Training methods and nutritional aspects to increase muscle mass: a systematic review

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Summary

Introduction: The increase of the muscle mass is one of the main challenges of the athletic trainers, either to optimize the performance, for esthetical reasons or for the health improvement. Therefore, the aim of this study was to analyse the training methods and nutritional aspects for the increase of muscle mass.
Material and method: A data search were conducted in PubMed and Google Scholar databases using the terms: "hypertrophy", "skeletal muscle", "strength" and "training", on the other hand, "hypertrophy", "skeletal muscle" and "nutrition".
Results: After applying the search strategies, a total of 322 articles on training methods and 269 regarding nutritional strategies were obtained. After reading the title and abstract, 238 and 212 articles were eliminated, respectively. Finally, 26 articles on training methods and 11 on nutritional strategies were selected, which met the inclusion criteria and were included in this review.
Conclusions: The results of this study suggest carrying out a training with external loads with the following characteristics: 3-5 series of 6-12 repetitions, with an intensity close to muscle failure (repetitions in reserve of 0 to 2), with a high weekly training volume, and a weekly frequency of 3 days per muscle group, at full range of several different exercises, combining concentric and eccentric contractions, using an internal attentional focus, and with a rest between sets of 2-3 minutes. The nutritional strategies play a fundamental role on the increase of the muscular mass, being essential a high energetic contribution so that hypertrophy occurs. In addition, the intake of nutrients such as whey protein, leucine and omega-3 fatty acids favour muscle protein accretion.

Key words:
Hypertrophy.
Strength training. Nutrition.

Métodos de entrenamiento y aspectos nutricionales para el aumento de la masa muscular: una revisión sistemática

Resumen

Introducción: El aumento de la masa muscular es uno de los principales retos de los entrenadores deportivos, ya sea para optimizar el rendimiento, por razones estéticas o para la mejora de la salud. Por ello, el objetivo de este trabajo fue analizar los métodos de entrenamiento y aspectos nutricionales de mayor importancia para el aumento de la masa muscular.
Material y método: Se realizó una búsqueda bibliográfica en las bases de datos PubMed y Google Scholar usando los siguientes términos: "hypertrophy", "skeletal muscle", "strength" y "training", y, por otro lado, "hypertrophy", "skeletal muscle" y "nutrition".
Resultados: Tras aplicar las estrategias de búsqueda, se obtuvieron un total de 322 artículos sobre métodos de entrenamiento y 269 respecto a estrategias nutricionales. Tras la lectura de título y resumen se eliminaron 238 y 212 artículos respectivamente. Finalmente, se seleccionaron 26 artículos sobre métodos de entrenamiento y 11 sobre estrategias nutricionales, los cuales cumplieron los criterios de inclusión, y fueron incluidos en esta revisión.
Conclusiones: Los resultados de este estudio sugieren la realización de un entrenamiento con cargas con las siguientes características: 3-5 series de 6-12 repeticiones realizadas en el rango de movimiento completo, con una intensidad cercana al fallo muscular (repeticiones en reserva de 0 a 2), con un volumen de entrenamiento semanal alto, y una frecuencia semanal de 3 días por grupo muscular, empleando varios ejercicios diferentes, combinando contracciones concéntricas y excéntricas, utilizando un foco atencional interno y con un descanso entre series de 2-3 minutos es el método más efectivo para el aumento de la masa muscular. Las estrategias nutricionales juegan un papel fundamental sobre el aumento de la masa muscular, siendo imprescindible un sobre aporte energético para que se produzca hipertrofia. Además, la ingesta de nutrientes como la proteína de suero de leche, la leucina y los ácidos grasos omega-3 favorecen la acreción proteica muscular.

Palabras clave:
Hipertrofia.
Entrenamiento con cargas.
Nutrición.

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Introduction

Millions of people worldwide are currently pursuing the goal of increasing muscle mass, from bodybuilders looking to perfect their body composition for aesthetic reasons to weightlifters and athletes aiming to improve their athletic performance[1]. Increased muscle mass is also sought for health purposes, mainly to avoid sarcopenia and related problems[2]. For these reasons, effectively increasing muscle mass has become a key challenge for sports educators.

In turn, this has generated greater interest in understanding the factors that lead to increased muscle mass[1]. Indeed, there seems to be a widespread consensus on the determinants of muscle growth. In particular, mechanical stress, metabolic stress and muscle damage have been identified as the fundamental aspects that must occur during resistance training with loads to generate increased muscle mass[3].

