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Review

Resistance training frequency and skeletal muscle hypertrophy: A review of available evidence

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ABSTRACT

Objectives: Current reviews and position stands on resistance training (RT) frequency and associated muscular hypertrophy are based on limited evidence holding implications for practical application and program design. Considering that several recent studies have shed new light on this topic, the present paper aimed to collate the available evidence on RT frequency and the associated effect on muscular hypertrophy.
Design: Review article.
Methods: Articles for this review were obtained through searches of PubMed/MEDLINE, Scopus, and SPORTDiscus. Both volume-equated (studies in which RT frequency is the only manipulated variable) and non-volume-equated (studies in which both RT frequency and volume are the manipulated variables) study designs were considered.
Results: Ten studies were found that used direct site-specific measures of hypertrophy, and, in general, reported that RT once per week elicits similar hypertrophy compared to training two or three times per week. In addition, 21 studies compared different RT frequencies and used lean body mass devices to estimate muscular growth; most of which reported no significant differences between training frequencies. Five studies were identified that used circumference for estimating muscular growth. These studies provided findings that are difficult to interpret, considering that circumference is a crude measure of hypertrophy (i.e., it does not allow for the differentiation between adipose tissue, intracellular fluids, and muscle mass).
Conclusions: Based on the results of this review, it appears that under volume-equated conditions, RT frequency does not seem to have a pronounced effect of gains in muscle mass.
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1. Introduction

The prescription of resistance training (RT) programs is often based on the recommendations provided by leading exercise and health organizations. In this regard, the most commonly cited and recognized recommendations are those provided by the American College of Sports Medicine (ACSM).[1] For novice individuals whose goal is to achieve muscular hypertrophy, the ACSM guidelines recommend an RT frequency of two to three days per week using a total body routine. For intermediate individuals (i.e., individuals with ~six months of RT experience), a frequency of four days per week using an upper/lower body split routine is considered ideal. Finally, for individuals advanced in RT, a training frequency of four to six days per week is recommended, in which, one to three muscle groups are trained per session using a split body routine.[1] However, some authors claim that there was insufficient evidence to support such recommendations at the time when the position stand was published, leaving these guidelines somewhat questionable.[2]

Schoenfeld et al.[3] performed a systematic review and a meta-analysis of studies assessing the effects of RT frequency on muscular hypertrophy. The authors concluded that training a muscle group two times per week compared to once per week promoted superior muscular hypertrophy. These findings were obtained from data that pooled both indirect measures, such as circumference and dual-energy X-ray absorptiometry (DXA) and direct measures, such as B-mode ultrasound imaging to assess muscle growth. Nonetheless, the researchers noted that the analysis was limited to the small number of studies (i.e., 10) that met the inclusion criteria, and only

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two studies used site-specific measures of hypertrophy. It has been reported that direct and indirect measures may produce different results, as for instance, changes in muscle size following 12-weeks of RT noted with computed tomography (a direct measure), were not observed using an indirect measure of hypertrophy (DXA).[4] Therefore, where possible, a case can be made that these different direct and indirect estimates of muscular hypertrophy should be analyzed separately,[5] as performed in a recent review by Schoenfeld et al.[6]

Since the publication of the review by Schoenfeld et al. several recent studies[7–13] have shed new light on this topic. Therefore, the present review aimed to collate the available evidence from studies that compared different RT frequencies and their effect on muscular hypertrophy grouped by direct and indirect measures. Although meta-analyses are widely used and well-accepted as a means to draw evidence-based conclusions in health-based research,[14] some have questioned their applicability in strength training studies.[15] Given these discussions and due to the broad range of methodological concepts across the included studies, the results are interpreted qualitatively, as done in other reviews.[16–18]

2. Methods

2.1. Literature search methodology

Articles for this review were obtained through searches of PubMed/MEDLINE, Scopus, and SPORTDiscus databases. The word syntax used for the search included the following combination of relevant terms: 'resistance training' AND frequency AND (hypertrophy OR circumference OR 'muscle mass' OR volume OR split OR total OR lean OR girth OR strength). The literature search was performed in March 2018. No limits to the search period were applied. As a part of a secondary search, the reference list of each read full-text was scanned, and the papers that cited the included studies were examined through the Scopus database.

