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PHYSICAL ACTIVITY, HEALTH AND EXERCISE

How many times per week should a muscle be trained to maximize muscle hypertrophy? A systematic review and meta-analysis of studies examining the effects of resistance training frequency

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ABSTRACT

Training frequency is considered an important variable in the hypertrophic response to regimented resistance exercise. The purpose of this paper was to conduct a systematic review and meta-analysis of experimental studies designed to investigate the effects of weekly training frequency on hypertrophic adaptations. Following a systematic search of PubMed/MEDLINE, Scoups, and SPORTDiscus databases, a total of 25 studies were deemed to meet inclusion criteria. Results showed no significant difference between higher and lower frequency on a volume-equated basis. Moreover, no significant differences were seen between frequencies of training across all categories when taking into account direct measures of growth, in those considered resistance-trained, and when segmenting into training for the upper body and lower body. Meta-regression analysis of non-volume-equated studies showed a significant effect favoring higher frequencies, although the overall difference in magnitude of effect between frequencies of 1 and 3+ days per week was modest. In conclusion, there is strong evidence that resistance training frequency does not significantly or meaningfully impact muscle hypertrophy when volume is equated. Thus, for a given training volume, individuals can choose a weekly frequency per muscle groups based on personal preference.

ARTICLE HISTORY
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KEYWORDS
Exercise frequency; hypertrophy; resistance training; dose-response

Introduction

Training frequency is considered an important variable in the hypertrophic response to regimented resistance exercise (Dankel et al., 2017). Although frequency is often thought to pertain to the total number of weekly resistance training sessions, perhaps even more important from a hypertrophic standpoint is the number of times that a given muscle group is trained per week. To this end, a recent survey of 127 competitive bodybuilders found that ~69% of respondents trained each muscle once per week; none reported training muscle groups more than twice per week (Hackett, Johnson, & Chow, 2013). While these data provide interesting insights into how bodybuilders train for augmenting muscle growth, these training practices are likely based on tradition and personal intuition as opposed to scientific evidence.

Recently, it has been proposed that training muscle groups very frequently – up to 6 days a week – with a reduced volume per session may provide a superior anabolic stimulus as compared to less frequent training with higher per-session volumes (Dankel et al., 2017). This hypothesis is based on evidence that the time course of muscle protein synthesis (MPS) is attenuated as an individual gains resistance training experience (Damas, Phillips, Vechin, & Ugrinowitsch, 2015). Combined with the supposition that a threshold exists for the amount of volume that can be performed in a session to stimulate growth (Dankel et al., 2017), the authors speculated that spreading out training volume over the course of a week would optimize the MPS area under the curve and thus enhance muscle protein accretion over time.

The literature to date does not provide clear guidelines as to optimal frequency for muscle hypertrophy. The 2009 American College of Sports Medicine (ACSM) position stand on progression models in resistance training for healthy adults recommends that novice lifters train 2–3 days/week, intermediates 2–4 days/week, and advanced trainees 4–6 days/week when the desired goal is muscular hypertrophy (American College of Sports Medicine, 2009). However, these recommendations are specific to the total number of sessions per week, not the frequency of training a given muscle group, thereby limiting implications to program design. The only recommendation from the ACSM position stand in this regard was for individuals to employ split routines when training with higher weekly frequencies, thereby allowing at least 48 hours of recovery between training the same muscle group.

In an effort to provide clarity on the topic, (Schoenfeld, Ogborn, & Krieger, 2016b) carried out a meta-analysis on the effects of resistance training frequency on muscle hypertrophy. The authors also conducted a subgroup analysis of studies that varied the number of times a muscle group was worked on a weekly basis. The analysis found that training a muscle group twice per week results in a greater increase in muscle size as compared to training a muscle group only once per week. However, only 7 studies met the inclusion criteria of

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the review for weekly frequency per muscle group at that time, thereby precluding the determination as to whether a benefit exists to training muscles more than twice per week. The meta-analysis was further limited by the inclusion of quasi-experimental studies (i.e., no random allocation to the training groups), which may have lowered the internal validity of the included studies and thus confounded the pooled findings.

Since publication of Schoenfeld et al.'s review (Schoenfeld et al., 2016b), numerous additional studies have been published on the topic exploring a variety of different resistance training frequencies, including several that have investigated the hypertrophic effects of very high training frequencies (4 + sessions per week per muscle group). Given the large amount of data currently available, the purpose of this paper was to conduct a systematic review and meta-analysis of experimental studies designed to investigate the effects of weekly training frequency on hypertrophic adaptations.

Methods

Inclusion criteria

Studies were deemed eligible for inclusion if they met the following criteria: (1) were an experimental trial published in an English-language refereed journal; (2) the participants were randomized to the training groups; (3) directly compared training muscle groups with different weekly resistance training frequencies using traditional dynamic exercise using coupled concentric and eccentric actions; (4) measured muscle hypertrophy or changes in lean body mass (LBM); (5) had a minimum duration of 6 weeks; (6) did not involve any structured exercise other than resistance training; and, (6) included adults (18 years of age and older) free from chronic disease or injury.

