Brief Review

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Does Varying Resistance Exercises Promote Superior Muscle Hypertrophy and Strength Gains? A Systematic Review

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[1]Metabolism, Nutrition and Exercise Laboratory, Physical Education and Sport Center, State University of Londrina, Londrina, Brazil; [2]Center for Research in Health Sciences, University of Northern of Paranà, Londrina, Brazil; and [3]Health Sciences Department, CUNY Lehman College, Bronx, New York

Abstract

Kassiano, W, Nunes, JP, Costa, B, Ribeiro, AS, Schoenfeld, BJ, and Cyrino, ES. Does varying resistance exercises promote superior muscle hypertrophy and strength gains? A systematic review. *J Strength Cond Res* 36(6): 1753–1762, 2022—Fitness professionals routinely employ a variety of resistance training exercises in program design as a strategy to enhance muscular adaptations. However, it remains uncertain whether such an approach offers advantages over a fixed-exercise selection. The objective of this review was to review the effects of exercise variation on muscle hypertrophy and strength. A search of the literature was conducted using PubMed/MEDLINE, Scopus, and Web of Science databases. Eight studies were identified as meeting inclusion criteria. The combined total sample of the studies was $N = 241$, comprising all young men. The methodological quality of included studies was considered "good" and "excellent" based on the Physiotherapy Evidence Database Scale. The available studies indicate that varying exercise selection can influence muscle hypertrophy and strength gains. Some degree of systematic variation seems to enhance regional hypertrophic adaptations and maximize dynamic strength, whereas excessive, random variation may compromise muscular gains. We conclude that exercise variation should be approached systematically with a focus on applied anatomical and biomechanical constructs; on the contrary, employing different exercises that provide a redundant stimulus, as well as excessive rotation of different exercises (i.e., high frequency of change), may actually hinder muscular adaptations.

Key Words: strength training, exercise variation, muscle size, programming

Introduction

Progressive overload and variation are 2 primary principles for promoting continuous muscular adaptations during regimented resistance training (RT) (1). Progressive overload is characterized by a gradual increase in stress imposed on the body, whereas variation refers to the systematic change of 1 or more variables (e.g., intensity, volume, exercise) throughout an RT program (1). Although the effects of the systematic changes in intensity and volume have been the most frequently investigated variables (1,18), variation also can be achieved by manipulating other RT components, such as exercise selection (1,19). In this regard, performing different exercises (i.e., exercise variation) has been proposed as a strategy to target multiple regions within a muscle group (i.e., different muscular heads) or even within a single muscle and thus potentially optimize muscle growth. Moreover, exercise variation might provide the ability to optimize neural drive to the active muscles, thereby maximizing strength gains (1,9,48).

Variation in exercise selection can be performed within the same session, on a session-by-session basis, or cycled throughout the weeks of a RT program. In this regard, exercise variation can be achieved by several strategies such as performing exercises that involve a different number of joints (single vs. multijoint) or limbs (unilateral vs. bilateral), different kinetic chains (open vs. closed), or by performing the same movement but with a different apparatus (e.g., machine vs. free weight, barbell vs. dumbbells, etc.). Furthermore, variation can be accomplished by performing exercises with different joint angles (inclined vs. declined), grips (e.g., pronated vs. supinated), stance/grip widths (wide vs. narrow), and initial joint positions (stretched vs. shortened) (35). However, despite the common use of exercise variation as a strategy to enhance RT responses (16,21,22,47), the topic remains largely underresearched (19), making it difficult to draw conclusions as to its true effects on RT-induced muscular adaptations.

Regarding muscular adaptations, literature reviews have indicated the magnitude of muscle hypertrophy occurs heterogeneously along the muscle length and between individual portions of a given muscle (3,53). In this regard, evidence suggests that exercise variation can promote increases in muscle size in different muscle regions (6,28,33,41). However, different exercises also induce gains in common regions of the same muscle group (6,28,33,41). This begs the question: Is exercise variation additive or redundant from a hypertrophic standpoint? Moreover, given

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that the specificity principle plays an important role in strength gains (7,8,36), it logically follows that to optimally improve strength capacity in a specific exercise, the exercise has to be trained preferentially (34). On the other hand, there is some degree of strength transfer from exercises with related movement patterns (8,32), and the use of complementary "accessory exercises" are frequently employed to indirectly enhance strength via hypertrophic increases while reducing joint stress over time. Despite a seemingly sound theoretical rationale, it remains questionable as to whether exercise variation promotes greater strength gains than repeatedly performing the same exercise. Accordingly, this review aimed to systematically review the effects of exercise variation on muscle hypertrophy and strength to draw practical conclusions for prescription and provide suggestions for future research.

Methods

Research Question

This review was carried out according to guidelines set forth by PRISMA and Prisma in Exercise, Rehabilitation, Sport medicine and SporTs science (PERSiST) (4,37). The research questions were defined by the PICOS (Population, Intervention, Comparator, Outcomes, and Study Design) model in accordance with PRISMA guidelines, as follows:

- Population: Subjects with or without RT experience and without a medical condition.
- Intervention: Chronic RT interventions that incorporated exercise variation.
- Comparator: Muscular adaptations compared with nonvaried exercises routines.
- Outcomes: Muscle hypertrophy and strength.
- Study design: Longitudinal randomized control trials employing either parallel group(s) or within-subject designs.