2.2. Inclusion criteria

Studies were included if they meet the following criteria: (i) compared different RT frequencies with the RT programs performed in a traditional dynamic fashion; (ii) included apparently healthy adults as participants; (iii) used either girth measures (i.e., circumference), lean body mass assessment, direct whole-muscle (B-mode ultrasound, magnetic resonance imaging, and computed tomography) or histological (muscle biopsy) measures of muscle hypertrophy; (iv) the training intervention lasted for a minimum of four weeks; and (v) the full-text of the study was available in English and was published in a peer-reviewed journal. For this review, RT frequency was defined as the number of training sessions performed per muscle group within a week. Thus, the studies that compared different RT frequencies while keeping the number of training sessions per muscle group between the intervention groups the same were not included.

2.3. Classification of training status and age

Resistance trained individuals were defined herein as having at least six months of RT experience.[1] For age groups, we used the following classification (i) participants aged 18–39 years were classified as young, (ii) participants aged 40–64 years were classified as middle-aged, and (iii) participants aged $\geq$65 years were classified as older adults.

2.4. The importance of equating training volume

Training volume has been suggested to be one of the most important RT variables when it comes to exercise prescription for muscle hypertrophy.[19] Recent studies have observed a dose–response relationship between RT volume and muscle hypertrophy, whereby greater volumes of training elicit greater increases in muscle size.[20,21] Therefore, when comparing the effects of different RT frequencies (e.g., training two vs. three times per week) training volume should ideally be equated between the groups. If equated for training volume, the only manipulated variable is RT frequency, which consequently allows for the isolation of the true effect of training frequency and thus the ability to draw causality as to its hypertrophic effects. If the comparison is not equated, and the higher training frequency group also does more training volume, a true effect of RT frequency cannot be isolated.

3. Direct measures of muscular hypertrophy

In total, 10 studies assessed the effect of RT frequency on muscular hypertrophy using site-specific measures.[8–10,22–28] Eight studies used B-mode ultrasound, one study used magnetic resonance imaging, and one study used muscle biopsies for assessing muscular hypertrophy. The pooled number of participants across the studies was 289 (234 males and 55 females). The median number of participants per study was 24. In five of the studies the participants were young individuals,[9,10,25,26,28] in four older adults[8,22,23,27] and in one study the participants were middle-aged individuals.[24] Seven studies were conducted in untrained participants[8,22–25,27,28] while three studies were performed in resistance trained population.[9,10,26] Mean $\pm$ standard deviation duration of the training interventions was 12 $\pm$ seven weeks (range: 6–30 weeks). All of the studies reported that the RT programs were supervised. The lowest training frequency was once per week, while the highest frequency was four times per week. A summary of the individual studies can be found in Table 1.

At present, three studies investigated the effects of RT frequency in young or middle-aged untrained populations while using direct measures of hypertrophy. Izquierdo et al.[24] compared non-volume-equated training once per week with training twice per week in a group of men aged 40–46 years. The training intervention consisted of performing seven exercises for upper and lower-body musculature. During the first eight weeks, participants performed three to four sets of 10–15 repetitions with loads in the range of 50–70% one repetition maximum (1RM). For the next eight weeks, the load was increased to 70–80% 1RM, and the number of sets and repetitions was three to five and five to six, respectively. No significant differences in muscular hypertrophy were observed between groups for changes in quadriceps muscle thickness. However, elbow flexor thickness increased by 9% in the group training twice per week, while no significant pre-to-post changes were observed in the group training once per week (+4%), suggesting a benefit for a higher training frequency. It should be noted that the group training once per week also did one session of aerobic training (i.e., cycling) per week. Aerobic exercise has been shown to stimulate muscle protein synthesis (MPS) and there is evidence that aerobic exercise alone can result in significant hypertrophy in those who are untrained (a more detailed discussion on this topic may be found elsewhere[29]). Given that aerobic exercise was included for the lower-body, but not upper-body, the higher upper-body volume (see Section 2.4) performed by the twice-per-week group may be explanatory for the differences observed between groups for elbow flexor thickness. In a cohort of college-aged men, Gentil et al.[25] reported statistically similar increases in muscle thickness between volume-equated RT frequencies of one and two times per

Table 1
Summary of the studies using direct measures of muscular hypertrophy.