Search strategy

A systematic literature search was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009). To carry out this review, English-language literature searches of PubMed/MEDLINE, SCOPUS, and SPORTDiscus databases were conducted from all time points up until August, 2018. The following syntax was used for the search process: ("frequency" OR "frequencies") AND ("resistance training" OR "resistance exercise" OR "strength exercise" OR "strength training" OR "weight training" OR "weight exercise") AND ("hypertrophy" OR "body composition" OR "muscle size" OR "muscle thickness" OR "cross-sectional area" OR "growth" OR "muscle fiber" OR "muscle fiber" OR "lean body mass" OR "muscle mass" OR "lean tissue" OR "biopsy" OR "fat-free mass" OR "fat free mass"). The search syntax was combined with Boolean operators and the quotation marks were used for phrase searching (i.e., combinations of two or more words). The reference lists of articles retrieved were subsequently screened as a part of a secondary search to uncover any additional articles that met inclusion criteria (Greenhalgh & Peacock, 2005).

A total of 972 studies were evaluated based on search criteria. In an effort to reduce selection bias, each study was independently reviewed by two of the investigators (JG and BJS), and the investigators mutually determined whether or not they met basic inclusion criteria. If a consensus could not be reached on inclusion for a given study, the matter was settled by consultation with the third investigator (JK). Of the abstracts initially reviewed, 38 studies were deemed potentially relevant to the topic. The full-text of these articles were then perused and 16 studies were excluded as they did not meet the inclusion criteria. One additional study was identified through perusal of the reference lists of papers on the topic, and two others were found through a search of the authors' personal library. Thus, the final number of studies included for analysis was 25 (Figure 1). Table 1 summarizes the studies analyzed.

Coding of studies

Studies were read and individually coded by two of the investigators (BJS and JG) for the following variables: descriptive information of subjects by group including sex, training status (trained subjects were defined as those with at least one year regular resistance training experience), age (classified as either young [18–39 years], middle-aged [40–64 years] or older adults [65+ years]); the number of subjects in each group; duration of the study; frequency of training each muscle group (days per week); whether volume was equated between groups (sets x reps); exercise selection (single-joint, multi-joint, or combination); number of sets per exercise; type of morphologic measurement (magnetic resonance imaging [MRI], computerized tomography [CT], B-mode ultrasound, biopsy, A-mode ultrasound, skinfolds, bioelectrical impedance analysis [BIA], dual-energy x-ray absorptiometry [DXA], and/or air displacement plethysmography [ADP]); site of measurement; and, region/muscle of body measured (upper, lower, or both). Coding was cross-checked between reviewers, with any discrepancies resolved by mutual consensus. As per the guidelines of (Cooper, Hedges, & Valentine, 2009), 30% of the included studies were randomly selected for recoding to assess for potential coder drift. Agreement was calculated by dividing the number of variables coded the same by the total number of variables; acceptance required a mean agreement of 0.90.

Statistical analyses

For each hypertrophy outcome, an effect size (ES) was calculated as the pretest-posttest change, divided by the pooled pretest standard deviation (SD) (Morris, 2008). A percentage change from pretest to posttest was calculated as well. A small sample bias adjustment was applied to each ES (Morris, 2008). A group-level ES was calculated for each outcome in each study by subtracting the ES for the lower frequency group from the ES for the higher frequency group within that particular study. A study-level ES was calculated as the average of the group-level ES within each study. The sampling variance around each ES was calculated using the sample size in each study (Borenstein, Hedges, & Higgins, 2009).

