic, farmers walk [kettlebell], row with elastics, hip lift bilateral, and plank front [bench 40 cm]) at RPE of 7-9. 18-36 sessions composed by 8 exercises (deadlift with sandbag, suspension strap row, squat with kettlebell, push-ups in a bench of 60 cm, farmers walk [kettlebell], row with knee elevation, hip lift unilateral, and plank front [step 15 cm]) at RPE of 7-9.	14 weeks (3x/week)	2 sets (8 - 10 repetitions)	~50 min (25 min for RT exercises)	Not clearly reported	Yes	RPE of 7 - 9 (scale was not clearly reported)
Bårdstu *et al.* (2020)	RT: 64 CON: 42	RT: 5-7 exercises (rowing, chest press, squats, biceps curl, knee extension, shoulder press, and up-and-go) using elastic bands, body weight, and water canes.	35 weeks (2x/week)	2 - 4 sets (8 - 12 repetitions)	30 - 45 min	Not clearly reported	Yes	Until fatigue (*i.e.*, unable to complete more repetitions with proper technique)

Continued

Bezerra *et al.* (2018)	MJ: 11 MJ+SJ: 11 CON: 8	MJ: cable chest press and seated row. MJ+SJ: cable chest press, seated row, elbow flexion, and elbow extension. Complementary program was performed by both MS and MJ+SJ groups: horizontal leg press and seated leg curl.	8 weeks (3x/week)	MJ: 2 sets (12 RM) MJ+SJ: 1 set (12 RM) Complementary program: 1 set of 10, 5, and 6 repetitions	Not clearly reported	MJ or MJ+SJ: 1 min Complementary program: 2 min	Yes	Until momentary failure (in the final set)
Bunout *et al.* (2004)	SE: 31 SN: 28 NE: 16 NN: 33	Exercise: Training consisted in a period of warming up and 3 levels of chair stands, 3 levels of modified squats (5 sets of 10 repetitions; levels included squats without therabands or with therabands to increase gravitational force), 3 levels of step ups in a stair (10 sets of 10 repetitions; levels included one step, two steps and two steps without using the hand rails) and 6 sets of 15 repetitions of arm pull-ups using rubber bands that are color coded to confer progressive resistance.	1 year (2x/week)	5 - 10 sets (10 - 15 repetitions)	60 min	Not clearly reported	Yes	Until fatigue (not clearly defined)
Bunout *et al.* (2005)	RT: 111 CON: 130	RT: moderate intensity resistance exercise training (functional weight bearing exercises, chair stands, modified squats, arm pull-ups using rubber bands, 15 min walking before and after resistance exercises).	1 year (2x/week)	5 - 10 sets (10 - 15 repetitions)	60 min	Not clearly reported	Yes	Until fatigue (not clearly defined)
Campa *et al.* (2021)	ST: 11 TT: 11 CON: 11	Suspension training (ST): squat, biceps curl, chest press, low row, rotational ward, squat with Y deltoid fly, and triceps pushdown. Traditional training (TT): squat, alternating lunge, alternating curl with elastic tube, push up, plank, row with elastic tube, and alternating lateral raise with elastic tub.	12 weeks (3x/week)	3 sets (12 repetitions)	~60 min	1 min	Yes	RPE of 13 (from 6 to 20 Borg scale)

