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Combined Exercise Methods in Resistance Training: A Brief Review of Acute Responses and Long-Term Adaptations

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Abstract: The purpose of this article was to review and synthesize the scientific literature on the acute effects and long-term adaptations of combined exercise methods (CEM) compared to traditional strength training (TST), with a focus on performance outcomes, physiological responses, strength gains, and muscle hypertrophy. A literature search was conducted in the PubMed, BIREME/BVS, and Google Scholar databases using the following search terms: 'strength training' OR 'resistance training' AND 'paired-set' OR 'bi-set' OR 'tri-set' OR 'superset' OR 'agonist-antagonist', in various combinations with the Boolean operators "OR" and "AND". Studies published in English that compared the effects of combined exercise training with traditional resistance training, evaluated acute physiological or performance-related responses, and investigated adaptations following a training period were included in this review. A total of 49 studies were included in this review, comprising 40 acute studies and 9 longitudinal studies. These studies evaluated metabolic and hormonal responses, electromyographic activity, performance outcomes, strength gains, and muscle hypertrophy. Overall, the findings suggest that CEM produce similar or, in some cases, superior responses compared to TST across several parameters. Thus, such methods represent a valuable alternative for athletes and individuals with limited time availability, as they can still promote significant training adaptations.

Keywords: Strength training; Muscle strength; Muscle hypertrophy; Physical performance

1. Introduction

Strength training is widely recognized for its benefits in improving muscular strength, hypertrophy, Endurance, and overall health (Kraemer *et al.*, 2002; Ratamess *et al.*, 2009; Williams *et al.*, 2007). Typically, training protocols involve the manipulation of various prescription variables, such exercise order, rest intervals between sets and exercises, the number of sets and repetitions, the speed of execution, among others (Kraemer *et al.*, 2002; Ratamess *et al.*, 2009). These variables are adjusted according to the priorities and desired objectives.

However, trained individuals require increased complexity in their training prescription, exploring the principle of progression in greater depth to continue achieving positive adaptations. One of the strategies for this is through different strength training methods and systems (Ratamess *et al.*, 2009; Krzysztofik *et al.*, 2019; Cardozo *et al.*, 2023). Several approaches have been adopted by trainers, athletes and recreational practitioners (Fleck and Kraemer, 2017; Krzysztofik *et al.*, 2019; Cardozo *et al.*, 2023), and the use of the combined exercise method is one of those.

In this study, the term *combined exercise method* refers to the sequential execution of two or more stimuli within a single training session. This may include performing strength exercises consecutively (as in the super-set and tri-set methods) or combining strength exercises with muscle activation strategies, such as stretching and myofascial release using foam rolling.

Combined exercise methods have been proposed as an alternative to optimize the time spent in training sessions by offering variation in stimulus (Robbins *et al.*, 2010a, 2010b, 2010c). In the super-set and bi-set methods, the exercises are performed successively, without rest interval, they can be organized in agonist, antagonist sequences or in different body segments, while the tri-set involves the

execution of three consecutive exercises (Fleck and Kraemer, 2017; De Camargo *et al.*, 2022; Enes *et al.*, 2024; Janicijevic *et al.*, 2024). The literature suggests that the method of combined exercises can stimulate greater energy expenditure and muscle recruitment compared to traditional training (Baker and Newton, 2005; Kelleher *et al.*, 2010; Maia *et al.*, 2014; Paz *et al.*, 2015; Maia *et al.*, 2015b; Realzola *et al.*, 2020; Enes *et al.*, 2024). This can be beneficial in improving body composition and muscle strength gains. However, the literature remains scarce regarding the acute effects on physiological and performance variables, as well as the long-term effects (strength gains and muscle hypertrophy).

Therefore, the aim of this study was to review and synthesize the scientific literature on the effects of combined exercise methods, including bi-set, super-set, tri-set, in the agonist-antagonist format, upper-lower limbs, agonist-agonist, of similar biomechanical movements and other forms of muscle activation (such as stretching and foam rolling) compared to traditional strength training. Specifically, we aim to evaluate the acute responses and long-term adaptations of theses methods in terms of performance, physiological responses, strength gains and muscle hypertrophy. This review also aims to identify gaps in current research and provide directions for future studies, contributing to the optimization of resistance training protocols for a range of training objectives.

