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REVIEW

Benefits of resistance training in physically frail elderly: a systematic review

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Abstract

Aim Exercise is one of the most important components in frailty prevention and treatment. Therefore, we systematically reviewed the effect of resistance training (RT) alone or combined with multimodal exercise intervention on muscle hypertrophy, maximal strength, power output, functional performance, and falls incidence in physically frail elderly.

Methods MEDLINE, Cochrane CENTRAL, PEDro, and SPORTDiscus databases were searched from 2005 to 2017. Studies must have mentioned the effects of RT (i.e., included or not in multimodal training) on at least one of the following parameters: muscle mass, muscle strength, muscle power, functional capacity, and risk of falls in frail elderly.

Results The initial search identified 371 studies and 16 were used for qualitative analysis for describing the effect of strength training performed alone or in a multimodal exercise intervention. We observed that RT alone or in a multimodal training may induce increases of 6.6–37% in maximal strength; 3.4–7.5% in muscle mass, 8.2% in muscle power, 4.7–58.1% in functional capacity and risk of falls, although some studies did not show enhancements.

Conclusion Frequency of 1–6 sessions per week, training volume of 1–3 sets of 6–15 repetitions and intensity of 30–70%1-RM promoted significant enhancements on muscle strength, muscle power, and functional outcomes. Therefore, in agreement with previous studies, we suggest that supervised and controlled RT represents an effective intervention in frailty treatment.

Keywords Aging · Frailty · Multimodal training · Exercise prescription · Physical outcomes

Introduction

Frailty is a highly prevalent geriatric syndrome during aging process, which leads elderly to an elevated number of undesired outcomes in health and social life [1]. It is not simple to define frailty due to the complexity of related outcomes and its interactions, but it includes the presence of physical components as non-intentional weight loss, weakness, poor resistance and energy, poor gait ability, and low physical activity levels. Due to the poor physical outcomes, frailty is associated with high level of dependence and difficulty to perform daily functional activities [2]. Although there are some differences in frail diagnostics, there is a consensus about the diminished interaction between systems leading to vulnerable state, and increased risk of disability, hospitalization and death [3, 4].

Physical activity seems to be an effective instrument for enhancing health and functionality in physically frail population, and taking into account these clinical applications, exercise interventions deserve attention and priority in public health [5]. Previous studies considered physical exercise as one of the most important components in frailty prevention and treatment, because of the functional capacity improvements, risk of falls decreases, and gait ability, balance, cardiorespiratory capacity, and muscle strength development [6–8]. Among several physical interventions proposed, resistance training (RT) has been shown as an important strategy to improve muscle mass, muscle strength

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and power output, as well as functional capacity. RT has been highlighted as an essential component in physical activity programs in frail population [5], and it is used as the main component in combined programs (i.e., multimodal training involving different training components as balance, endurance, and gait training) [5, 8]. Systematic reviews and meta-analytic data have approached physical exercise in frailty syndrome [8–12]. However, although RT is considered as a fundamental intervention to physically frail individuals, there is a lack of systematic review focusing its effects on neuromuscular function, morphological changes, and functional capacity outcomes in frail population. In addition, it is also lacking an analytic review of training variables to determine how to prescribe RT for improving neuromuscular function and functional capacity in frail individuals. Therefore, the purpose of the present study was to systematically review and integrate evidences regarding effects of RT alone or in a multimodal training on muscle mass, muscle strength and power output, functional performance, and risk of falls in physically frail elderly. Current study also aimed to review the training characteristics used in those studies, to identify RT interventions effectiveness for improving neuromuscular function, muscle mass and functional capacity in this population.

METHODS

Study selection procedure

This study was undertaken in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [13], and the used method was based on the minimum criteria established by the Cochrane Back Review Group (CBRG) [14].

