

Effect weight training on muscular hypertrophy: a systematic review

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim In the context of the growing importance of strength training, the analysis of the impact of strength loads on muscle hypertrophy becomes increasingly significant. Therefore, it is critical to comprehend both the effects of strength training on stimulating muscle growth and the potential ramifications. This study aimed to systematically analyze and collate the existing scientific evidence on the effects of weight training on muscle hypertrophy.

Material and Methods The research method involved the source selection of relevant studies from various databases, with predefined inclusion criteria. A thorough literature search was conducted, followed by data extraction focusing on study design, subject population, type of weight training, duration, and outcome measures of muscle hypertrophy. Databases such as PubMed, Google Scholar and Scopus were the primary sources of literature searches.

Results The results of this systematic review indicated evidence supporting the positive effect of weight training on muscle hypertrophy in most of the studies included. However, some studies produced controversial findings or even showed no significant impact. Factors such as variations in exercise type, intensity, and frequency also influence the outcome of weight training on muscle growth.

Conclusions While weight training has the potential to stimulate muscle hypertrophy, its effects may vary based on various factors. Therefore, selecting the correct type of exercise, setting the appropriate intensity, and planning the frequency of activity is essential in achieving optimal results. This study has strong relevance in fostering effective and safe exercise programs. It can also serve as a basis for further research in exploring other factors that may influence weight training-induced muscle hypertrophy outcomes.

Keywords: strength training, muscle hypertrophy, systematic review, exercise intensity, outcome measures

Introduction

Weight training has long been a significant focus on fitness and exercise programs, especially for individuals aiming to increase muscle mass or hypertrophy. This can be achieved through various training methods, including weight training. There is increasing interest in weight training to gain muscle hypertrophy due to its importance in improving sports performance, health and physical aesthetics.

Mechanism of Muscle Hypertrophy

Muscle hypertrophy is a physiological adaptation process in which the size and volume of muscle cells increase in response to regular, high-intensity weight training. During weight training, muscles experience microtrauma, and muscle cells respond by increasing protein synthesis to repair and enlarge damaged muscle fibres. This causes the power to become larger and more robust [7, 8].

Muscle hypertrophy occurs due to changes in muscle cells and biological processes. Weight training increases the production of hormones such as growth hormone and testosterone, which play a role in stimulating muscle protein synthesis. In

addition, weight training also triggers molecular signalling pathways such as the mTOR (mammalian target of rapamycin) pathway, which plays a vital role in regulating muscle growth [9, 10].

Protein plays a central role in the process of muscle hypertrophy. When a person is weight training, the protein consumed as part of the diet serves as the “building material” to repair and enlarge damaged muscles. This process is known as muscle protein synthesis. Therefore, adequate protein intake is essential to support optimal muscle growth during weight-training periods [11].

Various factors can influence the results of weight training in achieving maximum muscle hypertrophy. Training intensity, i.e. the load used relative to one's maximal capacity, is vital in triggering the hypertrophy response. In addition, training volume (total number of sets and reps), training frequency, movement variety, and rest periods between training sessions should also be well considered to achieve the desired results in muscle building [12, 13, 14].

Exercise periodization is an organized approach to planning an exercise program by varying the volume, intensity, and focus of exercise over time. To achieve optimal muscle hypertrophy, a periodized exercise program can be used. It includes periods of

high intensity with lower volume and then continues with periods of lower power but higher volume [15]. This approach is effective in stimulating sustained muscle growth.

The Role of Weight Training in Triggering Hypertrophy

Weight training plays a crucial role in triggering the process of muscle hypertrophy, which is the growth and increase in the size of muscle fibres. In weight training, weight or resistance is applied to the muscles through various movements such as weight lifting, squats, deadlifts, and other weight-training exercises. This process causes the muscles to experience microtrauma, which is microscopic damage to the muscle fibres. As the power recovers after exercise, there is an increase in protein synthesis that supports muscle growth and repair. Studies by Moesgaard et al. [16], show that weight training that results in a progressive increase in load on specific muscles can lead to a better adaptation response, including hypertrophy.