However, there is some controversy regarding the most appropriate training methods to effectively optimise muscle mass increases in different sports contexts and populations[4]. In this regard, the effects of modulating different training parameters have been studied, such as the intensity and volume of training, rest intervals and the type of contraction performed. Nevertheless, conclusive results have not been obtained[1]. Despite this, it has been observed that a fundamental aspect of generating muscle gains is exercising until muscular failure, regardless of the load used[5]. However, more studies are needed to confirm this theory; they must also be applied to a variety of populations.

Previous studies have shown that, along with exercise, nutritional strategies are critical to optimising increased muscle mass. In this sense, energy balance seems to play a key role. Indeed, hypocaloric diets are considered essential for athletes trying to increase their muscle mass[6]. Likewise, protein intake is of great importance, although the minimum recommended amount for such ends is not entirely clear[7,8]. Additionally, it has been established that pre- and post-exercise supplementation, mainly based on leucine or branched-chain amino acids, can help muscle hypertrophy[9]. However, the ideal nutritional principles and ergogenic aids to optimise the process of increasing muscle mass are not entirely clear.

Therefore, the objective of this review is to analyse the most significant training methods and nutritional aspects to increase muscle mass.

Materials and methods

To meet the objective of this study, a literature review was carried out in accordance with the PRISMA recommended guidelines for systematic reviews and meta-analyses[10]. Bibliographic research was carried out in the search engines and databases PubMed and Google Scholar, for which the terms "hypertrophy", "skeletal muscle", "strength" and "training" were searched on the one hand and, on the other, "hypertrophy", "skeletal muscle" and "nutrition". Once the articles had been selected, their references were analysed to identify other articles that could be included in the review. The inclusion criteria used were: (a) studies that analysed the impact of training and nutrition on muscle hypertrophy, (b) articles published in the past 15 years, and (c) articles published in peer-reviewed international journals *(Journal Citation Report)*. The exclusion criteria used were: (a) being written in a language other than English, (b) articles in which the sample is not healthy humans, (c) articles concerning a hypertrophy other than that of skeletal muscle, (d) articles combining training or nutrition with the consumption of anabolic steroids or other illegal substances, (e) articles that did not perform a pre-post assessment.

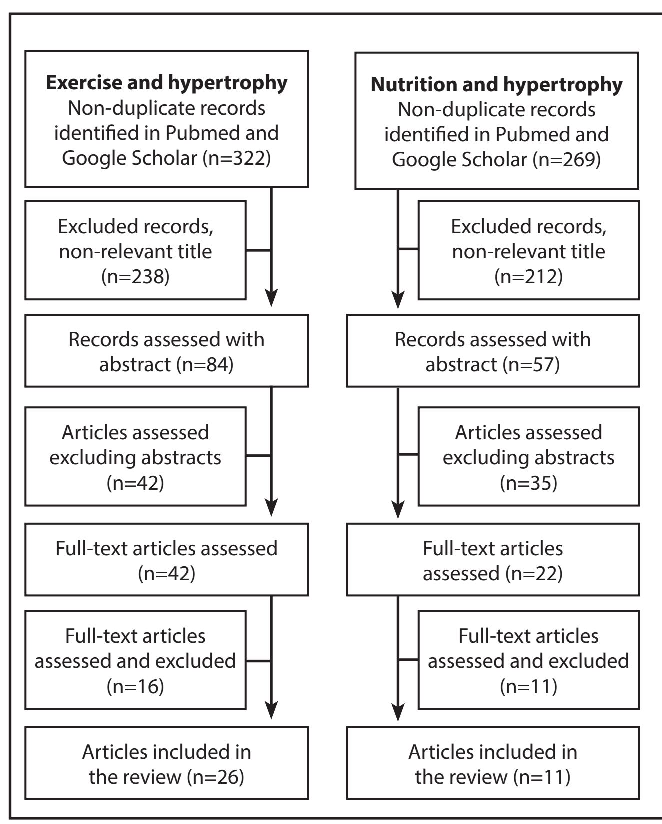
Results

Training methods

A total of 322 results were found through the initial search strategy regarding training and hypertrophy, applying the aforementioned filters. After reading the titles, 238 articles were deleted due to repetition or non-conformity with the relevant themes. Another 42 were deleted after reading their abstracts. The full text of the remaining 42 were read and 16 of these were removed, leaving 26 articles at the end of the selection process (Figure 1).

