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REVIEW

Effects of variable resistance training versus conventional resistance training on muscle hypertrophy: a systematic review

Miguel Angel Fuentes-García[1] · Ewa Malchrowicz-Mośko[2] · Arkaitz Castañeda-Babarro[1]

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Abstract

Purpose Various training factors in combination with high intensity methodologies and techniques have been extensively investigated, with the intention of increasing anabolic, endocrine responses and subsequent structural adaptations. Variable resistance training allows the demands of an exercise to be matched to the muscle's ability to exert force. The aim of this article is to examine whether variable resistance training produces significant gains in muscle mass compared to conventional resistance training.

Methods A literature search was performed via PubMed, Web of Science, Cochrane and Scopus with search terms including "variable resistance", "accommodating resistance", "flywheel resistance", "bands resistance", "eccentric overloading resistance", "isokinetic resistance", "elastic resistance", "variable cam", "chain loaded resistance training", "hypertrophy", "resistance training", strength training" and "power training" in July 2023. Inclusion criteria were studies that measured direct data related to muscle hypertrophy, compared variable resistance training and conventional resistance training and measured body composition using tape measures, ultrasound, dual-energy X-ray absorptiometry (DXA), magnetic resonance imaging and bioimpedance metres.

Results Our search identified a total of 528 articles, and 12 studies met the inclusion criteria. The results of the studies analysed show that similar improvements occur, with no significant differences between the two training protocols.

Conclusion This systematic review revealed that variable resistance training does not produce a greater gain in muscle mass compared to conventional training over a short–medium period of time and with untrained subjects. Therefore, it is necessary to compare these two training methods over longer training periods and with subjects with more experience in resistance training.

Keywords Strength training · Bulking · Muscle mass · Endurance profile

Introduction

Muscular strength is a physical capacity directly related to a large number of health parameters [1], such as a lower risk of coronary or cardiovascular disease, as well as to sporting performance in different sports [2]. In some sports, this performance is directly related to the amount of muscle mass, such as bodybuilding [2], or where hypertrophy becomes a differential factor, such as contact sports [3]. The main mechanisms for muscle mass development are mechanical strain, metabolic stress and muscle damage [2], which are achieved by training with loads mediated by the neuroendocrine system [4]. Other training variables influencing muscle mass gain, such as repetition range, volume, intensity, frequency and rest time have been extensively investigated [5].

Miguel Angel Fuentes-García and Ewa Malchrowicz-Mośko contributed equally to this work.

✉ Arkaitz Castañeda-Babarro
arkaitz.castaneda@deusto.es

Miguel Angel Fuentes-García
mfuentes@deusto.es

Ewa Malchrowicz-Mośko
malchrowicz@awf.poznan.pl

[1] Health, Physical Activity and Sports Science Laboratory, Department of Physical Activity and Sports, Faculty Education and Sport, University of Deusto, 48007 Bilbao, Spain

[2] Department of Kinesiology, Faculty of Sport Sciences, Poznan University of Physical Education, 61-871 Poznan, Poland

However, regarding exercise selection, no extensive research has been conducted [5].

It is common to use free weights or machines for this purpose [6] in combination with training methodologies based on high intensity, making use of techniques such as rest-pause, drop sets, supersets or extreme stretching under load, amongst others. However, the mechanics involved in the use of free weights are sometimes problematic to achieve maximal effort throughout the active range of motion (ROM) of the joint [7]. Due to the body's leverage systems, the maximum weight that can be used during an exercise is limited by a phenomenon commonly known as sticking point, which creates a more disadvantageous position in ROM, limiting maximal external resistance [8]. If this sticking point could be minimised with more evenly distributed external resistance, it would allow for greater loading in higher leverage positions and, as a result, greater average muscle tension across the entire range of motion could be achieved and greater muscle mass gains could be made [2]. Variable resistance training (VRT) may, therefore, be useful to achieve this end.

