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SYSTEMATIC REVIEW

Effect of Resistance Training Frequency on Gains in Muscular Strength: A Systematic Review and Meta-Analysis

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Abstract

Background Current recommendations on resistance training (RT) frequency for gains in muscular strength are based on extrapolations from limited evidence on the topic, and thus their practical applicability remains questionable.

Objective To elucidate this issue, we conducted a systematic review and meta-analysis of the studies that compared muscular strength outcomes with different RT frequencies.

Methods To carry out this review, English-language literature searches of the PubMed/MEDLINE, Scopus, and SPORTDiscus databases were conducted. The meta-analysis was performed using a random-effects model. The meta-analysis models were generated with RT frequencies classified as a categorical variable as either 1, 2, 3, or 4+ times/week, or, if there were insufficient data in subgroup analyses, the training frequencies were categorized as 1, 2, or 3 times/week. Subgroup analyses were performed for potential moderators, including (1) training volume; (2) exercise selection for the 1 repetition maximum (RM) test (for both multi-joint and single-joint exercises); (3) upper and lower body strength gains; (4) training to muscular failure (for studies involving and not involving training to muscular failure); (5) age (for both middle-aged/older adults and young adults); and (6) sex (for men and for women). The methodological quality of studies was appraised using the modified Downs and Black checklist.

Results A total of 22 studies were found to meet the inclusion criteria. The average score on the Downs and Black checklist was 18 (range 13–22 points). Four studies were classified as being of good methodological quality, while the rest were classified as being of moderate methodological quality. Results of the meta-analysis showed a significant effect ($p = 0.003$) of RT frequency on muscular strength gains. Effect sizes increased in magnitude from 0.74, 0.82, 0.93, and 1.08 for training 1, 2, 3, and 4+ times per week, respectively. A subgroup analysis of volume-equated studies showed no significant effect ($p = 0.421$) of RT frequency on muscular strength gains. The subgroup analysis for exercise selection for the 1RM test suggested a significant effect of RT frequency on multi-joint ($p < 0.001$), but not single-joint, 1RM test results ($p = 0.324$). The subgroup analysis for upper and lower body showed a significant effect of frequency ($p = 0.004$) for upper body, but not lower body, strength gains ($p = 0.070$). In the subgroup analysis for studies in which the training was and was not carried out to muscular failure, no significant effect of RT frequency was found. The subgroup analysis for the age groups suggested a significant effect of training frequency among young adults ($p = 0.024$), but not among middle-aged and older adults ($p = 0.093$). Finally, the subgroup analysis for sex indicated a significant effect of RT frequency on strength gains in women ($p = 0.030$), but not men ($p = 0.190$).

Conclusions The results of the present systematic review and meta-analysis suggest a significant effect of RT frequency as higher training frequencies are translated into

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greater muscular strength gains. However, these effects seem to be primarily driven by training volume because when the volume is equated, there was no significant effect of RT frequency on muscular strength gains. Thus, from a practical standpoint, greater training frequencies can be used for additional RT volume, which is then likely to result in greater muscular strength gains. However, it remains unclear whether RT frequency on its own has significant effects on strength gain. It seems that higher RT frequencies result in greater gains in muscular strength on multi-joint exercises in the upper body and in women, and, finally, in contrast to older adults, young individuals seem to respond more positively to greater RT frequencies. More evidence among resistance-trained individuals is needed as most of the current studies were performed in untrained participants.

Key Points

The results of the present analysis indicate a significant effect of resistance training (RT) frequency on gains in muscular strength, where higher training frequencies result in greater muscular strength gains.

The effects of higher training frequencies seem to be primarily due to higher training volume because when the training volume is equated, this analysis found no significant effect of RT frequency on muscular strength gains.

It is likely that trained individuals will use greater RT frequencies in their routines, and thus future research among this population is needed to draw more generalizable conclusions.

1 Introduction

Muscular strength can be defined as the capacity to exert force under a particular set of biomechanical conditions [1]. This physical characteristic is of great importance as it impacts the effectiveness of performing many tasks, both in sport and daily living [2, 3]. Engaging in resistance training (RT) can significantly increase muscular strength [4]. This is consistent with the 'Specific Adaptations to Imposed Demands' (SAID) principle because the body adapts to a resistive stimulus by enhancing its capacity to produce force in anticipation of similar future demands [5]. RT variables, such as training volume, intensity, rest interval duration, exercise selection, training to muscular failure, exercise order, repetition velocity, and training frequency, are manipulated in an endeavor to maximize muscular adaptations. Of these variables, volume and load have received the majority of attention in the literature [6–9]. In comparison, the potential of training frequency to influence increases in strength may be overlooked.

RT frequency pertains to the number of training sessions performed per muscle group in a given period. A common timeframe for classifying RT frequency is on a weekly basis. The current American College of Sports Medicine RT guidelines suggest that novice and intermediately trained individuals train each muscle group two to three times per week using either a total-body or split-body (i.e. upper and lower body) routine. For individuals who are more advanced in RT, a muscle group split routine is suggested, in which one to three muscle groups are trained per training session [4]; however, these recommendations are based on extrapolations from limited evidence [10, 11] on the topic and thus their practical applicability remains questionable. Since the publication of the position stand, several additional studies [12–20] have been published investigating the effects of RT frequency on muscular strength gains, some of them providing novel data among trained individuals [12, 13] and older adults [15, 19, 20], thus justifying the need for a comprehensive review of the available evidence. Therefore, the purpose of the present paper is threefold: (1) to perform a systematic review of the studies that compare different RT frequencies while assessing muscular strength outcomes; (2) to quantify the findings with a meta-analysis; and (3) to draw evidence-based conclusions guiding exercise program design.