Continued

Campa *et al.* (2018)	RT: 15 CON: 15	RT: program initially included very low-load joint mobility exercises, then squat, rear deltoid row, biceps curl, chest press, low row, rotational ward, and stretching.	12 weeks (2x/week)	4 sets (12 repetitions)	60 min	1 min	Yes	Partici-pants were free to modulate the exercise intensity by changing the body's inclina-tions
Chupel *et al.* (2017)	RT: 16 CON: 17	Chair-based elastic band RT group: warm-up (body mobilization and dynamic stretching), 8 - 10 elastic-band exercises using the yellow and red colors levels of elastic bands, and cool-down (specific exercises with easy stretching).	28 weeks (2x/week for 8 weeks, 3x/week for 12 weeks, and 2x/week for 8 weeks)	Phase 1: 1 - 2 sets (10 - 12 repetitions) Phase 2: 2 - 3 sets (10 repetitions)	45 min	45 sec	Yes	RPE of 6 to 8 (from 0 to 10 OMNI scale)
de Vreede *et al.* (2005)	RT: 34 FT: 33 CON: 31	RT: core resistance exercises included elbow flexors and extensors, shoulder abductors adductors and rotators, trunk flexors and extensors, hip flexors extensors abductors and adductors, knee flexors and extensors, and ankle dorsal and plantar flexors. FT: The program was divided into a practice phase (2 weeks), a variation phase (4 weeks), and a daily tasks phase (6 weeks).	12 weeks (3x/week)	3 sets (10 repetitions)	60 min	~2 min	Yes	RPE of 7 to 8 (from 0 to 10 OMNI scale
Gylling *et al.* (2020)	Heavy RT: 143 Moderate RT: 144 CON: 132	A progressive whole-body training program with increasing load was performed in both training groups. Heavy RT was a linear periodized regime using fitness machines. Moderate RT performed with rubber bands and own body weight.	1 year (3x/week)	Heavy RT: 3 sets (6 - 12 repetitions) Moderate RT: 3 sets (10 - 18 repetitions)	Not clearly reported	Not clearly reported	Yes	Heavy RT: ~70% - 85% of 1RM Moderate RT: ~50% - 60% of 1RM

Continued

Pereira *et al.* (2012)	RT: 28 CON: 28	RT: high-speed power training composed by 10-minute warm-up (brisk walking and several joint mobilization exercises), followed by the leg extension and bench press training was initiated. In each session, they performed curl-ups (3 sets of 12 reps) and lumbar exercises (3 sets of 10 reps). Two power exercises were then performed: the counter movement jump and medicine ball throw (1.5 kg).	12 weeks (3x/week)	RT: 3 sets (4 - 12 repetitions)	60 min	2 min (between sets) 3 min (between exercises)	Yes	40% - 75% of 1RM
Rhodes *et al.* (2000)	RT: 22[b] CON: 22[b]	RT: a whole-body progressive resistance training was applied in a circuit fashion. The circuit included large muscle exercises—for example, chest press, leg press, biceps curl, triceps extension, quadriceps curl, hamstrings curl. The first 3 months were performed under fully supervision and for the remaining nine months, subjects exercised in recreation facilities close to their homes. homes. They continued with the same volume (three sets, eight repetitions) of weight lifted while the training stimulus exact weight was adjusted every two weeks.	1 year (3x/week)	RT: 3 sets (8 repetitions)	60 min	Not clearly reported	Yes (in the first 3 months)	75% of 1RM
Richardson *et al.* (2019)	HVLL1: 10 HVLL2: 10 LVHL1: 10 LVHL2: 10 CON: 10	HVLL1 and HVLL2: concentric phase was performed "as fast as possible" followed by a 3-sec eccentric phase. LVHL1 and LVHL2: concentric phase was performed over 2-sec with a 3-sec eccentric phase.	HVLL1 and LVHL1: 10 weeks (1x/week) HVLL2 and LVHL2: 10 weeks (2x/week)	HVLL1 and HVLL2: 3 sets (14 repetitions) LVHL1 and LVHL2: 3 sets (7 repetitions)	Not clearly reported	1.5 min (between sets) 3 min (between exercises)	Yes	HVLL1 and HVLL2: 40% predicted 1RM LVHL1 and LVHL2: 80% predicted 1RM

Continued

Rogers *et al.* (2002)	RT: 16 CON: 6	RT: Warm-up (range of motion) activities, followed by strength training exercises (chair-based exercises for the upper body [chest, back, biceps, and triceps] using elastic fabands/dumbbells and the lower body [knee extension, knee flexion, leg press, toe raises, heel raises, foot abduction, and side leg lifts] using elastic bands), and relaxation activities.	4 weeks (3x/week)	3 sets (8 - 15 repetitions)	50 min	Not clearly reported	Yes (an exercise science student instructed the classes)	When subjects could easily complete 15 repetitions of an exercise, they were encouraged to increase load (rubber band or dumbbells)
Skelton *et al.* (1995)	RT: 20 CON: 20	RT: Groups of four to six women performed progressive resistance training once a week and were also asked to complete two unsupervised home sessions per week following an exercise prescription. Each class began with a 10-minute warm-up and stretch of the main muscle groups being trained; correct posture was stressed. The 30 to 40-minute strengthening component of the class involved exercises for shoulder and hip abductors, adductors, flexors and extensors, elbow flexors and extensors, and knee flexors and extensors. There was a 10-minute warm-down component at the end of the class.	12 weeks (3x/week)	3 sets (4 - 8 repetitions with body weight, rice bags [1 - 1.5 kg], or elastic tubing)	50 - 60 min	Not clearly reported	Partially (1 of the 3 weekly sessions)	Resistances were initially chosen so that the subject could almost complete 3 sets of 4 repetitions. As soon as a subject could complete 3 sets of 8 repetitions of an exercise, the resistance was increased, and the number of repetitions was reduced.
Thomas *et al.* (2008)	RT: 9[a] CON: 11[a]	RT: home-based resistance training program for the upper extremities (push-ups in the prone position, dips in the supine position, and shoulder stabilization in the prone position).	8 weeks (3x/week)	First 4 weeks: 3 sets (10 repetitions) Remaining weeks: 3 sets (15 repetitions)	Not clearly reported	Not clearly reported	Not clearly reported	Not clearly reported.