This method is based on a variation in the magnitude of resistance throughout the ROM of the exercise, altering the moment arm distance to provide greater resistance during certain phases of the ROM [7], giving the possibility of equalising the increases and decreases in muscle force (force curve) throughout the ROM [9]. This adaptation would allow a greater application of maximal force throughout the ROM by the muscles involved, thus being able to generate greater tension in each repetition and making training more efficient. The use of VRT has been shown to produce greater acute neural fatigue, higher total testosterone, growth hormone and cortisol compared to constant resistance training (CRT) [10], probably due to greater muscle activity [11]. Considering that adaptations occur in part due to fatigue of the neuromuscular system [12, 13], it is possible that the VRT has the potential to provide a greater stimulus in a smaller unit of training than a CRT. In this regard, studies have provided contradictory results. As we can see in a study proposed by Staniszewski et al. [14], they found significant differences in muscle mass gains using VRT for the elbow flexor musculature compared to CRT. However, other studies [15, 16] found no significant differences in measurements related to muscle hypertrophy.

Therefore, the aim of this systematic review is to observe whether VRT produces greater gains in muscle mass compared to CRT, as long as the rest of the variables remain stable throughout the programming (volume, intensity and duration of the training period).

Materials and methods

Literature search strategies

This article is a systematic review comparing VRT with CRT in terms of the hypertrophy potential that both provide.

A literature search of four databases was conducted in July 2023. The following databases were included: Pubmed, Cochrane, Web of Science and Scopus until July 2023. This ensured that adequate literature was obtained using high-quality databases, without including any language or year filters. The literature search was carried out using advanced searches with Title and Abstract (and keywords in the case of Cochrane and Scopus), which in combination with the Boolean operators resulted in the following search phrase: ("variable resistance" [Title/Abstract] OR "accommodating resistance" [Title/Abstract] OR "elastic resistance" [Title/Abstract] OR "variable cam" [Title/Abstract] OR "chain loaded resistance training" [Title/Abstract] OR "flywheel resistance" [Title/Abstract] OR "bands resistance" [Title/Abstract] OR "isokinetic resistance" [Title/Abstract] OR "eccentric overloading resistance" [Title/Abstract]) AND "hypertrophy" [Title/Abstract] AND ("resistance training" [Title/Abstract] OR "strength training" [Title/Abstract] OR "power training" [Title/Abstract]). In addition, articles found outside this search phrase and the databases were included by snowball effect. Relevant research was selected by screening the Titles and Abstracts of the databases used, and then reading the full articles to filter out those with potential for inclusion. These steps were done by two of the authors individually, and then discussed with a third.

Inclusion and exclusion criteria

No filters for gender, race or level of participants were included to cover the maximum available literature due to the scarcity of the subject matter.

Studies were eligible for further analysis if they met the following inclusion criteria: (a) measured direct data related to muscle hypertrophy, (b) compared VRT and CRT interventions, (c) measured body composition using tape measures, ultrasound, dual-energy X-ray absorptiometry (DXA), magnetic resonance imaging and bioimpedance metres.

In terms of exclusion criteria, articles that did not meet the following criteria were rejected: (a) no older adults were involved (≥ 18), (b) no subjects with pathologies or injuries were involved. Figure 1 shows the flow chart of the search strategy.

Search variable

In the present systematic review, 12 studies met the inclusion criteria, comparing 2 groups of individuals in which 1 group