2. Methods

This study is characterized as a narrative literature review on the manipulation of the combined exercise methods in resistance training sessions. The research was developed in the PubMed, BIREME/BVS and Google Scholar databases, without temporal delimitation in order to increase the number of studies found on this topic. The descriptors used in the research were: 'Strength training' OR 'resistance training' AND 'paired-set' OR 'bi-set' OR 'tri-set' OR 'superset' OR 'agonist-antagonist', using Boolean operators "OR/AND" in different combinations.

Studies were included in this review if they met the following inclusion criteria: a) studies in English only; b) studies that compared the effects of combined exercise training versus traditional training; c) studies that evaluated acute responses in some physiological/metabolic and performance/training outcome; and d) studies that evaluated chronic adaptations after a period of training. Studies not published in English or not available for open access were not considered. The literature review was carried out in December 2024. The search identified 7,047 studies in the selected databases: Pubmed = 2,825, Google School = 3,860, and BIREME/BVS = 362. After removing the duplicate texts and the articles excluded based on title and abstract and inclusion and exclusion criteria, a total of 48 articles were included in this review. The flow diagram is described in Figure 1.

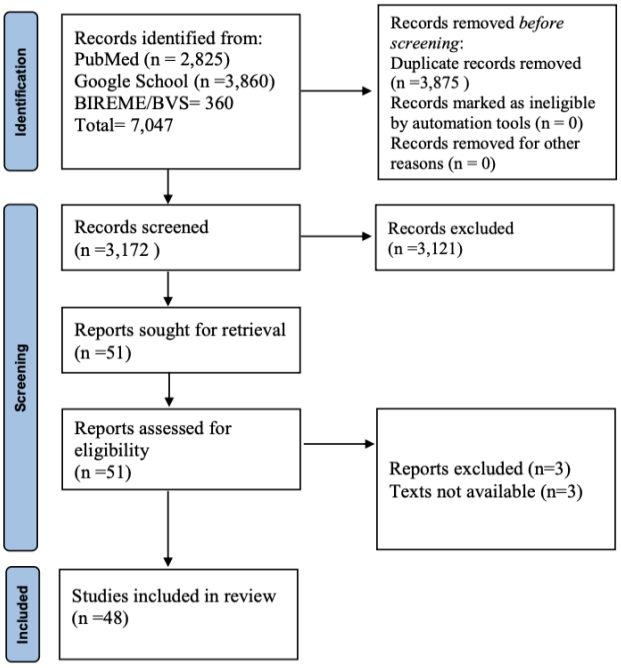

Figure 1. Flow diagram of the review.

3. Results

The temporal distribution of the included articles in this review was as follows: 1 article from 2003; 2 from 2005; 1 from 2006; 3 from 2010; 2 from 2011; 1 from 2012; 4 from 2013; 2 from 2014; 5 from 2015; 4 from 2017; 4 from 2018; 2 from 2019; 2 from 2020; 4 from 2021; 5 from 2022; 3 from 2023; and 3 from 2024. Among these, 38 studies investigated acute effects (Tables 1–7), and 10 studies examined longitudinal adaptations (Table 8). 40 studies included only men, 3 included only women, and 5 studies investigated both men and women (Tables 1–8). A total of 794 healthy individuals were evaluated, the sample was composed of young individuals with a mean age of 24.2 years. Training experience among participants ranged from 6 months to 5 years. The characteristics of the acute effect studies are presented in Tables 1–7, and those of the longitudinal studies in Table 8.

The methodological quality of the studies was assessed using the TESTEX scale (Smart *et al.*, 2015). Most studies were classified as of good or fair quality (Cardozo *et al.*, 2023).

Table 1. Performance, Training Volume, and Electromyographic Activity.

