World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Review Article)

Check for updates

Optimizing muscle health: The role of resistance training and frequency in muscle hypertrophy

Mayendra Jovan Pranata [1, *], Irfiansyah Irwadi [2], Damayanti Tinduh [3] and Hayuris Kinandita Setiawan [2]

[1] *Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia.*
[2] *Department of Physiology, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia.*
[3] *Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia*

World Journal of Advanced Research and Reviews, 2024, 24(03), 1403–1410

Publication history: Received on 05 November 2024; revised on 12 December 2024; accepted on 14 December 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.24.3.3835

Abstract

Resistance training (RT) is a key factor in promoting muscle hypertrophy and overall muscle health. Recent research highlights the role of RT frequency in optimizing hypertrophic outcomes. The purpose of this literature review is to explore the influence of training frequency on muscle hypertrophy and evaluates its effectiveness in tailoring programs to individual needs. A total of 63 research papers published between the years 2019 to 2024 were accessed and used for this review that met the criteria. The review indicates that while training volume is the primary driver of hypertrophy, frequency adjustments may enhance outcomes in specific contexts, such as recovery capacity and advanced adaptations. This review underscores the potential of frequency as a variable to optimize RT programs for improved muscle health.

Keywords: Muscle Hypertrophy; Resistance Training; Frequency; Exercise; Healthy Lifestyle

1. Introduction

Skeletal muscle hypertrophy, which is essential for both physical function and metabolic health, can be strongly stimulated by resistance training (RT) [1]. Muscle satellite cells (MuSCs) are necessary for both hypertrophy and regeneration, although the ways in which they are activated vary depending on the process [2]. Recent research has brought attention to the intricate biochemical processes that underlie hypertrophic increases, highlighting the complementary benefits of protein consumption and resistance training [3]. However, some research indicates that size and force are not always correlated, indicating that the relationship between muscular hypertrophy and strength is not always proportionate [4]. Both internal and external factors, such as mechanotransduction and gene expression, as well as exercise programming and diet, affect this variability in response to RT-induced hypertrophy [1]. Understanding these mechanisms is crucial for developing effective strategies to enhance muscle mass and function in various populations, including those with muscle atrophy or sarcopenia [2,3].

Reduced muscle mass, strength, and function are the hallmarks of sarcopenia, a degenerative skeletal muscle condition [5]. Malnutrition, age, chronic illnesses, and a lack of physical activity are all linked to it. As people age, the prevalence of sarcopenia rises, ranging from 3% to 24% [6]. Numerous detrimental health effects, such as falls, incapacity, metabolic abnormalities, and an increased risk of death, can result from sarcopenia [7,8]. Muscle mass measures and functional tests that assess physical performance or muscle strength are part of the diagnosis process. A multimodal approach is necessary for management, combining anti-inflammatory drugs, physical activity, and consumption of protein and fatty acids [6]. It has been demonstrated that resistance training is a successful strategy for both preventing and treating sarcopenia in older persons. Resistance training dramatically increases body fat mass, muscle strength, and

* Corresponding author: Mayendra Jovan Pranata

physical performance in older people with sarcopenia, according to meta-analyses [9,10]. In particular, the most effective technique seems to be moderate-intensity resistance training using elastic bands, done three times a week for a minimum of 12 weeks [10]. Residents of nursing homes who participated in a 12-week resistance training program saw improvements in their physical performance, muscle strength, and prevalence of sarcopenia [11]. Since blood-flow-restricted low-load resistance training (20–30% of 1RM) can increase muscle growth and function without having the possible adverse consequences of high-load training on arterial compliance, it has also become a viable strategy for older persons [12]. These results demonstrate the value of resistance training in the treatment of sarcopenia.

Muscle strength and mass are greatly increased by resistance training (RT), and up to a certain degree, a dose-response connection is seen [13]. Intensity, volume, frequency, and duration are important factors that affect the results of RT [13,14,15,16]. While volume influences both strength and hypertrophy, RT load and weekly frequency largely influence strength improvements [14]. Adaptations can also be influenced by other factors such as attention, range of motion, time under strain, contraction type, repetitions to failure, and inter-set rest [15]. To maximize RT results, these variables must be properly manipulated [16]. Training frequency is one of these variables that is still hotly debated in the scientific community. Research has shown that different muscle hypertrophy outcomes are influenced by individual characteristics like genetics, dietary habits, and daily activities [17,18]. Knowing the ideal RT frequency is essential for creating training plans that optimize muscle growth while lowering the possibility of overtraining.