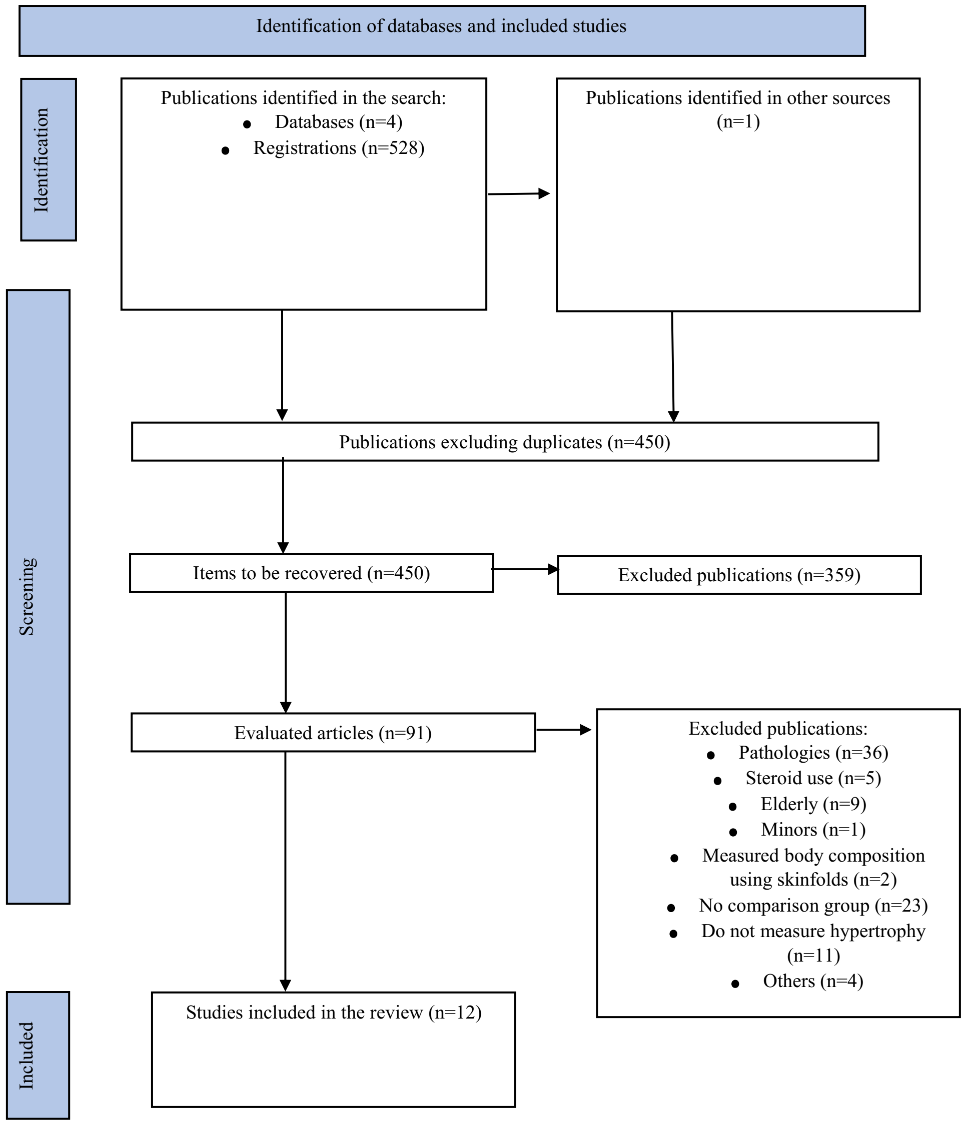

Fig. 1 Flowchart of item selection

used VRT and the other followed CRT, usually with methodologies aimed at muscle mass gain. The main intention of this systematic review is to compare whether VRT produces greater structural adaptations in the musculoskeletal system.

Results

Mains search

Of the 528 articles found in the various databases with the search phrase, only 12 were included for the systematic review (Fig. 1). Of the 528 articles, 76 were excluded as duplicates. Of the remaining 450 articles, only 91 fulfilled the inclusion and exclusion criteria for the systematic review. Of the 91, 79 were dismissed after looking at the Title or Abstract for including subjects with pathologies ($n=36$), older adults ($n=9$), not measuring hypertrophy ($n=11$), does not compare training methods ($n=23$) other reasons ($n=4$). Therefore, this systematic review includes 12 studies [6, 14, 16–25].

The effect of variable resistance on muscle hypertrophy

The characteristics of the participants, the variables measured and the protocols used in the different studies are shown in Table 1.

