Is power training effective to produce muscle hypertrophy in older adults? A systematic review and meta-analysis

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ABSTRACT

Power training has been suggested to be effective to improve strength, power, and functional capacity in older adults. However, there is still a lack of systematic investigations reporting its effectiveness for muscle hypertrophy. Thus, this study investigated the effect of power training on muscle hypertrophy and compared its magnitude with traditional moderate-velocity resistance training in older adults. A systematic search was conducted to identify clinical trials investigating the effect of power training on muscle hypertrophy (power training vs. control), and/or comparing the effect of power training vs. moderate-velocity resistance training for a meta-analytical approach. Ten studies comparing power training to control conditions and nine studies comparing power training to moderate-velocity resistance training were selected. Three studies were classified as high quality and two were preregistered. The meta-analysis showed that power training was superior for muscle hypertrophy compared to control condition (n=8 studies; SMD=0.31; 95%CI=0.04, 0.58; p=0.029), and resulted in similar hypertrophy compared to moderate-velocity resistance training (n=7 studies; SMD=0.07; 95%CI=-0.18, 0.32; p=0.50). No significant heterogeneity was observed (p=0.46 and 0.54, and $I^2=0$ and 0%, respectively). Our data suggest that power training is effective for muscle hypertrophy in older adults, with similar effectiveness as moderate-velocity resistance training.

Novelty

-It is known that power training might be superior to moderate-velocity resistance training for function improvements in older adults, but there was no meta-analysis investigating its effect on muscle hypertrophy.

-Power training is effective to induce muscle hypertrophy in older adults to a similar extent to moderate-velocity resistance training.

Key words: Ageing; Elderly; Hypertrophy; Strength training; Resistance training; Muscle mass. PROSPERO registration number: CRD42019128951
1. INTRODUCTION

The number of humans above 65 years of age is expected to reach approximately 1.6 billion globally, by the year of 2050. The expectation that older adults remain actively engaged in the work-force for longer, and the socioeconomic burden imposed by their loss of independence (Stevens et al. 2006; Burge et al. 2007; Heinrich et al. 2010; Cross et al. 2014; Hunter et al. 2014; Bruyère et al. 2019) makes the development of effective strategies to attenuate the negative effects of aging increasingly important. Aging is accompanied by a remarkable reduction in muscle mass, which accelerate after 60 years (Janssen et al. 2000; Kyle et al. 2001; Orssatto et al. 2018; Larsson et al. 2019). Therefore, it seems imperative to determine what strategies are optimal (or sub-optimal) to promote muscle hypertrophy in older adults.

Resistance training is considered the gold-standard treatment to increase or maintain muscle mass and counteract the age-related muscle wastage (Steib et al. 2010; Peterson et al. 2011; Borde et al. 2015; Csapo and Alegre 2015; Lopez et al. 2018; Orssatto et al. 2018; Beckwée et al. 2019). Resistance training is typically performed with moderate velocities (2-3 s) in older adults (Borde et al. 2015), but recently, it has been suggested that training with high-velocity movements (i.e. power training) would provide superior benefits for this population (Byrne et al. 2016; Cadore and Izquierdo 2018; Cadore et al. 2018; Orssatto et al. 2019a, 2019b). Power training may elicits greater improvements in functional capacity and muscular power (Steib et al. 2010; Straight et al. 2015; Byrne et al. 2016; Orssatto et al. 2019a, 2019b) and can improve muscular strength to a similar extent to that observed after slow to moderate-velocity resistance training (Steib et al. 2010; Tschopp et al. 2011; Byrne et al. 2016). However, the effects on muscle are contradictory, where some original studies reported muscle hypertrophy (Henwood et al. 2008; Correa et al. 2012; Cadore et al. 2014) while others did not (Marsh et al. 2009; Wallerstein et al. 2012; Zech et al. 2012). It has been recommended that
power training should be employed with lower intensity (40-60% and 70-85% of 1RM, respectively) and number of repetitions compared to traditional resistance training (Fragala et al. 2019; Orssatto et al. 2019b), resulting in lower training volume. It is important to note that training volume is probably the most important training variable to promote muscle hypertrophy (Figueiredo et al. 2017). In addition, this population presents a lower anabolic response to resistance training (i.e. anabolic resistance) when compared to young adults (Hodson et al. 2019). Thus it is not clear if, the typically low volume, power training is an enough stimulus to induce significant muscle hypertrophy in older adults. If so, it is also not known if it is as effective as the traditional moderate-velocity resistance training, since higher training volumes (typically observed during moderate-velocity resistance training) are required to enhance muscle hypertrophy in older adults (Peterson et al. 2011; Figueiredo et al. 2017).