Inclusion Criteria

We included studies that met the following criteria: (a) published in English-language peer-reviewed journals; (b) involved subjects with no known medical conditions or injury; (c) assessed muscle hypertrophy or strength at both pre- and postintervention; (d) involved at least 2 groups that underwent training programs with nonvaried vs. varied exercise selection, with at least 1 trained exercise in common (e.g., exercise A vs. A-B-C; but not A vs. B, or A vs. B-C-D). We accepted any validated measure of muscle hypertrophy (e.g., muscle thickness [MT] via ultrasound, cross-sectional area [CSA] via magnetic resonance imaging [MRI], muscle mass via dual-energy x-ray absorptiometry [DXA], or limb circumference) or muscular strength (e.g., repetitions maximum [RM] tests, concentric, eccentric, or isometric torques) for inclusion (23,34,49).

Search Strategy

A comprehensive search of the literature was conducted using PubMed/MEDLINE (Medical Literature Analysis and Retrieval System Online), Scopus, and Web of Science databases for all dates up to October 2021. Searches were carried out by 2 authors (W.K. and J.P.N.) using the following terms alone or in combination: (training OR exercise) AND ("exercise variation" OR "exercise choice" OR "exercise selection") AND (strength OR "1RM" OR "one-repetition maximum" OR isometric OR isokinetic OR hypertrophy OR "lean mass" OR "fat-free mass" OR "cross-sectional area" OR thickness OR "fascicle length" OR "pennation angle"). In studies where the abstracts did not provide enough information as to our inclusion criteria, we retrieved the full text for further evaluation. The bibliographies of the identified studies and seminal textbooks were scrutinized in an effort to find other relevant works.

Study Coding, Data Extraction, and Analysis

For all included articles, the following data were extracted: (a) study characteristics (author, year, sample size, and study design); (b) subject demographics (age, sex, and RT experience); (c) RT protocols; and (d) outcome measures (muscle hypertrophy and strength). We then coded data for the pre- and posttraining means and standard deviations of the included studies. We calculated average percentage changes (d%) and effect size (ES) scores of the variables of interest. Values of d% were calculated as follows: ([posttraining mean/pretraining mean × 100] − 100). The ES of each training group was calculated using the following formula: ([posttraining mean − pretraining mean]/[pooled pretraining standard deviations]) (31). Values of ES regarding the pre-to-post changes, as well as the differences between the groups (e.g., group 1 ES minus group 2 ES), were considered as follows: <0.20, trivial/negligible; 0.20–0.49, small; 0.50–0.79, moderate, and; ≥ 0.80, large (13). In cases where studies did not provide sufficient information as to results, data were extracted from studies' figures (if supplied) using WebPlotDigitizer. We opted to interpret the findings based on the calculated ES for each study.

Methodological Quality

The modified Physiotherapy Evidence Database (PEDro) scale was employed by 2 independent investigators (W.K. and J.P.N.) to assess the methodological quality of the articles included in the review, and agreement was mutually determined for any observed discrepancies. Given that it generally is not feasible to blind the subjects and investigators in supervised exercise interventions, we removed items 5–7 from the scale, which are specific to blinding. This approach has been used in previous systematic reviews in the area of RT (44,45). With the removal of these items, the maximum result on the modified "PEDro 8-point" scale was 7 because the first item, related to eligibility criteria, is not included in the total score. The studies were categorized as follows: 6–7 = "excellent quality"; 5 = "good quality"; 4 = "moderate quality"; 0–3 = "poor quality," consistent with previous exercise intervention reviews (27,45).

Results

Search Results

The search and screening process is presented as a flowchart in Figure 1. The initial search identified 475 potentially relevant articles. Analysis of reference lists of articles on the topic revealed 2 additional studies as potentially meeting the inclusion criteria and another study that had not yet been indexed was identified from the authors' private library. Therefore, a total of 478 studies were initially screened. After the removal of duplicates, 269 studies remained. An additional 261 articles were excluded following title and abstract screening, and 8 full-text articles were