Table 2 shows the results of the studies included in this review, which included subjects in the following categories: physical education students ($n=2$), professional handball players ($n=1$), trained athletes ($n=1$), people with previous experience in resistance training ($n=1$) and people with no sporting experience in the last months ($n=7$). The exercises

Table 1 Characteristics of the subjects and instruments used

Level of participants	Physical education student with no experience	2 studies [6, 14]
	Professional handball players	1 study [19]
	Athletes	1 study [17]
	With previous experience in resistance training	1 study [24]
	No training for at least 6 months	7 studies [18, 20, 20–23, 25]
Type of adapted resistance	Flywheel	7 studies [18, 19, 22, 6, 14, 23, 25]
	Isokinetic	2 study [20, 21]
	Eccentric overload	2 study [17, 24]
	Pulley vs. free weight	1 study [16]
Training load	6–12 × 3–5	10 studies [17, 16–23, 25]
	1–5 × 8	2 study [14, 24]
Duration	< 8 weeks	3 studies [19, 22, 24]
	> = 8 weeks	8 studies [18, 20, 21, 16, 6, 14, 23, 25]
Muscle group	Biceps	4 studies [16, 6, 14, 23]
	Quads	8 studies [17–22, 24, 25]
Weekly frequency by muscle group	2	7 studies [18–22, 24, 25]
	3	8 studies [17, 18, 16–19, 14, 23]
Inclusion of other exercises in addition to the two to be analysed	Yes	4 studies [19, 16, 24, 25]
	No	8 studies [17, 18, 16–18, 6, 14, 23]

to be compared generally involved a single joint such as the elbow ($n = 4$) or knee ($n = 8$). In addition, there were studies in which other exercises were included in the programme involving the muscle groups to be analysed apart from the exercises being compared ($n = 4$).

Discussion

The intention of this systematic review is to look at the differences in muscle mass gain when using exercises with a resistance profile adapted to the muscle's capacity to exert force compared to conventional resistance training. The results of the studies included in this review indicate that there are no significant differences between the two training protocols. For this reason, with the current evidence, it is not possible to state that the use of variable resistance is superior in generating structural adaptations. However, despite not finding significant improvements in the adaptations produced by variable resistance training, it is interesting to note the possible trend towards improvement recorded in many of the articles used for this systematic review.

On the one hand, as far as the methodologies used are concerned, the duration of most of the studies may not be sufficient to see the differences in structural adaptations between the two training methods, as it has been shown that during the first weeks, the adaptations to resistance training are mainly neural, whilst morphological changes occur later [26–28]. These neural adaptations may occur especially in the case of subjects who are not used to strength training [29], that is, the majority of the participants in these studies, so that morphological changes are more complex to obtain. Furthermore, according to findings by Pipes [29], they suggest that, in subjects who are not accustomed to strength training, variable resistance devices may not provide more benefits than those achieved by initiating a systematic strength training programme. Knowing that the response to training is, amongst other factors, dependent on the level of the subject [2, 4], it is possible that in these subjects, it does not provide an extra stimulus by adapting the load distribution.

On the other hand, it is conceivable that as far as muscle activity is concerned, the change in load distribution provided by the variable resistance altered muscle recruitment patterns [3]. This should keep the muscle working closer to its maximal capacity at all ROM by reducing the stagnation point, which could have led to greater recruitment of type IIX fibres [15] and hence greater adaptations of these fibres. During the movement of an exercise, the bar is accelerated up to this stagnation point which, once overcome, the force required to complete the muscle contraction becomes submaximal [8]. Thus, overcoming this stagnation point by means of different variable resistance techniques (specific machines, rubber bands, chains…) would allow a uniform intensity to be applied throughout the ROM, making it possible to squeeze every part of it and achieve a much more efficient stimulus when it comes to producing gains in muscle mass [3].