2 Methods

This systematic review was registered in advance in the PROSPERO register of systematic reviews (ref: CRD42017070090) and was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines [21].

2.1 Search Strategy

To carry out the review, English-language literature searches of the PubMed/MEDLINE, Scopus, and SPORTDiscus databases were conducted. In all of these databases, a search was performed from inception of indexing to 1 June 2017 by combining the following search terms: 'resistance training frequency', 'weight training frequency', 'strength training frequency', 'strength', 'split training', 'workout frequency', 'split routine', 'split weight training', 'volume load', 'effects'. Boolean operators (AND, OR) were used to concatenate the search terms. A secondary search was performed by screening the reference lists of the included studies and relevant review articles. Additionally, forward citation tracking of the included studies was conducted through Scopus and Google Scholar. The study selection was carried out independently by two authors (JG and BL) to minimize potential selection bias.

2.2 Inclusion Criteria

Studies meeting the following criteria were included in this review: (1) the study was published in English as a full-text manuscript; (2) the study compared the effects of different weekly RT frequencies with the RT program being performed using traditional dynamic exercise; (3) the pre- and post-assessments of muscular strength were performed using a 1 repetition maximum (RM) test, an isokinetic test, and/or an isometric test; (4) the RT trial lasted a minimum of 4 weeks; and (5) the study was conducted among human participants without pre-existing chronic disease or injury. We decided to include only the studies in which dynamic RT was investigated because dynamic exercise seems to be the predominant type of RT among most people, including athletes and fitness enthusiasts [22].

2.3 Data Extraction

The following variables from the included studies were extracted independently by two authors (JG and BL): (1) descriptive data, including the sample size, age, and RT experience; (2) characteristics of the RT trial, including training frequency, trial length, number of sets, and number of repetitions per set; (3) muscular strength test(s) used; and (4) the main findings related to the muscular strength outcomes. Participants were considered as trained if they were reported to have at least 1 year of regular RT experience. All data were tabulated in an Excel spreadsheet (Microsoft Corporation, Redmond, WA, USA) predesigned for this review. Coding sheets were cross-checked between authors, while discussion and consensus resolved any discrepancies.

2.4 Methodological Quality

To assess the methodological quality of the included studies we used the validated Downs and Black checklist [23]. This 27-item checklist was modified by adding two items, namely ‘adherence to the RT programs’ (item 28) and ‘RT supervision’ (item 29). Items 1–10 refer to reporting, items 11–13 refer to external validity, items 14–26 refer to internal validity, and item 27 relates to statistical power. The study quality was classified as in Davies et al. [24] and in previous reviews focused on RT interventions [25]. Specifically, studies were classified as being of ‘good quality’ if they scored 20–29 points, ‘moderate quality’ if they scored from 11–20 points, and ‘poor quality’ if they scored <11 points on the checklist [24]. Studies were independently rated by two reviewers (JG and TD) with discussions and agreement for any observed differences.

2.5 Statistical Analyses

The effect size (ES) was calculated as the difference between post-test and pretest scores, divided by the pretest standard deviation [26], with an adjustment for small sample bias [27]. The sample size and mean ES across all studies were used to calculate the variance around each ES. Robust variance random-effects meta-regression for multilevel data structures (adjusted for small samples [28, 29]) were used for performing the meta-analysis. To account for correlated effects within studies, a study was used as the clustering variable. Model parameters were calculated by the restricted maximum likelihood method, and the observations were weighted by the inverse of the sampling variance [30]. Our aim was to analyze different methods of measuring strength separately, as, for instance, there is evidence that 1RM testing and isokinetic peak torque can show large variations, even in the same individual, and in some cases can even be conflicting [31]. Separate meta-regressions were performed on ESs for 1RM outcomes only as insufficient data were available for other muscular strength outcomes. The meta-analysis models were generated with training frequency classified as a categorical variable as either 1, 2, 3, or 4+ times/week, or, if there were insufficient data, the training frequencies were categorized as 1, 2, or 3 times/week. A sensitivity analysis was performed by excluding the two studies that combined both RT and aerobic training, and then examining the effects [32, 33]. Subgroup analyses were performed for potential moderators, including RT volume, exercise selection for the 1RM test (multi-joint or single-joint exercises), upper and lower body strength gains, training to muscular failure (for studies involving and not involving training to muscular failure), age (middle-aged/older adults and young adults) and sex (for both men and women). A subgroup analysis including only trained participants could not be performed due to the low number of studies conducted in this population.

All analyses were performed using package metafor in R version 3.4 (The R Foundation for Statistical Computing, Vienna, Austria). Effects were considered significant at $p<0.05$. Data are reported as $\bar{x} \pm$ standard error of the mean (SEM) and 95% confidence interval (CI).