Continued

Tieland *et al.* (2015)	RT: 62 CON: 65	RT: whole body resistance-type exercise training program (leg press, leg extension, chest press, lat pull-down, pec-dec, and vertical row).	24 weeks (2x/week)	3 - 4 sets (started 10 - 15 repetitions, changed to 8 - 10 repetitions due to workload increase)	Not clearly reported.	1 min (between sets) 2 min (between exercises)	Yes	Started at 50% and increased to 75% of 1RM
Tsuzuku *et al.* (2018)	RT: 42 CON: 44	RT: squat, tabletop push-up, and sit-up, performing slowly eccentric and concentric phase (4 sec for each movement) using body weight as a load.	12 weeks (median of 5x/week)	2 sets (10 - 14 repetitions)	15 min	Not clearly reported	Yes (clinic session only, but not at home)	Exercise load varies from person to person due to body mass-based resistance exercise.
Vezzoli *et al.* (2019)	RT: 20 CON: 15	RT: chest press, horizontal leg-press, vertical row, and shoulder exercises with free weights (lateral raise) exercises.	12 weeks (3x/week)	3 sets (14 - 16 repetitions)	Not clearly reported.	1 min	Yes	60% of 1RM
Wanderley *et al.* (2015)	AT: 24 RT: 19 CON: 31	RT: 10-min warm-up that included stretching, gymnastics, and low intensity exercises (walking, biking), nine resistance exercises (leg press, chest press, leg extension, seated row, seated leg curl, abdominal flexion, biceps curl, low-back extension, and triceps extension), and a 10-min cooldown.	8 months (3x/week)	1st month: 2 sets (12 - 15 repetitions) 2nd to 8th month: 2 sets (8 - 12 repetitions)	50 min	2 min	Yes	1st month: 50% - 60% of 1RM; RPE of 4 to 6 (from 0 to 10 Borg scale) 2nd to 8th month: 80% of 1RM; RPE of 7 (from 0 to 10 Borg scale)

RT: resistance training. CON: control group. EBFT: element-based functional training. TSBFT: task-specific-based functional training. FT: functional-task exercise. ST: suspension training. TT: traditional training. MJ: multi-joint resistance training. MJ+SJ: multi- plus single-joint resistance training. SE: supplemented and trained. SN: supplemented and non-trained. NE: non-supplemented and trained. NN: non-supplemented and non-trained. HVLL1: high-velocity, low-load once-weekly. LVHL1: low-velocity, high-load once-weekly. HVLL2: high-velocity, low-load twice-weekly. LVHL2: low-velocity, high-load twice-weekly. RPE: rating of perceived exertion. 1RM: one-maximum repetition. AT: aerobic training. $HR_{reserve}$: reserve heart rate. min: minute. sec: seconds. [a]Total sample size was 41 individuals (27 females and 14 males), but only females were enrolled in the interventions (resistance training [n = 15] or control group [12]). [b]The final testing, one year later, included 20 exercisers and 18 control subjects.