Reference	Sample	Training protocol	Main Results
Maynard and Ebben (2003)	10 trained men (20.3 ± 0.7 years)	**Agonist-antagonist protocol:** hamstrings followed by quadriceps, 5RM, performed consecutively without rest.	With hamstring pre-fatigue, quadriceps peak torque was significantly reduced.
Baker and Newton (2005)	24 rugby players: experimental group (n = 12; 18.7 ± 0.6 years) and control group (n = 12; 19.0 ± 1.0 years).	**Antagonist protocol:** Bench pull-up followed by bench press throws. **Traditional protocol:** Bench press throws performed without prior antagonist activation.	The intervention strategy for the antagonist muscle resulted in a 4.7% increase in the post-test.
Robbins *et al.*, (2010a)	16 trained men (23.8 ± 5.2 years)	**Paired agonist-antagonist protocol:** Bench pull followed by bench press (BP), 3 sets, 4RM. **Traditional protocol:** 3 sets of bench pull and 3 sets of bench press, performed separately.	No significant differences were found in EMG activity; however, the paired protocol demonstrated greater efficiency.
Robbins *et al.*, (2010b)	16 trained men (23.6 ± 4.7 years)	**Paired agonist-antagonist protocol:** Pull-ups and bench press performed consecutively (3 sets, 4RM). **Traditional protocol:** 3 sets of pull-ups followed by 3 sets of BP (4RM each), performed separately.	The paired protocol was more efficient than the traditional protocol.
Paz *et al.*, (2015)	15 trained men (22.4 ± 1.1 years)	**Traditional protocol:** 3 sets of BP followed by three sets of seated row (SR); 10RM, with 2 minutes rest between sets. **Paired protocol:** 3 sets of BP and 3 sets of SR performed alternately; 10RM and 2 minutes rest between sets.	Load volume and fatigue indices were higher in the paired protocol compared to the traditional protocol.
Antunes *et al.*, (2018)	12 trained men (24.0 ± 3.3 years)	**Traditional protocol:** Three sets of leg extensions performed at a cadence of 60 bpm.	The total training volume (VTT) was higher during the paired protocol (PP) compared to the traditional method; however, cadence (fast or slow) did not significantly affect the VTT.

		Paired fast cadence protocol (PFCP): Three sets of leg extensions, each preceded by a set of leg curls performed at a fast cadence (90 bpm). **Paired slow cadence protocol (PSCP):** Identical to PFCP, but with leg curls performed at a slow cadence (40 bpm).	
Weakley *et al,.* (2017a)	10 trained male athletes (20.9 ± 0.6 years)	**Paired agonist-antagonist protocol;** **Paired alternating peripheral protocol;** **Paired similar biomechanical protocol;** Each exercise was performed for 3 sets of 10 repetitions at 65% of 1RM.	The agonist-antagonist (AA) protocol demonstrated greater training efficiency and was more effective in minimizing reductions in the kinetic and kinematic outputs of the agonist muscles during the BP.
Wallace *et al.* (2018)	11 trained men (24.0 ± 4.0 years)	**Traditional protocol (TST):** 5 sets of 10RM on the flat bench press, followed by five sets of 10RM on the incline bench press. **Superset protocol:** 5 sets of 10RM on the flat bench press immediately followed by 5 sets of 10RM on the incline BP, without rest between exercises and a 120-second rest interval between sets.	The superset protocol resulted in lower total load volume and greater fatigue compared to the other training protocols.
García-Orea *et al.*, (2022)	19 trained men (24.0 ± 5.0 years)	**Traditional protocol:** 3 sets of squats and 3 sets of BP, performed separately, and 3-minute rest intervals between sets. **Alternating superset protocol:** 3 sets of squats and BP performed alternately, and no rest between exercises.	No significant differences were observed between training conditions for any of the relative loads analyzed.
Janicijevic *et al.*, (2024).	14 men (24.0 ± 4.2 years) and 7 women (26.6 ± 9.1 years) trained	**Traditional protocol:** Six continuous repetitions of squats at 65% of 1RM, with no intra-set rest. **Paired protocol**: Two clusters of three squat repetitions at 65% of 1RM, and 30 seconds of intra-set rest. **Control protocol**: No exercise performed.	The rest redistribution set configuration enabled the squat exercise to be performed at a higher velocity compared to the traditional set configuration.
Andersen et al. (2022)	14 men (28.3 ± 7.4 years) and 15 women (26.1 ± 7.2) trained	**Traditional protocol**: 8 exercises, 3 sets each, performed at 9RM with 2 minutes of rest between exercises. **Superset protocol:** 8 paired exercises, 3 sets each, performed at 9RM with 2 minutes of rest between pairs.	The traditional session resulted in a significant increase in training volume and lasted 23 minutes longer than the superset session. Conversely, the superset session elicited higher ratings of perceived exertion and tended to be more enjoyable.