Reference	Sample	Training duration (weeks)	Exercise prescription	Were repetitions performed to momentary muscular failure?	Volume equated?	Frequency comparison (times/week)	Adherence to the training	Measurement tool (site)	Main findings
Brigatto et al.[9]	Young trained men ($n = 20$)	8	2–4 sets × 8–12 repetitions	Yes	Yes	1 vs. 2	1 = 100% 2 = 100%	B-mode ultrasound (elbow flexors, elbow extensors and quadriceps)	Significant pre- to post-intervention increases in elbow flexors, elbow extensors and quadriceps muscle thickness in both groups, with no significant between-group differences.
Ferrari et al.[23]	Older trained men ($n = 24$)	10	3 sets × 6–12 repetitions	Yes	No	2 vs. 3	2 = 95% 3 = 97%	B-mode ultrasound (elbow flexors and quadriceps)	Significant pre- to post-intervention increases in elbow flexors and quadriceps muscle thickness in both groups, with no significant between-group differences.
Gentil et al.[25]	Young untrained men ($n = 30$)	10	3 sets × 8–12 repetitions	Yes	Yes	1 vs. 2	A minimum of 80%	B-mode ultrasound (elbow flexors)	Significant pre- to post-intervention increases in elbow flexors thickness in both groups, with no significant between-group differences.
Izquierdo et al.[22]	Older untrained men ($n = 24$)	16	3–5 sets × 5–15 repetitions	No	No	1 vs. 2	A minimum of 90%	B-mode ultrasound (quadriceps)	Significant pre- to post-intervention increases in quadriceps thickness in both groups, with no significant between-group differences.
Izquierdo et al.[24]	Middle-age untrained men ($n = 31$)	16	3–5 sets × 5–15 repetitions	No	No	1 vs. 2	A minimum of 90%	B-mode ultrasound (elbow flexors and quadriceps)	Significant pre- to post-intervention increases in quadriceps thickness in both groups, with no significant between-group differences. For elbow flexors, only the group training two times per week increased muscle thickness from pre- to post intervention.
Schoenfeld et al.[26]	Young trained men ($n = 19$)	8	2–3 sets × 8–12 repetitions	Yes	Yes	1 vs. 3 and 2 vs. 3[a]	1 = 98% 3 = 97%	B-mode ultrasound (elbow flexors, elbow extensors and quadriceps)	Significant pre- to post-intervention increases in elbow extensors and quadriceps muscle thickness in both groups, with no significant between-group differences. For elbow flexors, the group training three times per week experienced significantly greater growth compared to the group training once per week.
Stec et al.[27]	Older untrained men ($n = 15$) and women ($n = 14$)	30	3 sets × 8–12 repetitions	Yes	No	2 vs. 3	2 = 91% 3 = 87%	Muscle biopsy (vastus lateralis)	No significant pre to post-intervention increases in type I muscle fiber cross-sectional area. Significant pre- to post-intervention increases in type II muscle fiber cross-sectional area in both groups, with no significant between-group differences.
Tavares et al.[28]	Young untrained men ($n = 22$)	8	2–4 sets × 6–12 repetitions	Yes	Yes	1 vs. 2	1 = 100% 2 = 100%	Magnetic resonance imaging (quadriceps)	No significant pre to post-intervention changes in quadriceps cross-sectional area in either of the groups.
Trupela et al.[8]	Older untrained men ($n = 31$) and women ($n = 41$)	12	2–5 sets × 4–12 repetitions	A minimum of one set was performed to muscular failure	No	1 vs. 2 vs. 3	A minimum of 90%	B-mode ultrasound (quadriceps)	No significant pre to post-intervention increases in quadriceps thickness in either of the groups.
Yue et al.[10]	Young trained men ($n = 18$)	6	2–4 sets × 8–12 repetitions	Yes	Yes	2 vs. 4 and 1 vs. 2[a]	1/2 = 100% 2/4 = 100%	B-mode ultrasound (elbow flexors, anterior deltoid and quadriceps)	Significant pre- to post-intervention increases in quadriceps muscle thickness in both groups, with no significant between-group differences. For elbow flexors, the group training two times per week experienced significantly greater growth compared to the group training four times per week. No significant pre to post-intervention increases in anterior deltoid thickness in either of the groups.

[a] The training frequency varied based on the muscle group.

week following a 10-week intervention. Tavares et al.[28] investigated the effects of RT frequency (i.e., one versus two times per week) during a period of reduced training volume. The training volume was equated between the groups and consisted of the squat and knee extension exercises performed for four sets per week with six to eight RM. The authors reported that training both once or twice per week is sufficient for maintaining muscular hypertrophy, as no significant decreases in muscle cross-sectional area were noted.