Intervention duration ranged from four weeks [41] to one year [31] [32] [37] [39], with 12 weeks being the most common (35%, n = 7) [33] [34] [36] [38] [42] [45] [46]. More than half of the resistance training protocols (60%, n = 12) were performed thrice a week [28] [30] [34] [36] [37] [38] [39] [41] [42] [43] [46] [47]. Five protocols were performed two times per week [29] [31] [32] [33] [44], one protocol was performed one to two times per week [40], one protocol was performed two to three times per week [35], and one protocol was performed five times per week [45]. Session duration ranged from 15 [45] to 60 minutes [31] [32] [33] [34] [36] [38] [39], with 60 minutes being the most common (35%, n = 7), followed by 50 minutes (15%, n = 3) [28] [41] [47]. Six studies (30%) did not clearly report the session duration [30] [37] [40] [43] [44] [46].

The number of sets per exercise ranged from one [35] to 10 [31] [32], with three sets (50%, n = 10) being the most common [34] [36]-[43] [46] (**Table 2**). Most of the studies (75%, n = 15) adopted a range of eight to 15 repetitions per set [28]-[36] [39] [41] [43] [44] [45] [47].

The intensity of effort for resistance training protocols was mostly prescribed and monitored by the percentage of one-repetition maximum (35%, n = 7) [37] [38] [39] [40] [44] [46] [47], and rating of perceived exertion (20%, n = 4) [28] [34] [35] [36]. The remaining studies used participants' body weight, rubber bands, rice bags, or dumbbells [33] [41] [42] [43] [45] or encouraged the participants to perform the repetitions until fatigue/momentary failure [29] [30] [31] [32].

Half of the studies (50%, n = 10) did not clearly report the rest interval between sets and/or exercises [28] [29] [31] [32] [37] [39] [41] [42] [43] [45]. Five studies (25%) applied a one-minute rest interval between sets [30] [33] [34] [40] [46], three studies (15%) applied two minutes [36] [38] [47], and one study applied 45 seconds [35]. Three studies clearly reported a rest interval between exercises of three minutes [38] [40] and only one study reported two minutes [44].

Sixteen studies (80%) provide supervision for all training sessions [28]-[38] [40] [41] [44] [46] [47], one study for the first three months of one-year intervention period [39], one study for one of three weekly sessions [42], and one study for only clinic session, but not home sessions [45]. The remaining study [43] did not clearly report the information about supervision.

3.4. Handgrip Measurements

Settings of the handgrip strength measurements are summarised in **Table 3**. Eighteen studies (90%) used electronic, digital, or mechanical hand dynamometers, while the remaining two studies [28] [42] did not clearly report what instrument was used to measure handgrip strength. Half of the included studies (50%, n = 10) did not clearly report which position (e.g., standing or sitting) and elbow angle were adopted for handgrip strength measurement [29] [31] [32] [36] [37] [39] [40] [41] [42] [47], seven studies (35%) adopted a sitting position with a 90˚ elbow flexion position [28] [30] [33] [34] [38] [43] [44], and three studies (15%) adopted a standing position [35] [45] [46], in which two of these three studies asked for participants to keep their upper limbs along the side of the body [35] [46], and one study did not report the arm and/or elbow position [45].

Most of the studies (55%, n = 11) measured both left and right participants'

Table 3. Main results of the resistance training and control groups of the included studies (n = 20).

Study	Handgrip measurement	Position	Hand	Handgrip strength results		RT group compared to control group
Aragão-Santos *et al.* (2020)	Not clearly reported	Sitting position at a 90˚ elbow flexion position	Left Right	EBFT: ↔ TSBFT: ↑ CON: ↓ No significant between-group differences.	-	↔ ↔
Bårdstu *et al.* (2020)	Handheld dynamometer (Baseline® Hydraulic Hand Dynamometer, Elmsford, NY, USA)	Not clearly reported	Preferred arm	RT: ↔ CON: ↔ No significant between-group differences.	-	↔
Bezerra *et al.* (2018)	Hand dynamometer (Saehan Corporation®, 973, Yangdeok-Dong, Masan, Korea)	Sitting position at a 90˚ elbow flexion position	Left Right	MJ: ↑ MJ+SJ: ↑ CON: ↔ No significant group effect. No significant group × time interaction.	-	↔ ↔
Bunout *et al.* (2004)	Hand grip dynamometer (Therapeutic Instruments, Clifton NJ, USA)	Not clearly reported	Left Right	Right hand: NE: ↑ NN (CON): ↔ No significant between-group differences.	Left hand: NE: ↑ NN (CON): ↔ No significant between-group differences.	↔↔
Bunout *et al.* (2005)	Hand grip dynamometer (Therapeutic Instruments, Clifton NJ, USA)	Not clearly reported	Dominant	RT: ↔ CON: ↔ No significant between-group differences.	-	↔
Campa *et al.* (2021)	Dynamometer (Takei Scientific Instruments Co., Niigata, Japan)	Sitting position at a 90˚ elbow flexion position	Dominant	ST: ↑ TT: ↔ CON: ↓ Significant group × time interaction.	-	↑ ↔
Campa *et al.* (2018)	Dynamometer (Takei K.K. 5001, Takei Scientific Instruments Ltd., Niigata, Japan)	Sitting position at a 90˚ elbow flexion position	Dominant	ST: ↑ CON: ↓ Significant group by time interaction.	-	?