The goal of this review of the literature is to compile the most recent data about the function of RT frequency in maximizing muscle growth. The overall advantages of resistance training, the control of hypertrophy, important RT variables that affect muscle growth, and, lastly, the optimal RT frequency for optimizing hypertrophy will all be covered. By discussing these subjects, this study aims to offer useful advice to researchers, fitness experts, exercise physicians, physiotherapists, rehabilitation specialists, and enthusiasts who want to maximize muscle health through training methods based on scientific knowledge.

2. Material and methods

To review the impact of resistance training frequency on increasing muscle mass and its implications for health, Google Scholar, a web-based search engine that offers a quick and simple way to search and access published literature from articles, journals, and books, was used to conduct the systematic literature review. The search was conducted using the keywords "frequencies, muscle mass, muscle hypertrophy, resistance training." and the following thematic search terms: "muscle hypertrophy, regulation, health benefits.". For this review, publications from 2019 to 2024 were gathered. The systematic review search produced a variety of findings. Some of the articles were unique to either resistance training and muscular hypertrophy, resistance training and muscle mass, resistance training and frequency, or even only resistance training, while others had all of the topic keywords. This literature review attempts to give a thorough overview of the impact of resistance training frequency on muscle hypertrophy by combining the pertinent research and emphasizing the various muscle gains and optimal frequencies.

3. Results

The result search at Google Scholar for information on the role of resistance training frequency in muscle hypertrophy, a total of 353,900 results were retrieved from both thematic searches: 32,900 from the “frequencies, muscle mass, muscle hypertrophy, resistance training” and 321,000 from the “muscle hypertrophy, regulation, health benefits.” Among the results obtained from the search, 31,600 were published within the years 2019-2024. Publications that reviewed the role of resistance training frequency in muscle hypertrophy showed 1,200 publications between 2019 and 2024.

However, using the previously stated search criteria, only 63 papers in total are selected for this literature review. The effects of varying resistance training frequencies on muscle growth were the specific focus of some of the publications that were obtained for this study. The resistance training elements that promote muscular growth are also explained in this review. Some research looked at the effects of resistance training on muscle health and other medical specialties, while others investigated the wider health advantages of resistance training, such as its effects on the body's metabolism and physical condition.

4. Discussion

4.1. The benefits of resistance training

Resistance training (RT) is an important part of physical activity since it provides numerous health advantages in different areas. Reductions in blood pressure and improved lipid profiles improve cardiovascular health, and increases in fat-free mass and resting metabolic rate help manage weight [19]. By improving bone density, muscle mass, and flexibility, RT fortifies the musculoskeletal system and helps treat diseases including osteoporosis and arthritis [19,20]. According to neuropsychology, RT improves cognitive performance while lowering stress, anxiety, and depression [19,21]. Additionally, it fights sarcopenia and frailty, lowers the incidence of falls and fractures in middle-aged and older persons, and works well in both the early and late stages of neuromuscular aging [22,23,24]. Additionally, RT improves general physical function and body composition, particularly in older populations and those who are overweight or obese, and is linked to a lower risk of mortality from cardiovascular disease, cancer, and all causes [25,26]. Crucially, RT is accessible to a wide range of people since these advantages can be obtained with lesser loads carried to failure [21,27].

In addition to enhancing overall health and athletic performance, resistance training is a potent intervention for controlling and preventing chronic diseases. It significantly increases strength and mobility and improves balance, coordination, and rehabilitation outcomes for a variety of musculoskeletal ailments [28,29]. RT helps middle-aged and older women become more functionally independent by strengthening their muscles, increasing bone density, and lowering their risk of fractures [30]. With moderate to significant gains in strength, gait speed, and mobility, the intervention has shown significant promise in addressing the impacts of neuromuscular aging and sarcopenia in older persons [22,23]. Consistent monitoring is advised during RT programs despite its many benefits in order to reduce the possibility of adverse effects, which are uncommon but do occur [31]. RT is a key component in attaining long-term health and vitality by reducing cardiovascular risk factors, enhancing physical functioning, and encouraging healthy aging.