There is a lack of high-quality systematic review comparing the effect of these two training modalities on muscle hypertrophy. In fact, only two studies have attempted to synthesise the literature on this topic. One was a narrative review that did not involve a meta-analysis (Orssatto et al. 2019a). The other was a systematic review and meta-analysis (Tschopp et al. 2011), however, the literature search was conducted 9 years ago and only two studies comparing both types of training were included. In regards to this last study, it is important to note two major limitations, which are the low statistical power, and the lack of risk of bias assessment. As a number of experimental trials have been published since the most recent systematic review, it is now possible to conduct a meta-analysis providing more robust evidence about the topic. This study aims to investigate the effect of power training on muscle hypertrophy in older adults. Thereafter, we aim to compare the effect of power versus moderate-velocity resistance training on muscle hypertrophy in older adults. It was hypothesised that power training does result in muscle hypertrophy and that this effect would be of similar magnitude to that observed after moderate-velocity resistance training.
2. MATERIALS AND METHODS

This study was registered at the International Prospective Register of Systematic Reviews (PROSPERO: CRD42019128951). The conduct and reporting of this review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al. 2009) and was designed based on criteria from A MeaSurement Tool to Assess systematic Reviews (AMSTAR) (Pollock et al. 2017).

2.1. Search strategy and eligibility criteria

A systematic literature search was undertaken in the PUBMED, SCOPUS, and Web of Science databases in May 2019. The adopted terms were related to aging, power and resistance training, and muscle mass. The complete search strategy adopted for each database is detailed in Supplementary File S1. After study selection, the reference lists of selected studies were screened for additional studies. The search included journal articles, conference proceeding and meeting abstracts, with no language restriction. Two different study selection criteria were used: 1) Studies in which power training was compared to a control condition; and 2) Studies in which power training was compared to moderate-velocity resistance training. The PRISMA flow diagram is illustrated in Figure 1 (Moher et al. 2009).

Study inclusion was decided by the consensus between authors LBRO and ESB. In cases of disagreement on the inclusion of an article, GST was consulted. Inclusion criteria were defined according to the PICOS approach (Liberati et al. 2009). Study selection criteria 1: Population: participants aged ≥60 years; Intervention: resistance training-based intervention; Comparator: Power training compared to control conditions; Outcome: changes in muscle or lean mass after the intervention; Study design: randomised controlled trials. Study selection criteria 2: Adopted a similar approach compared to the selection criteria 1, except for the
comparator considering the training velocity comparison (power training vs. moderate-velocity resistance training) and the study design (randomised trials).

Exclusion criteria were defined as follows: 1) did not compare the effects of power training (fast concentric velocity) with a control group and/or a moderate-velocity resistance training group (where moderate-velocity training was characterised by concentric contractions lasting ≥ 2 s); 2) did not report results adequately without accessibility to the data by alternative manners (e.g., contacting authors); 3) examination of the effects of combined training methods (i.e. power and moderate-velocity resistance training) within the same group (e.g., mixed session periodization (Bezerra et al. 2018)); 4) Adopted a doubly indirect body composition method (e.g., anthropometric or bioelectrical impedance measurements). In addition, when different published reports were derived from the same trial, we excluded the one with the shorter intervention period.

2.2. Data extraction

First, study characteristics were extracted: Country where the study was conducted, participants’ age, baseline and final sample size (n), muscle hypertrophy assessment method and the measured body part. Thereafter, training characteristics were extracted: Adopted exercises, training duration, weekly frequency, intensity, sets and repetition volume, rest interval and contraction velocities.

For the meta-analysis, the mean and standard deviation (or standard error) of the outcome measurements (muscle or lean mass) were extracted for each group. When data was presented in graphs, data was extracted with Web Plot Digitizer (version 4.1). When the standard error was reported, it was transformed in standard deviation by multiplying the standard error by the square root of the sample size.
2.3. Quality assessment

Methodological study quality was carried out using the Physiotherapy Evidence Database (PEDro) scale (Maher et al. 2003). This scale rates randomised clinical trials on a scale from 0 to 10 (low- to high-quality) with a cut-off score for high-quality of 6 points. With the intention of avoiding potential author’s bias, scores were obtained from PEDro database, in which the studies are scored by independent researches. When a study was not available on the PEDro database, LBRO and ESB independently rated the risk of bias. Any disagreement was resolved by GST. In addition, articles were screened to identify if prospective registration of the clinical trial was conducted.

2.4. Statistical analysis

Muscle hypertrophy were calculated for control, power training and moderate-velocity resistance training groups from the difference between final and baseline mean and standard deviation. For the studies in which change standard deviation was not reported, it was imputed with a specific equation (\( r = 0.5 \)) (Higgins and Green 2008).