The 26 selected works were read and analysed in depth to perform the systematic review of training methods to increase muscle mass. The review consisted of a total of 772 subjects with an average of 29 participants per study. In 22 of the included studies the sample was made up of men, in one the sample was of women and the remaining 3 involved

Figure 1 Flow chart describing the systematic review procedure.



both men and women. Regarding the training-related variables, the studies covered training load (4 articles), intensity (3 articles), weekly volume (1 article), number of sets per exercise (2 articles), frequency (4 articles), rest intervals between sets (2 articles), type of training (2 articles), exercise order (2 articles), muscle action (1 article), type of exercise (3 articles), focus of attention (1 item) and range of motion (1 item). Finally, the average duration of the intervention programmes was 10 to 12 weeks, with 6 months being the longest-lasting programme and 6 weeks being the shortest (Table 1).

Nutritional strategies

A total of 269 results were found through the initial search strategy regarding nutrition and hypertrophy, applying the aforementioned filters After reading the titles, 212 articles were deleted. Another 35 were

Table 1. Training methods to increase muscle mass.

Study	Variable	Sample	Intervention	Results
Holm *et al*. (2008)	Load	n=12 untrained male youth	Intra-individual cross-selection with all subjects performing a resistance exercise protocol 3 times per week, performing one training protocol with one leg and another with the other leg: A) Light load: 36 repetitions (1 repetition every 5 seconds for 1 minute) at 15.5% of 1RM. B) Heavy load: 8 repetitions per set at 70% of 1RM. 12 weeks	Significant gains in muscle hypertrophy and strength in the leg having done the heavy-weighted exercises.
Schoenfeld *et al*. (2014)	Load	n=20 young trained males 18 -35 years	Random assignment to one of two resistance exercise protocols: A) Strength-type exercise designed to induce high levels of mechanical stress (2-3 muscle groups per session, with sets of 8-12 repetitions and a 90-second rest between sets). B) Hypertrophy-type training designed to induce high levels of metabolic stress (all muscle groups per session, with sets of 2-4 repetitions and a 3-minute rest between sets). 8 weeks	No significant differences in volume were noted between muscle groups of either group. Likewise, no differences were identified in hypertrophy between groups. However, there was a greater increase in muscle strength in strength-type training.
Tanimoto *et al*. (2008)	Load	n=36 untrained male youth 19.0 ± 1.5 years	Random assignment to one of three groups: 2 resistance exercises (full body) and 1 control: A) Low load and low motion speed exercise group (55-60% 1RM with 3 seconds for eccentric and concentric actions). B) High load training group (80-90% 1RM with 1 second for concentric and eccentric actions). C) Control group: did not perform any training. 13 weeks	Both training groups experienced an increase in strength and muscle mass, with no significant differences between the two groups.
Schoenfeld *et al*. (2015)	Load	n=24 young trained males 18 -33 years	Random assignment to one of two resistance exercise protocols: A) Low load (25-35 repetitions at 30-50% 1RM). A) High load (8-12 repetitions at 70-80% 1RM). 8 weeks	No significant differences were noted in hypertrophy between both groups. However, there was a greater increase in absolute and relative strength among those training with higher loads, as well as a greater increase in muscular resistance among those training with lower loads.
Sampson *et al*. (2016)	Intensity	n=28 inexperienced young males	Random assignment to one of three resistance exercise protocols (85% 1RM 3 days/week): A) Non-failure rapid shortening (rapid concentric) B) Non-failure stretch-shortening (rapid concentric, rapid eccentric) C) Muscle failure 12 weeks	Similar gains in muscle mass for all 3 resistance training regimen
Nóbrega *et al.* (2018)	Intensity	n=32 inexperienced young men 23 ± 3.6 years	Random assignment to one of four resistance exercise protocols (3 sets at 80% 1RM): A) Non-failure, low intensity. B) Non-failure, high intensity. C) Muscle failure, low intensity. D) Muscle failure, high intensity. 6 week	Similar gains in muscle mass when exercising until muscle failure compared to non-failure, independently of the intensity applied.