Furthermore, in the study proposed by Staniszewski et al. [14], a decrease in bicipital and tricipital skinfolds was

Table 2 Summary of studies included in the systematic review

References	Population	Intervention	Parameters analysed	Conclusion
Maroto et al. [19]	29 athletes professional handball players They had a lot of experience with free weight exercise Experimental group 18 ± 1 years Control group 23.8 ± 1.6	Leg press with flywheel resistance Leg presses on a traditional weight stack machine 7 × 4/3′	Thickness of the lateral vastus of the right leg	↑ Vastus lateralis in proximal measurement 26.33 mm EXP, 23 CON Medial measurement 26 EXP, 21 CON Distal measurement 14 EXP, 13 CON
Norrbrand et al. [22]	15 mens Inexperienced	Knee extension on flywheel machine Knee extension on plate machine 4 × 7RM	Quadriceps volume	↔ Fw (6.2%) WS (3.0%)
Urbanik et al. [23]	45 subjects 21 ± 1 years Physical education students Do not currently train	Biceps machine with adapted resistance Disc machine with constant radius Control group 4 × 10/3′ TUT = 4″	Relaxed arm circumference Arm circumference in contraction	↔ A: Right arm at rest (machine with a variable cam) (5.4%) Left arm at rest (5.3%) B: Right arm at rest—machine with constant radius (3.7%) Left arm at rest (3.1%) ↔ A: Right arm in tension (3.3%) Left arm in tension (3.1%) B: Right arm in tension (0.7%) Left arm in tension (1.9%)
Walker et al. [25]	33 mens 28 ± 5 years Inexperienced Physically active	Press with variable resistance Press with constant resistance 2–3 × 12–14 (60–70% 1 RM)/1–2′ (w1-4) 2–3 × 10–12 (70–80% 1RM)/2′ (w5-7) 3–4 × 8–10 (75–85% 1RM)/2′(w8-10)	Body composition CSA of the vastus lateralis	↔ ↔
Staniszewski et al. [14]	32 subjects Physical education students Do not currently train	Biceps machine with adapted resistance Disc machine with constant radius Control group 1 (4 × 75%RM) 2 (2 × 85% RM) 3 (1 × 95% RM) 4 (1 × RM) 5 (1 × 95% RM) 6 (1 × RM) 7 (1 × 95% RM) 8 (1 × RM) Two-min pause between series TUT = 4″	Relaxed arm circumference Arm circumference in contraction	↔ Group C (variable cam) 1.2% Group D (constant cam) 0,4% ↔ Group C 1.6% Group D 1.6%

Table 2 (continued)