The totality of these data suggest that training as infrequently as training a muscle group once per week can elicit muscle growth in untrained individuals. Lack of time is commonly identified as the primary reason for poor adherence to exercise.[30] Therefore, these findings seem to have the largest practical application for individuals with limited opportunities to engage in RT and who decide to comprise their weekly exercise volume within one or two days per week, commonly termed as the 'weekend warriors.'[31] However, given the limited data on the topic, further research is required to consolidate the initial findings in untrained individuals.

The mechanical stimuli associated with voluntary muscle contractions can upregulate MPS. MPS is identified as an underlying factor in muscular growth.[32] In theory, hypertrophy of skeletal muscle cells is the cumulative difference between protein synthesis and protein degradation (i.e., net protein accretion[32]). Based on the blunted MPS response following RT in well-trained individuals[33] some authors have put forth the hypothesis that greater RT frequency, with lower individual session volume, may augment muscular growth via more frequent stimulation of MPS.[34] In the study by Schoenfeld et al.[26] following an 8-week volume-equated training intervention, significantly greater increases in elbow flexor hypertrophy were noted in the group that trained three times per week (+6.5%) in comparison to the group training once per week (+4.4%). Although no significant differences were noted for the elbow extensors or vastus lateralis muscles, effect size differences markedly favored the higher frequency condition for these outcomes. It is possible that the group training three times per week stimulated MPS more often which, in turn, resulted in greater hypertrophy in this training group. However, it has been argued that these results might be a novelty effect, as most of the participants trained muscle groups once per week before the intervention period.[26]

In opposition to the findings by Schoenfeld et al.[26] other research has failed to detect significant benefits of greater RT frequencies in trained individuals. For example, Brigatto et al.[9] randomly assigned resistance-trained men to either a group that trained muscle groups once per week with 16 sets per session or a group that trained muscle groups twice per week with eight sets per session. Given the set configuration between the groups, the total training volume was equated. No significant differences were noted in muscle thickness of the elbow extensors, elbow flexors, or quadriceps after an 8-week study period. Another recent volume-equated study performed in trained men compared training a muscle group two versus four times per week.[10] Although no significant between-group differences were noted between conditions for anterior deltoid and quadriceps thickness, only the group training two times per week experienced significant pre- to post-intervention increases in elbow flexor thickness, suggesting a benefit towards lower RT frequency.[10] It should be noted that in the study by Yue et al.[10] the groups training two and four times per week trained their back and arm muscles with this frequency, for the leg, chest, and lateral deltoideus muscles a training frequency of one and two times per weeks was employed.

Based on the limited data available data, it does not appear that additional hypertrophic benefits are achieved by training a muscle group more than twice per week in resistance-trained individuals. It is important to note, however, that current data using direct measures of hypertrophy is reported on the limb musculature, specifically, elbow flexors, elbow extensors, and quadriceps muscles. Therefore, the generalizability to other muscle groups remains unclear. Further research is required to determine the effects of higher training frequencies such as greater than three times per week in resistance-trained individuals, as there is some preliminary evidence[35] to corroborate the supposition by Dankel et al.[34] that very high RT frequencies may maximize the MPS area under the curve response. Future studies might consider exploring how training multiple times throughout a day in comparison with training once per day might affect muscular growth.

Under sedentary conditions, muscular atrophy is accelerated after 50 years of age.[36] This loss of muscle mass that occurs with aging (i.e., sarcopenia) can have implications for functionality and activities of daily living.[37] Therefore, older adults are encouraged to participate in RT.[37] However, it remains unclear what training frequency is the most efficient for eliciting hypertrophy in the older adult population.[38] Four studies investigated training frequency among older adults; all of the studies included untrained older adults. The seminal work by Izquierdo et al.[22] was the first to compare the effect of RT frequency on muscular hypertrophy using the ultrasound imaging technique in older men (67 ± 3 years). In a 16-week intervention, 20 participants were allocated either to RT once per week, or RT twice per week. Pre- to post-intervention muscle thickness data revealed that the hypertrophy of the quadriceps muscle was the same for between the groups (+11% for both groups). These findings have important implications for program design as they indicate that a training frequency of even once per week can elicit robust muscular hypertrophy in older adults. However, as in their study among middle-aged men,[24] the group training once per week did one weekly session of cycling. These methodological concepts might have confounded the training frequency comparison of this study and need to be taken into account when interpreting these findings. Ferrari et al.[23] compared concurrent training (i.e., combined RT and aerobic exercise) frequency of two versus three times per week in a group of older men (65 ± 4 years). Both groups did the same concurrent exercise program and the only manipulated training variable was training frequency. Following the intervention, both groups increased muscle thickness in the quadriceps and elbow flexor musculature with no significant between-group differences.