RStudio (Version 1.0.153) was used for all analyses (packages: meta (Balduzzi et al. 2019), metafor (Viechtbauer 2010), dmetar (Harrer et al. 2019), dplyr, and tidyverse (Wickham et al. 2019)). Meta-analysis was undertaken with the standardised mean difference, the inverse variance method, random effects (Hartung-Knapp adjustment), with Sidik-Jonkman estimator for \( \tau^2 \) (Sidik and Jonkman 2007). Heterogeneity was assessed by visual inspection of forest plots and using \( X^2 \) test for heterogeneity (\( \alpha = 10\% \)), and described inconsistency between trials using the \( I^2 \) statistic (\( I^2 = 0 – 40\%, \) might not be important; \( 30 – 60\% \), may represent moderate heterogeneity; \( 50 – 90\% \), may represent substantial heterogeneity; and \( 75 – 100\% \), considerable heterogeneity) (Deeks et al. 2008). Two meta-analyses were conducted: 1) comparing power
training and control groups; and 2) comparing power training and moderate-velocity resistance training groups.

When studies compared the control group with two power training groups (Correa et al. 2012; Strandberg et al. 2015), the standardised mean difference was pooled before the final meta-analysis. The same was performed when a study presented multiple measures of muscle hypertrophy. These results were pooled with the inverse variance and random effects method (Higgins and Green 2008). We adopted \( \alpha = 5\% \) for all meta-analysis.
3. RESULTS

3.1. Summary of findings

The systematic search retrieved 1749 studies, 609 of which were duplicates. 1140 titles and abstracts and 85 full-text were screened for eligibility. The selection of manuscripts comparing power training and control conditions resulted in ten included studies (Reid et al. 2008; Henwood et al. 2008; Marsh et al. 2009; Correa et al. 2012; Wallerstein et al. 2012; Zech et al. 2012; Cadore et al. 2014; Strandberg et al. 2015; Hvid et al. 2016; Gray et al. 2018), and the selection of manuscripts comparing power training and moderate-velocity resistance training resulted in nine included studies (Reid et al. 2008; Henwood et al. 2008; Marsh et al. 2009; Nogueira et al. 2009; Claflin et al. 2011; Correa et al. 2012; Wallerstein et al. 2012; Zech et al. 2012; Gray et al. 2018). A PRISMA flow diagram of the articles search, included, and excluded studies are described in Figure 1. A list of excluded studies is presented in Supplementary File S2.

** Figure 1 near here **

3.2. Methodological Quality

PEDro scores ranged from 3 to 7 for the selected studies, with only three studies ranked as high-quality (Reid et al. 2008; Zech et al. 2012; Cadore et al. 2014) (Table 1 and Supplementary File S3). The low overall rating resulted mainly from the lack of allocation concealment, participant, therapist, and assessor blinding, adequate follow-up, and the lack of intention-to-treat analysis for most of the studies (Supplementary File S3 provided a detailed description for each study). From the selected studies, only two pre-registered their clinical trials (Zech et al. 2012; Hvid et al. 2016) (Table 1).
3.3. Studies characteristics

Ten studies were included in the power training vs. control comparison with a total of 257 and 200 participants at the commencement of training and control interventions, respectively. However, 195 of 257 experimental and 149 of 200 control participants completed the studies and were included in the analyses; giving dropout rates of ~25% and ~27%, for power training and control groups, respectively. Regarding the muscle/lean mass assessment methods, the studies used computed tomography (n = 1), magnetic resonance imaging (n = 1), ultrasonography (n = 2), and dual-energy x-ray absorptiometry (n = 6). Six studies assessed lower limbs and four assessed the whole body (Table 1).

Nine studies were included in the power training vs. moderate-velocity resistance training comparison. A total of 193 and 184 participants started the power training and moderate-velocity training interventions, respectively, while 157 and 136 concluded the final measurements and were included in the analyses, with dropout rates of ~22% and ~25% for power training and moderate-velocity training, respectively. The studies used magnetic resonance imaging (n = 1), muscle fibre biopsy (n = 1), ultrasonography (n = 2), and dual-energy x-ray absorptiometry (n = 5). Five of them assessed lower limbs, one the upper limbs, and four the whole body (Table 1).

Participants’ age means ranged from 63.0 to 93.4 years, eight studies included apparently health and active elderly and four studies included institutionalised frail, mobility-limited, or pre-frail elderly. All studies reported that included participants were untrained. One study tested only men, two tested only women, two did not report the participants’ sex, and the other studies mixed men and women.

** Table 1 near here **
3.4. Training Characteristics

The training characteristics varied among studies. Training duration ranged from 10 to 48 weeks and training session frequency ranged from 2 to 3 sessions per week and these were similar between power and moderate-velocity resistance training for all the studies. On the other hand, training intensity for power training ranged from 30 to 85% and for moderate-velocity resistance training from 40 to 85% of 1RM. The intensity was similar between groups in four studies and lower for power training in three studies compared to moderate-velocity resistance training. The number of sets (2-4) and repetition range (4-15) were similar between power and moderate-velocity resistance training groups, except in one study (Wallerstein et al. 2012) (Table 2).