References	Population	Intervention	Parameters analysed	Conclusion
Matta et al. [20]	35 men with no previous experience of resistance training Conventional ($n=12$, age 19.1 ± 0.3) Control group ($n=11$, age 19.5 ± 1.5)	Unilateral concentric eccentric knee extension (right lower limb) Conventional 9–11 × 3/1′ Isokinetic 3 × 10/1′	Thickness of the lateral vastus	CSA ↔ Conventional CSA proximal (19.5%), distal (62.1%) (Isokinetic distal (64.7%) MT ↔ Mt proximal Conventional (11.4%) Mt Isokinetic (11.35%) Mt distal Conventional (47.4%) Isokinetic (31.8%) AF ↔ Distal (20.3% conventional)
Nunes et al. [16]	35 subjects 25 ± 5 years 6 months without training	Barbell preacher curl (adapted resistance profile) Preacher curl on pulley 3 × 8–12(RIR2)/90-120 s tempo 1:2	Muscle thickness	↔ CAB (7%) BAR (8%)
Staniszewski et. [6]	75 men 21 ± 1 years Physical education students 6 months without training	Machine with adapted resistance Disc machine Control group 4 × 10RM/3′	Relaxed arm circumference Arm circumference in contraction	↔ Variable 32.8 ± 3.1 Constante 31.7 ± 2.6 ↔ Variable 35.7 ± 3.0 Constante 35.2 ± 2.7
Matta et al. [21]	35 men from the physical education school of the Brazilian army. Conventional group ($n=12$, 19.3 + 0.9) Isokinetic ($n=12$, 19.1 + 0.3 years) Control group ($n=11$, 19.6 + 1.3)	Knee extension machine conventional groupIsokinetic knee extension dynamometer Continuous control group doing regular military physical activity Isokinetic group, 10 × 3/1′ Conventional group 9–11 × 3/1′	Quadriceps thickness	↔
Friedmann-Bette et al. [17]	30 active male athletes CON/ECC $n=11$ 24.5 + 4.2 years CON/ECC + $n=14$ 24.3 + 3.7 years	Knee extension on conventional device, computer controlled knee extension allowing eccentric load to be adjusted 8 × 6/4′	Thickness of the lateral vastus	CSA of the quadriceps in the CON/ECC + /CON/ECC ↔ FCSA CON/ECC + ↑ CON/ECC ↔ group
Walker et al. [24]	28 healthy young men. Subjects had previous resistance training experience (21 + 3). AEL age 21 ± 2 years TRAD (age 21 ± 2 years, CON (age 24 ± 2 years)	Bilateral leg press and unilateral knee flexion and extension exercises TRAD performed the exercises with the same load for the concentric and eccentric phases, whilst AEL performed the exercises with 40% more load during the eccentric phase compared to the concentric phase 3 × 6-RM Session 1/3 × 10-RM (session 2) tempo 2:2 s (4 s)	Quadriceps thickness	↔ For 5 weeks TRAD: + 2.6 ± 2.4% AEL: + 3.3 ± 3.9% 10 weeks 10 weeks (TRAD: + 1.6 ± 2% AEL: + 4.2 ± 4.5%
Lundberg et al. [18]	8 active men and 8 active women aged 18–35 years	Flywheel knee extension Traditional weight stack knee extension 7 × 4/2′ flywheel 8–12 × 4/2′ weight stack	Measured cross-sectional area of LV, MV and RF, LV. It was evaluated at a proximal and distal site	↔ (8% FW and 9%WS)

obtained after only 4 weeks of training, without significant changes in arm circumferences. It is possible to assume that these changes are due to some gain in muscle mass [30]. In other studies, in which no differences were seen between the two types of exercise, it is possible to deduce that similar internal physiological stress may have been produced by different means: on the one hand, in the preacher curl with pulley, training at longer muscle lengths produces more interactions between actin and myosin filaments [31, 32], which would produce greater mechanical tension and, therefore, greater muscle growth. On the other hand, the barbell preacher curl works at shorter muscle lengths, which can lead to greater metabolic stress and also increase mechanical stress [33]. Thus, the balance between lower and higher torque in the different phases of the movement and between mechanical and metabolic stress, which are important factors, amongst others, for muscle growth [2], may explain the similarity of the results between variable resistance and constant resistance.

When looking at the case of the quadriceps muscles analysed by Norrbrand et al. [22], it is possible to see how with constant resistance training, only the size of the rectus femoris increased, whilst with variable resistance training, all muscle bellies improved. Surprisingly, even though these differences were not statistically significant, the growth of the subjects who used variable resistance was more than double that of those who used a plate machine (6.2% vs. 3%). This could indicate a much greater difference if the training sessions were of longer duration. This could imply a greater performance in the different sports modalities and a greater hormonal response.

In terms of hormonal responses, different responses were found in the two types of training [34]. After 8 weeks, analysis of the different hormonal parameters shows that, with the exception of growth hormone (GH), the adapted endurance group had a greater hormonal change despite not having statistically significant differences: a greater increase in IGF-1 and follistatin and a decrease in myostatin and cortisol. IGF-1 is one of the most studied anabolic hormones along with GH [35], whilst cortisol and myostatin have a mostly catabolic function through protein degradation [35, 36]. Follistatin, on the other hand, is a myostatin inhibitor [36], so it also exerts an anti-catabolic role. Considering these changes and hormonal differences, it is possible to predict an increase in muscle mass and strength [37], possibly to a greater extent in the adapted endurance group in the long term.