3 Results

3.1 Study Selection

The primary search through the databases yielded 1835 results, of which 21 studies met the inclusion criteria. Forward citation tracking of the included studies through Google Scholar (1135 search results) and Scopus (610 search results) yielded another 1745 search results. This search led to the inclusion of one additional paper. Scanning the reference lists did not result in the inclusion of any additional studies; therefore, the total number of studies included in this review is 22 [10–20, 32–42]. The stages of the search and study selection process are presented in Fig. 1.

3.2 Study Characteristics

The pooled number of participants across all included studies was 912. Sample sizes in individual studies ranged from 11 to 152, and the median number of participants per study was 29. Only three studies included participants with previous RT experience (pooled $n = 56$), while the rest included untrained individuals. The mean duration of RT programs was approximately 12 weeks (range 6–24 weeks), and the most common comparison of RT frequency was between two- and three-weekly training sessions (in 14 studies). The number of sets performed per exercise in individual studies during a training session varied from 1 to 18 sets. Twenty-one studies assessed dynamic muscular strength using 1RM tests, and several included studies used both multi-joint and single-joint exercises for the 1RM strength assessment (Table 1). Two of those studies assessed both dynamic and isometric strength, and one study assessed only isokinetic strength. Table 1 summarizes the studies analyzed.

3.3 Methodological Quality

The average score on the Downs and Black checklist was 18 (range 13–22 points). Four studies were considered to be of good quality, while the rest were considered to be of moderate methodological quality. None of the included studies were classified as being of low methodological