Research conducted by Bass et al. [1, 2], showed that weight training can stimulate muscle growth through cellular adaptation processes, including activation of the mTOR pathway and muscle protein synthesis. In addition, another study by Fukada et al. [3, 4], stated that mechanical tension induced by weight training can trigger the proliferation of satellite cells, which are stem cells that play a role in muscle regeneration and growth. Thus, there is a solid scientific basis supporting the hypothesis that weight training has the potential to promote muscle hypertrophy.

Research conducted by Alves et al. [5], also found that weight training volume can significantly influence the level of muscle hypertrophy. Their study showed that higher training volumes could result in a more significant increase in hypertrophy than lower training volumes, although both training groups experienced increased muscle mass. These findings highlight the importance of attention to exercise design factors that may influence its effects on muscle hypertrophy.

In addition, to exercise design factors, individual factors such as initial fitness level, age, gender, and diet may also influence one's response to weight training. Research by Yoshida and Delafontaine [6], showed that individuals who have a lower initial fitness level tend to experience a more significant increase in hypertrophy compared to individuals with a higher initial fitness level.

The intensity of weight training also plays a vital role in influencing muscle hypertrophy. Weight training with a high enough power, measured as a percentage of the maximum weight a person can lift, was positively associated with a hypertrophic response. Research by Schoenfeld et al. [17], found that training at intensities of around 60% to 85% of

maximal capacity can promote significant muscle hypertrophy. This emphasizes matching the training load to the individual's ability to achieve optimal results.

Another factor that plays a role in influencing hypertrophy is the volume of weight training. Training volume refers to the muscles' total work during a single training session. According to Baz-Valle et al. [18, 19], high training volumes (i.e., many sets and reps) tend to be more effective in stimulating hypertrophy than low training volumes. However, it should be remembered that increased training volume should be balanced with adequate recovery planning to prevent the risk of overtraining and injury.

In addition, the frequency of weight training also affects the results of muscle hypertrophy. Study by B. Schoenfeld et al. [20] concluded that a high training frequency (e.g., 3-6 training sessions per week) tends to be more favourable in promoting hypertrophy than a lower training frequency. Thus, planning an appropriate and regular training schedule is crucial in achieving the desired hypertrophy results.

In achieving optimal muscle hypertrophy, it is essential to pay attention to movement variety and type of weight training. Exercises that involve various movements and focus on different muscle groups help stimulate the overall growth of the body's muscles. Studies by Stien et al. [21], showed that variations in weight training with a combination of multijoint and single-joint exercises were more effective in increasing muscle size than single-joint exercises alone.

In conclusion, weight training plays a central role in stimulating muscle hypertrophy. Applying the right load, the right intensity, adequate volume, the right frequency, and a good variety of movements will help achieve optimal results to increase muscle size and strength. Therefore, an evidence-based and carefully planned approach to weight training will be the key to gaining muscle hypertrophy.

Factors Affecting Weight Training Results

Weight training intensity refers to how heavy or heavy the weights used during exercise are. Research has shown that higher powers are more effective in stimulating muscle hypertrophy. A study found that weight training at higher intensities, around 70-85% of 1RM (Repetition Maximum), resulted in more significant increases in muscle size compared to lower intensities [22].

Weight training volume refers to the total work performed during an exercise session, i.e. the number of sets, reps, and weights used. Studies have shown that high training volume can contribute to more significant muscle hypertrophy. Study conducted by Schoenfeld et al. [17], concluded that the group that performed a higher volume of exercise had a significant increase in muscle size compared to the

group that performed a lower book of practice.

Weight training frequency refers to how often weight training is performed weekly. A systematic review by Yu et al. [23] states that a weight training frequency of 2-3 times per week seems to provide better results in terms of muscle hypertrophy compared to lower training frequencies.

The selection of exercise types and movement variations in a weight training program also plays a vital role in achieving optimal muscle hypertrophy. Zabaleta-Korta et al. [24] and Rosa et al. [25] states that incorporating exercises that engage various muscle groups can improve overall muscle growth potential. This includes basic activities such as squats, deadlifts and bench presses that simultaneously engage multiple large muscle groups.