** Table 2 near here **

3.5. The effect of power training vs. control condition on muscle hypertrophy

The meta-analysis comparing power training to a control condition included eight studies because it was not possible to access the data from Reid et al. (2008) and Gray et al. (2018). Meta-analysis indicated that power training had a positive effect on muscle hypertrophy compared to the control condition (p = 0.0296). There was no heterogeneity between studies ($\chi^2$ statistics, p = 0.457) (Figure 2).

** Figure 2 here **
3.6. Power training vs. Moderate-velocity resistance training and muscle hypertrophy

The meta-analysis comparing power training to moderate-velocity resistance training included seven studies because it was not possible to access the data from Reid et al. (2008) and Gray et al. (2018). Meta-analysis indicated similar effects for muscle hypertrophy between groups ($p = 0.499$). There was no significant heterogeneity in these results ($\chi^2$ statistics, $p = 0.536$) (Figure 3).

** Figure 3 here **
4. DISCUSSION

4.1. Effects of power training on muscle hypertrophy

The main findings of the present systematic review and meta-analysis indicate a positive effect of power training on muscle hypertrophy when compared to control conditions. When comparing the effects of power training vs. moderate-velocity resistance training, the meta-analysis resulted in a standardised mean difference almost equal to zero, which suggests similar muscle hypertrophy when training with either method.

The comparison between power training and control conditions demonstrated a significant effect favouring power training. However, it could be noted that for three studies the effect was null, two studies presented a very small effect, and three studies resulted in an advantage for power training with effect higher than the pooled standardised mean difference. This varied response is also reflected in the 95% predictive interval, which shows that it is expected in future study effects ranging from -0.28 to 0.89. It was not possible to find any determinant factor to speculate the reasons for the observed differences in effects. For example, participants’ characteristics (age and health status) and muscle hypertrophy measurement methods varied similarly between the studies with small and large effect (See Table 1 and Figure 2). The same is observed for the power training characteristics, where studies with smaller and larger effects varied similarly for exercise quantity, training duration, frequency, intensity, sets per exercise, repetitions per set, and between-sets rest interval (See Table 2 and Figure 2). Therefore, these results might have been influenced by the small number of studies and the heterogeneity observed for participants, training characteristics, and hypertrophy measurement sites and methods (Tables 1 and 2). However, it does not allow any speculation trying to understand the differences between-studies magnitude of effect differences when compared to control conditions.
There was a similar effect observed for the comparison between power and moderate-velocity resistance training. Of the seven studies included, two showed an advantage for moderate-velocity resistance training (Henwood et al. 2008; Wallerstein et al. 2012), while two showed an advantage for power training (Nogueira et al. 2009; Correa et al. 2012). Interestingly, the studies favouring moderate-velocity resistance training adopted lower volume-load (i.e., lower % of 1RM for both studies and less repetitions were used in Wallerstein et al. (2012)) for the power training groups, while studies favouring power training employed similar volume-load between groups (Nogueira et al. 2009; Correa et al. 2012). It is important to note that the two studies that reported favourable results for power training lasted six (Correa et al. 2012) and 10 weeks (Nogueira et al. 2009), while the two studies favouring moderate-velocity resistance training were 16 (Wallerstein et al. 2012) and 22 (Henwood et al. 2008) weeks in duration. Thus, it is unclear if power training induces a faster muscle hypertrophy response and moderate-velocity resistance training a higher response after longer periods, or if it is just because the total training volume-load (Figueiredo et al. 2017) was lower for power training in these studies favouring moderate-velocity. Other training variables (exercise selection, duration, frequency, sets per exercise, reps per set, and between-sets interval) were matched between power training and moderate-velocity resistance training for most of the studies, which allows us to speculate that simply increasing the contraction velocity did not reduce the magnitude of muscle hypertrophy when compared to moderate velocity. As mentioned for the power training vs control conditions comparison, the small number of studies and the heterogeneity observed for participants, training characteristics, and hypertrophy measurement sites and methods (Tables 1 and 2) might have influenced the results. However, all this heterogeneity makes it difficult the understanding of the reasons or mechanisms related to the between-studies dissimilar responses.
4.2. Agreement and disagreement with other reviews

To the best of the authors’ knowledge, no previous meta-analysis has investigated the effects of power training, compared to a control group, on muscle hypertrophy in older adults. Borde et al. (2015) reported a standardised mean difference of 0.42 (95% CI = 0.18 – 0.66) comparing resistance training with a control group in older adults, which is similar to our results for power training.

Two previous reviews attempted to compare the effects of power and moderate-velocity resistance training on muscle hypertrophy in older adults (Tschopp et al. 2011; Orsatto et al. 2019a). Tschopp et al. (2011) reported similar muscle hypertrophy between moderate-velocity resistance training and power training. However, their meta-analysis included only two studies (Marsh et al. 2009; Nogueira et al. 2009). Orsatto et al. (2019a) reported a similar percentage change per week with these two training methods; although, they did not conduct a systematic review and meta-analysis to compare training methods. Despite these limitations, these reviews are in agreement with our findings.