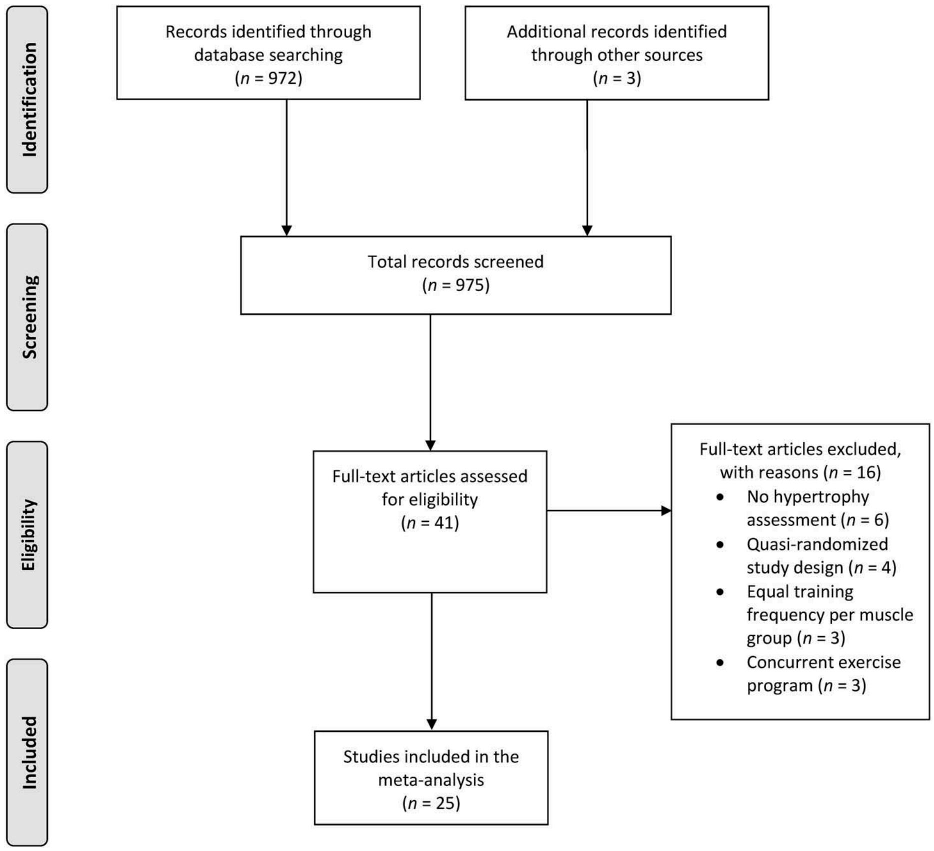

Figure 1. Flow diagram of search process.

Meta-analyses were performed using robust variance random-effects modeling for multilevel data structures, with adjustments for small samples using package robumeta in R (Hedges, Tipton, & Johnson, 2010; Tipton, 2015). Study was used as the clustering variable to account for correlated group effects within studies. Observations were weighted by the inverse of the sampling variance. The primary meta-analysis was performed on all volume-equated studies. Additional meta-analyses were performed on the following subgroups: (i) volume-equated studies using direct measurements of hypertrophy, (ii) volume-equated studies using direct measurements of hypertrophy on upper-body muscle groups, (iii) volume-equated studies using direct measurements of hypertrophy on lower-body muscle groups, (iv) volume-equated studies using indirect measurements of hypertrophy, (v) volume-equated studies on trained subjects, and (vi) volume-equated studies on untrained subjects. For each meta-analysis, an additional Bayesian random-effects meta-analysis with vague priors was performed using package bmeta in R.

To assess the effects of individual training frequencies, random-effects meta-regression for multilevel data structures, using study as the clustering variable, was performed on all volume-equated studies using package metafor in R. Moderators included frequency (1, 2, 3, or 4–6 d/wk), duration (weeks), and measurement method (direct or indirect). A separate regression was performed with only frequency as the moderator. A meta-regression was also performed on all non-volume-equated studies, with frequency (1, 2, or 3+ d/wk), duration (weeks), and measurement method (direct or indirect) as moderators. A separate analysis was performed with only frequency as the moderator. Heterogeneity was assessed using the I^2 statistic with I^2 values of <50% suggesting low heterogeneity, 50–75% moderate heterogeneity, and >75% high level of heterogeneity.

All analyses were performed in R version 3.5 (The R Foundation for Statistical Computing, Vienna, Austria). Effects were considered significant at $P \leq 0.05$. Data are reported as ± standard error of the means (SEM) and 95% confidence interval (CI) unless otherwise specified.

Results

Meta-analysis of volume-equated studies

The analysis of volume-equated studies comprised 29 outcomes from 13 studies. There was no significant difference between higher and lower frequency on a volume-equated basis (ES difference = 0.07 ± 0.04; CI: −0.02, 0.17; P = 0.11; Figure 2(a)). The percentage point difference was 1.2 ± 0.7 (CI: −0.33, 2.7). Heterogeneity was low (I^2 = 0). Bayesian meta-analysis resulted in a similar estimate of ES difference (0.07; 95% credible interval: −0.09, 0.24). Posterior distribution was consistent with a trivial effect of higher frequency vs. lower frequency (Figure 2(b)).

Meta-analysis of volume-equated studies using direct measurements of hypertrophy

The analysis of volume-equated studies using direct measurements of hypertrophy comprised 24 outcomes from 9

Table 1. Summary of the studies found meeting the inclusion criteria.