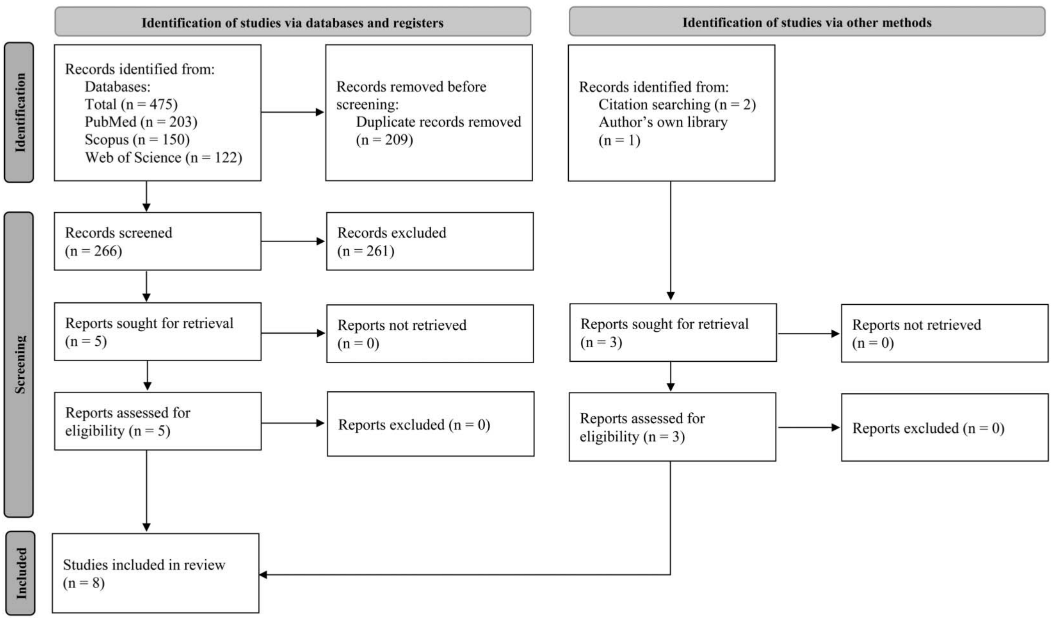

Figure 1. PRISMA flow diagram.

then assessed for eligibility. After screening, 8 studies (2,5,10,14,15,20,39,40) ultimately met inclusion criteria and were included in the present systematic review. The combined total sample of the studies was $N = 241$, comprising all young men.

Methodological Quality

The PEDro scores for the studies in this review ranged from 5 to 7 (mean = 6.1 ± 0.6) (Table 1). Of the 8 studies, 2 had a total score of 7, 5 had a total score of 6, and one had a total score of 5. These results indicate that the evidence used in this review comes from studies with "good" to "excellent" methodological quality.

Main Outcomes

A summary of the methodology and main findings of included studies are displayed in Table 2. Seven studies assessed the effects of exercise variation on measures of both muscle hypertrophy and strength (2,10,14,20,39,40), and 1 assessed only muscular strength (15). The studies from Aerenhouts and D'Hondt (2), Chaves et al. (10), Costa et al. (14), Costa et al. (15), Fonseca et al. (20), and Rossi et al. (40) compared 1 fixed predetermined exercise per muscle group vs. predetermined variations of exercises (e.g., A vs. A, B, C). Rauch et al. (39) compared multiple exercises per muscle group with a predetermined exercise selection vs. multiple exercises per muscle group with an autoregulatory exercise selection that resulted in less variation (e.g., A, B, C, A, B, C vs. A, B, C, A, A, C). Baz-Valle et al. (5) compared multiple exercises per muscle group with a predetermined exercise selection vs. multiple exercises per muscle group with a random selection of predetermined exercises (e.g., A, B, C vs. B, D, E, A, C, F). The exercise variation was made within the same session in 3 studies (10,20,40), session by session in 4 studies (5,14,15,39), and through 2, 5-week training blocks in 1 study (2).

Fonseca et al. (20) conducted the first study that sought to investigate the effects of exercise variation on muscular adaptations. The authors observed that varied exercise groups showed modestly greater increases in vastus medialis CSA compared with fixed groups, although the changes were similar for the vastus lateralis, vastus intermedius, and rectus femoris. Moreover, the varied groups showed modestly greater increases in squat 1RM compared with fixed groups. Subsequently, Rossi et al. (40) randomized a group of young men to perform either the horizontal leg press, parallel back squat, or a combination of both exercises. Results showed that the squat-only, leg press–only, and varied (squat and leg press) groups had similar effects on fat-free mass. The varied group had a less favorable effect on squat 1RM compared with squat only, whereas results were similar between the 3 groups for leg press 1RM. In a similar research design, Chaves et al. (10) analyzed the effects of performing the Smith machine horizontal or incline bench press, or a combination of both, on measures of strength and hypertrophy in young men.

Table 1

Physiotherapy evidence database (PEDro) ratings of the included studies.*

	Criteria								
Studies	**1**	**2**	**3**	**4**	**8**	**9**	**10**	**11**	**Total**
Aerenhouts and D'Hondt (2)	Yes	1	1	1	0	1	1	1	6
Baz-Valle et al. (5)	Yes	1	1	1	1	1	1	1	7
Chaves et al. (10)	Yes	1	1	1	0	1	1	1	6
Costa et al. (14)	Yes	1	1	1	0	1	1	1	6
Costa et al. (15)	Yes	1	1	1	0	1	1	1	6
Fonseca et al. (20)	No	1	1	0	0	1	1	1	5
Rauch et al. (39)	Yes	1	1	1	0	1	1	1	6
Rossi et al. (40)	No	1	1	1	1	1	1	1	7

*Items in the PEDro scale: 1 = eligibility criteria were specified; 2 = subjects were randomly allocated to groups; 3 = allocation was concealed; 4 = the groups were similar at baseline regarding the most important prognostic indicators; 8 = measures of one key outcome were obtained from 85% of subjects initially allocated to groups; 9 = all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least 1 key outcome were analyzed by "intention to treat"; 10 = the results of between-group statistical comparisons are reported for at least one key outcome; 11 = the study provides both point measures and measures of variability for at least one key outcome.