Before starting this systematic review, a prior protocol was previously developed to establish the search procedure, including the search term determination, subject characteristics, variables to assess, criteria of including/excluding studies, and risk of bias assessment. The search was conducted up to January 2017, using the following electronic databases: MEDLINE, accessed through PubMed, the Cochrane Central Register of Controlled Trials (Cochrane CENTRAL), Physiotherapy Evidence Database (PEDro) and SPORTDiscus. We proposed to explore these period due to a greater quantity of articles published in the last 12 years about frailty and physical exercise, more specifically involving RT. In addition, there was an improvement on the methodological approach in physical evaluations, e.g., familiarization, test–retest, which allows more precise post-training values. Moreover, a manual search of references in published studies about the population of interest as well as queries of the literature was performed using the electronic databases Cochrane CENTRAL, SPORTDiscus and MEDLINE. In addition, we performed a manual search in the manuscript reference lists to detect studies potentially eligible for inclusion. The terms used were: ‘frail older adult’ and ‘RT’ in association with a list of sensitive terms for experimental studies searching. The reference lists were examined to detect potentially eligible studies and the complete PubMed searching strategy is summarized in Table 1.

Intervention, controls and outcome measures

This review included experimental studies that assessed the effects of RT interventions alone or combined with other training components (i.e., multimodal exercise training) on muscle mass, muscle strength, functional capacity, and falls incidence in frail older adults. In this sense, parameters assessed were muscle hypertrophy, maximal strength, gait speed, timed up and go (TUG) test, sit-to-stand test, Short Physical Performance Battery (SPPB) scores, and falls incidence.

The inclusion criteria were: participants should be (1) over 65 years and older and (2) defined as frail according to standardized criteria (i.e., Fried criteria) in which frailty is defined by five components such as non-intentional weight loss, weakness, poor resistance and energy, poor gait ability, and low physical activity levels [1], or considered frail according to reduced physical function measured with physical performance scales (e.g., SPPB) or performance-based measures such as gait and mobility (i.e., Rockwood criteria) [2], or considering the reduced physical function and status (i.e., institutionalized). Taking into account the large number

Table 1 Search strategy

#1 Frail Older [MeSh]: Elderly, Frail OR Frail Elders OR Elder, Frail OR Elders, Frail OR Frail Elder OR Functionally-Impaired Elderly OR Elderly, Functionally-Impaired OR Functionally Impaired Elderly OR Frail Older Adults OR Adult, Frail Older OR Adults, Frail Older OR Frail Older Adult OR Older Adult, Frail OR Older Adults, Frail
#2 Resistance Training [MeSh]: Training, Resistance OR Strength Training OR Training, Strength OR Weight-Lifting Strengthening Program OR Strengthening OR Program, Weight-Lifting OR Strengthening Programs, Weight-Lifting OR Weight Lifting Strengthening Program OR Weight-Lifting OR Strengthening Programs OR Weight-Lifting Exercise Program OR Exercise Program, Weight-Lifting OR Exercise Programs, Weight-Lifting OR Weight Lifting Exercise Program OR Weight-Lifting Exercise Programs OR Weight-Bearing Strengthening Program Strengthening Program, Weight-Bearing OR Strengthening Programs, Weight-Bearing OR Weight Bearing Strengthening Program OR Weight-Bearing Strengthening Programs OR Weight-Bearing Exercise Program OR Exercise Program, Weight-Bearing OR Exercise Programs, Weight-Bearing OR Weight Bearing Exercise Program OR Weight-Bearing Exercise Programs
#3 #1 AND #2

of definitions of frailty criteria, we choose to approach these different frailty criteria due to their importance for understanding the effect of multimodal training in frail elderly.

The exclusion criteria were as follows: (1) the inclusion of participants with disability (e.g., advanced disability in performing ADL, dementia, or end-stage disease), (2) lack of control group and (3) crossover design and pilot studies. The studies based on the same sample, but with different outcomes were included.

Risk of bias assessment

The risk of bias assessment was performed by two investigators independently (P.L. and R.G.) and took into consideration the following characteristics of the included studies: random sequence generation, blinding of outcome assessors, concealed allocation concealment, description of losses and exclusions, and intention-to-treat analysis. Studies without a clear description of these features were considered unclear or not reported.

Data extraction

Titles and abstracts of all identified articles by the search strategy were independently evaluated by two researchers, in duplicate (P.L. and R.G.). Abstracts that did not provide sufficient information regarding the inclusion and exclusion criteria were selected for full-text evaluation. In the second phase, the same reviewers independently evaluated these full-text articles and selected them in accordance with the eligibility criteria. Disagreements among reviewers were solved by consensus, and if disagreement persisted, a third reviewer (R.R.) was consulted.