Study	Sample	Training frequency comparison	Exercise prescription	Volume equated?	Duration of intervention	Hypertrophy assessment (site)	Main findings
Barcelos et al. (2018)	Young untrained men (n = 20)	2 vs. 3 vs. 5	3 sets of 9–12 repetitions performed to concentric failure	No	8 weeks	Ultrasound (vastus lateralis)	Muscle thickness RT 2: ↑ Muscle thickness RT 3: ↑ Muscle thickness RT 5: ↑
Brigatto et al. (2018)	Young trained men (n = 20)	1 vs. 2	4 or 8 sets of 8–12 repetitions performed to concentric failure	Yes	8 weeks	Ultrasound (elbow flexors, elbow extensors, vastus lateralis, and anterior quadriceps)	Muscle thickness RT 1: ↑ Muscle thickness RT 2: ↑
Candow and Burke (2007)	Young and middle-aged untrained women (n = 23) and men (n = 6)	2 vs. 3	2 or 3 sets of 10 repetitions performed to concentric failure	Yes	6 weeks	DXA	LBM RT 2: ↑ LBM RT 3: ↑
Carneiro et al. (2015)	Untrained older women (n = 53)	2 vs. 3	1 set of 10–15 repetitions performed to concentric failure	No	12 weeks	DXA	LBM RT 2: ↑ LBM RT 3: ↑
Cavalcante et al. (2018)	Untrained older women (n = 38)	2 vs. 3	1 set of 10–15 repetitions performed to concentric failure	No	12 weeks	DXA	LBM RT 2: ↑ LBM RT 3: ↑
Colquhoun et al. (2018)	Young trained men (n = 28)	3 vs. 6	2 or 4 sets of 3–8 repetitions performed to concentric failure	Yes	6 weeks	Ultrasound (LBM)	LBM RT 3: ↑ LBM RT 6: ↑
Fernandez-Lezaun, Schumann, Makinen, Kyrolainen, and Walker (2017)	Untrained older men (n = 29) and women (n = 39)	1 vs. 2 vs. 3	2–4 sets of 4–20 repetitions	No	24 weeks	DXA	LBM RT 1: ↔ LBM RT 2: ↔ LBM RT 3: ↔
Gentil, Fischer, Martorelli, Lima, and Bottaro (2015)	Young untrained men (n = 30)	1 vs. 2	3 sets of 8–12 repetitions to concentric failure	Yes	10 weeks	Ultrasound (elbow flexors)	Muscle thickness RT 1: ↑ Muscle thickness RT 2: ↑
Gentil et al. (2018)	Young trained men (n = 16)	1 vs. 2	3 sets of 8–12 repetitions to concentric failure	Yes	10 weeks	Ultrasound (elbow flexors)	Muscle thickness RT 1: ↑ Muscle thickness RT 2: ↔
Gomes, Franco, Nunes, and Orsatti (2018)	Young trained men (n = 23)	1 vs. 5	1–10 sets of 8–12 repetitions performed to concentric failure	Yes	8 weeks	DXA	LBM RT 1: ↑ LBM RT 5: ↑
McLester, Bishop, and Guilliams (2000)	Young trained men (n = 12) and women (n = 6)	1 vs. 3	1 or 3 sets of 8–10 repetitions performed to concentric failure	Yes	12 weeks	Skinfolds	LBM RT 1: ↔ LBM RT 3: ↔
Murlasits, Reed, and Wells (2012)	Untrained older men (n = 9) and women (n = 15)	2 vs. 3	3 sets of 8 repetitions performed to concentric failure	No	8 weeks	DXA	LBM RT 2: ↑ LBM RT 3: ↑.
Nascimento et al. (2018)	Untrained older women (n = 45)	2 vs. 3	1 set of 10–15 repetitions performed to concentric failure	No	12 weeks	DXA	LBM RT 2: ↑ LBM RT 3: ↑
Ochi et al. (2018)	Young untrained men (n = 20)	1 vs. 3	2 or 6 sets of 12 repetitions not performed to concentric failure	Yes	11 weeks	Ultrasound (vastus lateralis, rectus femoris, vastus medialis, vastus intermedius)	Muscle thickness RT 1: ↑ Muscle thickness RT 3: ↑
Ribeiro et al. (2017)	Untrained older women (n = 39)	2 vs. 3	1 set of 10–15 repetitions performed to concentric failure	No	12 weeks	BIA	LBM RT 2: ↑ LBM RT 3: ↑
Richardson, Duncan, Jimenez, Juris, and Clarke (2018)	Untrained older men (n = 20) and women (n = 20)	1 vs. 2 (high-velocity, low-load or low-velocity, high-load)	3 sets of 7 or 14 repetitions not performed to concentric failure	No	10 weeks	BIA	LBM RT 1 (high-velocity, low-load): ↔ LBM RT 2 (high-velocity, low-load): ↓ LBM RT 1 (low-velocity, high-load): ↔ LBM RT 2 (low-velocity, high-load): ↔

(Continued)

Table 1. (Continued).