Fig. 1 Study retrieval process

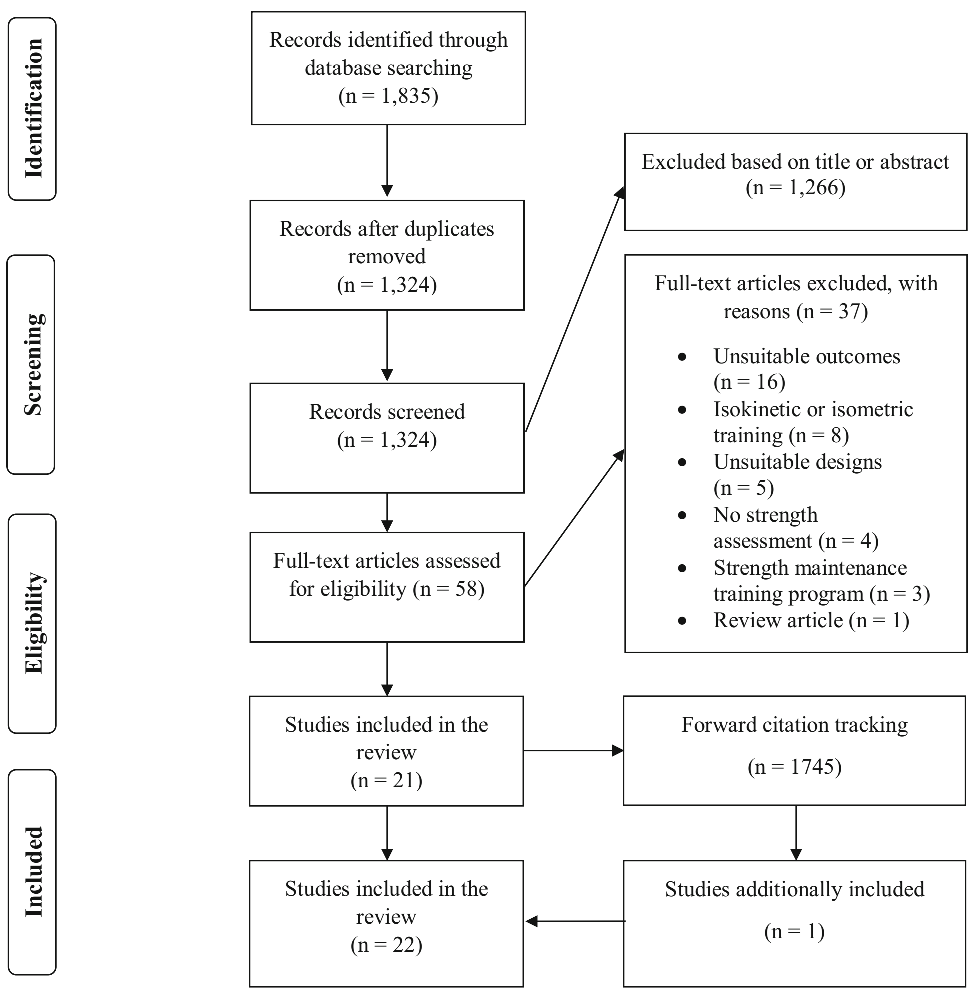

Table 1 Summary of the study and participant characteristics

Study	Sample	Resistance training frequency comparison	Exercise prescription (sets × repetitions)	Was the training performed to muscular failure?	Duration (weeks)	Volume equated?	Muscular strength test(s)
Arazi and Asadi [34]	Young untrained men ($n = 29$)	1/2	1 × 6–12	No	8	Yes	1RM bench press 1RM leg press
Benton et al. [14]	Middle-aged untrained women ($n = 21$)	2/3	3 × 8–12; 6 × 8–12	No	8	Yes	1RM chest press 1RM leg press
Brazell-Roberts and Thomas [36]	Young untrained women ($n = 112$)	2/3	3 × 10	No	12	No	1RM bench press 1RM squat
Candow and Burke [10]	Young and middle-aged untrained men and women ($n = 29$)	2/3	2–3 × 10	Yes	6	Yes	1RM bench press 1RM squat
Carroll et al. [37]	Young untrained men and women ($n = 11$)	2/3	3 × 4–10	Yes	6	No	1RM squat Isometric leg extension Isokinetic leg extension
DiFrancisco-Donoghue et al. [38]	Older untrained men and women ($n = 18$)	1/2	1 × 10–15	Yes	9	No	1RM leg press 1RM leg extension 1RM leg curl 1RM chest fly 1RM biceps curl 1RM seated dip
Faigenbaum et al. [39]	Untrained boys and girls ($n = 42$)	1/2	1 × 10–15	Yes	8	No	1RM chest press 1RM leg press
Fernández-Lezaun et al. [15]	Older untrained men and women ($n = 68$)	1/2/3	2–5 × 30–90% 1RM	No	24	No	1RM leg press
Ferrari et al. [32]	Older untrained men ($n = 22$)	2/3	2–3 × 6–12	Yes	10	No	1RM leg extension 1RM elbow flexion

Table 1 continued

Study	Sample	Resistance training frequency comparison	Exercise prescription (sets × repetitions)	Was the training performed to muscular failure?	Duration (weeks)	Volume equated?	Muscular strength test(s)
Fisher et al. [33]	Older untrained women ($n = 63$)	1/2/3	1–2 × 10	No	16	No	1RM leg press 1RM leg extensions 1RM hamstring curl 1RM biceps curl 1RM chest press 1RM shoulder press
Gentil et al. [16]	Young untrained men ($n = 29$)	1/2	3 × 8–12	Yes	10	Yes	Elbow flexion peak torque
Gregory [40]	Young untrained men ($n = 152$)	2/3	3 × 6–8	Yes	14	No	1RM leg press 1RM biceps curl 1RM shoulder press 1RM bench press
Hunter [35]	Young untrained men and women ($n = 46$)	3/4	2–3 × 7–10	Yes	7	Yes	1RM bench press
Lera Orsatti et al. [17]	Middle-aged and older untrained women ($n = 30$)	1/2/3	3 × 8–12	Yes	16	No	1RM bench press 1RM leg press 1RM leg extensions 1RM biceps curl 1RM triceps extensions
McKenzie Gillam [41]	Young untrained men ($n = 68$)	1/2/3/4/5	18 × 1	Yes	9	No	1RM bench press
McLester et al. [11]	Young trained men and women ($n = 18$)	1/3	3 × 8–10	Yes	12	Yes	1RM bench press 1RM lateral pulldown 1RM triceps press 1RM biceps curl 1RM lateral raise

Table 1 continued

Study	Sample	Resistance training frequency comparison	Exercise prescription (sets × repetitions)	Was the training performed to muscular failure?	Duration (weeks)	Volume equated?	Muscular strength test(s)
Murlasits et al. [18]	Older untrained men and women ($n = 29$)	2/3	3 × 8	Yes	8	No	1RM chest press 1RM leg press
Padilha et al. [19]	Older untrained women ($n = 27$)	2/3	1 × 10–15	No	12	No	1RM chest press 1RM leg extensions 1RM biceps curl
Schoenfeld et al. [12]	Young trained men ($n = 19$)	1/3	2–3 × 8–12	Yes	8	Yes	1RM bench press 1RM squat
Silva et al. [20]	Older untrained women ($n = 30$)	2/3	1–2 × 10–15	Yes	24	No	1RM chest press 1RM leg extensions 1RM biceps curl
Taaffe et al. [42]	Older untrained men and women ($n = 39$)	1/2/3	3 × 80% 1RM	No	24	No	1RM bench press 1RM shoulder press 1RM seated lateral pulldown 1RM biceps curl 1RM back extensions 1RM leg press 1RM leg extensions 1RM leg curl
Thomas and Burns [13]	Young trained men and women ($n = 19$)	1/3	3 × 8–12	Yes	8	Yes	1RM chest press 1RM hack squat

RM repetition maximum

quality. Quality assessment scores for individual studies can be found in Table 2.

3.4 Meta-analysis Results

The final analysis comprised 156 ESs from 49 treatment groups from 21 studies. Results for training frequency as a categorical variable for all analyses are shown in Table 3. ESs gradually increased in magnitude with each additional training day per week, with a significant overall effect of training frequency ($p = 0.003$). Removal of the studies that combined RT and aerobic training [32, 33] did not impact the results.

Table 2 Results of the methodological quality evaluation using the modified Downs and Black checklist