Table 2 Influence of Exercise Order.

Reference	Sample	Training protocol	Main Results
Carregaro *et al.*, (2011a)	Physically active men (23.9 ± 4.2 years)	**Reciprocal contraction protocol:** Reciprocal concentric contractions of antagonistic and agonistic muscles. **Superset protocol:** Alternating concentric exercises for antagonistic and agonistic muscle groups.	The results indicated that the decline in muscle strength is not influenced by different forms of antagonist muscle pre-activation. However, reciprocal actions appear to allow better maintenance of training volume.
Balsamo *et al.*, (2012)	12 trained men (23.0 ± 4.3 years)	**Sequence 1:** Quadriceps (leg extension) followed by hamstrings (leg curl) **Sequence 2:** Hamstrings followed immediately by quadriceps. The training sessions consisted of 3 sets of 10RM and 90 seconds of rest between sets.	The results revealed that total training volume was greater when exercises were performed in a posterior-to-anterior sequence, with lower perceived exertion compared to the reverse order.
Maia *et al.*, (2015a)	12 trained men (22.1 ± 1.2 years)	**Sequence 1**: Bench press (BP) followed by seated row (SR) **Sequence 2**: Seated row (SR) followed by bench press (BP) Participants performed three sets to failure using an 8RM load, with 2 minutes of rest between sets.	The exercise sequence significantly influenced strength performance and agonist muscle activation during paired agonist-antagonist sets for the seated row exercise.

Table 3 Influence of rest interval.

Reference	Sample	Training protocol	Main Results
Maia *et al.*, (2014)	15 trained men (22.5 ± 1.9 years)	**Traditional protocol (TP):** One set of knee extensions (KE) performed to failure **Paired protocols**: Paired sets of KE performed with different rest intervals between exercises: **PMR**: Paired with minimal rest **P30**: Paired with 30 seconds of rest **P1, P3, P5**: Paired with 1, 3, and 5 minutes of rest, respectively	A significantly greater number of KE repetitions was completed during the PMR, P30, and P1 protocols compared to the TP. The electromyographic (EMG) activity in the rectus femoris (RF) muscle was higher in the PMR and P30 conditions compared to TP, P3 and P5.

Maia *et al.*, (2015b)	14 trained men (24.2 ± 1.1 years)	**2-minute paired protocol (P2)**: Paired sets of bench press (BP) and seated row (SR), with 2 minutes of rest between sets **4-minute paired protocol (P4)**: Paired sets of BP and SR, with 4 minutes of rest between sets. Three sets were performed until failure using a load of 8RM.	No significant differences were found in the total number of repetitions completed between the rest interval protocols. However, the P2 protocol resulted in a significantly higher fatigue index compared to P4.
Behenck *et al.*, (2020)	18 trained men (21.5 ± 2.1 years)	The exercises were performed in paired sets as follows: lying bench row + bench press, and seated lat pull-down + overhead press. The investigated rest intervals were 1 minute, 2 minutes, 3 minutes, and self-selected.	The P1 protocol resulted in a lower total training volume (TTV) compared to the other conditions. P2 also showed a significantly lower TTV than P3, while no significant difference was found between the self-selected rest interval (SRI) and P3. Regarding session duration, P1 was significantly shorter and P3 significantly longer than the other protocols.