Study	Sample	Training frequency comparison	Exercise prescription	Volume equated?	Duration of intervention	Hypertrophy assessment (site)	Main findings
Saric et al. (2018)	Young trained men (*n* = 27)	3 vs. 6	2 or 4 sets of 6–12 repetitions performed to concentric failure	Yes	6 weeks	Ultrasound (elbow flexors, elbow extensors, rectus femoris, and vastus intermedius)	Muscle thickness (elbow extensors, rectus femoris, and vastus intermedius) RT3: ↑ Muscle thickness (elbow extensors, rectus femoris, and vastus intermedius) RT6: ↑ Muscle thickness (elbow flexors) RT3: ↑ Muscle thickness (elbow flexors) RT6: ↔
Schoenfeld, Ratamess, Peterson, Contreras, and Tiryaki-Sonmez (2015)	Young trained men (*n* = 19)	1 vs. 3 for lower-body and 2 vs. 3 for upper-body	2 or 3 sets of 8–12 repetitions performed to concentric failure	Yes	8 weeks	Ultrasound (elbow flexors, elbow extensors, and vastus lateralis)	Muscle thickness RT 1: ↑ Muscle thickness RT 3: ↑ Significantly greater increases in muscle thickness of the elbow flexors in the group training 3 times per week
Serra et al. (2018)	Untrained young men (*n* = 43) and women (*n* = 31)	2 vs. 3 vs. 4	3 sets of 10–12 repetitions performed to concentric failure	No	12 weeks	Skinfolds	LBM RT 2: ↔ LBM RT 3: ↔ LBM RT 4: ↔
Stec et al. (2017)	Untrained older men and women (*n* = 29)	2 vs. 3	3 sets of 8–12 repetitions performed to concentric failure	No	30 weeks	DXA and biopsies (vastus lateralis)	Type I CSA RT 2: ↔ Type I CSA RT 3: ↔ Type II CSA RT 2: ↑ Type II CSA RT 3: ↑ LBM RT 2: ↑ LBM CSA RT 3: ↑
Taaffe, Duret, Wheeler, and Marcus (1999)	Untrained older men (*n* = 29) and women (*n* = 17)	1 vs. 2 vs. 3	3 sets with 80% 1RM not performed to concentric failure	No	24 weeks	DXA	LBM RT 1: ↑ LBM RT 2: ↑ LBM RT 3: ↑
Tavares et al. (2017)	Young trained men (*n* = 22)	1 vs. 2	2 or 4 sets of 6–8 repetitions performed to concentric failure	Yes	8 weeks	MRI (quadriceps)	CSA RT 1: ↔ CSA RT 2: ↔
Turpela, Hakkinen, Haff, and Walker (2017)	Older untrained men (*n* = 31) and women (*n* = 41)	1 vs. 2 vs. 3	2–5 sets of 4–12 repetitions with at least one set performed to concentric failure	No	24 weeks	DXA; ultrasound (quadriceps)	LBM RT 1: ↔ LBM RT 2: ↔ LBM RT 3: ↔ CSA RT 1: ↔ CSA RT 2: ↔ CSA RT 3: ↔
Yue, Karsten, Larumbe-Zabala, Seijo, and Naclerio (2018)	Young trained men (*n* = 18)	1 vs. 2 for lower-body and 2 vs. 4 for upper-body	2 or 4 sets of 8–12 repetitions performed to concentric failure	Yes	6 weeks	BOD-POD; ultrasound (elbow flexors, vastus medialis, and anterior deltoids)	LBM RT 1–2: ↑ LBM RT 2–4: ↑ Muscle thickness (vastus medialis) 1–2: ↑ Muscle thickness (vastus medialis) 2–4: ↑ Muscle thickness (elbow flexors) 1–2: ↑ Muscle thickness (elbow flexors 2–4: ↔ Muscle thickness (anterior deltoids) 1–2: ↔ Muscle thickness (anterior deltoids) 2–4: ↔
Zaroni et al. (2018)	Young trained men (*n* = 18)	1 vs. 5 for lower-body and 2 vs. 5 for upper-body	3 sets of 10–12 repetitions performed to concentric failure	Yes	8 weeks	Ultrasound (elbow flexors, elbow extensors, and vastus lateralis)	Muscle thickness RT 1: ↑ Muscle thickness RT 5: ↑ Significantly greater increases in muscle thickness of the elbow flexors and vastus lateralis were noted in the group training 5 times per week.

BIA: bioelectrical impedance analysis; CSA: cross-sectional area; DXA: dual-energy X-ray absorptiometry; LBM: lean-body mass; MRI: magnetic resonance imaging; 1RM: one-repetition maximum; RT: resistance training; ↑ significant pre-to-post increases; ↔ no significant pre-to-post changes; ↓ significant pre-to-post decreases

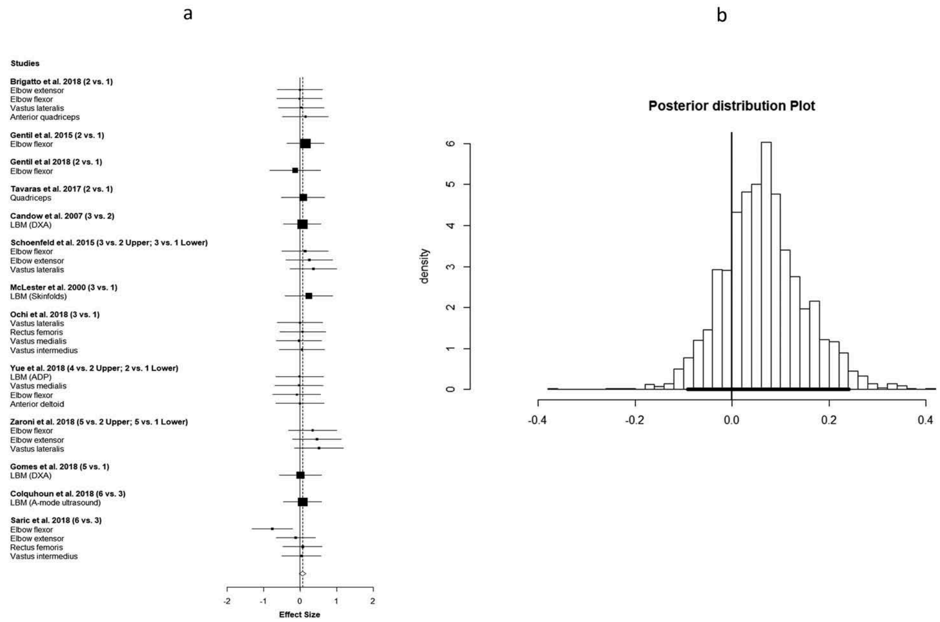

Figure 2. (a) Forest plot of all volume-equated studies. (b) Posterior distribution plot of all volume-equated studies.

studies. There was no significant difference between higher and lower frequency on a volume equated basis (ES difference = 0.07 ± 0.06; CI: −0.08, 0.21; P = 0.32). The percentage point difference was 0.6 ± 0.8 (CI: −1.2, 2.5). Heterogeneity was low (I^2 = 0). Bayesian meta-analysis resulted in a similar estimate of ES difference (0.07; 95% credible interval: −0.18, 0.34).