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Study	Variable	Sample	Intervention	Results
Martorelli *et al.* (2017)	Intensity	n=18 inexperienced young women 22 ± 3.3 years	Random assignment to one of 3 resistance exercise protocols (70% 1RM): A) Muscle failure. B) Non-failure, equalised volume. C) Not to muscle failure, low volume. 10 weeks	Similar muscular gains when muscle failure was attained or not while maintaining an equalised exercise volume.
Schoenfeld *et al.* (2019)	Volume (weekly sets)	n=34 young trained males 18 -35 years	Random assignment to one of three resistance exercise protocols: A) Low volume (6 to 9 sets per muscle group per week). B) Medium volume (18 to 27 sets per muscle group per week). C) High volume (30 to 45 sets per muscle group per week). 8 weeks	Greater increases in muscle mass as the weekly training volume increases, showing a significant dose-response ratio.
Radaelli *et al.* (2015)	Volume (sets per exercise)	n=48 young men inexperienced in weight training, but experienced in traditional military exercises 24.4 ± 0.9 years	Random assignment to one of four groups, 3 resistance exercises (3 exercises per week with at least 48-72 hours rest between sessions) and 1 control: A) Group performing 1 set per exercise. B) Group performing 3 sets per exercise. C) Group performing 5 sets per exercise. D) Control group: did not perform the weight training program but did follow a traditional military regime with their own body weight. 6 months	Significant gains in hypertrophy in the group that performed 5 sets per exercise in comparison to all other groups. A greater increase in hypertrophy was also observed in the group performing 3 sets per exercise in comparison to that which did only 1
Sooneste *et al.* (2013)	Volume (sets per exercise)	n=8 sedentary, untrained male youth 19 -29 years	Intra-individual cross-selection with all subjects performing a resistance exercise protocol 2 times per week, performing one training protocol with one arm and another with the other arm: A) 3 sets per session. B) 1 set per session. 12 weeks	Significant increases in strength and hypertrophy in the arm that did 3 sets per session.
Brigatto *et al.* (2019)	Frequency	n=20 young trained males 19 -35 years	Random assignment to one of two resistance exercise protocols: A) Frequency of 1 day per week for each muscle group. B) Frequency of 2 days per week for each muscle group. 8 weeks	No significant differences were observed in increased muscle mass when training with a weekly frequency of 1 or 2 days per muscle group.
Zaroni *et al.* (2019)	Frequency	n=18 young trained males 18 -30 years	Random assignment to one of two resistance exercise protocols: A) Frequency of 1 day per week for each muscle group. B) Frequency of 5 days per week for each muscle group. 8 weeks	Significantly higher increases in muscle mass in the group that trained with a frequency of 5 days/week compared to the group that trained 1 day/week, both in the lower and upper body muscles.
Saric *et al.* (2019)	Frequency	n=27 young trained males aged over 18	Random assignment to one of two resistance exercise protocols: A) Frequency of 3 days per week for each muscle group. B) Frequency of 6 days per week for each muscle group. 6 weeks	No significant differences were observed in increased muscle mass when training with a weekly frequency of 3 or 6 days per muscle group.
Schoenfeld *et al.* (2015)	Frequency	n=20 young trained males 19 -29 years	Random assignment to one of two resistance exercise protocols: A) Frequency of 1 day per week for each muscle group. B) Frequency of 3 days per week for each muscle group. 8 weeks	Greater significant increases in hypertrophy for the group that trained each muscle group 3 days per week.
Buresh *et al.* (2009)	Rest between sets	n=12 untrained male youth 19 -27 years	Random assignment to one of two rest protocols during resistance training: A) 1-minute rest between sets B) 2.5-minute rest between sets 10 weeks	Significant gains in increased hypertrophy for the group with longer rest intervals, without any differences in terms of strength.