Table 2

Summary of the methods and characteristics from the included studies.*

Study	Sample	Duration and frequency	Groups	Exercises	Outcomes	Findings (varied groups over the others)
Aerenhouts and D'Hondt (2)	Untrained young men (n = 36)	10 wk, 2x/week	1) Fixed: machine exercises (M) 2) Fixed: free-weights exercises (FW) 3) Variation: combination of M and FW (COMB) The exercise variation was made through 2, 5-wk training blocks	M: leg press, chest press, hip extension, seated row, and shoulder press FW: barbell back squat, dumbbell bench press, deadlift, bent-over dumbbell row, and dumbbell shoulder press	Tape-measured circumferences of chest, thigh, and upper arm Estimated 1RM via 10-12RM loads of leg press, chest press, hip extension, seated row, shoulder press, barbell back squat, dumbbell bench press, deadlift, bent-over dumbbell row, and dumbbell shoulder press exercises	COMB had small increased results, compared FW, on relaxed upper arm (5%; ES = 0.62 vs. 2%; ES = 0.23) and thigh circumferences (2%; ES = 0.46 vs. 1%; ES = 0.14), although the changes were similar for the remaining outcomes (2–4%; ES = 0.18–0.44) M, FW, and COMB improved estimated 1RM in a similar way on machine and free-weight exercises overall (31–34%; ES = 1.01–1.17)
Baz-Valle et al. (5)	Trained young men (n = 21)	8 wk, 4x/week	1) Fixed: control (CON) 2) Varied: experimental (EXP)† The exercise variation was made session by session	CON: bench press, pendlay row, shoulder press, lat-pulldown, dumbbell fly, dumbbell pullover, back squat, deadlift, leg press, hip thrust, leg extension, and leg curl EXP: 80 nonspecified exercises	MT of rectus femoris, vastus lateralis, and vastus intermedius (at medial sites; via US) 1RM in squat and bench press	EXP had reduced results, compared to CON, on rectus femoris MT (5%; ES = 0.22 vs. 12%; ES = 0.49), whereas the changes were similar for the remaining MT (8–10%; ES = 0.32–0.53) and 1RM (5–10%; ES = 0.22–0.48)
Chaves et al. (10)	Untrained young men (n = 47)	8 wk, 1x/wk	1) Fixed: HBP 2) Fixed: IBP 3) Varied: horizontal and incline bench presses (VAR) The exercise variation was made within the same session	Horizontal and incline bench presses	MT of pectoralis major at second, third, and fifth intercostal spaces Maximum isometric strength in horizontal and incline bench presses	VAR and HPB had reduced results, compared with IBP, on pectoralis MT at second intercostal space (31–32%; ES = 1.03–1.22 vs. 62%; ES = 2.54); VAR had reduced results compared with HBP and IBP at 3rd intercostal space (24%; ES = 0.96 vs. 46–55%; ES = 1.43–1.97); VAR and HBP had minor increases over IPB at 5th intercostal space (42–43%; ES = 1.31–1.62 vs. 58%; ES = 2.03) VAR, HPB, and IBP had similar improvements on horizontal bench press isometric strength (12–18%; ES = 0.42–0.61); VAR presented a small benefit on improving incline bench press isometric strength compared with HBP (23%; ES = 0.86 vs. 10%; ES = 0.39), but to a similar magnitude compared with IBP (19%; ES = 0.70)
Costa et al. (14)	Detrained young men (n = 22)	9 wk, 3x/wk	1) Fixed: nonvaried (N-VAR) 2) Varied: varied (VAR) The exercise variation was made session by session	N-VAR (and VAR): horizontal bench press (incline bench press, decline bench press), front-grip lat pull-down (neck lat-pull-down, narrow-neutral grip lat pull-down), barbell arm curl (preacher curl, inclined dumbbell curl), pulley triceps extension (cable overhead triceps extension, cable triceps	MT of lateral thigh, anterior thigh, elbow flexors, and elbow extensors (at proximal, medial, and distal sites; via US)	VAR had (small-to-moderate) increased results, compared with N-VAR, MT measures of the proximal lateral thigh (10%; ES = 0.66 vs. 5%; ES = 0.31), middle lateral thigh (5%; ES = 0.38 vs. 2%; ES = 0.18), proximal elbow flexors (16%; ES = 1.11 vs. 7%; ES = 0.54), middle elbow flexors (10%; ES =

Table 2

Summary of the methods and characteristics from the included studies.* *(Continued)*