4.2. Skeletal muscle hypertrophy regulation

Skeletal muscle growth is regulated by intricate molecular mechanisms such as satellite cell activity, transcriptional activation, and protein synthesis. This mechanism depends on the mTORC1 pathway, which is also involved in protein synthesis and ribosome biogenesis [32]. New research suggests that mTOR signaling can be activated without Akt to promote hypertrophy, despite the fact that muscle growth has traditionally been linked to the IGF-1/Akt pathway [33]. Satellite cell-mediated myonuclear addition and ribosome biogenesis are thought to be essential for sustaining muscle growth, however their requirement is still debatable [34]. Through the PI3K/Akt/mTOR and PI3K/Akt/GSK3β pathways, IGF-1 promotes protein synthesis and inhibits protein breakdown by controlling E3 ubiquitin ligases and maybe autophagy. Furthermore, IGF-1 activates satellite cells, which prevent atrophy and encourage muscle regeneration, both of which contribute to overall hypertrophy [35].

Resistance exercise training causes skeletal muscle growth through a complex interplay between molecular cues and mechanical stimulation. Ribosome biogenesis has emerged as a critical factor, driven by increased ribosomal RNA transcription and regulated by mTORC1 signaling [36,37,38]. The mTORC1 pathway is essential for coordinating protein synthesis and degradation in response to mechanical stress, which emphasizes its role in regulating muscle mass [39]. Moreover, translational regulatory mechanisms that affect muscle growth include RNA-binding proteins and microRNAs [40]. Resistance training activates key signaling pathways, such as IGF-1-PI3K-Akt-mTOR and Myostatin-SMAD3, that regulate the balance between hypertrophy and atrophy [41,42]. Recent advances in human research, which emphasize the importance of ribosome biogenesis and translational capacity in exercise-induced hypertrophy, have broadened our understanding of these regulatory processes [43].

4.3. Resistance training factors to increase muscle hypertrophy

Resistance training (RT), a very effective non-pharmacological technique for improving muscle growth, strength, and physical function, is essential for individuals of all ages [44]. Important elements influencing RT adaptations include exercise choice, training volume, frequency, and intensity. Higher training volume, specifically more sets per exercise, is positively connected with muscular hypertrophy and strength improvements, even though too much volume may hinder muscle growth [45,46]. Programs that last 12 weeks or more and involve exercise at least three days a week are particularly beneficial for older adults since they build muscle and strength [47,48].

RT intensity has a significant effect on strength increases, but its effect on hypertrophy is yet unknown [14]. Multi-joint exercises are recommended for their effectiveness because they train greater muscle mass than single-joint workouts [46]. Additionally, factors such as blood flow restriction, eccentric contractions, and range-of-motion manipulation can be used to further improve hypertrophy [49,50]. Optimizing adaptations necessitates tailoring RT parameters to each person's requirements, including metabolic stress and mechanical tension, and monitoring results with regular one-repetition maximum (1RM) assessments [46]. Even though RT can effectively reverse age-related muscle loss, the anabolic response declines with age. This implies that more treatments might be required to enhance outcomes [48].

4.4. The optimal resistance training frequency on muscle hypertrophy

According to recent studies, when training volume is equal, the frequency of resistance training may not have a significant effect on muscle hypertrophy [51,52,53,54]. When volume was matched, several studies have found no discernible differences in muscle growth between training frequencies of one to three times per week and two to three times per week. The results are consistent for both upper and lower body exercises and both trained and untrained individuals [51,52,55]. Similarly, when volume is equal, it has been demonstrated that resistance training three or six times a week results in comparable hypertrophy [56]. High and low frequency in well-trained men shows no significant difference in muscle growth [57]. Training muscle groups 1 day per week vs. 2 days per week with equated sets per muscle group resulted in similar neuromuscular and morphological adaptations in trained men [58]. Higher training frequencies in older persons do not significantly enhance muscle growth, although they may marginally increase maximal strength [59]. However, a slight hypertrophic benefit for greater training frequencies was noted in trials that did not equate volume [52].

Individual responses may differ, even though the majority of research indicates that weekly training frequency can be selected according to personal desire without limiting muscle growth, provided that total volume is maintained [51,52]. Individual responses to high versus low frequency training have been used to identify differences in hypertrophy and strength gains [17]. In comparison to lower-frequency split-body exercises, higher-frequency whole-body training may also result in more hypertrophy [60,61]. Similar increases in muscle mass, strength, and quality have been demonstrated across a range of demographics, including trained males and elderly women, when muscle groups are trained two to three times per week [62,63]. Nevertheless, there is still little evidence supporting frequency higher than three times per week, especially when non-equated quantities are involved [52].