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Study	Variable	Sample	Intervention	Results
Schoenfeld *et al*. (2016)	Rest between sets	n=23 young trained males 18-35 years	All participants performed full-body training 3 times per week composed of 3 sets of 8-12 repetitions with 7 different exercises per session. Random assignment to one of two rest protocols during resistance training: A) 1-minute rest between sets B) 3-minute rest between sets. 8 weeks	Slightly significant major increase in additional load volume in the group with longer rest intervals. Significant major gains in hypertrophy and maximum strength in the group with longer rest intervals.
Fonseca *et al*. (2014)	Type of training	n=70 untrained male youth 26.1 ± 4.3 years	Random assignment to one of five groups, 4 hypertrophy-oriented lower-limb strength training (2 sessions per week, 6-10 repetitions per set) and 1 control: A) constant intensity and constant exercise: 8 repetitions of squats. B) constant intensity and varied exercise: 8 repetitions of squats, leg-press, dead lift and lunges. C) varied intensity and constant exercise: 6-10 repetitions of squats. D) varied intensity and varied exercise: 6-10 repetitions of squats, leg-press, dead lift and lunges. E) Control group: did not perform any training. 12 weeks	Significant major increases in hypertrophy in the group that performed varied exercise, both with varied and constant intensity; the latter making greater strength gains.
Stasinaki *et al*. (2015)	Type of training	n=25 young trained males 21.9 ± 1.9 years	Random assignment to one of three resistance exercise groups: A) Compound training group: 3 weekly training sessions alternating low-speed, high load (strength) sessions with high-speed, low load (power) sessions. B) Complex training group: 3 weekly training sessions including strength and power in all sessions. C) Control group: did not perform any training. 6 weeks	Significant major increases in strength and hypertrophy in the group that did complex training. On the other hand, the compound training group showed greater increases in power levels.
Fisher *et al*. (2014)	Exercise order	n=41 trained men and women	All subjects trained two days per week with one single set and moderate intensity load until muscle failure. Random assignment to one of three resistance exercise protocols: A) Training group with isolated exercises, progressing to compound exercises, without resting between exercises. B) Training group with isolated exercises, progressing to compound exercises, including rests between exercises. C) Control group, trained with compound exercises, progressing to isolated exercises, with rests. 12 weeks	No significant differences were noted in hypertrophy between the groups.
Spineti *et al*. (2010)	Exercise order	n=30 young trained males 22 -30 years	Random assignment to one of three groups, 2 resistance exercises (2 sessions per week with at least 72 hours rest between sessions) and 1 control: A) Group trained with large muscle group exercises, progressing to small muscle group exercises. B) Group trained with small muscle group exercises, progressing to large muscle group exercises. C) Control group: they did not carry out the weight training program but did perform a traditional military program. 12 weeks	No significant differences were noted in hypertrophy between the groups.
Reeves *et al*. (2009)	Type of muscular action	n=19 untrained senior men and women 65 -77 years	All subjects performed 3 weekly training sessions with 5 repetitions at 80% of 1RM. Random assignment to one of two resistance exercise protocols: A) Conventional training: performing concentric and eccentric contractions. B) Eccentric training: performing only eccentric contractions. 14 weeks	No significant differences were noted in hypertrophy between both groups, but adaptations to the muscle architecture and strength were different.

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Study	Variable	Sample	Intervention	Results
Paoli *et al.* (2017)	Type of exercise	n=36 athletic men without experience in strength training 28 ± 4.5 years	Random assignment to one of two resistance exercise groups: A) Based on single-joint exercises. B) Based on multiple-joint exercises.	There were no significant differences in hypertrophy between both groups despite using different types of exercises.
De França *et al.* (2015)	Type of exercise	n=20 trained men 28 ± 4.5 years	Random assignment to one of two resistance exercise groups: A) Based on single-joint and multiple-joint exercises. B) Based on multiple-joint exercises.	No significant differences were noted in hypertrophy between both groups.
Gentil *et al.* (2015)	Type of exercise	n=29 men without experience in strength training 28 ± 4.5 years	Random assignment to one of two resistance exercise groups: A) Based on single-joint exercises. B) Based on multiple-joint exercises	There were no significant differences in hypertrophy between both groups despite using different types of exercises.
Schoenfeld *et al.* (2018)	Attentional focus	n=30 male university students 18 -35 years	Random assignment to one of two groups, (3 sessions per week with 4 sets 8-10 repetitions): A) Internal focus (concentrating on muscular contraction). B) External focus (concentrating on the outcome of the lift). 8 weeks	Significant increases in greater hypertrophy in the internal focus group both in muscle thickness of elbow flexors and quadriceps
McMahon *et al.* (2014)	Range of motion	n=26 Young physically active men and women 18 -26 years	Random assignment to one of three groups, 2 resistance exercises (3 exercises per week with 3 sets of 80% 1RM) and 1 control: A) Group training with partial range of motion (ROM). B) Group training with complete ROM. C) Control group: did not perform any training. 8 weeks	Significant increases in hypertrophy in the group that trained with a complete range of motion.

deleted after reading their abstracts. The full text of the remaining 22 were read and 11 of these were removed, leaving 11 articles at the end of the selection process (Figure 1).