The data extraction was performed by the same two reviewers independently via standardized form. Information about interventions, outcomes and patients was collected. Discordance between reviewers was solved by consensus or by a third reviewer (R.R.). The primary outcomes analyzed were muscle mass, muscle strength, muscle power output, gait speed, TUG performance and SPPB. In addition, country, sex ratio, frailty criteria, intervention period, RT variables (i.e., frequency, intensity and volume), and adverse events were informed and extracted.

RESULTS

All studies aimed to investigate the effects of RT alone or in a multimodal exercise training program in frail elderly population. Searches in the electronic databases were performed on January 2017. We retrieved 373 studies (PubMed, 303; Cochrane Central, 64; PEDro, 4; SPORTDiscus, 2), and 102 studies were excluded after searching the literature published in the last 12 years. After, 271 studies were eligible for future titles and abstracts assessment, and 256 studies were excluded after inclusion criteria analysis. Fifteen studies were eligible for full-text assessment, and 4 were excluded (i.e., two did not present control group, and two utilized protein supplementation). Eleven studies were included by database search and five by manual search totaling 16 included studies (Fig. 1). Studies characteristics are presented in Table 2 with their sample size, inclusion criteria, training protocol, main outcomes and results, and in Table 3 with their training frequency, volume (sets × repetitions), intensity (%1-RM), and adverse events.

Studies characteristics

Frailty criteria

From included studies, the sample was composed mostly for women in all studies. Regarding the frailty criteria, six studies used Fried criteria (37.5%), while the others studies used different methods to define frailty as Kaltz index, or difficult to perform daily physical activities, or falls, or status (i.e., institutionalized) (Table 2).

Physical assessment methods

Regarding studies which assessed muscle mass, two studies used dual-energy X-ray absorptiometry (DXA) [15, 16], one study used bioimpedance [17], 1 used computerized tomography (CT) [18], and one used magnetic resonance imaging (MRI) [19]. From these methods, studies assessed total muscle mass [15, 16], appendicular muscle mass and legs muscle mass [15–17], and specifically quadriceps femoris, hamstrings and hip adductors muscle mass [18, 19]. When assessing muscle strength, studies used dynamometer (e.g., isometric and isokinetic contraction at 30 and 60°/s) [15, 17–25], and one repetition maximum (1-RM) [19, 25–27]. These studies evaluated knee extension strength [15, 17, 18, 20, 22–25], knee flexion strength [24, 26], hip flexion strength [18], and leg press strength [27, 28]. Regarding muscle power output, isokinetic contractions (e.g., 180°/s) [22], and power measured during functional test [16] were used. For gait speed assessment, eight studies measured 2.4–8 m for usual speed [15, 17, 18, 21–23, 27, 28], three measured 4–6 m time in fastest gait [15, 22, 25], and one study measured dual task in usual gait speed [18]. For sit-to-stand test, time to perform ten repetitions [21, 29] and number of repetitions in 30 s were the used tests [18]. Eight studies utilized TUG test [15, 18, 21–24, 28, 29], and one study utilized TUG with dual-task [18]. Regarding physical tests battery, two studies used Short Physical Performance