4.3. Potential biases in the review process and data analyses

The systematic literature search resulted in ten studies comparing the effects of power training to control condition, and nine studies comparing power and moderate-velocity resistance training methods. Eight studies were included in the power training vs. control comparison, and seven in the power training versus moderate-velocity resistance training meta-analyses.

We tried to reduce bias during data analyses by excluding different articles from the same clinical trial, thereby avoiding results duplication (Higgins and Green 2008). Strandberg et al. (2015) published a second study from the same clinical trial two years later (Edholm et al. 2017). Zech et al. (2012) performed a clinical trial with a duration of 36 weeks but also
published data from the first 12 weeks of their study (Drey et al. 2012). Unfortunately, Reid et al. (2008) and Gray et al. (2018) did not report the complete body composition data and did not respond to our request for data so these studies could not be included in the meta-analyses.

We also attempted to minimise bias by selecting only studies that did not adopt doubly indirect body composition measurements. However, some limitations regarding the different muscle assessment methods should be mentioned. Magnetic resonance imaging and computed tomography measured the cross-sectional area of the selected muscles, while ultrasound was used to measure the muscle thickness (distance from the most superficial to the deepest muscle aponeurosis on a cross-sectional section), and dual-energy x-ray absorptiometry measured total body or appendicular lean mass, which contains other tissues different from fat. Thus, different methods might result in different magnitude of changes (Vigotsky et al. 2018; Haun et al. 2019). However, this bias is minimised because between-group comparisons (power training vs. control and power vs. moderate-velocity resistance training) always involved a single method of measurement, and studies effects sizes were pooled with a standardised mean difference.

4.4. Heterogeneity, publication bias, quality of the evidence, and pre-registration

No significant heterogeneity was observed for either meta-analyses, which indicate homogeneity of study results. The small number of studies included in the meta-analysis disallowed assessment of small-studies publication bias with a funnel plot and Egger’s test analysis, which requires >10 studies for enough statistical power to distinguish real asymmetry (Higgins and Green 2008).

Our results might be influenced by a high risk of bias, derived from their methodological quality because only two studies (Zech et al. 2012) included in the current
meta-analyses achieved a high-quality classification according to the PEDro scale (≥ 6 points). Future studies should attempt to address some feasible criteria not addressed in most of the included studies, such as concealed allocation, blinding of assessors, and intention-to-treat analysis. Moreover, only two studies conducted a prospective registration of their clinical trials (Zech et al. 2012; Hvid et al. 2016). It has been suggested that pre-registration can increase research transparency by reporting all the methods, procedures, and outcomes before the intervention commencement, avoiding selective reporting of outcomes and manipulation of statistical analysis favouring significant effects (Zarin et al. 2011; Kaplan and Irvin 2015).

4.5. Relevance of muscle hypertrophy for older adults

The loss of muscle mass during aging is detrimental for older adults’ health. For example, skeletal muscle plays a role in determining insulin resistance (Matta et al. 2016), cardiovascular disease (Baumgartner et al. 1999), arterial stiffness (Ochi et al. 2010), bone mineral content (Baumgartner et al. 1996), and in the secretion of myokines (e.g., growth factors and cytokines), which can affect the age-related deterioration of several others biological systems (Demontis et al. 2013). Higher levels of muscle loss combined with decreases in muscle strength and functional capacity can lead to sarcopenia (Cruz-Jentoft et al. 2019). Thus, benefit of muscle hypertrophy induced by using the power training method, which might be more effective than moderate-velocity resistance training for other training outcomes, has an important implication for older adults’ health. It has been shown that power training favours power and explosive force adaptations (Steib et al. 2010; Straight et al. 2015; Byrne et al. 2016; Orsatto et al. 2019a). However, the potential advantage for functional capacity improvements remains unclear (Orsatto et al. 2019b).
4.6. Implications for research

Most of the studies included in our meta-analysis were of low methodological quality and only two were pre-registered. Further high quality, pre-registered trials are required to conclusively evaluate the relative effectiveness of power training for muscle hypertrophy in older adults. In addition, the use of similar intensities between groups should be considered because this is a potentially confounding factor when comparing power and moderate-velocity resistance training. Future studies should also consider the use of more robust and accurate methods of assessing muscle volume (e.g., magnetic resonance imaging, computed tomography or ultrasound) rather than muscle thickness, anatomical cross-sectional area, and lean mass assessment.

Researchers should also consider the typical ~25% dropout rates observed in studies of this type when determining participant numbers. This may help to ensure adequate statistical power for the final statistical analyses.
5. CONCLUSIONS

Based on the available data, our findings suggest that power training is as effective as moderate-velocity resistance training for muscle hypertrophy in older persons. However, the lack of high-quality and pre-registered studies and the lack of more accurate methods use for muscle hypertrophy assessment indicates the need to adopt more robust methods in future studies. Nevertheless, the current evidence indicates that power training can be prescribed to muscle hypertrophy in older adults. Caution should be taken when extrapolating these findings for trained individuals.
6. IMPLICATIONS FOR PRACTICE

- Our findings have significant implications for clinical practice. Exercise professionals may consider both the use of power training or moderate-velocity resistance training for muscle hypertrophy in untrained older persons.