Scale items																														
Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Total score—rating
Arazi and Asadi [34]	1	1	1	1	0	1	1	0	1	0	0	0	1	0[a]	0[a]	1	1	1	0[a]	1	0[a]	0[a]	1	0[a]	0[a]	1	1	0	1	16—M
Benton et al. [14]	1	1	1	1	1	1	1	1	1	1	0[a]	0	1	0[a]	0[a]	1	1	1	1	1	1	0[a]	0	0	0	1	1	1	1	21—G
Brazell-Roberts and Thomas [36]	1	1	0	1	0	1	1	0	0	0	1	1	1	0[a]	0[a]	1	1	1	0[a]	1	1	0[a]	0	0	0[a]	1	1	0	1	16—M
Candow and Burke [10]	1	1	1	1	0	1	1	0	1	0	0	0	1	1	1	1	1	1	0[a]	1	0[a]	0[a]	1	0[a]	0[a]	1	1	0	1	18—M
Carroll et al. [37]	1	1	1	1	0	1	1	0	1	0	0	0	1	0[a]	0[a]	1	1	1	0[a]	1	0[a]	0[a]	1	0[a]	0[a]	1	1	0	1	16—G
DiFrancisco-Donoghue et al. [38]	1	1	1	1	0	1	1	1	1	1	0[a]	0[a]	1	0[a]	0[a]	1	1	1	0[a]	1	1	0[a]	1	0	0	1	1	0	0[a]	18—M
Faigenbaum et al. [39]	1	1	1	1	1	1	1	1	1	1	0[a]	0[a]	1	0[a]	0[a]	1	1	1	1	1	0[a]	0[a]	0	0	0	1	1	1	1	20—M
Fernández-Lezaun et al. [15]	1	1	1	1	0	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	0[a]	1	0[a]	0	1	1	1	1	22—G
Ferrari et al. [32]	1	1	1	1	0	1	1	0[a]	1	0	0[a]	0[a]	1	0	1	1	1	1	1	1	0[a]	0[a]	1	0[a]	0	1	1	1	1	19—M
Fisher et al. [33]	1	1	1	1	0	1	1	0	1	1	0[a]	0[a]	1	0[a]	0[a]	1	0	1	1	1	0[a]	0[a]	1	0[a]	0	1	1	1	1	18—M
Gentil et al. [16]	1	1	1	1	0	1	1	0	1	0	1	0[a]	1	0[a]	0[a]	1	1	1	1	1	1	0[a]	1	0[a]	0	1	1	1	1	20—M
Gregory [40]	0	1	1	1	0	1	1	0	0	0	1	1	1	0[a]	0[a]	1	1	1	0	1	1	0[a]	0	0	0	1	1	0	0[a]	15—M
Hunter [35]	1	1	1	1	0	1	1	0	1	0	0[a]	0[a]	1	0[a]	0[a]	1	1	1	0[a]	1	1	0[a]	0	0	0	1	1	0	1	16—M
Lera Orsatti et al. [17]	1	1	1	1	1	1	1	0	1	0	0[a]	0[a]	1	0[a]	0[a]	1	1	1	0[a]	1	0[a]	0[a]	0	0	0	1	1	0	1	16—M
McKenzie Gillam [41]	1	1	0	1	0	1	1	1	1	0	1	0[a]	1	0[a]	0[a]	1	1	1	0[a]	1	1	1	1	0[a]	1	1	1	0	1	20—M
McLester et al. [11]	1	1	1	1	0	1	1	0	1	0	0[a]	0[a]	1	0[a]	0[a]	1	1	1	0[a]	1	0[a]	0[a]	1	0[a]	0	1	1	0	0[a]	15—M
Murlasits et al. [18]	1	1	1	1	0	1	1	1	1	1	0[a]	0[a]	1	0[a]	0[a]	1	1	1	1	1	0[a]	0[a]	1	0[a]	0	1	1	1	1	20—M
Padilha et al. [19]	1	1	1	1	0	1	1	0	1	0	0[a]	0[a]	1	0[a]	0[a]	1	1	1	1	1	0	0[a]	1	0[a]	0	1	1	1	1	18—M
Schoenfeld et al. [12]	1	1	1	1	1	1	1	0	1	1	0[a]	0[a]	1	0[a]	0[a]	1	1	1	1	1	1	0[a]	1	0[a]	1	0	1	1	1	21—G
Silva et al. [20]	1	1	1	1	0	1	1	0	1	1	0[a]	0[a]	1	0[a]	0[a]	1	1	1	1	1	0[a]	0[a]	0	0	0	1	1	1	1	18—M
Taaffe et al. [42]	1	1	1	1	0	1	1	1	1	0	0[a]	0[a]	1	0[a]	0[a]	1	1	1	1	1	0	0[a]	1	0[a]	0	1	1	1	1	19—M
Thomas and Burns [13]	1	1	1	1	0	1	1	0	0	0	0[a]	0[a]	1	0[a]	0[a]	1	1	1	0[a]	1	0[a]	0[a]	0	0	0	0[a]	1	0	1	13—M

1 criteria met, *0* criteria not met, scored 0, *G* good methodological quality, *M* moderate methodological quality

[a] Item was unable to be determined

3.4.1 Training Volume

The subgroup analysis of volume-equated studies comprised 42 ESs from 16 treatment groups from 7 studies and did not show a significant effect of training frequency ($p = 0.421$).

3.4.2 Multi-joint and Single-Joint Exercises

The subgroup analysis of multi-joint exercises comprised 94 ESs from 45 treatment groups from 19 studies. ES gradually increased in magnitude with each additional training day per week, with a significant overall effect of training frequency ($p < 0.001$). The subgroup analysis of single-joint exercises comprised 60 ESs from 19 treatment groups from 8 studies and did not show a significant effect of training frequency ($p = 0.324$).