The 11 selected works were read and analysed in depth to perform the systematic review of nutritional aspects to increase muscle mass. The review consisted of a total of 1,071 subjects with an average of 97 participants per study. In 9 of the included studies, the sample was made up of men, while the remaining 2 involved both men and women. Furthermore, most of the articles presented an intervention period of 12 weeks. The longest duration of an intervention was 40 months, while the shortest duration was 4 weeks (Table 2).

Discussion

This study aimed to analyse the most significant training methods and nutritional aspects to increase muscle mass.

Training methods

In relation to the training load, an increase in muscle mass was observed with very different loads, from very light[11], low[12,13] or medium loads[14] to high[11,12,14] or very high loads[13]. Differences between loads were only observed in the study conducted by Holm *et al.*[11], which found a greater increase in muscle mass in subjects who trained with heavier loads. This is indicative of the need to customise loads to meet the requirements of each athlete, as well as the importance of using a wide range of loads to favour different types of adaptation.

Various authors have postulated that muscle failure needs to take place to maximise muscle growth[15,16]. However, recent studies with both men and women have shown that this is not necessary and that training at an intensity close to muscle failure (ending the set 2-3 repetitions before reaching failure) produces similar effects on increased muscle mass to those of training to reach actual muscle failure[17–19]. In this sense, Zourdos *et al.*[20] proposed the concept of repetitions in reserve (RIR), which indicates the number of repetitions that a subject could perform at the end of each series. An RIR of 0 would represent actual muscle failure, while an RIR of 2 would mean finishing the series two repetitions before reaching muscle failure. However, subjects need to become familiar with this concept in order to apply it reliably when training[21]. Regardless, there are times when it may be advantageous to achieve real muscle failure. This would be, for example, when training with low loads, in the first set of a training program or in small training blocks (maximum of 4 weeks), as well as with low weekly training frequencies, due to the long recovery time required when applying this method[22]. Failure to follow these guidelines regarding muscle failure in

Table 2. Nutritional strategies to increase muscle mass.

Study	Theme	Sample	Intervention	Results
Boone *et al.* (2015)	Protein supplementation	n=20 untrained male youth 21.4 ± 1.9 years	All performed resistance training (3 sessions per week on non-consecutive days, 3 sets per exercise of 8-10 repetitions at 80% of 1RM). Random assignment to one of two nutritional groups: A) Protein intake. B) Placebo intake. 4 weeks	Both groups revealed an increase in strength and muscle mass, with no significant differences between the two groups.
Chappell, Simper y Barker (2018)	Nutritional habits	n=51 Male and female competitors in natural bodybuilding	The dietary practices of all bodybuilders were surveyed, requiring participants to fill out a 34-item questionnaire assessing their diet in three moments. 22 ± 9 weeks	Bodybuilders' nutritional habits proved to reflect a high carbohydrate and protein intake together with low fat intake.
Farup *et al.* (2014)	Protein supplementation	n=22 young males	Random assignment to one of two nutritional groups: A) Whey protein hydrolysate (with high leucine content) and carboyhdrate intake. B) Carbohydrates intake. In addition, within these groups an intra-individual cross selection was undertaken with subjects performing one exercise protocol with one leg and another with the other leg: A) Concentric contractions. B) Eccentric contractions. 12 weeks	Significant increases in greater hypertrophy in the group that consumed whey protein hydrolysate with high leucine content, regardless of the type of contraction.
Garthe *et al.* (2013)	Energy balance	n=47 Elite athletes 17 -31 years	All subjects continued their sports-specific training, including four additional strength training sessions per week. Random assignment to one of two nutritional groups: A) Group with nutritional guidance: following a meal plan that provided a positive energy balance (+500 kcal/day). B) "Ad libitum" group: on-demand energy intake. 8 -12 weeks	Greater fat-free mass increases in the group with a positive energy balance, in addition to greater increases in fatty deposits.
Hulmi *et al.* (2015)	Whey protein and carbohydrates	n=86 physically active men	Random assignment to one of three post-training nutritional groups: A) 30 g. whey protein. B) Isocaloric carbohydrates C) Whey protein and carbohydrates. Within those groups, subjects were randomly assigned to one of two training methods (both whole-body training, with 2-3 sessions per week): A) Maximum-strength training 4-6 repetitions at 86-95% of 1RM. B) Muscular hypertrophy training 8-12 repetitions at 75-85% of 1RM. 12 weeks	Increase in fat-free mass and strength in training with no differences between post-exercise nutritional groups. The increase in fat-free mass was slightly greater in the group that took protein after exercising, owing to a relative increase, as whey proteins increased abdominal fat loss in this group.
Kukuljan *et al.* (2009)	Supplementation: fortified milk	n=180 adult men 50 -79 years	Random assignment to one of four study groups: A) Exercise + fortified milk. B) Exercise C) Fortified milk. D) Control group. 18 months	Consuming fortified milk did not demonstrate any additional benefit in terms of strength and hypertrophy. The increase in strength and hypertrophy that took place was associated with exercise and not with supplementation.
Rahbek *et al.* (2014)	Supplementation: proteins and carbohydrates	n=24 young physically active men 23.9 ± 0.8 years	Random assignment to one of two nutritional groups: A) Whey protein hydrolysate and carbohydrate intake. B) Isocaloric carbohydrates intake. Within those groups, subjects were randomly assigned to one of two training types: A) Concentric contractions. B) Eccentric contractions. 12 weeks	Regardless of the type of contraction performed, there was a significantly greater increase in muscle hypertrophy, anabolic signalling and muscle protein synthesis in the group that consumed whey protein hydrolysate and carbohydrates.