Continued

Chupel *et al.* (2017)	Dynamometer (Lafayette, 78010, Indiana, USA)	Standing position with the elbow at the side of the body	Left Right	RT: ↑ CON: ↔ Significant difference between groups.	-	↑
de Vreede *et al.* (2005)	Handgrip dynamometer (Takei Kiki Kogyo 5101, Tokyo, Japan)	Not clearly reported	Left Right	RT: ↔ FT: ↔ CON: ↔ No significant between-group differences.	-	↔ ↔
Gylling *et al.* (2020)	SAEHAN DHD-1 Digital Hand Dynamometer	Not clearly reported	Not clearly reported	Heavy RT: ↔ Moderate RT: ↔ CON: ↔ No significant group × time interaction.	-	↔ ↔
Pereira *et al.* (2012)	Hand dynamometer (Lafayette Instrument, Lafayette, IN)	Sitting position at a 90˚ elbow flexion position	Dominant Non-dominant	Dominant hand: RT: ↑ CON: ↔ No significant between-group differences.	Non-dominant hand: RT: ↑ CON: ↔ Significant between-group differences.	↔↑
Rhodes *et al.* (2000)	Hand dynamometer	Not clearly reported	Dominant	RT: ↔ CON: ↔ No significant between-group differences.	-	↔
Richardson *et al.* (2019)	Digital strain-gauge dynamometer (Takei TKK 5401, Takei Scientific Instruments, Tokyo, Japan)	Not clearly reported	Dominant Non-dominant	Dominant hand: HVLL1: ↔ HVLL2: ↔ LVHL1: ↔ LVHL2: ↔ CON: ↔ No significant between-group differences.	Non-dominant hand: HVLL1: ↔ HVLL2: ↔ LVHL1: ↔ LVHL2: ↑ CON: ↔ Significant difference between LVHL2 and CON.	↔↔ ↔↔ ↔↔ ↔↑
Rogers *et al.* (2002)	Handgrip dynamometer (Jamar, Inc.)	Not clearly reported	Not clearly reported	RT: ↑ CON: ↔ Between group statistics were not clearly reported.	-	?

Continued

Skelton *et al.* (1995)	Not clearly reported	Not clearly reported	Left Right	RT: ↑ CON: ↔ Significant between-group differences.	-	↑
Thomas *et al.* (2008)	Grippit® dynamometer (AB Detector, Gothenburg, Sweden)	Sitting position at a 90˚ elbow flexion position	Left Right	Right hand RT: ↑ CON: ↔ Significant between-group differences.	Left hand RT: ↔ CON: ↔ No significant between-group differences	↑↔
Tieland *et al.* (2015)	Hydraulic hand dynamometer (Jamar, Jackson, MI, USA)	Sitting position with the arm in a 90˚ angle position	Dominant Non-dominant	Dominant hand RT: ↑ CON: ↑ Significant time effect. No significant group effect. No significant group × time interaction.	Non-dominant hand RT: ↑ CON: ↑ Significant time effect. No significant group effect. No significant group × time interaction.	↔↔
Tsuzuku *et al.* (2018)	Hand grip dynamometer (Grip-D; Takei Instruments, Niigata, Japan)	Standing position	Right	RT: ↔ CON: ↔ No significant between-group differences	-	↔
Vezzoli *et al.* (2019)	Dynamometer (JAMAR PLUS+, Sammors Preston, Rolyon, Bolingbrook, IL, USA)	Standing position, the upper limbs along the sides, and the legs slightly apart	Left Right	RT: ↔ CON: ↔ No significant between-group differences	-	↔
Wanderley *et al.* (2015)	Handgrip dynamometer (Takei, TKK 5101 Grip-D)	Held the dynamometer in the dominant hand with his/her arm by his/her side and had to squeeze using maximum force	Dominant	RT: ↔ CON: ↔ No significant group × time interaction.	-	↔