3.4.3 Upper and Lower Body Strength Gains

The subgroup analysis of studies assessing upper body strength comprised 86 ESs from 43 treatment groups from 17 studies. ES gradually increased in magnitude with each additional training day per week, with a significant overall effect of training frequency ($p = 0.004$). The subgroup analysis of studies assessing lower body strength comprised 68 ESs from 40 treatment groups from 17 studies. ES gradually increased in magnitude with each additional day per week, but the effect was not significant ($p = 0.070$).

3.4.4 Muscular Failure

The subgroup analysis of studies involving training to muscular failure comprised 90 ESs from 32 treatment groups from 14 studies. ESs across the included studies gradually increased in magnitude with each additional training day per week, but the linear trend was not significant ($p = 0.078$). The subgroup analysis of studies not involving training to muscular failure comprised 66 ESs from 17 treatment groups from 7 studies. No significant effect of training frequency was found ($p = 0.160$).

3.4.5 Age Groups

The subgroup analysis of middle-aged and older adults comprised 95 ESs from 24 treatment groups from 10 studies. ESs across the included studies gradually increased in magnitude with each additional training day per week, but the linear trend was not significant ($p = 0.093$). The subgroup analysis of young adults comprised 53 ESs from 21 treatment groups from 9 studies. ES gradually increased

Table 3 Meta-analysis results

Frequency (times/week)	ES (mean ± standard error of the mean)	95% CI	*p* value
All studies			
1	0.74 ± 0.13	0.48–1.01	0.003
2	0.82 ± 0.13	0.55–1.09	
3	0.93 ± 0.13	0.65–1.21	
4+	1.08 ± 0.16	0.74–1.42	
Volume-equated studies			
1	0.53 ± 0.13	0.13–0.93	0.421
2	0.80 ± 0.33	−0.25 to 1.86	
3	0.64 ± 0.14	0.21–1.07	
4+	0.58 ± 0.04	0.45–0.72	
Multi-joint exercises			
1	0.67 ± 0.13	0.39–0.95	< 0.001
2	0.79 ± 0.15	0.47–1.11	
3	0.94 ± 0.15	0.61–1.26	
4+	1.07 ± 0.16	0.73–1.42	
Single-joint exercises			
1	0.89 ± 0.13	0.55–1.23	0.324
2	0.97 ± 0.12	0.67–1.27	
3	0.99 ± 0.10	0.73–1.25	
Upper body strength			
1	0.70 ± 0.13	0.42–0.98	0.004
2	0.77 ± 0.13	0.48–1.05	
3	0.92 ± 0.17	0.56–1.28	
4+	1.06 ± 0.17	0.68–1.43	
Lower body strength			
1	0.81 ± 0.16	0.46–1.15	0.070
2	0.93 ± 0.18	0.55–1.32	
3	0.97 ± 0.14	0.66–1.28	
Training to muscular failure			
1	0.58 ± 0.07	0.42–0.74	0.078
2	0.69 ± 0.06	0.55–0.82	
3	0.81 ± 0.10	0.59–1.03	
4+	0.90 ± 0.23	0.38–1.41	
Not training to muscular failure			
1	1.06 ± 0.36	0.06–2.06	0.160
2	1.14 ± 0.35	0.16–2.11	
3	1.19 ± 0.37	0.17–2.22	
Middle-aged and older adults			
1	0.76 ± 0.12	0.47–1.05	0.093
2	0.86 ± 0.11	0.60–1.11	
3	0.91 ± 0.12	0.64–1.19	
Young adults			
1	0.80 ± 0.30	0.03–1.56	0.024
2	0.83 ± 0.34	−0.04 to 1.70	
3	0.99 ± 0.32	0.16–1.82	
4+	1.15 ± 0.32	0.34–1.97	

Table 3 continued

Frequency (times/week)	ES (mean ± standard error of the mean)	95% CI	*p* value
Men			
1	0.45 ± 0.13	0.02–0.87	0.190
2	0.67 ± 0.14	0.21–1.12	
3	0.81 ± 0.20	0.19–1.43	
4+	0.92 ± 0.31	−0.06 to 1.90	
Women			
1	1.03 ± 0.33	0.10–1.96	0.030
2	1.11 ± 0.34	0.17–2.06	
3	1.22 ± 0.34	0.26–2.17	
4+	1.62 ± 0.24	0.95–2.28	

ES effect size, *CI* confidence interval

in magnitude with each additional training day per week, with a significant overall effect of training frequency ($p = 0.024$).

3.4.6 Sex

The subgroup analysis of studies involving men comprised 30 ESs from 17 treatment groups from 7 studies. ES gradually increased in magnitude with each additional training day per week, but the effect was not significant ($p = 0.190$). The subgroup analysis of studies involving women comprised 54 ESs from 19 treatment groups from 8 studies. ES gradually increased in magnitude with each additional training day per week, with a significant overall effect of training frequency ($p = 0.030$). The estimate for 4+ times/week should be interpreted with caution as the analysis included only one ES from one study [35] with this training frequency.

4 Discussion

The present paper is the first systematic review of studies comparing different RT frequencies and their effects on muscular strength gains. Based on the current evidence, the main results of this review suggest that there is a dose-response relationship between RT frequency and muscular strength gains; however, when volume is equated, we found no significant effect. Therefore, it remains unclear whether RT frequency on its own has significant effects on muscular strength gains. Still, several important practical and clinical implications need to be discussed.