Study	Sample	Duration and frequency	Groups	Exercises	Outcomes	Findings (varied groups over the others)
				kickback), leg press 45° (Smith machine half squat, hack squat), and bilateral lying leg curl (seated leg curl, seated unilateral leg curl)		0.79 vs. 7%; ES = 0.59), medial elbow extensors (13%; ES = 0.97 vs. 8%; ES = 0.65), and distal elbow extensors (17%; ES = 1.13 vs. 12%; ES = 0.82) sites, whereas the changes were similar for the remaining outcomes (8–10%; ES = 0.57–0.74)
Costa et al. (15)	Detrained young men (*n* = 23)	9 wk, 3x/wk	1) Fixed: nonvaried (N-VAR) 2) Varied: varied (VAR) The exercise variation was made session by session	N-VAR (and VAR): horizontal bench press (incline bench press, decline bench press), front grip lat pull-down (neck lat pull-down, narrow neutral grip lat pull-down), barbell arm curl (preacher curl, inclined dumbbell curl), pulley triceps extension (cable overhead triceps extension, cable triceps kickback), leg press 45° (Smith machine half squat, hack squat), and bilateral lying leg curl (seated leg curl, seated unilateral leg curl)	1RM in horizontal bench press, front grip lat pull-down, barbell arm curl, pulley triceps extension, leg press 45°, and unilateral lying leg curl in both thighs Knee extension and flexion isometric strength	VAR and N-VAR had similar improvements on majority 1RM tests (15–23%; ES = 0.74–1.04), although VAR had increased results, compared with N-VAR, on unilateral lying leg curl (left thigh) (26%; ES = 1.03 vs. 15%; ES = 0.70) and knee flexion isometric strength (11%; ES = 0.57 vs. 5%; ES = 0.31) and reduced results on knee extension isometric strength (5%; ES = 0.20 vs. 10%; ES = 0.43)
Fonseca et al. (20)	Untrained young men (*n* = 49)	12 wk, 2x/wk	1) Nontraining control 2) Fixed: CICE 3) Fixed: CIVE 4) Varied: VICE 5) Varied: VIVE The exercise variation was made within the same session	Fixed: squat Varied: squat, leg press, deadlift, lunge	CSA of rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius (at medial sites; via MRI) 1RM in squat	Varied groups (mean of CIVE and VIVE) and fixed groups had increases in rectus femoris (7%; ES = 0.31–0.34), vastus lateralis (8–10%; ES = 0.51–0.62), vastus intermedius (8%; ES = 0.50–0.55) with small advantage for varied exercises in vastus medialis CSA increase (16%; ES = 0.88 vs. 10%; ES = 0.62) Varied groups had increased results, compared with fixed groups, on squat 1RM (51%; ES = 1.95 vs. 28%; ES = 1.30)
Rauch et al. (39)	Trained young men (*n* = 17)	9 wk, 3x/wk	1) Varied less: AES‡ 2) Varied more: FES The exercise variation was made session-by-session	Squat, leg press, leg extension, barbell bench press, dumbbell incline press, cable fly, bent barbell row, pull-up, straight arm lat pull-down, dumbbell military press, dumbbell lateral raises, cable face pulls, dumbbell bicep curls, E-Z bar preacher curls, dumbbells incline curls, cable press down, dumbbell incline skull crusher, cable overhead triceps extension	Total body lean mass (via DXA) 1RM in squat and bench press	AES (varied less) and FES (varied more) had relatively similar results on lean mass (1%; ES = 0.17 vs. 2%; ES = 0.28), and similar 1RM squat (11%; ES = 0.59 vs. 9%; ES = 0.54) and bench press (5%; ES = 0.30 vs. 6%; ES = 0.37) increases
Rossi et al. (40)	Untrained young men (*n* = 26)	10 wk, 2x/wk	1) Fixed: squat (SQ) 2) Fixed: leg press (LP) 3) Varied: squat and leg press (VAR)	Squat and leg-press	Total body fat-free mass (via ADP) 1RM in squat and leg press	SQ, LP, and VAR had similar results on fat-free mass (1–2%; ES 0.10–0.15) VAR had higher gains on 1RM squat when compared with LP (20%; ES 0.94 vs. 7%;

Table 2

Summary of the methods and characteristics from the included studies.* *(Continued)*

Study	Sample	Duration and frequency	Groups	Exercises	Outcomes	Findings (varied groups over the others)
			The exercise variation was made within the same session			ES = 0.35) but reduced results compared with SQ group (32%; ES = 1.33), while results were similar between the 3 groups for 1RM leg-press (31–35%; ES = 1.46–1.51)

*RM = repetition maximum; MT = muscle thickness; US = ultrasound; AES = autoregulatory exercise selection; IBP = incline bench press; CICE = constant intensity and constant exercise; CIVE = constant intensity and varied exercise; VICE = varied intensity and constant exercise; HBP = horizontal bench press; VIVE = varied intensity and varied exercise; CSA = cross-sectional area; FES = fixed exercise selection; MRI = magnetic resonance imaging; DXA = dual-energy X-ray absorptiometry; ADP = air-displacement plethysmography; ES = effect size; SQ = squat group; LP = leg press group; VAR = varied exercise group; N-VAR = non varied exercise group. E-Z bar concerns the shape of the bar used..

†Exercises were randomly selected from a database.

‡AES condition permitted the practitioners to choose the exercises to be performed among the same ones of which FES performed regularly.

Varied exercise resulted in an attenuated effect (small-to-large) on pectoralis MT at the second, third, and fifth intercostal spaces compared with incline bench press. Alternatively, varied, horizontal and incline bench presses elicited similar improvements on horizontal bench press isometric strength. Varied exercise presented a small benefit on improving incline bench press isometric strength compared with the horizontal bench press but to a similar magnitude compared with the incline bench press group.

Costa et al. explored the effects of exercise variation on measures of hypertrophy (14), and strength (15). The authors randomized a group of detrained young men to perform an RT program either a nonvaried or varied exercise selection. The varied exercise group showed (small-to-moderate) greater increases in MT measures of the proximal lateral thigh, midpoint of the lateral thigh, proximal elbow flexors, midpoint of the elbow flexors, midpoint of the elbow extensors, and distal elbow extensors sites compared with the nonvaried group; hypertrophic changes were similar for the remaining MT measures. Both conditions showed similar improvements on all 1RM tests, although the varied group demonstrated (small) greater increases in knee flexion isometric strength and (small) negative effects on knee flexion isometric strength. Similarly, Rauch et al. (39) compared a group that varied more versus another group that varied less (i.e., fixed exercise selection vs. autoregulated exercise selection, respectively) on whole-body RT on resistance-trained men; both groups had relatively similar increases in lean mass, 1RM squat, and bench press.