Meta-analysis of volume-equated studies using direct measurements of hypertrophy, upper-body

The analysis of volume-equated studies using direct measurements of hypertrophy on the upper-body comprised 12 outcomes from 7 studies. There was no significant difference between higher and lower frequency on a volume equated basis (ES difference = 0.01 ± 0.11; CI: −0.27, 0.28; P = 0.95). The percentage point difference was 0.06 ± 1.3 (CI: −3.1, 3.3). Heterogeneity was low (I^2 = 0). Bayesian meta-analysis resulted in a similar estimate of ES difference (0.01; 95% credible interval: −0.30, 0.33).

Meta-analysis of volume-equated studies using direct measurements of hypertrophy, lower-body

The analysis of volume-equated studies using direct measurements of hypertrophy on the lower-body comprised 12 outcomes from 7 studies. There was no significant difference between higher and lower frequency on a volume equated basis (ES difference = 0.15 ± 0.07; CI: −0.02, 0.32; P = 0.08; Figure 3(a)). The percentage point difference was 1.5 ± 0.86 (CI: −0.6, 3.6). Heterogeneity was low (I^2 = 0). Bayesian meta-analysis resulted in a similar estimate of ES difference (0.15; 95% credible interval: −0.11, 0.42). The posterior distribution was consistent with a trivial (ES < 0.2) to small (0.2 < ES < 0.5) effect of higher frequency vs. lower frequency (Figure 3(b)).

Meta-analysis of volume-equated studies using indirect measurements of hypertrophy

The analysis of volume-equated studies using indirect measurements of hypertrophy comprised 5 outcomes from 5 studies. There was no significant difference between higher and lower frequency on a volume equated basis (ES difference = 0.07 ± 0.03; CI: −0.03, 0.17; P = 0.11). The percentage point difference was 1.7 ± 1.2 (CI: −1.5, 5.0). Heterogeneity was low (I^2 = 0). Bayesian meta-analysis resulted in a similar estimate of ES difference (0.07; 95% credible interval: −0.29, 0.41).

Meta-analysis of volume-equated studies using trained subjects

The analysis of volume-equated studies using trained subjects comprised 23 outcomes from 10 studies. There was no significant difference between higher and lower frequency on a volume equated basis (ES difference = 0.07 ± 0.06; CI: −0.06, 0.20; P = 0.26). The percentage point difference was 1.2 ± 0.9 (CI: −0.8, 3.2). Heterogeneity was low (I^2 = 0). Bayesian meta-analysis resulted in a similar estimate of ES difference (0.07; 95% credible interval: −0.13, 0.29).

Meta-analysis of volume-equated studies using untrained subjects

There was an insufficient number of studies (i.e., 3 studies) to analyze the impact of frequency in untrained subjects on a volume-equated basis.

Meta-regression of volume-equated studies

Meta-regression analysis of volume-equated studies comprised 58 outcomes from 13 studies. While the omnibus test for moderators was significant (P = 0.003), frequency category was not

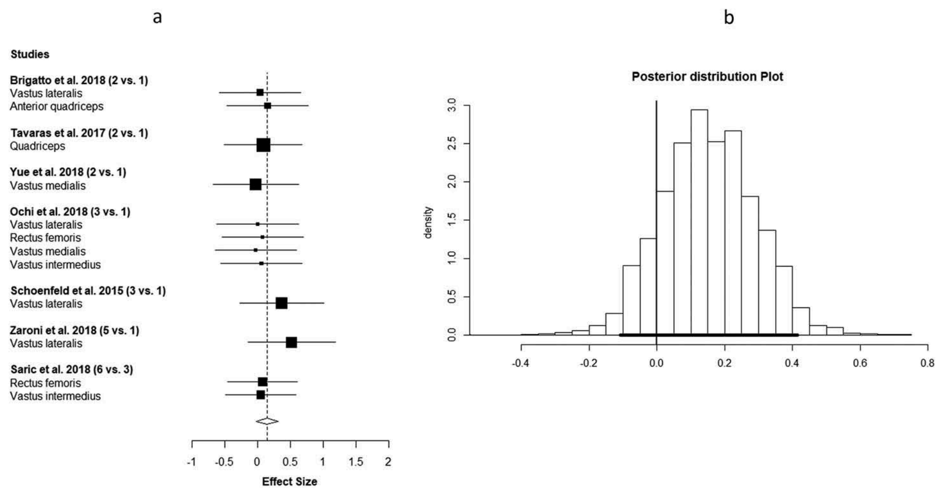

Figure 3. (a) Forest plot of volume equated studies using direct measurement modalities. (b) Posterior distribution plot of volume equated studies using direct measurement modalities.