- Based on the evidence available to date this type of training could be preferred over moderate-velocity resistance training since our data showed similar muscle hypertrophy between methods, and previous studies indicated that power training might be superior for functional capacity and power (Steib et al. 2010; Straight et al. 2015; Byrne et al. 2016; Orssatto et al. 2019a) improvements in older adults. It is important to highlight that all studies adopted untrained participants, which does not allow certain extrapolation of our findings for resistance-trained participants.

- The wide heterogeneity observed between studies’ training protocols should be considered when prescribing power training for older adults.

- It is important to consider, however, that the interventions included in the current study were 6-24 weeks in duration, so it is not possible to determine how power training compares to moderate-velocity training over longer periods.
CONFLICT OF INTEREST

The authors have no conflicts of interest to report
REFERENCES


Hunter, D.J., Schofield, D., and Callander, E. 2014. The individual and socioeconomic...


Figures legends:

**Figure 1.** PRISMA flow diagram for the systematic review. MVRT, moderate-velocity resistance training; PT, power training.

**Figure 2.** Forest plot presenting standardised mean differences and 95% confidence intervals from studies comparing the effect of power training to control conditions. SMD, standardised mean difference; PI, predictive interval; CI, confidence interval. Red, low-quality studies (PEDro score <6); Green, high-quality study (PEDro score ≥6).

**Figure 3.** Forest plot presenting standardised mean differences and 95% confidence intervals from studies comparing the effect of power training and moderate-velocity resistance training. MVRT, moderate-velocity resistance training; SMD, standardised mean difference; PI, predictive interval; CI, confidence interval. Red, low-quality studies (PEDro score <6); Green, high-quality study (PEDro score ≥6).
<table>
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<tr>
<th>Reference</th>
<th>Search</th>
<th>Country</th>
<th>Intervention method</th>
<th>Age</th>
<th>Health and training status</th>
<th>Initial n</th>
<th>Final n (W%)</th>
<th>Subjects exclusion n</th>
<th>Muscle/lean mass method</th>
<th>Assessed region</th>
<th>PEDr scores (0-10)</th>
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<td>Cadore et al. 2014</td>
<td>1</td>
<td>Spain</td>
<td>Power</td>
<td>93.4±3.2</td>
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<td>USA</td>
<td>Power</td>
<td>81.6±5.9</td>
<td>Apparently healthy (at least 12 months untrained)</td>
<td>34</td>
<td>20 (70%)</td>
<td>14</td>
<td>DXA</td>
<td>Total body lean mass</td>
<td>4*</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Traditional</td>
<td>81.0±5.5</td>
<td></td>
<td>41</td>
<td>25 (60%)</td>
<td>16</td>
<td></td>
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<td></td>
<td>Control</td>
<td>81.3±5.3</td>
<td></td>
<td>24</td>
<td>8 (63%)</td>
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<td>Henwood et al. 2008</td>
<td>1 and</td>
<td>Australia</td>
<td>Power</td>
<td>71.2±5.7</td>
<td>Apparently healthy (at least 6 months untrained)</td>
<td>23</td>
<td>19 (63%)</td>
<td>3</td>
<td>DXA</td>
<td>Total body lean mass</td>
<td>4</td>
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Table 1. Studies’ characteristics
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<tr>
<th>Study</th>
<th>Country</th>
<th>Group</th>
<th>Measurement</th>
<th>Power</th>
<th>Control</th>
<th>Power</th>
<th>Control</th>
<th>Measure</th>
<th>N</th>
<th>Yes/No</th>
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<tr>
<td>Hvid et al. 2016</td>
<td>Denmark</td>
<td>Traditional</td>
<td>69.6±4.8</td>
<td>69.3±3.9</td>
<td>12 months untrained</td>
<td>22</td>
<td>19 (63%)</td>
<td>3</td>
<td>Combined measure of the Vastus intermedius rectus femoris thickness</td>
<td>5</td>
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<tr>
<td></td>
<td></td>
<td>Power</td>
<td>82.3±5.2</td>
<td>81.6(4.4)</td>
<td>Mobility-limited (training level not reported)</td>
<td>33</td>
<td>16 (56%)</td>
<td>17</td>
<td>B-mode Ultrasound</td>
<td></td>
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<tr>
<td>Marsh et al. 2009</td>
<td>USA</td>
<td>Traditional</td>
<td>74.6±5.4</td>
<td>74.4±5.2</td>
<td>Apparently healthy and having a self-reported disability (not currently participating in regular exercise sessions)</td>
<td>15</td>
<td>11 (82%)</td>
<td>4</td>
<td>DXA Total body lean mass</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power</td>
<td>76.8±6.4</td>
<td>74.6±5.4</td>
<td></td>
<td>15</td>
<td>12 (58%)</td>
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<td></td>
<td></td>
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<tr>
<td>Nogueira et al. 2009</td>
<td>Brazil</td>
<td>Traditional</td>
<td>66.6±5.7</td>
<td>66.3±4.5</td>
<td>Apparently healthy (at least 6 months untrained)</td>
<td>12</td>
<td>11 (0%)</td>
<td>1</td>
<td>B-mode Ultrasound Rectus femoris and Biceps Brachii thickness</td>
<td>3</td>
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<tr>
<td>Reid et al. 2008</td>
<td>USA</td>
<td>Traditional</td>
<td>72.3±6</td>
<td>73.1±6</td>
<td>Mobility-limited</td>
<td>23</td>
<td>21 (100%)</td>
<td>2</td>
<td>DXA Leg lean mass</td>
<td>6</td>
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<td></td>
<td></td>
<td>Control</td>
<td>70.7±9</td>
<td>70.7±9</td>
<td></td>
<td>12</td>
<td>11 (100%)</td>
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<tr>
<td>Strandberg et al. 2015</td>
<td>Sweden</td>
<td>Power</td>
<td>68±8.2</td>
<td>74.5±5.2</td>
<td>Apparently healthy and active (no mobility limitation)</td>
<td>21</td>
<td>17 (100%)</td>
<td>4</td>
<td>DXA Leg lean mass</td>
<td>4*</td>
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<tr>
<td>Study</td>
<td>Country</td>
<td>Power + Diet</td>
<td>History of resistance training practice</td>
<td>Control</td>
<td>Gender</td>
<td>Measurement</td>
<td>Search</td>
<td>Modality</td>
<td>Cross-sectional area</td>
<td>Study Design</td>
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<tr>
<td>Wallerstein et al. 2012</td>
<td>Brazil</td>
<td>Power</td>
<td>Apparently healthy (sedentary or performing light aerobic activities)</td>
<td>Control</td>
<td></td>
<td>Magnetic resonance imaging</td>
<td>4</td>
<td>Yes</td>
<td>Quadriceps femoris cross-sectional area</td>
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<td></td>
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<td>Traditional</td>
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<tr>
<td>Zech et al. 2012</td>
<td>Germany</td>
<td>Power</td>
<td>Pre-frail (not currently participating in regular resistance training sessions)</td>
<td>Control</td>
<td></td>
<td>DXA</td>
<td>7</td>
<td>Yes</td>
<td>Appendicular lean mass</td>
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</table>