For untrained older individuals, significant muscular hypertrophy with regimented RT can be with as little as six weeks of RT.[39] Surprisingly, in a recent study comparing training frequencies of one, two, and three times per week in older adults, 12 weeks of an RT intervention was insufficient to increase muscle thickness in either of the training groups.[8] No significant increases in muscle thickness occurred likely because the training program also included an initial three-month preparatory training phase. It is, therefore, possible that the majority of the adaptations occurred during this initial training phase. In a longer duration training intervention lasting for 30 weeks, Stec et al.[27] investigated the effects of RT frequency performed two times per week compared to a training frequency of three times per week. Muscle biopsies of the vastus lateralis muscle were used for the assessment of muscular hypertrophy. Following the RT intervention, no significant growth of type I muscle fibers occurred in either group. However, both groups increased the cross-sectional area of type II muscle fibers, with no significant between-group differences.

There is evidence to indicate that older adults might need more training volume to maintain myofiber hypertrophy than young adults.[40] However, the studies conducted among older adults included in the present review did not equate training volume and despite the non-volume-equated comparison, they did not show any added benefit with higher RT frequencies and more training volume. Therefore, it may be inferred that after a certain amount of volume is achieved, additional work does not provide further hypertrophic benefits in this population and might only delay recovery from exercise.

4. Indirect measures of muscular hypertrophy

4.1. Lean body mass

In total, 21 studies assessed the effect of RT frequency on changes in lean body mass.[7,8,11–13,22,27,41–53] Ten of the studies used DXA for assessing lean body mass; five studies used skinfolds, three studies used bioelectric impedance analysis, two studies used air displacement plethysmography, and one study used A-mode ultrasound. The pooled number of participants across the studies was 2472 (1772 females and 700 males). The median number of participants per study was 30. Nine studies included older adults[7,8,22,27,41,45,47,48,51] seven studies included young participants[10–13,46,50,52] while in two studies the sample size comprised of middle-aged individuals.[43,44] Two studies study included a mixture of young and middle-aged participants,[42,53] and one included all adult age groups.[49] Only five studies included resistance trained individuals.[11–13,46,52] Mean ± standard deviation duration of the training interventions was 13 ± seven weeks (range: 6–30 weeks). Only one study[46] did not report that the RT programs were supervised (the importance of exercise supervision is discussed elsewhere[54]). The lowest training frequency was once per week, while the highest frequency was six times per week. A summary of the individual studies can be found in Table 2.

In a large-scale study of untrained individuals (n = 1725) lasting for 10 weeks, Westcott et al.[49] reported that the groups training one, two and three times per week increased their lean body mass by 0.33 kg, 1.40 kg, and 1.40 kg, respectively. Statistical analysis showed the groups that trained two and three times per week increased lean body mass significantly more than the group training once per week. MPS studies report that, following a bout of RT, MPS remains elevated for ∼48 h in untrained individuals.[55] Therefore, training a muscle group two or three times per week conceivably would keep the protein synthetic response in an elevated state in between subsequent sessions, which theoretically should augment the growth of skeletal muscle. While the results from Westcott et al.[49] seem to support this proposition, the RT sessions were performed with very low training volume, specifically, with one set per exercise. Due to the dose-response between training volume and increases in muscle size,[21,22] an argument can be made that such a low volume would require a greater weekly training frequency to stimulate muscular gains.

In contrast to the findings by Westcott et al.[49] most of the other included studies that compared the effects of RT frequencies on lean body mass gains report no significant differences between the training conditions. No significant differences between training frequencies were found when comparing training frequencies of: (i) one versus two times per week, (ii) one versus three times per week, (iii) two versus three times per week, and (iv) three versus four times per week.[7,8,12,13,17,27,41–48,50,51,53] In addition, very limited evidence has shown no difference between in lean body mass accrual between groups training a muscle group one versus five times[13] per week and three versus six times per week[52]; at least over a short-term period (i.e., six to eight weeks). Still, most of the studies assessed training frequencies up to four days per week and among untrained individuals (Table 2); therefore, it remains unclear whether similar results would be observed with higher training frequencies and in participants with regular RT experience.