It is important to take into account a number of limitations when interpreting these results. The generalizability of the conclusions of many studies is limited by their small scale or reliance on observational methodologies. Furthermore, differences in individuals' dietary intake, which have a big impact on muscle development, were frequently overlooked. Studies examining the impact of doing resistance training four or more days a week or combining resistance training frequency with non-equated volume are similarly lacking. To gain a better understanding of the relationship between frequency, volume, and muscle hypertrophy, future studies should concentrate on long-term trials that account for dietary factors and look into greater training frequencies

5. Conclusion

In conclusion, the findings of 63 earlier studies demonstrate that resistance training (RT) is an important tactic for encouraging muscle growth and enhancing muscle health. Frequency is a supporting factor in muscle growth, especially when it comes to customizing programs to meet the needs and recuperation capacity of each individual, but training volume is still the key factor. Research indicates that training frequency has little effect on hypertrophy when volume is matched; however, tailored modifications may maximize results depending on variables like training status and recuperation capacity. It also emphasizes the necessity of additional research to examine the long-term impacts of these interventions under equal settings and in combination with RT frequency and non-equated volume. Gaining insight into both responses may help create fresh approaches to the prevention and management of muscle-wasting conditions, ultimately raising the quality of life for those who are susceptible to these illnesses.

Compliance with ethical standards

Acknowledgments

For making this project possible, the authors are grateful to the Department of Physiology, Faculty of Medicine, Universitas Airlangga.

Disclosure of conflict of interest

There is no conflict of interest to declare.

References

[1] Lim C, Nunes EA, Currier BS, Mcleod JC, Thomas AC, Phillips SM. An Evidence-Based Narrative Review of Mechanisms of Resistance Exercise–Induced Human Skeletal Muscle Hypertrophy. Medicine and science in sports and exercise. 2022 Sep;54(9):1546.

[2] Fukada SI, Akimoto T, Sotiropoulos A. Role of damage and management in muscle hypertrophy: different behaviors of muscle stem cells in regeneration and hypertrophy. Biochimica et Biophysica Acta (BBA)-Molecular Cell Research. 2020 Sep 1;1867(9):118742.

[3] Joanisse S, Lim C, McKendry J, Mcleod JC, Stokes T, Phillips SM. Recent advances in understanding resistance exercise training-induced skeletal muscle hypertrophy in humans. F1000Research. 2020 Feb 24(9):141.

[4] Reggiani C, Schiaffino S. Muscle hypertrophy and muscle strength: dependent or independent variables? A provocative review. European journal of translational myology. 2020 Sep 9;30(3).

[5] Park WT, Shon OJ, Kim GB. Multidisciplinary approach to sarcopenia: a narrative review. Journal of Yeungnam medical science. 2023 Sep 7;40(4):352-63.

[6] Tournadre A, Vial G, Capel F, Soubrier M, Yves Boirie. Sarcopenia. Joint Bone Spine. 2018 Aug 8;86(3):309–14.

[7] Larsson L, Degens H, Li M, Salviati L, Lee YI, Thompson W, Kirkland JL, Sandri M. Sarcopenia: aging-related loss of muscle mass and function. Physiological reviews. 2019 Jan 1;99(1):427-511.

[8] Sayer AA, Cruz-Jentoft A. Sarcopenia definition, diagnosis and treatment: consensus is growing. Age and Ageing. 2022 Oct 1:51(10).

[9] Chen N, He X, Feng Y, Ainsworth BE, Liu Y. Effects of resistance training in healthy older people with sarcopenia: a systematic review and meta-analysis of randomized controlled trials. European Review of Aging and Physical Activity. 2021 Dec;18:1-9.

[10] Zhao H, Cheng R, Song G, Teng J, Shen S, Fu X, Yan Y, Liu C. The effect of resistance training on the rehabilitation of elderly patients with sarcopenia: a meta-analysis. International journal of environmental research and public health. 2022 Nov 22;19(23):15491.