Table 4. Effect on metabolic and hormonal responses

Reference	Sample	Training protocol	Main Results
Kelleher *et al,.* (2010)	10 trained men (21.7 ± 2.1 years)	**Superset protocol**: bench press paired with bent-over row, biceps curl paired with triceps extension, and leg extension paired with leg curl; **Traditional protocol**: same exercises performed separately, without paired sets.	No significant difference was observed in energy expenditure (EE) between protocols; however, when expressed relative to time, EE was significantly greater during the superset protocol compared to the traditional protocol. Additionally, lactate levels were higher in the superset protocol.
Miranda *et al.*, (2018)	12 trained men (25.7 ± 4.7 years)	**Traditional protocol**: 3 sets of 10 repetitions at 85% of 10RM for seated row (SR) and bench press (BP), 2-minute rest intervals between sets; **Paired protocol**: 3 sets of 10 repetitions at 85% of 10RM, alternating between SR and BP, 2-minute rest intervals.	Both training protocols elicited similar hormonal responses.

Realzola *et al.*, (2021)	18 trained individuals: 9 men (24.1 ± 3.7 years) and 9 women (22.8 ± 3.9 years)	**Superset protocol (SS):** hexagonal bar deadlift paired with leg press; chest press paired with SR, overhead dumbbell press paired with lat pulldown; **Traditional protocol (TP**): same exercises performed in the traditional sets format, with rest intervals between sets.	Regardless of sex, the SS elicited significantly higher mean $\dot{V}O2$, heart rate (HR), blood lactate concentration ([BLa]), rating of perceived exertion (RPE), as well as anaerobic and aerobic energy expenditure, and was completed in a shorter duration compared to the PT.
Enes *et al.*, (2024)	15 trained men (29.7 ± 6.1 years)	**Bi-set protocol**: 3 sets of 10 repetitions at 70% 1RM on the barbell bench press, immediately followed by 10 repetitions at 60% 1RM on the incline bench press; **Drop-set protocol**: 3 sets, 10 reps (70% 1RM) followed by 10 reps (50% 1RM) on the barbell bench press; **Traditional protocol**: 3 sets, 20 reps (60% 1RM) on the barbell bench press.	The bi-set protocol resulted in greater aerobic energy expenditure and oxygen consumption compared to the other training regimens. No differences were observed in total training volume among protocols.

Table 5. Effect on cardiovascular responses

Reference	Sample	Training protocol	Main Results
Bentes *et al.*, (2017)	13 trained men (20.0 ± 1.3 years)	**Traditional protocol:** participants performed the following exercises sequentially: bench press (BP), low row (LR), leg extension (LE), leg curl (LC), pulldown (PD), and shoulder press (SP); **Superset protocol**: exercises were organized in an agonist-antagonist paired format.	Greater total work (TW) was observed in the traditional protocol compared to the superset protocol. Post-exercise hypotension was evident only after the traditional session, with significant reductions in systolic blood pressure at 30 and 40 minutes post-exercise.
Paz *et al.*, (2017)	13 trained men (26.2 ± 3.9 years)	**Traditional protocol:** 3 successive sets of bench press (LBP), pulldown (LPD), 45° incline bench press (BP45), seated row with a close grip (SCR), triceps extension (TE), and biceps curl (BC), with 90 seconds of rest between sets and exercises. **Superset protocol:** 3 supersets composed of LBP followed by LPD, BP45 followed by SCR, and TE followed by BC, without rest between the paired exercises.	Training volume was significantly higher in the superset protocol compared to the traditional protocol. However, no differences were observed between protocols for heart rate variability (HRV) and post-exercise hypotension (PEH).