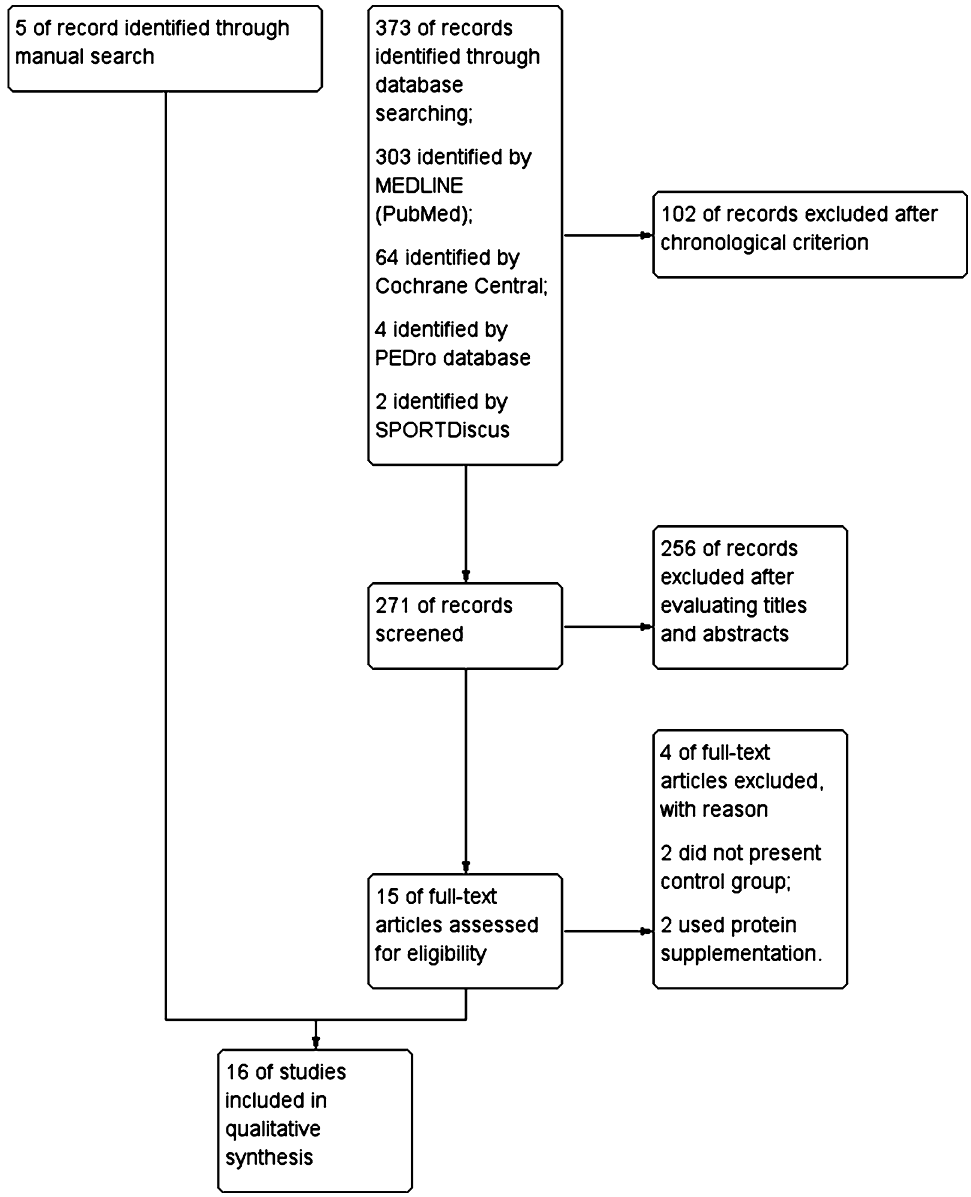

Fig. 1 Flowchart of literature review presents the different steps of search and study selection

Battery (SPPB) [16, 23]. Furthermore, to evaluate risk of fall, falls record [18], Fall Self-Efficacy [24, 29] and ABC Scale [30] were used.

Risk of bias

From studies included, 13 studies met the random allocation criteria (81.3%). Fourteen did not present information about concealed allocation criteria (93.8%). Nine studies met the criteria for blinded assessment (62.5%). Regarding descriptions of the losses and exclusion, 11 studies met these criteria (75%). The intention-to-treat analysis criteria were met in six studies (37.5%). The results of the risk of bias assessment are presented in Table 4.

RT prescription

All studies investigated the effects of RT. Four studies investigated the effects of RT alone [19, 20, 22, 26], whereas 12 studies investigated the effects of RT combined with other components (e.g., endurance, balance, gait retraining) in frail [15–18, 21, 23–25, 27–30]. Among these components, eight used RT combined with balance training [15, 16, 18, 21, 24, 25, 27, 29], five used RT combined with gait retraining [15–18, 27], two used RT combined endurance training [24, 28], and one used RT plus flexibility training [24].

In summary, nine studies assessed the RT effects performed during 12 weeks [15–18, 21, 24, 28–30], one study assessed 48 weeks of intervention [20], two studies assessed RT performed during 24 weeks [23, 25], two studies

Table 2 Studies characteristics: sample size, frailty criteria, intervention time, training protocol, and main outcomes