Search 1, power training vs. control condition comparison; search 2, power training vs. moderate-velocity resistance training; *Scored by the present study’s authors. DXA, Dual-energy X-ray Absorptiometry; M, men; W, women; NR, not reported.
<table>
<thead>
<tr>
<th>Reference</th>
<th>Intervention</th>
<th>Exercises</th>
<th>Duration</th>
<th>Frequency</th>
<th>Intensity</th>
<th>Sets/exercise</th>
<th>Reps per set</th>
<th>Rest (s)</th>
<th>Conc vel</th>
<th>Ecc vel</th>
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<tbody>
<tr>
<td>Cadore et al. 2014</td>
<td>Power</td>
<td>Bilateral leg extension, bilateral knee extension, and seated bench press</td>
<td>12</td>
<td>2</td>
<td>40-60% 1RM</td>
<td>NR</td>
<td>8-10</td>
<td>NR</td>
<td>High-velocity</td>
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<td>Claflin et al. 2011</td>
<td>Power</td>
<td>Standard seated leg press and standing hip flexion.</td>
<td>14</td>
<td>3</td>
<td>To perform 2 sets of 10 reps and a third set with failure between 5-15 reps</td>
<td>3</td>
<td>10 and concentric failure between 5-15 reps</td>
<td>NR</td>
<td>Hip flexion = 250-350°/s Leg press = 100-160°/s</td>
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<td>Moderate-velocity</td>
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<td>Correa et al. 2012</td>
<td>Rapid strength</td>
<td>Knee extension Knee flexion Lateral box jump.</td>
<td>CP6+6</td>
<td>2</td>
<td>8–12 RM and Box heights 10 - 30 cm</td>
<td>3-4</td>
<td>8 - 12</td>
<td>120s</td>
<td>AFAP 2s</td>
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<tr>
<td>Power</td>
<td>Leg press Knee extension Knee flexion</td>
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<td>AFAP 2s</td>
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<td>AFAP 2s</td>
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<td>AFAP 2s</td>
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<td>2s</td>
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<tr>
<td>Gray et al. 2018</td>
<td>Power</td>
<td>Standing knee curl, Heel raises, Chair stand or Half lunge.</td>
<td>CP24+24</td>
<td>2</td>
<td>80% 1RM for 24 weeks and 50% 1RM for the remaining 24 weeks.</td>
<td>3</td>
<td>10</td>
<td>NR</td>
<td>AFAP 2s</td>
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<td>Study</td>
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<td>Exercise Mode</td>
<td>Exercise Reps</td>
<td>Training RM</td>
<td>MVIC</td>
<td>Time to Fatigue</td>
<td>Comments</td>
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<td>Henwood et al. 2008</td>
<td>Power</td>
<td>Leg press, leg curl, and Leg extension</td>
<td>CP2+22</td>
<td>80%1RM</td>
<td>45-75%1RM</td>
<td>3</td>
<td>8 - Failure</td>
<td>AFAP</td>
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<td>Hvid et al. 2016</td>
<td>Power</td>
<td>Leg press and plantar flexion</td>
<td>12</td>
<td>70-80%1RM</td>
<td>3</td>
<td>8 - 10</td>
<td>NR</td>
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<td>Marsh et al. 2009</td>
<td>Power</td>
<td>Leg press and Knee extensors</td>
<td>12</td>
<td>70%1RM</td>
<td>3</td>
<td>8 - 10</td>
<td>NR</td>
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<tr>
<td>Nogueira et al. 2009</td>
<td>Power</td>
<td>Horizontal leg press, knee extension, knee flexion, chest press, seated row, elbow extension, and elbow flexion</td>
<td>10</td>
<td>40-60%1RM</td>
<td>3</td>
<td>8 - 10</td>
<td>90</td>
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<td>Reid et al. 2008</td>
<td>Power</td>
<td>Bilateral leg press and unilateral knee extension</td>
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<td>70%1RM</td>
<td>3</td>
<td>8</td>
<td>NR</td>
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<tr>
<td>Strandberg et al. 2015</td>
<td>Power</td>
<td>Squat, leg extension, leg press, seated row, and pull down.</td>
<td>24</td>
<td>50-85%1RM</td>
<td>3</td>
<td>8 - 15</td>
<td>120-180</td>
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<tr>
<td>Wallerstein et al. 2012</td>
<td>Power</td>
<td>Horizontal leg press, knee flexion, hip extension, plantar flexion in the horizontal leg press, lat pull-down, and upright row</td>
<td>16</td>
<td>30-50%1RM</td>
<td>2-4</td>
<td>4 - 7</td>
<td>180</td>
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<td>Zech et al. 2012</td>
<td>Power</td>
<td>Hip Extension and flexion, Hip adduction/abduction</td>
<td>36</td>
<td>Borg’s RPE 10-16</td>
<td>2</td>
<td>6 - 15</td>
<td>120 s</td>
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<td>Tip-toe raises</td>
<td>Chair rise</td>
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</tbody>
</table>