Adequate rest and recovery after a weight training session also play a role in the outcome of muscle hypertrophy. Studies by Lopez et al. [26] and Zhu et al. [27] show that adequate recovery between training sessions helps optimize the recovery process and muscle growth. So, ensuring proper rest time between weight training sessions is critical to achieving the desired results.

Exercise Progression in the Context of Muscle Hypertrophy

Exercise progressions play an essential role in achieving optimal muscle hypertrophy. Progression involves increasing exercises' intensity, volume and complexity over time to trigger adaptation and sustained muscle growth. Research by Krzysztofik et al. [28] and Borde et al. [29] found that exercise progression by adding weight and reducing the number of reps on each exercise helps achieve more significant muscle hypertrophy gains.

In addition, periodized exercise programs are an effective method to ensure regular progression in weight training and achieve sustained muscle hypertrophy. In a meta-analysis by Bernárdez-Vázquez et al. [30], researchers found that periodized exercise programs were significantly more effective in increasing muscle size than non-periodized exercise programs. Well-planned progressions in a periodized program help avoid stagnation and provide opportunities for muscles to continue growing over a more extended period.

However, it is essential to remember that training progressions should be tailored to the individual's abilities and fitness level. Study by Alves et al. [5] emphasized the importance of considering one's baseline fitness level when designing a progression program. Progression that is too fast or excessive can increase the risk of injury and overtraining, ultimately hindering muscle hypertrophy development.

To achieve proper progression, it is essential for individuals to regularly monitor their progress and record important figures such as the weight

used, the number of reps, and training volume. In this way, an athlete or beginner in weight training can systematically increase their muscles' demands, stimulating more significant muscle growth [31].

Exercise progression is a crucial element in achieving maximum muscle hypertrophy. Increasing weight, changing the number of reps, and using periodized training programs are effective strategies that can help promote sustained muscle growth.

Myths and Facts Around Muscle Hypertrophy and Weight Training

Several myths surrounding muscle hypertrophy and weight training need to be better understood. One common myth is that the more weight you lift, your muscles will grow faster. However, the truth is that muscle growth can occur with a wide variety of training intensities. Kassiano et al. [32] showed that the progressive principle in weight training is the key to achieving optimal muscle hypertrophy.

In addition, there is also a myth that weight training is only practical if done every day. Muscles need time to recover and grow after weight training. Witard et al. [33] suggest that adequate rest between training sessions helps in the process of muscle protein synthesis.

Similarly, the myth that weight training is only practical for specific muscle groups must also be clarified. Mertz et al. [34] asserts that weight training causes an increase in muscle protein in various areas of the body involved in the movement. Therefore, an exercise program that involves the whole body will be more effective in triggering overall muscle hypertrophy. In addition, there is often a perception that women will develop large, masculine muscles if they engage in weight training. However, Currier et al. [35] found that women tend to experience more moderate muscle hypertrophy even with intense weight training. Thus, weight training for women can help improve strength and muscle tone without causing excessive muscle development. Also, it's important to remember that building muscle doesn't only require high protein consumption. Although protein is essential in muscle protein synthesis [36], a balanced intake of calories and macronutrients is also crucial in supporting effective muscle hypertrophy. Therefore, meeting the needs of calories and other nutrients is essential for optimal weight training results.

The primary objective of this review is to systematically assess and consolidate the existing scientific literature to enhance understanding of the impact of weight training on muscle hypertrophy.

Methodology

Study Source Selection (tabl. 1)

To obtain relevant information, various databases of journals, books, and other reliable scientific sources were utilized. In selecting these sources,

consideration was given to the data's quality, relevance, and completeness. Databases such as PubMed, Google Scholar, and Scopus were the primary sources of literature searches. Additionally, references were also searched for through the official websites of organizations related to this field of research.