(Continúa)

Study	Theme	Sample	Intervention	Results
Smith *et al.* (2011)	Omega-3 fatty acids	n=16 senior aged men and women 65 years or older	Random assignment to one of two post-exercise nutritional groups: A) Omega-3 fatty acid intake. B) Corn oil intake. 8 weeks	Supplementation with omega-3 fatty acids caused an increase in muscle protein synthesis while corn oil intake proved to be nonsignificant.
Snijders *et al.* (2015)	Protein before sleeping	n=44 young physically active men 22 ± 1 years	All subjects performed resistance training (3 sessions per week on non-consecutive days, gradually increasing loads from 10-15 repetitions at 70% of 1RM to 8-10 repetitions at 80% of 1RM). Random assignment to one of two pre-sleep nutritional groups: A) Protein intake. B) Placebo intake. 12 weeks	Significantly greater increases in muscle mass and strength in the group that took protein before sleeping.
Verdijk *et al.* (2009)	Protein supplemen-tation	n=28 senior aged men 72 ± 2 years	All subjects performed resistance training (3 sessions per week on non-consecutive days, gradually increasing loads from 10-15 repetitions at 60% of 1RM to 8-10 repetitions at 75% of 1RM). Random assignment to one of two nutritional groups for before and after each session: A) Protein intake. B) Placebo intake. 12 weeks	Both groups revealed an increase in strength and muscle mass, with no significant differences between the two groups.
Wardenaar *et al.* (2017)	Macronu-trients	n=553 well-trained athletes 17 -31 years	Twenty-four-hour dietary recalls and questionnaires were obtained from each athlete with the aim of comparing total energy and macronutrient intake among discipline-categories. 40 months	Strength athletes were those with the greatest quantity of protein intake.

training can negatively affect athletes' performance by increasing the chances of suffering overtraining syndrome or psychological burnout[23].

Regarding training volume, which is defined as the number of sets dedicated to each muscle group per week, a tendency of increased hypertrophy is observed when the weekly volume is increased. In this sense Schoenfeld *et al.*[24] observed a significant dose-response ratio between weekly training volume and increased muscle mass. The same trend appeared when training with untrained subjects, although without significant differences between the different training volumes. Thus, it is advisable to adapt this volume to the individual characteristics of each athlete--namely, the higher the level of the athlete, the higher the volume. On the other hand, regarding the number of sets per exercise, it was observed that levels of hypertrophy were higher in training protocols that performed more sets (3-5 sets) per exercise[25,26]. In both studies, it is recommended to increase training volumes in accordance with athletes' experience in resistance training with loads, following the principle of load progression[27].