Study	*N*	Country	Sex ratio (female/male)	Frailty criteria	Intervention time (weeks)	Training protocol	Main outcomes
Cadore et al. [18]	24	Spain	17/7	3 Fried's criteria	12	MM: RT + BAL + GR	Muscle strength (~ 20%) Gait speed TUG Sit-to-stand test Muscle mass (~ 3–8%) Falls
Giné-Garriga et al. [21]	51	Spain	25/15	Functional daily difficulties (i.e., >10 s fastest gait speed, not stand up in 5 sit-to-stand tests)	12	MM: RT + BAL	Muscle strength (19%) Gait speed (~ 15%) Sit-to-stand test
Giné-Garriga et al. [30]	51	Spain	25/16	3 Fried's criteria	12	MM: RT + BAL	Falls
Gudlaugsson et al. [23]	117	Iceland	63/54	SPPB (< 7 pts)	24	MM: RT + END	Muscle strength (~ 12%) TUG (~ 1%) SPPB
Hess et al. [26]	27	United States of America	22/5	Functional daily difficulties (i.e., 53/56 Berg Balance score; ≥11.8 s on TUG; self-reported of balance impairment; >4 errors in tandem walk; gait abnormalities)	10	RT	Muscle strength (~ 35%) Muscle power
Ikezoe et al. [20]	28	Japan	28/0	Institutionalized older adults	48	RT	Muscle strength (~ 15%)
Jeon et al. [29]	62	–	62/0	> 65 years; residence in rural areas; and 3 falls recorded in the last year	12	MM: RT + BAL + END	TUG (1%) Sit-to-stand test Falls
Kim et al. [17]	155	Japan	155/0	Appendicular muscle mass (< 6.42 kgo m^{-2}); knee extension strength (1.01 nm nm• kg^{-1}); gait speed (< 1.22 m• s^{-1}); BMI (< 22)	12	MM: RT + BAL + GR	Muscle mass Muscle strength Gait speed (~ 14%)
Kim et al. [15]	131	Japan	131/0	3 Fried's criteria	12	MM: RT + BAL + GR	Muscle mass Gait speed (~ 18%) TUG (0.2%)
Kryger et al. [19]	23	–	–	Functional daily difficulties	12	RT	Muscle strength (37%)
Lee et al. [24]	616	Taiwan	336/280	Recurrent falls; or high risk of falls; or 1 fall coupled with gait or balance problems ascertained by TUG test	12	MM: RT + BAL + END + FLEX	Muscle strength TUG (~ 1%)
Lustosa et al. [22]	32	Brazil	32/0	3 Fried's criteria	10	RT	Muscle strength Muscle power Gait speed TUG (~ 1%)
Ng et al. [25]	246	Singapore	151/95	3 Fried's criteria	24	MM: RT + BAL	Muscle strength Gait speed

Table 2 (continued)

Study	N	Country	Sex ratio (female/male)	Frailty criteria	Intervention time (weeks)	Training protocol	Main outcomes
Rosendahl et al. [27]	191	Sweden	68/31	65 years; dependent on assistance from a person in one or more personal activities of daily living according to the Kaltz Index	12	MM: RT + BAL + GR	Muscle strength (~ 13%) Gait speed
Serra-Rexach et al. [28]	40	Spain	32/8	Institutionalized older; 90 years	8	MM: RT + END	Muscle strength (~ 20%) Gait speed TUG
Zech et al. [16]	69	–	–	3 Fried's criteria	12	MM: RT + BAL + GR	Muscle mass Muscle power Sit-to-stand test SPPB

MM multimodal training, *RT* resistance training, *END* endurance, *BAL* balance, *GR* gait retraining, *FLEX* flexibility, *COORD* coordination

evaluated individuals after 10 weeks of training [22, 26], and one study assessed outcomes after 8 weeks of intervention [28]. The training frequency ranged from 1 to 6 sessions per week [15–18, 21, 23, 25, 27, 28, 30]; RM (RM's and percentage of 1-RM (%1-RM)) [18, 19, 21, 23, 25–28], and rate of perceived effort (RPE) [15–17, 20, 30] were used to prescribe intensity, while among %1-RM prescription, intensity ranged from 30 to 100% of 1-RM. Regarding RT volume, four studies used 1 set of 8–15 repetitions [18, 20, 25, 27], three studies used 2 sets of 6–12 repetitions [21, 23, 30], and three studies used 3 set of 8–10 repetitions [19, 26, 28].

Effect of RT in main outcomes

Muscle mass

Five studies assessed the effect of RT in muscle mass [15–19]. Magnitude of improvement in the studies that found significant improvements ranged from 3.35 to 7.5% after 12 weeks [18, 19]. Conversely, there were studies that did not find differences after 12 weeks [15–17].