Inclusion and Exclusion Criteria

Literature Search Process

The literature search process was conducted systematically using relevant keywords. The search was conducted on databases such as PubMed, Google Scholar, and Scopus, spanning the last 5 years, while also including several key publications from an earlier period. The study was also limited to the English language to ensure relevant output. After the initial search, duplicates were removed, and titles and abstracts were evaluated to match the predefined inclusion and exclusion criteria. Suitable studies were then selected for data retrieval.

Data Extraction and Analysis

Relevant data were extracted from the selected studies according to the research protocol, including information on sample size, population characteristics, type of weight training intervention, study duration, measured outcomes, study design, and statistical methods used in data analysis. The collected data from the various studies were subsequently analyzed to comprehensively describe the effect of weight training on muscle hypertrophy. During the analysis stage, results from the various studies were synthesized to formulate solid and valid conclusions.

Statistical Data

In the literature selection process using the PRISMA method (fig. 1), the initial count was 110 references. After removing duplicates, 70 remained. Subsequently, titles and abstracts were evaluated

to narrow it down to 51 references that met the PRISMA criteria. Following this, a risk of bias and methodological quality assessment was conducted to mitigate publication bias. In total, 51 references were selected for inclusion in the systematic review.

Results

The most common method of measuring muscle hypertrophy is using muscle circumference measurements and determining the percentage increase in muscle mass. In addition, some studies also used imaging methods such as MRI to evaluate changes in muscle volume.

The findings of the studies showed mixed results (tabl. 2). Some studies supported the positive effects of weight training on increasing muscle hypertrophy, while others showed controversial results or even found no significant effect. Several factors may have influenced these differences in outcomes, such as duration and type of weight training, intensity, and individual characteristics of the participants. Nonetheless, most studies indicate the potential of weight training to induce muscle hypertrophy, albeit with varying degrees of variation.

The results of the systematic review showed consistency in support of the effect of weight training on muscle hypertrophy. Several studies showed significant increases in muscle size following weight training interventions. However, it should be kept in mind that variations in study design and methods may affect the interpretation of the findings.

Although this systematic review provides a comprehensive view of the current literature regarding the effect of weight training on muscle hypertrophy, we need to acknowledge some weaknesses. Most existing studies focus on novice populations or pre-trained athletes, with little research on intermediate people. Future research should address this issue by involving more diverse and representative samples.

Table 1. Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Subject Population	Individuals are undergoing weight training for muscle hypertrophy.	Individuals with musculoskeletal injuries or disorders
Type of Intervention	Studies involving weight training as the primary intervention.	Studies that did not use weight training.
Durasi Studies	Studies with a minimum duration of 4 weeks to 6 months.	Studies with a duration of less than four weeks.
Result Type	Studies that present data on muscle size or other parameters relevant to measuring muscle hypertrophy.	Studies that lacked data on muscle size or relevant parameters to measure muscle hypertrophy.
Data Quality	Studies with good data quality and robust research methodology.	Studies with questionable methods or poor data quality.
Publication Language	A study published in English.	Studies published in languages other than English.