Baz-Valle et al. (5) also investigated the effects of exercise selection in a whole-body RT program in young, resistance-trained men. Training was carried out with a fixed vs. random exercise selection in an AB2x routine (4x/week), whereby upper- and lower-body exercises were performed separately in sessions A and B, respectively. The varied group showed a (small) impairment in rectus femoris MT compared with the fixed exercise selection, although changes for the remaining outcomes (MT and 1RM) were similar between conditions. Finally, Aerenhouts and D'Hondt (2) investigated the effects of whole-body RT using machines, free weights, or a combination/variation of both in untrained young men. Training was performed twice per week for 10 weeks, and measurements of the variables of interest were taken at pretraining and after 5 and 10 weeks of training. The varied group showed a (small) greater increase in relaxed upper-arm and thigh circumferences compared with the free-weight group, although the changes were similar for the remaining outcomes. All groups showed similar increases in estimated 1RM.

Of the 7 studies that included measures of muscle hypertrophy, Costa et al. (14) and Fonseca et al. (20) observed small-to-moderate advantages for varied versus a nonvaried exercise selection on increases in CSA or MT of some muscle regions. Somewhat consistent with these results, Aerenhouts and D'Hondt (2) found a modest benefit for variation; however, assessments were obtained via limb circumference measurements, a crude estimate of muscle growth, and the difference of only approximately 1%, calls into question the practical meaningfulness of findings. Alternatively, Baz-Valle et al. (5) and Chaves et al. (10) observed that variation of exercises blunted ultrasound-derived measures of MT compared with a fixed exercise selection. Moreover, Rauch et al. (39) and Rossi et al. (40) assessed measures of total-body lean mass and found trivial differences between the experimental conditions, with between-group ES differences of ≤ 0.11. When considering the literature as a whole, it can be inferred that exercise variation may enhance hypertrophy in a regional-specific manner over relatively short-term periods (8–12 weeks; 8–27 sessions), but these changes are less evident in surrogate measures of whole muscle mass. Unpublished data from our research group (see Supplementary Material, http://links.lww.com/JSCR/A324) indicated similar increases in DXA-derived measures of total-body muscle mass for nonvaried and varied groups by 1.2 kg (ES = 0.30) and 1.0 kg (ES = 0.26), respectively, lending further support to this conclusion.

Chaves et al. (10) found that incline bench press training elicited superior increases in pectoralis major MT compared with the training on the horizontal bench press (55–62% vs. 32–43%, respectively). Importantly, the varied exercise group, which performed both incline and horizontal bench press exercises, showed inferior MT gains (24–42%) compared with the incline bench press group. This seemed to occur because the set volume was reduced (i.e., half the number of total sets; 2–3 sets/session, 1 weekly session) in the exercise with the greater hypertrophic potential (i.e., incline bench press, in this case) for the varied exercise condition. Given evidence that training volume (i.e., set-number) is an important variable for maximizing muscle hypertrophy (46), it remains to be investigated if a greater volume per exercise would induce more favorable results in the varied exercise group.

Consistent with the findings of Chaves et al. (10), Baz-Valle et al. (5) reported that exercise variation blunted hypertrophic gains in the rectus femoris compared with a fixed exercise selection; however, changes in MT of the vastus lateralis and vastus intermedius were similar between conditions. The discrepancies between the vastus muscles and rectus femoris may be explained by the fact that the fixed-exercise group regularly performed the leg extension, squat, and leg press, but the variation group performed more multijoint exercises (i.e., they randomly performed exercises from a database that contained 1 single- and 9 multijoint exercises for the legs). Emerging evidence indicates that single-joint exercises (such as the leg extension) preferentially target the rectus femoris vis-a-vis the vastus musculature (17,20,26). Thus, the inclusion of more single-joint exercises over the course of the training program may have biased results to favor greater hypertrophy of the rectus femoris in the fixed exercise group. This highlights the fact that exercise selection for hypertrophy-related goals should not simply involve random selection among diverse exercises but rather an integrated strategy designed to target each muscle group (43).

In contrast to above mentioned studies, the studies of Costa et al. (14) and Fonseca et al. (20) suggest a modest benefit for exercise variation. In each of these studies, the subjects varied exercises that target the vastus muscle heads of the quadriceps predominantly with multijoint exercises, such as the traditional barbell back squat, and its variations on hack or Smith machines, or lunge, deadlift, and leg press. For the vastus medialis and midportion of the lateral quadriceps (vastus lateralis and intermedius), Fonseca et al. (20) and Costa et al. (14) reported modestly higher ESs (between-group ES = 0.26 and 0.21, respectively) than fixed exercise groups following 24 and 27 RT sessions, respectively. Furthermore, Costa et al. (14) also observed a superior anterior arm (biceps brachialis) hypertrophy at the proximal and midportion aspects (between-group ES = 0.57 and 0.20, respectively). Such advantages observed in the studies of Costa et al. (14) and Fonseca et al. (20) may be related to the characteristics of the implemented exercises. For example, in the study by Costa et al. (14), the varied exercise group performed 3 arm curl variations: barbell curl, preacher curl, and incline dumbbell curl, whereas the nonvaried condition performed only the barbell curl. Only the varied exercise group increased MT in the proximal aspect of anterior arm. The authors postulated that this finding was likely because of the implementation of the incline dumbbell curl; given the more elongated position of the biceps, this exercise potentially favors stretch-mediated hypertrophy (14,42). This hypothesis is supported by emerging evidence demonstrating the superiority of training certain muscles in more stretched positions (28,38,41). Hence, these 2 studies (14,20) taken together with previous findings (5,10) suggest that exercise variation should be carefully planned and implemented to optimize benefits from exercise variation. In this regard, it seems imperative to use a variety of biomechanically different exercises that take into account applied anatomical principles; otherwise, the stimulus may be redundant and thus not impose an additive hypertrophic stimulus. From a methodological standpoint, these works (5,10,14,20) highlight the importance of measuring hypertrophic changes at different portions of a muscle (e.g., heads of the quadriceps) as well as along their length (i.e., from proximal to distal sites).