Muscle strength

Twelve studies evaluated muscle strength [15, 17, 19–22, 24–28]. In general, studies have found significant enhancements ranging from 6.6 to 37.0% in the isometric knee extension, and from 13.1 to 20.5% in leg press 1-RM after 8 [28], 10 [26], 12 [18, 19, 21, 24, 27, 28], and 48 weeks of intervention [20]. However, some studies have not found differences after 10 [22] and 12 weeks of intervention [15, 17, 25].

Muscle power

One study has found a significant increase of 8.2% after 10 weeks [22], whereas one study has not found differences after 12 weeks [16]. Diverse study observed significant improvement in muscle power output at 30 and 60% of leg press 1 RM (96 and 116%, respectively) [18], although this study had not controlled muscle power output variables.

Functional outcomes

Gait speed (usual, fastest, and dual-task walking ability) Eight studies assessed usual gait speed [15, 17, 18, 21–23, 27, 28]. Magnitude of improvement in these studies ranged from 5.88 to 14.5% after 10 [22], and 12 weeks [17, 18, 27]. However, there are studies that have not found differences after 8 [28], and 12 weeks [15, 23] in the usual gait ability.

Table 3 Strength training characteristics

Study	Frequency	Volume (sets × repetitions)	Intensity (%1-RM)	Adverse events
Cadore et al. [18]	2	1 × 8–10	40–60% de 1-RM	3 subjects report medicines complication
Giné-Garriga et al. [21]	2	1–2 × 6–15	8RM	No adverse event
Giné-Garriga et al. [30]	2	1–2 × 6–15	–	–
Gudlaugsson et al. [23]	2	2 × 12	50% de 1-RM	No adverse event
Hess et al. [26]	3	3 × 8	50–80% de 1-RM	–
Ikezoe et al. [20]	4–6	1 × 10	–	–
Jeon et al. [29]	3	–	–	No adverse event
Kim et al. [17]	2	–	–	No adverse event
Kim et al. [15]	2	–	–	No adverse event
Kryger et al. [19]	3	3 × 8	50–80% de 1-RM	–
Lee et al. [24]	1	–	–	No adverse event
Lustosa et al. [22]	3	–	–	No adverse event
Ng et al. [25]	2	1 × 8–15	60–80% de 1-RM	2 subjects report pain
Rosendahl et al. [27]	2	1 × 8–12	8–12 RM	–
Serra-Rexach et al. [28]	2	2–3 × 8–10	30–70% de 1-RM	–
Zech et al. [16]	2	–	–	–

1-RM, one repetition maximum

Table 4 Risk of bias assessment

Study	Random sequence generation	Concealed allocation	Blinding of outcome assessor	Description of losses and exclusions	Intention-to-treat analysis
Cadore et al. [18]	Y	–	Y	Y	–
Giné-Garriga et al. [21]	N	–	Y	Y	–
Giné-Garriga et al. [30]	Y	–	Y	Y	–
Gudlaugsson et al. [23]	Y	–	–	–	–
Hess et al. [26]	N	–	–	–	–
Ikezoe et al. [20]	N	–	–	Y	–
Jeon et al. [29]	Y	–	Y	Y	–
Kim et al. [17]	Y	–	Y	Y	Y
Kim et al. [15]	Y	Y	Y	Y	Y
Kryger et al. [19]	Y	–	–	Y	–
Lee et al. [24]	Y	–	–	–	Y
Lustosa et al. [22]	Y	–	Y	–	–
Ng et al. [25]	Y	N	Y	Y	Y
Rosendahl et al. [27]	Y	–	Y	Y	Y
Serra-rexach et al. [28]	Y	–	Y	Y	Y
Zech et al. [16]	Y	–	–	Y	–

Four studies assessed the fastest gait speed [15, 21, 25, 27]. Magnitude of improvement in these studies that found significant increases ranged from 5.88 to 18.6% after 12 weeks [17, 21, 27]. Dual-task during usual walking was assessed by one study which has not observed significant differences after 12 weeks [18].