In summary, most of the current body of evidence does not indicate a significant difference in lean body mass accretion when training with different RT frequencies. These results imply that comparable changes in lean body mass may be observed across a large spectrum of training frequencies and the choice for a given frequency can likely be based on personal preference. However, while lean body mass estimates can indeed provide good insights into the hypertrophic effects, they also might not be sensitive enough to detect subtle, but potentially meaningful changes in muscle growth.[4,56] Therefore, it is possible that in some studies, training with different RT frequencies indeed resulted with differences in hypertrophy adaptations between the groups at the whole-muscle level; however, these changes were not observed due to the measurement tools employed. Thus, where possible, direct measures of hypertrophy should be utilized in future research.

4.2. Circumference measures

A total of only five studies have investigated the effects of RT frequency and subsequent muscular hypertrophy using circumference measures.[10,25,46,50,57] The pooled number of participants across these studies was 121 (86 males and 35 females). The median number of participants per study was 28 and all studies included young participants. Three studies were conducted in untrained individuals[25,50,57] and two in trained participants.[10,46] Mean ± standard deviation duration of the training interventions were nine ± two weeks (range: 6–12 weeks). All but one study[46] reported supervision of the RT programs. The lowest training frequency was once per week, while the highest frequency was four days per week. A summary of the individual studies can be found in Table 3.

The study by Arazi and Asadi[57] investigated the effects of training one versus two times per week, reporting that the group training once per week increased arm (+3.6%) but not thigh circumference (+2.2%). By contrast, the group training twice per week increased thigh but not arm circumference. Given that the study employed a volume-equated design these results might imply that upper and lower-body musculature might warrant different RT frequency prescription. Using the same RT frequency comparison, Gentil et al.[25] reported significant pre to post-intervention increases in arm girth in both groups, with no significant between-group differences. Also under volume-equated conditions, Hunter[50] reported that a group training four days per week compared to a group training three times per week experienced greater increases in chest circumference; albeit, the differences between groups were rather small (+0.2% versus +3.2%). One study reported significant pre to post-intervention increases in arm girth in the group training two times per week but not in the group training a muscle group four times per week.[10] And finally, one study[46] did not report any significant pre-to-post intervention changes in girth in either group.

Collectively, results from studies using circumference measures are difficult to interpret. Circumference can be considered as a crude measure of hypertrophy given that changes in circumference may also be related to changes in subcutaneous adipose tissue and intracellular fluids, and not necessarily in muscle mass.[58] Therefore, the findings from these studies should be viewed with circumspection, particularly given that none of the included studies controlled for nutritional intake. While acknowledging the limitations that researchers face when designing a study and taking into account that circumference measures might be a good field-based measure, future studies should emphasize the use of direct measures of muscle growth to draw accurate evidence-based conclusions as to the hypertrophic effects of differing RT frequencies.

Table 2
Summary of the studies using lean body mass as an estimate of muscular hypertrophy.