RT: resistance training. CON: control group. EBFT: element-based functional training. TSBFT: task-specific-based functional training. FT: function training. ST: suspension training. TT: traditional training. MJ: multi-joint resistance training. MJ+SJ: multi-plus single-joint resistance training. SE: supplemented and trained. SN: supplemented and non-trained. NE: non-supplemented and trained. NN: non-supplemented and non-trained. HVLL1: high-velocity, low-load once-weekly. LVHL1: low-velocity, high-load once-weekly. HVLL2: high-velocity, low-load twice-weekly. LVHL2: low-velocity, high-load twice-weekly. Note: only resistance training and control groups were included in this table? authors did not clearly reported the between-group statistics. ↑ : increased. ↓ : decreased. ↔: not changed/different.

handgrip strength [28] [30] [31] [35] [36] [38] [40] [42] [43] [44] [46], five studies (25%) measured only dominant participants' handgrip strength [32] [33] [34] [39] [47], one study (5%) measured only right participants' handgrip strength [45], one study (5%) measured participants' preferred arm [29], and the remaining two studies (10%) did not clearly report which hand (e.g., left, right or both and/or dominant, non-dominant or both) was used to measure handgrip strength [37] [41].

3.5. Impact of Intervention

Twelve studies (60%) reported no significant difference in handgrip strength change between the resistance training group and control group following an intervention study [28] [29] [30] [31] [32] [36] [37] [39] [44] [45] [46] [47]. Two studies (10%) included results for multi-training groups and found increased handgrip strength compared to controls, but only in one training group [34] [40]. Two studies (10%) measured the handgrip strength of the right and left or dominant and non-dominant hands and reported a training effect on one hand but not on the other [38] [43]. Two studies (10%) showed increased handgrip strength in the resistance training group compared with the control group [35] [42]. Finally, two studies (10%) did not clearly report differences in intervention effects [33] [41].

3.6. Risk of Bias

Overall, the randomized and non-randomized clinical trials presented moderate ("some concerns") risk of bias (**Figure 2(a)** and **Figure 2(b)**, respectively). Among the randomized trials in the risk of bias assessment, only three studies (17.6%) reported that the allocation sequence was concealed until participants were enrolled and assigned to interventions [33] [34] [47]. Only four studies (23.5%) used blind assessors [28] [36] [37] [47]. The remaining studies (n = 13) did not blind the assessors, or this information was unclear. Only two studies analyzed the data in accordance with a pre-specified plan [37] [47]. Among the three non-randomized studies included in the risk of bias assessment, none of them used blind assessors [38] [41] [44]. All the non-randomized studies presented a low risk of bias in the classification of interventions due to deviations from intended interventions. Due to the characteristics of the intervention studies, none of the randomized and non-randomized studies could blind participants and personnel (trainers). **Supplementary Material** shows traffic light risk-of-bias plots for randomized and non-randomized included studies.