TUG test (usual and dual task) Eight studies evaluated TUG test performance [15, 18, 21–24, 28, 29]. Some of them have found significant enhancements (from 5.5 to 20.4%) after 10 [22] and 12 weeks of RT intervention [15, 18, 24, 29]. Conversely, one study has not found significant differences after 8 weeks [28]. One study assessed TUG performance with dual task (i.e., verbal task), and observed significant improvement after 12 weeks of intervention (14.7%) [18].

Sit-to-stand test performance Three studies evaluated sit-to-stand performance [18, 21, 29] and both presented significant improvements of 58.1% in repetitions [18] and 20.5–23.7%, respectively, in the test performance after 12 weeks [21, 29].

SPPB Two studies assessed SPPB [16, 23], and observed significant enhancements ranging from 4.7 to 11.4% after 12 [16] and 24 weeks [23].

Falls incidence

Four studies assessed falls incidence [18, 24, 29, 30]. Three studies have found significant reductions after 12 weeks [18, 29, 30], while one study has not found differences after 12 weeks [24].

Adverse events

Seven studies did not present any adverse events during RT and multimodal interventions [15, 17, 21–24, 29], while one study presented some adverse events not related to intervention [18] and pain [25]. Seven studies have not reported any information about adverse events.

DISCUSSION

The present study reviewed systematically the effects of resistance training on neuromuscular functional, muscle morphology and functional outcomes in physically frail elderly. The main findings of the present review were the positive effects of RT performed alone or combined with different training components (i.e., balance, gait) in muscle mass, muscle strength and power output, as well as functional capacity, whereas there were some studies that have not found positive results in all variables. Based on positive results and the reduced number of adverse events, supervised RT may be a safety physical intervention in frail individual to prevent functional capacity losses, dependence and falls incidence.

Sarcopenia (i.e., unintentional loss of muscle mass) is a critical pathophysiological component of frailty. However, few studies investigated the effect of RT on muscle mass in frail population [15–19]. Among the six studies that evaluated RT effect on muscle mass, Kryger et al. [19] and Cadore et al. [18] presented significant improvement in frail individuals. Their results may be attributed to RT intensity, as well as the control of intensity used (e.g., 65–100%, 50–80% and 40–60%1-RM, respectively), whereas RPE was used in studies which have not found significant changes. Along with total muscle cross-sectional area, Kryger et al. [19] demonstrated significant increases in type 2a muscle fiber (e.g., 22%), concomitant whit a relative reduction in type 1 percentage area in frail elderly. These results support that RT alone or combined with other training components may stimulate muscle hypertrophy in frail elderly. In addition, Cadore et al. [18] investigated the explosive resistance training effects in frail individuals, and the authors identified an increase in muscle CSA in the muscle portion with lower fat infiltration (i.e., high-density muscle CSA), suggesting that these subjects did not improve only the muscle size but also the muscle quality. Taken together, these results suggest that frail individuals preserve their muscle plasticity and are able to increase muscle size. Notwithstanding, it seems that RT prescription based on % of 1-RM is a better intensity control method and may optimize muscle size gains.

Neural impairment is a natural process during biological aging, reducing neural and functional capacity in frail elderly [29]. Despite both muscle strength and power output decreases over aging, muscle power, that seems to be more closely associated to functional capacity, shows a greater reduction compared to muscle strength [31]. Significant improvements were found in those studies which investigated muscle strength and power output [16, 18]. However, some studies have not shown significant increments in these neuromuscular parameters [15, 17, 22]. Curiously, in those studies which no enhancements in muscle strength and power were observed, RT intensity was prescribed using RPE, which could explain the absence of changes. It is possible that physically frail elderly may present a reduced capacity to exercising based on effort perception, which could result in an underestimated intensity, and consequently, affecting the magnitude of increases in muscle strength and power. On the other hand, it should be highlighted that even in a very poor health condition, frail individuals keep the capacity to present neural and morphological adaptations which induce marked increases in muscle strength and power, as observed in study by Cadore et al. [18] (e.g., 97 and 117% of increases in 30–60%1-RM muscle power test).