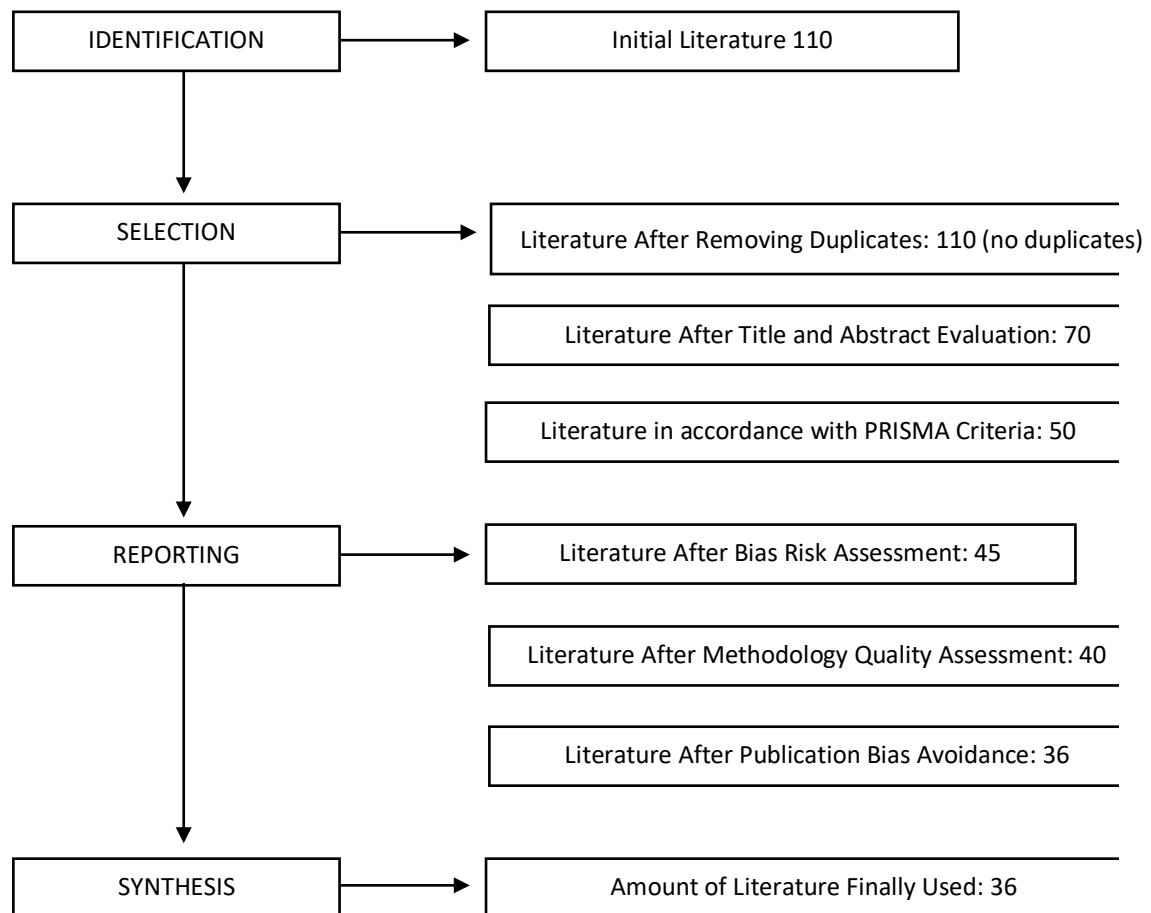


Figure 1. The article selection process used to use the PRISMA guidelines

Table 2. Supporting, controversial, and non-significant studies

Author and year	Article Title	Title of the journal	Results
Studies That Support Positive Influence			
[37]	Effects of plyometric vs. resistance training on skeletal muscle hypertrophy: A review	Journal of Sport and Health Science	This review highlights that plyometric and resistance training interventions may produce similar effects on whole muscle hypertrophy, at least for the muscle groups of the lower extremities, in untrained and recreationally trained individuals, and over short-term (i.e., ≤12 weeks) intervention periods.
[38]	Influence of Resistance Training Proximity-to-Failure on Skeletal Muscle Hypertrophy: A Systematic Review with Meta-analysis.	Sports medicine (Auckland, N.Z.)	Overall, our main findings suggest that (i) there is no evidence to support that resistance training performed to momentary muscular failure is superior to non-failure resistance training for muscle hypertrophy and (ii) higher velocity loss thresholds, and theoretically closer proximities-to-failure do not always elicit greater muscle hypertrophy. As such, these results provide evidence for a potential non-linear relationship between proximity-to-failure and muscle hypertrophy.
Studies that Show Controversial Results			
[39]	Why exercise builds muscles: titin mechanosensing controls skeletal muscle growth under load	Biophysical Journal	This article explores the role of titin mechanosensing in controlling skeletal muscle growth under load.