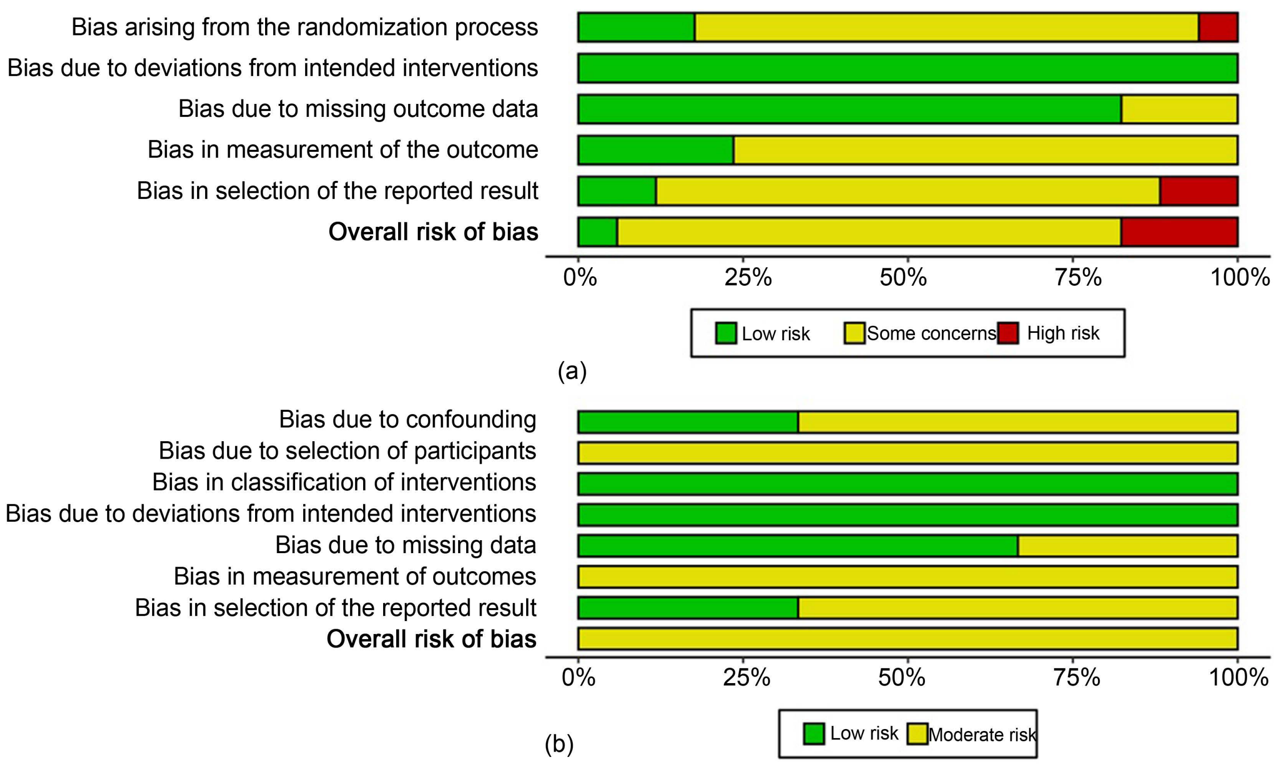

Figure 2. Assessment of risk of bias.

4. Discussion

This systematic review aimed to search and understand the impact of resistance training intervention on handgrip strength in adults of all ages, including young adulthood. However, contrary to our expectations, we found only one study that examined the impact of resistance training on handgrip strength in study participants with a mean age of less than 60. Even though low and decreasing handgrip strength is inversely associated with morbidity/mortality, there is limited interest and emphasis on the impact of resistance training on handgrip strength in young and middle-aged adults. Therefore, most of the studies selected in this review had participants with a mean age of 60 years or older.

4.1. Training Program and Its Impact on Handgrip Strength

Handgrip exercise training may improve handgrip strength in middle-aged and older adults [48] [49], but this systematic review did not include studies involving such exercise programs. However, when resistance exercise is offered using resistance training machines, study participants sit on a chair. The participants' hands often grip a bar to maintain body position during the exercise. Even when training with a rubber band, participants may hold onto one end of the band during exercise. This type of exercise makes determining exercise intensity or contraction time difficult but indicates an indirect handgrip exercise. In this systematic review, twelve of the 20 selected studies found no difference in handgrip strength changes between the resistance training and control groups. Most of those studies employed moderate- to high-intensity resistance exercises using resistance training machines and rubber/elastic bands [28] [29] [30] [31] [32] [36] [37] [39] [44] [46] [47]. On the other hand, two studies that reported a significant increase in handgrip strength in the resistance training group compared to the control group involved training programs using their body weight and rubber/elastic bands [35] [42]. These results did not explain the difference in the impact of resistance training on handgrip strength due to differences in exercise modes. Furthermore, there were no differences in other training variables, such as the volume of exercise (number of repetitions and sets) and intervention period, depending on whether they affected handgrip strength. Participants in the two studies [35] [42] that observed a significant increase in handgrip strength with resistance training were older adults with a mean age of about 80. Of the two, in the study where resistance training had the most change in handgrip strength, an increase of approximately 3 kg was observed in the training group [35]. While Labott and colleagues [19] recently concluded in a meta-analysis that different types of exercise training were capable of increasing handgrip strength compared to different control groups (e.g., other exercise interventions or non-exercise control groups), the observed effect size was small. Of the studies included in the analysis, Labott and colleagues [19] observed that only four of the 24 included studies found statistically significant increases in handgrip strength relative to the control group; however, only one of these four studies in fact compared resistance training intervention to a non-exercise control group. Thus, had we been able to perform a meta-analysis, it is possible that pooling all studies together would demonstrate a statistically significant effect of resistance training on handgrip strength relative to the control group, but the effect size would be expected to be small.