Weekly training frequency seems to be an important aspect to increasing muscle mass. Brigatto *et al.*[28] observed that there were no significant differences in increased muscle mass after training each muscle group with a weekly frequency of 1 or 2 days. However, by substantially increasing the weekly training frequency for each muscle group (1 day *vs.* 5 days, with the same total volume), Zaroni *et al.*[29] observed a larger increase in the group that trained each muscle group 5 days per week. Likewise, the study conducted by Schoenfeld *et al.*[30] found increased muscle mass to be evident in individuals subject to a higher training frequency (1 day *vs.* 3 days, with the same total volume). Finally, Saric *et al.*[31] observed a similar increase in muscle mass when training each muscle group 3 or 6 days per week. In the light of the above, training each muscle group 3 times per week seems to be an adequate and sufficient frequency to optimise increases in muscle mass. Therefore, full body routines might be a good option to increase the weekly frequency of training for each muscle group.

In reference to rest, no significant differences were observed when applying different rest intervals between sets[32,33]. However, Schoenfeld *et al.*[33] claims that applying longer rest intervals between sets (2-3 minutes) facilitates higher training volumes and, consequently, greater increases in muscle mass.

Several studies have shown greater increases in muscle mass in subjects who performed more varied sessions in terms of the number and type of exercises[34,35]. Yet, no differences in increased muscle mass have been observed by varying the order of exercises within the same training session[36,37]. On the other hand, Reeves *et al.* [38] showed that while both concentric and eccentric contractions produce similar muscle growth, each type of contraction results in different muscle responses and adaptations. Therefore, it is recommended to incorporate both types of contractions into training sessions.

Previous studies have shown that there are no differences in increased muscle mass when using single-joint or multiple-joint exercises[39,40]. It has even been studied whether including additional single-joint exercises into training programs with mainly multiple-joint exercises would produce greater increases in hypertrophy levels, but significant results were not obtained[41]. This evidence suggests that single-joint or multiple-joint exercises are equally effective for increasing muscle mass. Accordingly, selection criteria for the type of exercise to be performed should be based on each athlete's individual needs, such as the time and equipment available, the specificity of the movements or the athlete's particular preferences.

Another aspect to consider is the focus of attention while performing strength training programs aimed at increasing muscle mass. Although there is little evidence to this effect, Schoenfeld *et al.*[42] observed a higher level of hypertrophy when the focus of attention was internal (i.e., the individual thinks of his/her body's movements while performing the exercises). This seems to be due to the existence of a "mind-muscle" connection, owing to which it is recommended to visualise the target muscle and consciously direct one's neural impulse to it for increased activation.

Finally, it has been shown that performing strength exercises with a full range of motion produces a greater increase in muscle growth, mainly because the muscles are exposed to different stimuli and adaptations at each angle of the range of motion[43].

Nutritional strategies

In reference to energy balance, Garthe *et al.*[44] demonstrated that combining a strength training program together with a positive energy intake enhances the anabolic effect, leading to fat-free mass gains. In this respect, Chappell *et al.*[45] observed that bodybuilders had nutritional habits with markedly high carbohydrate and protein intake, together with low fat intake. Despite this, excessive energy intake should be deliberated with caution due to the possible adverse effects of increasing body fat levels[46].

Upon analysing the effect of combining protein supplementation with training with loads on untrained subjects, several studies showed that no further increase in muscle mass was achieved when compared to simply training[47–50]. By contrast, Farup *et al.*[9] and Rahbek *et al.*[51] observed greater increases in muscle mass following supplementation with whey protein hydrolysate--with high leucine content--combined with carbohydrates. In this way, they demonstrated that this amino acid is a potent driver of muscle protein synthesis. In addition, it has been observed that protein-based supplementation prior to sleeping represents an effective dietary strategy to increase muscle mass when performing resistance-type exercise training[52].

As for fatty acids, Smith *et al.*[53] demonstrated that omega-3 fatty acid supplementation increases the rate of muscle protein synthesis.

Conclusion

The results obtained suggest that performing resistance-type training with the following characteristics is the most effective method to increase muscle mass: 3-5 sets of 6-12 repetitions performed with a full range of motion, with an intensity close to muscle failure (RIR 0 to 2), with a high weekly training volume, and a weekly frequency of 3 days per muscle group, using several different exercises, combining concentric and eccentric contractions, using an internal attentional focus and a rest interval of 2-3 minutes between sets. Moreover, an energy intake based on leucine and omega-3 fatty acids is suggested, as well as including an intake of whey protein before sleeping.

Conflicts of interest

The authors declare no conflict of interests.

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