Table 2. Continuation

Author and year	Article Title	Title of the journal	Results
[40]	The Mechanisms of Muscle Hypertrophy and Their Application to Resistance Training	The Journal of Strength & Conditioning Research	To extensively review the literature regarding the mechanisms of muscle hypertrophy and its application to sports training and to draw conclusions from the research regarding the optimal protocol for maximising muscle growth.
Studies that Found No Significant Effect			
[41]	The Effects of Creatine Supplementation Combined with Resistance Training on Regional Measures of Muscle Hypertrophy: A Systematic Review with Meta-Analysis.	Nutrients	A pooled analysis of the current data suggests that creatine supplementation promotes a small increase in skeletal muscle hypertrophy in both the upper and lower body musculature when combined with a regimented RT program. Those considering creatine supplementation for the goal of regional muscle hypertrophy should consider the practical significance of the small magnitude of effect. Furthermore, young adults appear to derive a greater hypertrophic benefit compared to older individuals, but the magnitude of this difference is relatively modest, calling into question the practical relevance of this finding.
[42]	The influence of resistance exercise training prescription variables on skeletal muscle mass, strength, and physical function in healthy adults: An umbrella review	Journal of Sport and Health Science	Overall, RT increased muscle mass, strength, and physical function compared to no exercise. RT intensity (load) and weekly frequency impacted RT-induced increases in muscular strength but not muscle hypertrophy. RT volume (number of sets) influenced muscular strength and hypertrophy.

Discussion

This systematic study has important implications for weight training practice. These findings suggest that weight training can be an effective strategy for stimulating muscle hypertrophy. Therefore, weight training should be a major component in exercise programs for individuals who wish to achieve optimal muscle growth [16, 43, 44, 45, 46]. In addition, using variety in exercise programs, such as changing the intensity and type of exercise, can help avoid burnout and maintain continuous progression [47, 48].

The findings from this systematic review support previous research showing a positive association between weight training and muscle hypertrophy [49, 50]. However, there are differences in study design and methods that may explain some of the contradictions in the results of previous studies. This systematic review contributes to a more in-depth understanding of this topic by highlighting the consistency and concordance of results. We need to note some limitations in this systematic review. The limited number of studies that met the inclusion criteria suggests a lack of data in some areas, such as the effects of weight training on the elderly population. In addition, the diversity of study methods and intervention periods may make it difficult to incorporate consistent data [51]. Future research could address these limitations by expanding the scope of the study and using more sophisticated statistical analyses.

This systematic review has identified several opportunities for future research. For example, research on differences in muscle hypertrophy responses between weight training types and exercise selection variations still needs further exploration. In addition, identifying individual factors that influence the hypertrophy response may help tailor exercise programs to individual needs. Other studies in this area will make important contributions to our understanding of the effects of weight training on muscle growth.

The results of this systematic review provide an in-depth insight into how weight training can contribute to muscle growth in individuals who follow it. From the results of this systematic review, weight training has a significant positive impact on muscle hypertrophy. Many studies support that weight training consistently increases muscle size and mass in various population groups, including beginners, athletes, and the elderly population. Biological mechanisms, including the triggering of muscle growth and protein synthesis, drive these positive effects.

Nonetheless, the results of this systematic review also revealed some studies that showed controversial results. Some factors that may influence these differences include variations in exercise protocols, intensity, duration, and individual characteristics such as age, gender, and baseline fitness level.

Conclusions

The conclusion of this systematic review on the effect of weight training on muscle hypertrophy presents the main findings obtained from the analysis of several relevant studies.

These conclusions have important implications both in sports practice and in future research. Sports practitioners and coaches can use these findings to design weight training programs that are more effective and efficient in achieving the goal of muscle hypertrophy. In addition, future research needs to

consider the limitations of this systematic review, such as the number and variety of studies available, to improve the validity and generalizability of the results.

In conclusion, weight training is an effective method to achieve muscle hypertrophy. Each individual has a different response to weight training, so using an individualized approach and proper supervision by a trainer or exercise professional is necessary to maximize the results of weight training safely and effectively.

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Cite this article as:

Ihsan F, Nasrulloh A, Nugroho S, Yuniana R. Effect weight training on muscular hypertrophy: a systematic review. *Pedagogy of Physical Culture and Sports*, 2023;27(6):439–447. <https://doi.org/10.15561/26649837.2023.0601>

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Received: 23.08.2023

Accepted: 29.09.2023; Published: 30.12.2023