4.2. Discrepancies in Handgrip Strength Changes between Training Groups within a Study

When a single study includes two or more training groups, and there is a difference in handgrip strength change between the groups, knowing the factors behind this difference is meaningful from the perspective of handgrip strength improvement strategies. Our selected studies included two [34] or four [40] training groups that found increasing handgrip strength compared to controls in only one training group within each study. Campa and colleagues [34] compared the impact of suspension and traditional resistance training on handgrip strength and found that only suspension training produced increasing handgrip strength. The elastic bands employed in the traditional training program used different tube sizes specific to the given exercise. The suspension training was carried out using gripping straps attached to the tip of the elastic tube, which helped to grip firmly. A predicted factor for the difference in impact on handgrip strength could be attributed to the need for repeated firmer grip during the suspension exercise. Richardson and colleagues [40] observed the impact on handgrip strength when resistance training was performed in eight whole-body exercises (four in the upper body and four in the lower body) at high load (80% 1RM)-low velocity or low load (30% 1RM)-high velocity. In addition to each load-velocity condition, four training conditions differing in frequency (once a week vs. twice a week) were compared. As a result, handgrip strength increased only under the training program with high load-low velocity twice a week. The reasons for these results are unclear, but some possibilities exist. When performing high-load, low-velocity exercises using training machines, the time required to grip the movable bar during upper-body exercise is more extended than under other conditions. For lower-body movements, the time needed to hold the bar to stabilize the body is also longer than other conditions. Training load, volume, and frequency in resistance training using machines may impact the grasping movements of the machine's bar, which may train handgrip strength indirectly. However, this issue has yet to be investigated.

5. Limitations of the Study

The present systematic review is not without limitations. First, several studies included in this review were classified as having "moderate" risk of bias. Second, there is a paucity of studies on the present topic using randomized controlled trials that compared a resistance training group versus a control group comprising older adults. Hence, we were unable to provide a strong discussion for studies comprising middle-aged adults. Third, the included studies applied different resistance training protocol settings (e.g., exercises, intervention duration, weekly frequency, session duration, number of sets and repetitions, rest interval between sets and exercises, and intensity control/monitoring), which makes difficult to compare the handgrip strength results. Fourth, the available data in the included studies did not allow us to perform all pre-planned main meta-analysis, subgroup analysis, and sensitivity analysis.

6. Perspectives

The impact of resistance training interventions on handgrip strength has been primarily observed in older adults, and there needs to be more studies in young and middle-aged adults. From a meta-analysis perspective, we recommend that future randomized controlled trials with low risk of bias and larger sample sizes evaluating the effects of different resistance training protocols on handgrip strength compared to a non-exercise control group in middle-aged and older adults report the mean difference between groups and their standard deviation or at least mean changes within groups and its standard deviation. Furthermore, although handgrip strength is a biomarker [50], whether it can improve morbidity and mortality when increased by environmental factors such as resistance training has yet to be demonstrated [51] [52]. When handgrip strength is increased through whole-body resistance training or through select sports (*i.e.*, whether or not an athlete plays with sports equipment in their hands) [53], the effects on risk factors for lifestyle-related diseases are complex, but the impact on risk factors that occur when handgrip strength is directly increased by handgrip exercise has not been fully elucidated [54]. These studies are considered important in helping to elucidate the mechanisms of the inverse association between handgrip strength and morbidity/mortality.

7. Conclusion

The present systematic review showed that due to the lack of low risk of bias randomized controlled trials, different research designs, different resistance training protocols, small sample sizes, and different populations investigated, the existing evidence is insufficient to support resistance training for increasing handgrip strength in apparently healthy middle-aged and older adults. Furthermore, as the included studies presented an overall "moderate" risk of bias, future low-risk-of-bias randomized clinical trials comprising middle-aged and older adults are required. Finally, future studies may build upon these limitations to discern the optimal manner by which to develop and employ resistance training to improve handgrip strength.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Supplementary Material: Traffic-Light Plots for the Randomized (A) and Non-Randomized (B) Included Studies