Reference	Sample	Training duration (weeks)	Exercise prescription	Were repetitions performed to momentary muscular failure?	Volume equated?	Frequency comparison (times/week)	Adherence to the training	Measurement tool	Main findings
Benton et al.[44]	Middle-aged untrained women (n = 21)	8	3–6 sets × 8–12 repetitions	No	Yes	2 vs. 3	2 = 98% 3 = 98%	BOD-POD	Significant pre- to post-intervention increases in lean body mass in both groups, with no significant between-group differences.
Candow and Burke[42]	Young and middle-aged untrained men (n = 6) and women (n = 23)	6	2–3 sets × 10 repetitions	Yes	Yes	2 vs. 3	Not presented	DXA	Significant pre- to post-intervention increases in lean body mass in both groups, with no significant between-group differences.
Carneiro et al.[41]	Untrained older women (n = 53)	12	1 set × 10–15 repetitions	Yes	No	2 vs. 3	Not presented	DXA	Significant pre- to post-intervention increases in lean body mass in both groups, with no significant between-group differences.
Colquhoun et al.[52]	Trained young men (n = 28)	6	2–4 sets × 3–8 repetitions	Yes	Yes	3 vs. 6	Not presented	A-mode ultrasound	Significant pre- to post-intervention increases in lean body mass in both groups, with no significant between-group differences
Fernández-Lezaun et al.[7]	Untrained older men (n = 29) and women (n = 39)	24	2–4 sets × 4–20 repetitions	No	No	1. vs. 2. vs. 3	A minimum of 90%	DXA	No significant pre- to post-intervention increases in lean body mass in all groups.
Fisher et al.[45]	Untrained older women (n = 63)	16	1–2 sets × 8–10 repetitions	No	No	1. vs. 2. vs. 3	1 = 100% 2 = 100% 3 = 100%	DXA	Significant pre- to post-intervention increases in lean body mass in all groups, with no significant between-group differences.
Gomes et al.[13]	Young trained men (n = 23)	8	1–10 sets × 8–12 repetitions	Yes	Yes	1 vs. 5	1 = 97% 5 = 98%	DXA	Significant pre- to post-intervention increases in lean body mass in both groups, with no significant between-group differences.
Hunter[50]	Young untrained men (n = 22) and women (n = 24)	7	2–3 sets × 7–10 repetitions	Yes	Yes	3 vs. 4	Not presented	Skinfolds	Significant pre- to post-intervention increases in lean body mass in both groups, with no significant between-group differences.
Izquierdo et al.[22]	Older untrained men (n = 24)	16	3–5 sets × 5–15 repetitions	No	No	1 vs. 2	Minimum of 90%	Skinfolds	Significant pre- to post-intervention increases in quadriceps thickness in both groups, with no significant between-group differences.
Lee et al.[12]	Young untrained women (n = 17)	12	3 sets × 10 repetitions	No	No	1 vs. 3	Not presented	BIA	No significant pre- to post-intervention increases in lean body mass in both groups.
Lera Orsatti et al.[43]	Middle-aged untrained women (n = 30)	16	3 sets × 8–12 repetitions	Yes	No	1 vs. 2. vs. 3	Not presented	BIA	Significant pre- to post-intervention increases in lean body mass in all groups, with no significant between-group differences.

McLester et al.[46]	Young trained men ($n = 14$) and women ($n = 11$)	12	1–3 sets × 8–10 repetitions	Yes	Yes	1 vs. 3	Not presented	Skinfolds	No significant pre- to post-intervention increases in lean body mass in both groups.
Murlasits et al.[47]	Untrained older men ($n = 11$) and women ($n = 18$)	8	3 sets × 8 repetitions	Yes	No	2 vs. 3	2 = 90% 3 = 90%	DXA	Significant pre- to post-intervention increases in lean body mass in both groups, with no significant between-group differences.
Ribeiro et al.[51]	Untrained older women ($n = 39$)	12	1 sets × 10–15 repetitions	Yes	No	2 vs. 3	2 = 95% 3 = 97%	BIA	Significant pre- to post-intervention increases in lean body mass in both groups, with no significant between-group differences.
Serra et al.[53]	Untrained young and middle-aged men ($n = 41$) and women ($n = 27$)	12	3 sets × 10–12 repetitions	Yes	No	2 vs. 3 vs. 4	Mean of 95%	Skinfolds	No significant pre- to post-intervention increases in lean body mass in either group.
Stec et al.[27]	Untrained older men ($n = 15$) and women ($n = 14$)	30	3 sets × 8–12 repetitions	Yes	No	2 vs. 3	2 = 91% 3 = 87%	DXA	Significant pre- to post-intervention increases in lean body mass in both groups, with no significant between-group differences.
Taaffe et al.[48]	Untrained older men ($n = 29$) and women ($n = 17$)	24	3 sets × 8 repetitions	No	No	1 vs. 2 vs. 3	1 = 98% 2 = 99% 3 = 97%	DXA	Significant pre- to post-intervention increases in lean body mass in all groups, with no significant between-group differences.
Thomas and Burns[11]	Young trained men ($n = 12$) and women ($n = 7$)	8	3–6 sets × 8–12 repetitions	Yes	Yes	1 vs. 3	Not presented	DXA	Significant pre- to post-intervention increases in lean body mass in both groups, with no significant between-group differences.
Trupela et al.[8]	Older untrained men ($n = 31$) and women ($n = 41$)	12	2–5 sets × 4–12 repetitions	A minimum of one set was performed to muscular failure	No	1 vs. 2 vs. 3	A minimum of 90%	DXA	No significant pre- to post-intervention increases in lean body mass in either group.
Westcott et al.[49]	Young to older untrained men ($n = 397$) and women ($n = 1328$)	10	1 set × 8–12 repetitions	Yes	No	1 vs. 2 vs. 3	1 = 84% 2 = 83% 3 = 80%	Skinfolds	Significant pre- to post-intervention increases in lean body mass in all groups. The groups training two and three times per week experienced greater gains in lean body mass compared to the group training once per week.
Yue et al.[10]	Young trained men ($n = 18$)	6	2–4 sets × 8–12 repetitions	Yes	Yes	2 vs. 4	2 = 100% 4 = 100%	BOD-POD	Significant pre- to post-intervention increases in lean body mass only in the group training two times per week.