[11] del Campo Cervantes JM, Cervantes MH, Torres RM. Effect of a resistance training program on sarcopenia and functionality of the older adults living in a nursing home. The Journal of nutrition, health and aging. 2019 Nov 1;23(9):829-36.

[12] Yasuda T. Selected methods of resistance training for prevention and treatment of sarcopenia. Cells. 2022 Apr 20;11(9):1389.

[13] Lyristakis MP, Wundersitz DD, Cousins DS, Zadow DE, Gordon AP. THE INFLUENCE OF RESISTANCE TRAINING VARIABLES ON MUSCLE STRENGTH: A SYSTEMATIC REVIEW AND META-ANALYSIS. Journal of Clinical Exercise Physiology. 2024 May 1;13(s2):462-2.

[14] Mcleod JC, Currier BS, Lowisz CV, Phillips SM. 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. 2024 Jan 1;13(1):47-60.

[15] Coratella G. Appropriate reporting of exercise variables in resistance training protocols: much more than load and number of repetitions. Sports Medicine-Open. 2022 Dec;8(1):99.

[16] Machado WM, de Oliveira CE, de Assis Arantes F, de Matos DG, Maroto-Izquierdo S, Moreira OC. Resistance training variables on muscle hypertrophy: a systematic review. Motricidade. 2022 Jun 30;18(2):339-54.

[17] Damas F, Barcelos C, Nóbrega SR, Ugrinowitsch C, Lixandrão ME, d Santos LM, Conceição MS, Vechin FC, Libardi CA. Individual muscle hypertrophy and strength responses to high vs. low resistance training frequencies. The Journal of Strength & Conditioning Research. 2019 Apr 1;33(4):897-901.

[18] Scarpelli MC, Nóbrega SR, Santanielo N, Alvarez IF, Otoboni GB, Ugrinowitsch C, Libardi CA. Muscle hypertrophy response is affected by previous resistance training volume in trained individuals. The Journal of Strength & Conditioning Research. 2022 Apr 1;36(4):1153-7.

[19] Tyler J, Thanos P. Raising the bar for public health: resistance training and health benefits. International Journal of Strength and Conditioning. 2023 Mar 29;3(1).

[20] Syed-Abdul MM. Benefits of resistance training in older adults. Current Aging Science. 2021 Mar 1;14(1:5-9.

[21] Sawan SA, Nunes EA, Lim C, McKendry J, Phillips SM. The health benefits of resistance exercise: beyond hypertrophy and big weights. Exercise, Sport, and Movement. 2023 Jan 1;1(1):e00001.

[22] Talar K, Hernandez-Belmonte A, Vetrovsky T, Steffl M, Kałamacka E, Courel-Ibáñez J. Benefits of resistance training in early and late stages of frailty and sarcopenia: a systematic review and meta-analysis of randomized controlled studies. Journal of clinical medicine. 2021 Apr 12;10(8):1630.

[23] Fragala MS, Cadore EL, Dorgo S, Izquierdo M, Kraemer WJ, Peterson MD, Ryan ED. Resistance training for older adults: position statement from the national strength and conditioning association. The Journal of Strength & Conditioning Research. 2019 Aug 1;33(8).

[24] Lavin KM, Roberts BM, Fry CS, Moro T, Rasmussen BB, Bamman MM. The importance of resistance exercise training to combat neuromuscular aging. Physiology. 2019 Feb 6;34(2):112–22.

[25] Shailendra P, Baldock KL, Li LK, Bennie JA, Boyle T. Resistance training and mortality risk: a systematic review and meta-analysis. American journal of preventive medicine. 2022 Aug 1;63(2):277-85.

[26] Orange ST, Madden LA, Vince RV. Resistance training leads to large improvements in strength and moderate improvements in physical function in adults who are overweight or obese: a systematic review. Journal of Physiotherapy. 2020 Oct 1;66(4):214-24.

[27] Weakley J, Schoenfeld BJ, Ljungberg J, Halson SL, Phillips SM. Physiological responses and adaptations to lower load resistance training: Implications for health and performance. Sports Medicine-Open. 2023 May 12;9(1):28.

[28] Pal CP, Agarwal V, Srivastav R, Gupta M, Singh S. Physiological adaptations of skeletal muscle and bone to resistance training and its applications in orthopedics: a review. Journal of Bone and Joint Diseases. 2023 Jan 1;38(1):3-10.