A recent review suggested that there is a graded dose–response relationship between RT volume and muscular strength adaptations [6]. Therefore, not equating the training volume in studies that are comparing the effects of RT frequency on muscular strength gains might be misguided. Under such study designs, it cannot be inferred if the effects of higher RT frequency are attributable to the RT frequency itself or are a result of greater RT volume associated with more weekly RT sessions. The subgroup analysis of volume-equated studies did not show a significant effect of RT frequency on changes in muscular strength as the ESs were similar across training conditions. Therefore, it can be assumed that the higher muscular strength gains associated with higher RT frequencies are observed largely because of the additional training volume. However, even under volume-equated conditions, it seems reasonable that undertaking too much training volume in a given RT session would be suboptimal due to the accumulation of fatigue that would ultimately impair performance [43]. Higher RT frequencies allow a distribution of training volume throughout the week while keeping the performance on each RT session high, which may translate into greater gains in muscular strength. Nonetheless, future research using volume-equated study designs is warranted to elucidate the topic of RT frequency and muscular strength gains.

While the current body of evidence suggests that RT volume is a contributing factor to increasing muscular strength [6], it is relevant to emphasize that simply testing the 1RM can lead to substantial increases in muscular strength [44]. Recently, Mattocks et al. [45] reported that practicing the muscular strength test can lead to equivalent gains in strength compared with traditional high-volume RT. Such gains in muscular strength, without any evident muscle hypertrophy, suggest that the increases could be governed by the principle of specificity [46, 47]. Interestingly, our subgroup analysis for exercise selection for the 1RM test suggests a significant effect of RT frequency for multi-joint, but not for single-joint, exercises. These findings might be explained from a motor learning standpoint. Specifically, more complex RT exercises, such as multi-joint movements, require a precise timing of muscle recruitment and coordination and a higher degree of motor proficiency [1]. Thus, higher RT frequency would allow more opportunities for ‘practicing’ the test/exercise, which can result in a better performance on that test. From a practical standpoint, it is also important to highlight that several acute studies reported that the recovery rates might differ between multi-joint and single-joint exercises [48, 49]. Specifically, when comparing unilateral seated row exercise (i.e. a multi-joint exercise) with a unilateral biceps preacher curl exercise (i.e. a single-joint exercise), Soares and colleagues [49] reported that the latter induced greater decreases in isometric peak torque and increases in delayed-onset muscle soreness. Therefore, exercise selection effects might also dictate RT frequency prescription.

The results of the subgroup analyses for upper and lower body strength gains showed that there is a significant effect of training frequency for the upper, but not lower, body. Differences between the upper and lower body neuromuscular adaptations following RT have been previously noted in the literature [50]. For example, following an 8-week RT intervention, Housh et al. [51] reported greater gains in upper body strength than in lower body strength. Others did not find significant differences in strength gains between upper and lower body muscle groups [52]. While our review found a benefit of a higher RT frequency for upper, but not lower, body strength, from a practical perspective, possible individual variations also need to be taken into account. As noted by Gentil [53], some individuals can experience decreases in upper body strength with large increases in lower body strength, and vice versa. One muscle group might experience strength gain with one training frequency, while another muscle group might be more susceptible to different stimuli. Therefore, there is an evident need for individualization when designing training programs for strength gains.

Regarding training to muscular failure, a recent meta-analysis suggested that similar muscular strength gains can be achieved with failure and non-failure RT [54]. Both subgroup analyses for studies in which the training was carried out to muscular failure and in which sets were stopped short of failure indicated no significant effect of RT frequency. However, from a practical standpoint, it should be acknowledged that acute studies indicate that training to muscular failure significantly impacts the recovery of neuromuscular function and metabolic and hormonal homeostasis [55]. For example, Morán-Navarro et al. [55] reported that the time course of recovery is prolonged when RT is performed to muscular failure. By contrast, even when matched for total training volume, avoiding muscular failure allowed faster recovery, which might enable training with higher RT frequency [55]. Ferreira et al. [56] reported that after performing eight sets of bench press to muscular failure, pectoralis major peak torque remained lower than baseline for 72 h, suggesting a presence of muscle damage.

As the decline in muscular strength that is associated with aging (i.e. dynapenia) is related to a plethora of adverse effects, older adults are especially encouraged to regularly participate in RT [57]. A recent meta-regression suggested that older adults should engage in two RT sessions per week for the most efficient muscular strength results [58]. However, the meta-regression was not explicitly designed to evaluate RT frequency as other RT variables were not held constant in the included studies, thus precluding more definite conclusions. To answer the question about the effects of RT frequency on muscular strength gains among older adults, we conducted a subgroup analysis of studies that included middle-aged and older adults. In line with the primary findings, this subgroup analysis also did not show a significant effect of RT frequency on muscular strength gains. Currently, there are no studies comparing training frequencies of more than 3 days per week in this population. While future studies might consider exploring higher training frequencies, from a practical standpoint it is not likely to expect long-term adherence to a high training frequency RT program in this age group as population-based studies report meager participation rates of older adults in RT [59]. Indeed, several studies have shown that training a muscle group as infrequent as once per week can lead to strength gains, hypertrophy, and enhanced components of functionality among older adults [60, 61]. The subgroup analysis for young adults suggested that they may respond better to higher training frequencies. These findings might be explained by the difference in recovery rates between older and young adults. Roth et al. [62] showed that older women, in comparison to young women, exhibit higher levels of muscle damage after RT, which can lead to prolonged recovery duration. Therefore, it can be hypothesized that due to the differences in recovery rates between the age groups, young adults potentially respond more positively to higher training frequencies, which, in turn, translates to greater gains in muscular strength with higher training frequencies.