2 IRM, 1-repetition maximum; RPE, rating of perceived exertion; AFAP, as fast as possible; NR, not reported; CP, conditioning period; Con, concentric; Ecc, eccentric; Vel, velocity.
Records identified through database searching, n = 1746
(Pubmed = 405, Scopus = 478, Web of Science = 863)

Additional records identified through other sources
(n = 3)

Records after duplicates removed
(n = 609)

Records screened
(n = 1140)

Records excluded
(n = 1055)

Full-text articles assessed for eligibility
(n = 85)

Studies included in qualitative synthesis
(PT vs Control, n = 10)
(PT vs MVRT, n = 9)

Studies included in quantitative synthesis
(meta-analysis)
(PT vs Control, n = 8)
(PT vs MVRT, n = 7)

Full-text articles excluded
PT vs Control (n = 75):
▪ No control or proper control group (n = 32);
▪ No muscle/lean mass outcome (n = 32);
▪ No power training (n = 1);
▪ Participants < 60 years old (n = 1);
▪ Not chronic intervention (n = 1);
▪ Secondary analysis of an included study (n = 3);
▪ Adopted doubly indirect method for body composition (n = 4)
▪ Tested the effect of medication (n = 1).

PT vs MVRT (n = 76):
▪ No power vs. traditional resistance training comparison (n = 72);
▪ No muscle/lean mass outcome (n = 2)
▪ Adopted doubly indirect method for body composition (n = 1)
▪ Participants < 60 years old (n = 1);
Figure 2. Forest plot presenting standardised mean differences and 95% confidence intervals from studies comparing the effect of power training to control conditions. SMD, standardised mean difference; PI, predictive interval; CI, confidence interval. Red, low-quality studies (PEDro score <6); Green, high-quality study (PEDro score ≥6).

174x76mm (96 x 96 DPI)
Figure 3. Forest plot presenting standardised mean differences and 95% confidence intervals from studies comparing the effect of power training and moderate-velocity resistance training. MVRT, moderate-velocity resistance training; SMD, standardised mean difference; PI, predictive interval; CI, confidence interval. Red, low-quality studies (PEDro score <6); Green, high-quality study (PEDro score ≥6).