Table 2. Effect size estimates and 95% confidence intervals for the frequency categories for volume-equated studies.

	All volume-equated studies			Volume-Equated studies, direct measurements only		
Frequency Category	Estimate	95% CI	Percentage Gain	Estimate	95% CI	Percentage Gain
1 d/wk	0.37 ± 0.13	0.07, 0.66	4.1 ± 1.4	0.45 ± 0.16	0.03, 0.86	5.4 ± 1.9
2 d/wk	0.32 ± 0.11	0.08, 0.56	4.3 ± 1.2	0.37 ± 0.13	0.03, 0.72	5.4 ± 1.7
3 d/wk	0.49 ± 0.10	0.26, 0.72	6.3 ± 1.2	0.64 ± 0.08	0.42, 0.85	7.6 ± 1.5
4–6 d/wk	0.39 ± 0.13	0.08, 0.70	5.1 ± 1.6	0.49 ± 0.18	0.03, 0.96	6.3 ± 2.3

CI: confidence interval

significant (P = 0.88 for 2 d/wk, P = 0.15 for 3 d/wk, and P = 0.60 for 4–6 d/wk). Only measurement type (indirect vs. direct) was near statistical significance (estimate = –0.30 ± 0.14; CI: –0.63, 0.03; P = 0.07). Frequency category as the lone moderator was also not significant (P = 0.41). ES estimates and 95% CIs for the four frequency categories are shown in Table 2.

Meta-regression of volume-equated studies, direct measurements only

Meta-regression analysis of volume-equated studies using direct measurements of hypertrophy comprised 48 outcomes from 9 studies. The omnibus test for moderators was not significant (P = 0.18). Frequency category was not significant (P = 0.77 for 2 d/wk, P = 0.25 for 3 d/wk, and P = 0.64 for 4–6 d/wk). Only training duration in weeks was near statistical significance (estimate = 0.10 ± 0.04; CI: –0.01, 0.22; P = 0.07). Frequency category as the lone moderator was also not significant (P = 0.12). ES estimates and 95% CIs for the four frequency categories are shown in Table 2.

A separate meta-regression was carried out, regressing the within-study difference in frequency (e.g., 2 for a study comparing 1 and 3 days per week) as a continuous variable on the outcomes. There was no significant effect of frequency (estimate = 0.004 ± 0.11; CI: –0.26, 0.26; P = 0.98).

Meta-regression of non-volume-equated studies

Meta-regression analysis of non-volume-equated studies comprised 44 outcomes from 12 studies. The omnibus test for moderators was not significant (P = 0.08). Frequency category was not significant (P = 0.17 for 2 d/wk, P = 0.054 for 3 + d/wk). Frequency category as the lone moderator was significant (P = 0.04). ES estimates and 95% CIs for the three frequency categories are shown in Table 3.

Discussion

The present paper sought to compare the effects of resistance training frequency on muscle hypertrophy based on a systematic pooled analysis of the current literature. Primary results showed that the number of times a muscle group is trained on a weekly basis has a negligible impact on hypertrophic outcomes on a volume-equated basis. In general, these results were constant even when studies were subanalyzed to account for the potential influence of different covariates. Alternatively, there was an effect of frequency when training volume was not equated between conditions, although the magnitude of the effect was modest.

Our findings build on previous meta-analytic data that showed a significant benefit to higher versus lower resistance

Table 3. Effect size estimates and 95% confidence intervals for the frequency categories for non-volume-equated studies.

	Non-Volume equated studies		
Frequency Category	Estimate	95% CI	Percentage Gain
1 d/wk	–0.03 ± 0.07	–0.18, 0.13	1.9 ± 1.6
2 d/wk	0.08 ± 0.05	–0.04, 0.20	2.1 ± 1.2
3 + d/wk	0.15 ± 0.09	–0.04, 0.34	3.4 ± 1.3

CI: confidence interval

training frequencies on muscle growth when considered from a binary standpoint (Schoenfeld et al., 2016b). In that analysis, higher frequencies were associated with an ES of 0.49 compared to an ES of 0.30 for lower frequencies, which translated to mean percentage growth increases of 6.8% vs. 3.8%, respectively, favoring higher frequency training. However, these conclusions were drawn from a relatively small number of volume-equated studies that met inclusion criteria at the time (7 studies encompassing a total of 200 subjects) and thus statistical power was somewhat compromised. Moreover, there was insufficient data to determine differences between training muscle groups more than 2+ days/week. The plethora of research that has been carried out on the topic since the publication of that meta-analysis now supplies data from 25 studies encompassing over 800 subjects for the present analysis, providing strong confidence in the veracity of our findings. The large number of studies meeting inclusion also allowed for subgroup analysis of covariates that provided novel insights into the nuances of the topic.