[29] Ehrman JK. Resistance Training: Simple and Effective. Journal of Clinical Exercise Physiology. 2024 Mar 1;13(1):1-2.

[30] Pardo PJ, Cristobal RV, Huber G. The Power of Resistance Training: Evidence-based Recommendations for Middle-aged and Older Women's Health. Retos: nuevas tendencias en educación física, deporte y recreación. 2024(51):319-31.

[31] El-Kotob R, Ponzano M, Chaput JP, Janssen I, Kho ME, Poitras VJ, Ross R, Ross-White A, Saunders TJ, Giangregorio LM. Resistance training and health in adults: an overview of systematic reviews. Applied Physiology, Nutrition, and Metabolism. 2020;45(10):S165-79.

[32] Schiaffino S, Reggiani C, Akimoto T, Blaauw B. Molecular mechanisms of skeletal muscle hypertrophy. Journal of neuromuscular diseases. 2021 Jan 1;8(2):169-83.

[33] Fukada SI, Ito N. Regulation of muscle hypertrophy: Involvement of the Akt-independent pathway and satellite cells in muscle hypertrophy. Experimental Cell Research. 2021 Dec 15;409(2):112907.

[34] Brook MS, Wilkinson DJ, Smith K, Atherton PJ. It's not just about protein turnover: the role of ribosomal biogenesis and satellite cells in the regulation of skeletal muscle hypertrophy. European journal of sport science. 2019 Aug 9;19(7):952-63.

[35] Yoshida T, Delafontaine P. Mechanisms of IGF-1-mediated regulation of skeletal muscle hypertrophy and atrophy. Cells. 2020 Aug 26;9(9):1970.

[36] Kim HG, Guo B, Nader GA. Regulation of ribosome biogenesis during skeletal muscle hypertrophy. Exercise and sport sciences reviews. 2019 Apr 1;47(2):91-7.

[37] Figueiredo VC. Revisiting the roles of protein synthesis during skeletal muscle hypertrophy induced by exercise. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology. 2019 Nov 1;317(5):R709-18.

[38] Bodine SC. The role of mTORC1 in the regulation of skeletal muscle mass. Faculty Reviews. 2022 Nov 11;11.

[39] Goodman CA. Role of mTORC1 in mechanically induced increases in translation and skeletal muscle mass. Journal of applied physiology. 2019 Aug 1;127(2):581-90.

[40] Dupont-Versteegden EE, McCarthy JJ. Translational control of muscle mass. Journal of Applied Physiology. 2019 Aug 1;127(2):579-80.

[41] Machado M. IGF-1-PI3K-Akt-mTOR and Myostatin-SMAD3 Pathways Signaling for Muscle Hypertophy. Journal of Endocrinology and Thyroid Research. 2021 Nov 19:6(3).

[42] Sartori R, Romanello V, Sandri M. Mechanisms of muscle atrophy and hypertrophy: implications in health and disease. Nature communications. 2021 Jan 12;12(1):330.

[43] Zheng LF, Chen PJ, Xiao WH. Signaling pathways controlling skeletal muscle mass. Sheng li xue bao:[Acta Physiologica Sinica]. 2019 Aug 1;71(4):671-9.

[44] McKendry J, Stokes T, Mcleod JC, Phillips SM. Resistance exercise, aging, disuse, and muscle protein metabolism. Comprehensive Physiology. 2011 Jan 17;11(3):2249-78.

[45] Benito PJ, Cupeiro R, Ramos-Campo DJ, Alcaraz PE, Rubio-Arias JÁ. A systematic review with meta-analysis of the effect of resistance training on whole-body muscle growth in healthy adult males. International journal of environmental research and public health. 2020 Feb 17;17(4):1285-5.

[46] Pawlina M, Ziętara K, Raksa K, Nowakowska K, Lewkowicz M. Maximizing the efficiency of resistance training. Journal of Education, Health and Sport. 2022 May 10;12(7):16-23.

[47] Polito MD, Papst RR, Farinatti P. Moderators of strength gains and hypertrophy in resistance training: A systematic review and meta-analysis. Journal of Sports Sciences. 2021 Oct 2;39(19):2189-98.

[48] Endo Y, Nourmahnad A, Sinha I. Optimizing skeletal muscle anabolic response to resistance training in aging. Frontiers in physiology. 2020 Jul 23;11:874.