Another important factor to consider is the frequency of exercises changes. It seems likely that very frequent rotation of exercises may not be as effective as more moderate variations to induce muscle hypertrophy, potentially because of the difficulty of achieving and quantifying the progressive overload. Also, if the exercise rotation is very frequent (e.g., different exercises every training session), it is likely that the individual will experience more prolonged fatigue, conceivably because of the exercise-induced muscle damage promoted by an unaccustomed stimulus (12). This may have detrimental consequences on training frequency and volume and, consequently, impair the magnitude of hypertrophic adaptations. In other words, the effects of variation on muscle growth may follow an inverted U-shaped curve, with benefits achieved up to a certain point and then detrimental effects experienced thereafter (i.e., hormetic response). This hypothesis may help to explain, for example, the less favorable hypertrophy observed by Baz-Valle et al. (5) and Rauch et al. (39). In the former (5), the rectus femoris showed an inferior growth response and in the latter (39), despite the apparently similar gains, only the group of resistance-trained men that employed less variety (i.e., repeated some exercises more times in a week) significantly increased pre- to poststudy measures of lean body mass (39).

Importantly, research on the topic should be considered preliminary and thus interpreted with caution. For example, in the Rauch et al. (39) study, the morphological changes were assessed for the entire body via DXA; given that the effects of variation may occur on a regional basis, whole-body measurements would not allow the detection of subtle changes within and across muscles. Second, although we have interpreted the study by Rauch et al. (39) as a comparison of a group that varied exercises to a greater extent than another group, the primary objective of the study was to assess the effects of granting autonomy to subjects; thus, it is unclear as to whether findings were a function of variation, autonomy, or a combination of the 2 variables. It therefore remains to be determined the threshold at which frequency of exercise variation becomes excessive and actually impairs muscle growth. When considering the research as a whole, substantial gaps in the literature remain that require further study to better elucidate the effects of variation on muscle hypertrophy.

Of the 7 studies that investigated muscular strength, Aerenhouts and D'Hondt (2) estimated 1RM strength, Baz-Valle et al. (5), and Rauch et al. (39) employed 1RM testing, whereas Chaves et al. (10) conducted isometric strength tests, and Costa et al. (15) conducted both 1RM and isometric strength tests. Aerenhouts and D'Hondt (2), Baz-Valle et al. (5), Rauch et al. (39), and Chaves et al. (10) showed similar strength responses between varied and nonvaried protocols. Conversely, Fonseca et al. (20) observed greater gains favoring varied-exercise groups, whereas Costa et al. (15) and Rossi et al. (40) observed conflicting results depending on the specific test. Consistent with hypertrophic results, the effect of exercise variation on strength-related changes seems to be highly dependent on study characteristics and RT program design.

Fonseca et al. (20) found that those who performed a combination of the squat, leg press, deadlift, and lunge improved 1RM performance in the squat more than those who performed only the squat. Alternatively, Rossi et al. (40) also compared within-session exercise variation but observed blunted effects in the 1RM squat for the varied exercise (squat and leg press) group when compared with performing the squat only. The difference between these works was that Fonseca et al. (20) included the leg press only in the first 3 4-week mesocycles, whereas Rossi et al. (40) included it during all the sessions of the 10-week training period. Thus, it seems that reducing the squat training volume to include bouts of leg press may blunt squat

1RM performance. Interestingly, Costa et al. (15) observed that including squats in a leg press training protocol did not negatively impact increases in the 1RM leg press. Furthermore, in the work of Rauch et al. (39), the groups that had a greater degree of exercise variation performed both squat and leg press for 9 sessions during the 9-week intervention, while the groups that had less variation performed the squat and leg press 8 and 14 times, respectively, suggesting that adding the leg press to squat training does not potentiate squat 1RM gains in the short term. As Rossi et al. (40) hypothesized, this may occur because the leg press is not as specific as the squat from a motor learning standpoint. Specifically, the squat involves greater ranges of motion from the hip and knee joints, and it thus may increase the performance of hip-knee movements regardless of the exercise tested (squat or leg press), whereas the leg press does not have such capacity (40). That is, the squat appears to have a greater transfer effect for other exercises (e.g., leg press) (40,51). Although this hypothesis has a logical rationale, its veracity needs further investigation.

The strength transfer effect refers to the capacity of one exercise to induce strength improvements in other nontrained exercise or movement tasks. Differences in the "transferability" between exercises might be linked to their degrees of freedom and consequently their neuromuscular demand. For instance, given that the lunge involves greater degrees of freedom than the leg press, and, therefore, conceivably requires a higher level of intermuscular coordination; this can confer a higher degree of "transferability" of this exercise for other movements (e.g., squat) (40). Accordingly, this hypothesis may help to explain why Fonseca et al. (20) observed pronounced 1RM strength gains when including the lunge in combination with squat training (47–55% vs. 25–32%, varied and nonvaried exercises, respectively), whereas other studies did not observe the same superiority when incorporating the leg press within the squat sessions (39,40). Again, this hypothesis remains largely untested and requires more empirical evidence.