Functional capacity is considered one of the most important health outcomes in elderly. There is an expressive reduction in daily activities resulting in worsening of fear and risk of falls, independence, and quality of life [32]. Fried et al. [1] showed that slowness is an essential evidence to frailty diagnosis. In the present review, included studies investigated the RT effects in usual and fastest gait speed, as well as TUG performance, and have shown significant improvements [15, 17, 18, 21, 22, 24, 27, 29], whereas only one study has observed significant enhancement in a dual-task test [18]. Previous meta-analyses by Giné-Garriga et al. [12] and Liu et al. [6] have shown a positive effect of physical exercise on gait speed, although no changes were demonstrated on TUG performance. However, even though we did not perform statistical approach, it seems that greater changes in gait ability were observed in those studies which investigated RT combined with other training stimuli (i.e., balance, gait retraining) compared with those studies which applied RT alone [17, 18, 22, 27]. Possible discrepancies between the present results and previous meta-analyses could be explained because these studies focused on the effect of different physical activity interventions while we focused specifically on RT effects. Thus, we suggest that improvements on gait speed and TUG (e.g., 5.5–20.4%) may occur after a short-term intervention (e.g., 10–12 weeks). Although there was only one study showing improvement on dual-task performance, the absence of declines in its performance in several studies may suggest that physical training was able to maintain this outcome stable, and it is an important result since this performance also depends on the cognitive system.

Sit-to-stand test represents an important component of functional independence and has been used as a predictor of postural sway, risk of falls, and proprioception [33–35]. Significant improvements were found among three studies which investigated the effect of multimodal exercise training including RT. There are different methods for assessing sit-to-stand capacity, which can represent different neuromuscular parameters: ten repetitions test shows the capacity to perform sit-to-stand capacity "as fast as possible", which is more associated with muscle power, whereas the test using the capacity to sit-to-stand in 30 s may be more associated with endurance capacity. Despite this difference, based on observed results, we may suggest that RT improves both power and endurance capacity of lower limbs, resulting in better sit-to-stand ability in frail elderly.

SPBB is a useful tool for clinical evaluation, and lower scores are predictors of hospitalization, primary care need, disability and mortality [35]. Some SPPB components were described above as gait speed and sit-to-stand test. Three studies found significant increases in SPPB [16, 23] after 12 and 24 weeks of intervention, and these improvements are expected since RT promotes neuromuscular and metabolic adaptations that are able to enhance all the tests composing SPPB.

One of the most dangerous consequences of frailty is the increased risk of falls, and it represents a higher incidence of death [36–39]. A single fall event may produce a great impact on individual life, leading to fear of falling, and consequently decreasing functional activities. This review included studies that used different instruments to assess incidence of falls as recordatory, ABC scale and Fall Self-Efficacy [21, 24, 29], presenting significant improvements. However, questionnaire evaluations as ABC scale and Fall self-efficacy may present a lower sensibility for identifying eventual falls and perhaps limiting this variable. After intervention, Cadore et al. [18] demonstrated significant improvements because of the falls absence reported during intervention. Based on observed results, we suggest that RT combined with balance and gait exercise reduce falls incidence, besides to be a safety and tolerable intervention for frail elderly.

This review has some limitations that should be mentioned. Inclusion criteria used for considering subjects of articles included as physically frail were different among studies (i.e., Fried criteria, difficult to perform daily living activities, institutionalized individuals, and physical battery performance), and this may represent a limitation due to the high heterogeneity of subjects. However, regardless of the different frailty criteria of diagnosis, all those subjects presented outcomes such as poor gait ability, weight loss, sarcopenia, fatigue, and overall functional decline, which make our conclusions clinically applicable to frail elderly individuals. Another possible limitation is that we focused specifically on RT interventions, but in some studies, the adaptations observed could be the consequence of other types of exercise which were combined with RT, since some studies included RT as one component of multimodal exercise intervention. However, this review focused on the main outcomes which are specifically targeted by RT prescription, such as muscle mass, muscle strength, and functional capacity.

Present systematic review observed evidences that RT promotes neuromuscular, morphological and functional improvements. Even with a higher heterogeneity of included studies, frequency as 1 at 6 sessions per week, training volume as 1–3 sets of 6–15 repetitions and intensity of 30–70%1-RM; 2 at 3 sessions per week, training volume as 2–3 sets of 8–10 repetitions and intensity of 40–60%1-RM and; 1 at 3 sessions per week, training volume as 1–3 sets of 6–15 repetitions and intensity of 40–60%1-RM promoted significant enhancements on muscle strength, muscle power, and functional outcomes, respectively. Therefore, in agreement with previous studies, which considered RT as the main intervention in frailty, we suggest that supervised and controlled RT represents an effective intervention in frailty treatment outcomes.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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