[49] Bernárdez-Vázquez R, Raya-González J, Castillo D, Beato M. Resistance training variables for optimization of muscle hypertrophy: An umbrella review. Frontiers in sports and active living. 2022 Jul 4;4:949021.

[50] Viecelli C, Aguayo D. May the force and mass be with you—evidence-based contribution of mechano-biological descriptors of resistance exercise. Frontiers in physiology. 2022 Jan 5;12:686119.

[51] Grgic J, Schoenfeld BJ, Latella C. Resistance training frequency and skeletal muscle hypertrophy: A review of available evidence. Journal of science and medicine in sport. 2019 Mar 1;22(3):361-70.

[52] Schoenfeld BJ, Grgic J, Krieger J. How many times per week should a muscle be trained to maximize muscle hypertrophy? A systematic review and meta-analysis of studies examining the effects of resistance training frequency. Journal of sports sciences. 2019 Jun 3;37(11):1286-95.

[53] Hamarsland H, Moen H, Skaar OJ, Jorang PW, Rødahl HS, Rønnestad BR. Equal-volume strength training with different training frequencies induces similar muscle hypertrophy and strength improvement in trained participants. Frontiers in physiology. 2022 Jan 5;12:789403.

[54] Franco CM, Carneiro MA, de Sousa JF, Gomes GK, Orsatti FL. Influence of high-and low-frequency resistance training on lean body mass and muscle strength gains in untrained men. The Journal of Strength & Conditioning Research. 2021 Aug 1;35(8):2089-94.

[55] Lasevicius T, Schoenfeld BJ, Grgic J, Laurentino G, Tavares LD, Tricoli V. Similar muscular adaptations in resistance training performed two versus three days per week. Journal of human kinetics. 2019 Aug 21;68(1):135–43.

[56] Saric J, Lisica D, Orlic I, Grgic J, Krieger JW, Vuk S, Schoenfeld BJ. Resistance training frequencies of 3 and 6 times per week produce similar muscular adaptations in resistance-trained men. The Journal of Strength & Conditioning Research. 2019 Jul 1;33:S122-9.

[57] Gomes GK, Franco CM, Nunes PR, Orsatti FL. High-frequency resistance training is not more effective than low-frequency resistance training in increasing muscle mass and strength in well-trained men. The Journal of Strength & Conditioning Research. 2019 Jul 1;33:S130-9.

[58] Brigatto FA, Braz TV, da Costa Zanini TC, Germano MD, Aoki MS, Schoenfeld BJ, Marchetti PH, Lopes CR. Effect of resistance training frequency on neuromuscular performance and muscle morphology after 8 weeks in trained men. The Journal of Strength & Conditioning Research. 2019 Aug 1;33(8):2104-16.

[59] Kneffel Z, Murlasits Z, Reed J, Krieger J. A meta-regression of the effects of resistance training frequency on muscular strength and hypertrophy in adults over 60 years of age. Journal of sports sciences. 2021 Feb 1;39(3):351-8.

[60] Currier BS, Mcleod JC, Banfield L, Beyene J, Welton NJ, D'Souza AC, Keogh JA, Lin L, Coletta G, Yang A, Colenso-Semple L. Resistance training prescription for muscle strength and hypertrophy in healthy adults: a systematic review and Bayesian network meta-analysis. British Journal of Sports Medicine. 2023 Sep 1;57(18):1211-20.

[61] Zaroni RS, Brigatto FA, Schoenfeld BJ, Braz TV, Benvenutti JC, Germano MD, Marchetti PH, Aoki MS, Lopes CR. High resistance-training frequency enhances muscle thickness in resistance-trained men. The Journal of Strength & Conditioning Research. 2019 Jul 1;33:S140-51.

[62] Pina FL, Nunes JP, Nascimento MA, Ribeiro AS, Mayhew JL, Cyrino ES. Similar effects of 24 weeks of resistance training performed with different frequencies on muscle strength, muscle mass, and muscle quality in older women. International Journal of Exercise Science. 2019 May;12(6):623.

[63] Neves RP, Vechin FC, Teixeira EL, da Silva DD, Ugrinowitsch C, Roschel H, Aihara AY, Tricoli V. Effect of different training frequencies on maximal strength performance and muscle hypertrophy in trained individuals—a within-subject design. Plos one. 2022 Oct 13;17(10):e0276154.