In contrast, when exercise variation is carried out on a session-by-session basis as opposed to within session, maximum dynamic strength (i.e., 1RM) gains do not seem to differ substantially between varied and nonvaried protocols. For example, Costa et al. (15) investigated the effects of exercise variation on 1RM of the bench press, lat pull-down, arm curl, triceps extension, leg press 45°, and unilateral lying leg curl (both thighs). The 1RM changes were similar between the groups, with the exception of the unilateral lying leg curl (left thigh) where between-group differences modestly favored the variation group (between-group ES = 0.33). Together, these works (15,20,40) suggest that exercise variation may have a beneficial effect on dynamic maximum strength with the inclusion of exercises that require greater degrees of freedom—and consequently greater neuromuscular demand—(e.g., squat and lunge), and when the exercise variation is carried out within session. We speculate that the greater "transferability" of specific exercises plus the higher frequency of performance of these exercises provided by the within-session variation strategy (compared with session-by-session variation strategy) may help to explain the superiority over the fixed exercise selection. Importantly, further studies are required to expand on this preliminary evidence on maximum dynamic strength and to test our hypotheses.

Regarding nonspecific strength measurements, the preliminary findings suggest that the adaptations follow the principle of specificity—at least in some results. For example, Costa et al. (15) reported that differences for peak torque on seated isometric knee flexion modestly favored the variation group (between-group ES = 0.26), and this group performed the seated unilateral leg curl exercise over the RT program, whereas the nonvaried group exclusively performed the lying leg curl exercise (15). Notwithstanding, results showed inferior gains for the varied group on measures of knee extension peak torque compared with the nonvaried group (between-group ES = −0.23) (15). Intriguingly, neither group performed exercises that had a motor pattern similar to the isometric knee extension test (e.g., leg extension); rather, both performed multijoint movements, such as the incline leg press, hack squat, and Smith-machine half squat. Therefore, the potential mechanisms for this finding remain elusive.

In regard to the upper limbs, results also seem to follow the principle of specificity. For example, Chaves et al. (10) found a modest superiority in incline bench press isometric peak torque increases for a varied exercise group that performed both the incline and horizontal bench press compared with a nonvaried exercise group that exclusively performed the horizontal bench press (between-group ES = 0.30) and a similar increase compared with a nonvaried group that exclusively performed the incline bench press (between-group ES = 0.16). The 3 groups had similar improvements on horizontal bench press isometric strength. In other words, the varied group increased peak torque of both bench press variations that were trained. Nevertheless, we reiterate the preliminary nature of these findings, which calls for caution regarding the extrapolations and interpretations proposed in the present review.

Several limitations must be acknowledged when attempting to draw evidence-based conclusions about the effects of exercise variation on muscular adaptations. First, there is a relative paucity of research on the topic to date, and the studies that have been carried out employed relatively small samples and heterogeneous designs. Thus, more research needs to be conducted so that sufficient data exist to quantify effects via meta-analytic methods. Second, because muscle growth often manifests in an inhomogeneous manner, future studies should consider assessing muscle size for each muscle head (where applicable), as well as along the length of the given muscle belly. Third, exercises have different external moment arms, active ranges of motion, and strength curves (e.g., ascending, descending, bell shaped); such features afford the ability to prioritize different muscles groups or portions via a varied exercise selection (29,42,50). Accordingly, exercise selection should take into account these characteristics to ensure that the variation does not provide redundant stimuli for a particular muscle group. Fourth, muscular strength remains to be further investigated in terms of specific and nonspecific tests to better understand the transfer effects of exercise variation, as well as the effects of this strategy on sports-related tasks, such as jumping and sprinting. Also, the optimal frequency of exercise rotation (e.g., within the same session, session-by-session, weekly, etc.) for maximizing hypertrophy and strength adaptations should be further investigated. Finally, given that studies on the topic have been conducted exclusively in young men, it is necessary to investigate the effects of exercise variation in women and alternative age groups because these factors may influence muscular adaptations (1,24,25). For example, evidence indicates differences in muscle activation between young men and women even when performing the same exercises (11,30,52), which may have implications on chronic strength and hypertrophy outcomes.

Practical Applications

Current evidence suggests that exercise variation can influence muscle hypertrophy and strength gains, either in a positive or negative manner. These effects seem to be related both to the specific exercises selected and the frequency of exercise rotation. With respect to muscle hypertrophy, programming should focus on targeting specific portions of a given muscle. In this regard, exercise variation should be carried out in a planned, systematized manner taking into account applied biomechanical and anatomical principles. To the contrary, variation of resistance exercises that provide a redundant stimulus, as well as excess variation (i.e., high frequency of change), do not seem to optimize, and may actually even hinder, hypertrophy. For muscular strength, the specificity principle should be considered whereby the exercise desired for maximum strength increases should be trained with priority and kept in a regular rotation within the RT program. Furthermore, the exercise variation can be focused on including exercises that have similar movement patterns to the main exercise and inducing muscle hypertrophy on prime mover while decreasing joint stress.

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