A study by Flores et al. [63] showed that following an RT session, men recovered faster than women. Based on this difference in recovery rates between sexes, it could be suggested that men would respond better to higher RT frequencies. However, our subgroup analysis performed for sexes indicated a significant effect of RT frequency in women but not in men. It should be noted that both analyses were limited to a small number of studies as there were only seven studies for men and eight for women. Besides, three of the seven studies included for men used a volume-equated design, while only two of the eight studies for women used a volume-equated design, which might partly explain the observed discrepancy. Several studies did include a mixed-sex sample; however, in most such studies, only pooled results (for both sexes together) were presented. Future studies that include both men and women might consider plotting the results separately for men and women in order to examine potential differences in ESs between sexes.

Unfortunately, there are currently only three studies performed in trained individuals that investigated the effects of RT frequency on muscular strength gains [11–13], all of which compared training once a week versus three times a week and used a volume-equated design. McLester et al. [11] reported that 1RM strength gains in leg press were greater for the group training three times a week compared with the group training once a week; however, no significant between-group differences were found for the remaining three lower body and five upper body 1RM tests. The studies by Schoenfeld et al. [12] and Thomas and Burns [13] support these findings as they showed that training either once or three times a week elicits similar improvement in both upper and lower body muscular strength. While these results would suggest that RT frequency might not be of great importance in trained individuals, the limited data makes such conclusions premature. The relatively short duration of these studies further limits the ability to draw inferences, with the longest study lasting 12 weeks. An unpublished 15-week intervention among 16 Norwegian powerlifters, known as the Norwegian Frequency Project, showed that under volume-equated conditions, RT six times per week in comparison with RT three times per week produced significantly greater gains in squat and bench press 1RM [64]. These findings suggest that greater RT frequency as a method of progressive overload might be warranted for individuals approaching their genetic potential; however, the results of that paper remain to be published and scrutinized.

4.1 Methodological Quality and Future Research Questions

Based on the methodological quality scores, we can conclude that the results obtained in this review were not influenced by poor methodological study designs as all studies were classified as being of good or moderate methodological quality. Nonetheless, several limitations were noted in the literature. Only 32% of the included studies reported important adverse events that occurred as a consequence of the intervention. The remaining studies failed to document injury data, and therefore the safety of higher versus lower frequency protocols in these studies remains uncertain. Eleven of the 22 included studies reported adherence to the training programs. The RT interventions were supervised in 19 studies, while for the remaining three studies, this item was marked as 'unable to determine.' Therefore, based on these limitations, future studies should ensure that (1) adverse events are tracked and reported; (2) adherence rates for all groups are presented; and (3) all RT programs are supervised as supervision can result in greater strength gains compared with unsupervised training [65–67].

There is a paucity of studies applying high RT frequencies, such as five or six training days per week, thereby opening an avenue for future research. As per the paper by Dankel et al. [68], it would be interesting for future studies to compare two groups that are using vastly different training frequencies, (1 versus 6 days per week) while equating RT volume. Dankel et al. [68] also stated that frequency is a method of increasing weekly RT volume. Therefore, it would also be interesting to assess different frequencies of training with higher and lower volumes. As muscular strength responses to regimented RT can vary substantially between individuals [69], it would be desirable for future studies to plot the individual responses to different RT frequencies. Because of the interindividual variability, future studies might consider employing a crossover design, which would allow for each participant to act as their control and thus minimize the possible differences that might occur due to genetic variation, sleep, nutritional intake, and other confounding factors.

4.2 Limitations of this Review

The most apparent limitation of the current review is the small number of studies that included trained participants. This lack of empirical evidence limits the generalizability of the findings to trained individuals. Furthermore, the designs across the included studies were heterogeneous. We tried to alleviate this issue by employing a random-effects model [70] and performing several different subgroup analyses. Nevertheless, the results should still be interpreted with caution. Overall, more homogenous research is needed to answer the question about the effects of RT frequency on gains in muscular strength.

5 Conclusions

The results of the present systematic review and meta-analysis suggest a significant effect of RT frequency on muscular strength gain, with higher RT frequencies resulting in more strength gains. However, these effects seem to be primarily driven by training volume because when volume is equated, there was no significant effect of RT frequency on muscular strength gains. Therefore, from a practical standpoint, greater training frequencies might be used as a means of increasing total training volume, which may impact muscular strength accrual. However, it remains unclear whether RT frequency on its own has a significant effect on muscular strength gains. In addition, it seems that higher training frequencies result in greater strength gains for multi-joint exercises in the upper body, among young adults, and in women, findings that should be considered in RT program design. Finally, trained individuals are more likely to use greater RT frequencies in their routines, and thus future research among this population is needed to draw more generalizable conclusions.

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Compliance with Ethical Standards

Conflict of interest Jozo Grgic, Brad J. Schoenfeld, Timothy B. Davies, Bruno Lazinica, James W. Krieger and Zeljko Pedisic declare that they have no conflicts of interest relevant to the content of this review.

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