BOD-POD air displacement plethysmography, *DXA* dual energy X-ray absorptiometry, *BIA* bioelectric impedance analysis

Table 3
Summary of the studies using circumference as an estimate of muscular hypertrophy.

Reference	Sample	Training duration (weeks)	Exercise prescription	Were repetitions performed to momentary muscular failure?	Volume equated?	Frequency comparison (times/week)	Adherence to the training	Measurement site	Main findings
Arazi and Asadi[57]	Young untrained men ($n = 20$)	8	1 set × 6–12 repetitions	No	Yes	1 vs. 2	Not presented	Upper arm and thigh	Significant pre- to post-intervention increases in arm circumference in the group training once per week. Significant pre- to post-intervention increases in thigh circumference in group training two times per week.
Gentil et al.[25]	Young untrained men ($n = 30$)	10	3 sets × 8–12 repetitions	Yes	Yes	1 vs. 2	A minimum of 80%	Upper arm	Significant pre- to post-intervention increases in arm circumference in both groups, with no significant between-group differences.
Hunter[50]	Young untrained men ($n = 22$) and women ($n = 24$)	7	2–3 sets × 7–10 repetitions	Yes	Yes	3 vs. 4	Not presented	Upper arm and chest	Significant pre- to post-intervention increases in arm circumference in both groups, with no significant between-group differences. Significant pre- to post-intervention increases in chest circumference in both groups; however, the group training four days per week increased chest circumference significantly more than the group training three days per week.
McLester et al.[46]	Young trained men ($n = 14$) and women ($n = 11$)	12	1–3 sets × 8–10 repetitions	Yes	Yes	1 vs. 3	Not presented	Upper arm, chest, and thigh	No significant pre- to post-intervention increases in girth in both groups.
Yue et al.[10]	Young trained men ($n = 18$)	6	2–4 sets × 8–12 repetitions	Yes	Yes	2 vs. 4 and 1 vs. 2[a]	2 = 100% 4 = 100%	Upper arm and thigh	Significant pre- to post-intervention increases in arm circumference only in the group training two times per week. No significant pre to post-intervention increases in thigh girth occurred.

[a] The training frequency varied based on the muscle group.

5. Conclusions

Based on the data from the 28 included studies, this review provides a complete overview of the current literature with respect to the effect of RT frequency of muscle hypertrophy, and may help to facilitate future research in this area. Most of the studies that compared different RT frequencies report no significant differences between the training conditions, irrespective of the hypertrophy measurement tool, although evidence suggests a potential benefit (albeit, a slight one) to frequencies greater than one day-per-week. Thus, it appears that the magnitude of muscular hypertrophy is more influenced by training variables such as training volume[19,20,21,59] and it can be inferred that RT frequency plays a secondary role in this regard, at least for training frequencies up to four days per week. Given the reported dose–response relationship between training volume and muscle growth,[20,21] higher training frequencies might be used to increase the total weekly training volume and achieve progressive overload.

In some cases, greater RT frequencies can be employed for variety, which conceivably might augment muscle growth due to a novelty effect. Therefore, higher/lower RT frequencies can be employed in various stages of an annual training plan. Given the limited research to date, further studies should consider comparing training frequencies of four or more days per week, preferably by employing a volume-equated design (Section 2.4). Most of the studies examined very similar training frequencies, such as one versus two, two versus three, and three versus four times per week. Therefore, the area is ripe for future studies comparing vastly different training frequencies, such as RT one or two times per week versus RT six or seven times per week, under volume-equated conditions.

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