Subgroup analysis showed no effect of training frequency when only direct measures of hypertrophy (i.e., MRI, CT, and ultrasound) were taken into account on a volume-equated basis. These imaging modalities are generally believed to afford greater accuracy in detecting subtle changes in muscle growth that may occur over relative short time-frames as compared to LBM estimates (Delmonico, Kostek, Johns, Hurley, & Conway, 2008; Snijders et al., 2015), thereby providing better internal validity. The ES difference between the spectrum of training frequencies was trivial (ES = 0.07) and the small 95% CI spanning both sides of the null value further indicate no hypertrophic effects of varying resistance training frequency. When sub-analyzing between upper and lower-body segments using direct measures of hypertrophy, there again were no significant differences on the effects of training frequency. For the lower-body, the p-value was suggestive of a potential benefit of higher frequencies ($p = 0.08$) as was the 95% CI (−0.02 to 0.32); however, the trivial mean ES value (0.15) indicates that any beneficial effects are of questionable practical consequence. While the previous meta-analytic data on the topic of resistance training frequency and muscle hypertrophy contained only 2 studies involving resistance-trained individuals (Schoenfeld et al., 2016b), the present analysis included 10 studies that employed subjects with previous resistance training experience. Given that the time-course of post-exercise MPS is somewhat attenuated in overall magnitude and shorter in duration compared with untrained individuals in resistance-trained individuals, it has been speculated that this population may achieve a hypertrophic benefit from higher training frequencies by optimizing the MPS area under the curve (Dankel et al., 2017). Our findings seem to refute this hypothesis. The miniscule ES difference (0.07) and narrow non-significant 95% CI (−0.06 to 0.20) indicate that resistance training frequency is likely not an important variable for maximizing the muscular growth response in trained individuals. These findings highlight that caution is needed when extrapolating prescription for resistance training frequency solely based on the acute MPS response.

When considering resistance training with non-equated volumes, the omnibus test showed a significant hypertrophic effect of altering frequency ($p = 0.04$). This finding would seem to support the concept that frequency can be used as a tool to increase resistance training volume, which has been shown to increase muscle size in a dose-response manner (Schoenfeld, Ogborn, & Krieger, 2016a). That said, the CIs for each of the various frequency categories overlapped the null value and the overall difference in the magnitude of effect between frequencies of 1 and 3+ times per week was modest (ES = 0.18), calling into question the practical benefit from the standpoint of increasing muscle mass.

One matter that must be acknowledged when discussing the results of this subgroup analysis is that the majority of studies that did not equate volume between conditions included untrained older adults. It is possible that a greater effect would be seen for higher frequencies if more non-volume equated studies were carried out in young individuals. This speculation is based on the observation that older adults seem to have impaired recovery following exercise in comparison to their younger counterparts (Fell & Williams, 2008). Given a superior ability to recover from intense exercise, young adults might conceivably respond better to greater training frequencies with a correspondingly higher training volume. With that being said, a recent study indicates that this may not be the case. Barcelos et al. (2018) employed a non-volume equated study design in young participants and compared training 2 vs. 3 vs. 5 times per week while using a direct measure of changes in muscle size (i.e., B-mode ultrasound). The authors reported that all training conditions were comparably effective for inducing lower-body muscular hypertrophy. However, these results are only specific for lower-body exercise and given the scarcity of current evidence, future studies among young individuals that do not equate training volume between groups training with different resistance training frequencies are needed to explore this area further.

While our meta-analysis indicates that, on average, comparable increases in muscle size might be expected across a broad range of resistance training frequencies, one matter that needs to be highlighted are the inter-individual responses to this variable. There is evidence that even in resistance training protocols with non-equated total training volumes the individual hypertrophic response can substantially differ among subjects, with some responding better to higher resistance training frequencies (and volumes), while others respond better to lower training frequencies (Damas et al., 2018). Therefore, individualization of the training protocols is paramount from an exercise prescription standpoint.

Limitations

A limitation of the current research is that the vast majority of the included studies that directly measured muscle growth did so in the upper arms and thighs. Thus, the findings cannot necessarily be generalized to other muscle groups, which may or may not benefit from lower/higher training frequencies. Moreover, it was not possible to tease out the effects of resistance training frequency using single- versus multi-joint exercises. The performance of multi-joint exercises such as squats, rows, and presses tax the neuromuscular system to a greater degree than single-joint movements, and hence may require greater recovery between sessions. Moreover, our analysis did not directly control for various training (e.g., tempo, rest, failure vs. not-failure) and non-training (e.g., protein intake) variables that may influence the effect of resistance training on frequency. However, most studies did in fact attempt to keep these variables constant and our meta-analytic approach employed a random-effects model to account for heterogeneity between study designs. There also was insufficient data to sub-analyze the age-related effects of resistance training frequency, limiting the ability to generalize findings to young versus older individuals. The manner in which these factors affect muscle growth when employing varied resistance training frequencies requires further study. Finally, meta-analyses do not discriminate between study quality and thus results can be unduly influenced by inherent qualitative differences in protocols.

Conclusion

In conclusion, the present meta-analysis provides strong evidence that weekly resistance training frequency does not significantly or meaningfully impact muscle hypertrophy when volume is equated. These findings are consistent even when adjusted for moderators such as training status and body segment (i.e., upper and lower-body). Thus, for a given volume of training, individuals can choose a weekly frequency per muscle groups based on personal preference. Alternatively, higher training frequencies can help to accumulate greater volumes of training, which may in turn enhance the hypertrophic response. However, the modest magnitude of effect associated with this strategy calls into question its practical utility.

Disclosure statement

No potential conflict of interest was reported by the authors.

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