Despite the above, little is known about the heterogeneity of hormonal responses to strength training [34]. However, according to Bouchard and Rankinen [38], there is a link between genetic variations and skeletal muscle characteristics such as muscle fibre composition that could affect adaptations to training [39]. Taking into account hormonal changes at rest to a more anabolic state, improvements in muscle mass and strength would be expected [37]. Accordingly, the findings of Arazi et al. [34] indicated that there were significant correlations between FFM with anabolic and catabolic hormones and myokines including IGF-1, cortisol, myostatin, and phylostatin, which would predict an increase in muscle mass and strength, possibly occurring to a greater extent with long-term variable resistance training.

All training groups demonstrated a similar time course of changes in creatine kinase (CK) activity [6, 23]. However, hypertrophy training using variable resistance was a less strenuous stimulus for inducing muscle damage than the use of a machine with a disc plate. It can, therefore, be concluded that in strength training methods that require a higher number of repetitions in sets, it is more effective to train on a machine with variable resistance. Taking into account the findings of the work of Damas et al. [40] in which it was seen that protocols with less muscle damage achieved similar hypertrophy to those that did, it may be that this method is less harmful and more efficient [6] to achieve this objective, although we cannot find a conclusive conclusion.

In all the studies analysed, there are several limitations that do not allow a conclusive conclusion to be drawn, due to the fact that, on the one hand, the level of the participants is, in most of them, that of beginners with no previous experience. This means that it is not possible to extrapolate the results obtained to the rest of the population, since the response to training is, amongst other factors, dependent on the level of the subject [2, 4], so it is possible that, in this type of subject, adapting the endurance profile does not promote extra gains compared to not doing so.

Conclusion

The use of a conventional resistance causes muscles to work at maximum load over only a portion of the entire range of motion. However, the use of a variable resistance allows the external load to be adjusted to a muscle's ability to exert force throughout the entire range of motion. This allows for greater efficiency, comfort and safety for the athlete. However, although the results have been superior for variable resistance in terms of muscle mass gain in the different studies, they have not been significantly so in the short–medium term (8 weeks) and with untrained subjects. Therefore, research is needed to compare variable and conventional resistance over longer periods of training and with subjects with more experience in resistance training.

Practical applications

Muscle strength training is widely used as a primary or supplemental training method to increase muscle size and strength in most sports disciplines [6]. Therefore, any performance support in this regard should be taken into account when developing a training programme. The use of variable resistance allows the load to be adjusted to the muscle's ability to exert force over the full range of motion [3], allowing for greater efficiency, comfort and safety for the athlete [6]. After having analysed the current evidence of this training methodology, it is worth mentioning that the use of variable resistance training is as effective a training method as conventional resistance training. In addition, it is possible that this method could be interesting to apply it in those sports where muscle mass is a differential factor, such as bodybuilding [2], because in some of the articles observed, it has been seen that variable resistance training, without significant difference, produces a slightly greater hypertrophy compared to conventional training [14, 16, 22, 23].

However, there are some variables that may influence the subject's response to improve performance in variable resistance training: sex, age, experience in resistance training, inclusion of other exercises (in addition to those we want to investigate), physical fitness, duration of training. Therefore, we believe that it would be convenient to continue investigating the effect of accommodating the resistance profile compared to not doing it, although taking into account these variables.

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Data availability All data analysed during this study are included in this published article.

Declarations

Conflict of interest Miguel Angel Fuentes-García, Ewa Malchrowicz-Mośko and Arkaitz Castañeda-Babarro have nothing to disclose.

Ethical approval This project is a systematic review, and thus ethics approval is not applicable.

Consent to participate Not applicable to this systematic review.

Consent for publishing Not applicable to this systematic review.

Informed consent Since this is a systematic review, there is no informed consent.

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