Corso *et al.*, (2024)	9 trained men (30.7 ± 4.1 years)	**Traditional protocol**: execution of 6 exercises, performed in 3 sets each, with a 90-second rest interval between exercises; **Superset protocol**: execution of 6 exercises organized in pairs (2 exercises performed consecutively without rest); **Triset protocol**: execution of 6 exercises organized in groups of three (3 exercises performed consecutively without rest).	The results revealed that systolic blood pressure (SBP) remained reduced for up to 60 minutes following the traditional protocol, whereas the superset and triset protocols showed reductions at 30 and 40 minutes post-exercise, respectively. Additionally, the triset protocol elicited greater cardiac stress compared to the traditional protocol

Table 6. Effect of stretching and other forms of preactivation

Reference	Sample	Training protocol	Main Results
McBride *et al.*, (2007)	8 active men (21.4 ± 0.7 years)	**Control condition (C)**: consisted of 10 minutes of quiet sitting. **Stretching condition (S):** involved three sets of 33-second static stretches targeting the quadriceps muscle group (total stretch duration: 270 seconds). Each repetition was followed by 30 seconds of rest, and a 2-minute rest interval was provided between sets.	Following the stretching condition (S), peak isometric knee extension force was significantly lower than in the control condition (C) at 1, 2, 8, and 16 minutes post-intervention. Additionally, electromyographic activity of the biceps femoris (BF) was significantly reduced at 1 minute post-intervention in the S condition compared to the C condition in the knee extension and isometric squat tasks.
Carregaro *et al.*, (2011b)	14 trained men (29.4 ± 6.1 years)	**Control protocol (CP):** 3 sets of 10 isokinetic knee extension repetitions; **Reciprocal action protocol (RAP)**: 3 sets of 10 reciprocal repetitions of knee flexion and extension; **Superset protocol (SP)**: 3 sets consisting of 10 knee flexion repetitions immediately followed by 10 knee extension repetitions.	There were no significant differences between protocols for peak torque at 60°/s or 180°/s. However, total work was significantly greater in the RAP compared to the superset protocol at 60°/s.
Paz *et al.*, (2013)	15 trained men (22.4 ± 1.1 years)	**Traditional protocol**: 1 set to failure; **Static stretching protocol:** Static stretching of the antagonist (pectoralis major) followed by one set of seated row (SR); **PNF protocol**: Proprioceptive Neuromuscular Facilitation (PNF) for the pectoralis major followed by one set of SR;	The APS and AS approaches may enhance repetition performance in the SR exercise compared to traditional training.

		Resistance training protocol: 1 set of bench press with 10 RM load followed by 1 set of SR.	
Carregaro *et al.*, (2013)	24 trained men (25.3 ±3.6 years)	**Traditional protocol:** 4 sets of knee flexion (KF) followed by four sets of knee extension (KE); **Reciprocal protocol:** knee flexion contractions immediately followed by knee extension contractions; **Superset protocol**: 1 set of knee flexion followed by 1 set of knee extension.	Total work was significantly greater in the reciprocal action (RA) protocol, which also exhibited greater activation of the biceps femoris. The superset (SS) protocol resulted in higher lactate values compared to the other protocols.
Miranda *et al.*, (2015)	10 trained men (22.4 ± 0.9 years)	**Passive recovery (PR) protocol:** participants performed 3 sets of the seated row (SR) to repetition failure with a 2-minute rest interval between sets, without any pre-exercise stretching; **Antagonist stretching (AS) protocol:** forty seconds of stretching of the pectoralis major was applied before each SR set.	Significant increases in the number of repetitions were observed in the AS protocol compared to the PR protocol. Additionally, the AS protocol elicited significantly greater muscle activity in the latissimus dorsi and biceps brachii compared to the PR condition.
Santana *et al.*, (2021)	20 trained men (30.3 ± 6.5 years)	Protocols included agonist foam rolling (AFR), antagonist foam rolling (ANTFR), combined agonist-antagonist foam rolling (A-ANTFR), and a traditional control protocol (TP) with no foam rolling. All sessions consisted of 3 sets performed to maximum repetitions using a 10RM load on the leg extension exercise.	The total number of repetitions was significantly higher in the A/ANTFR, ANTFR, and AFR sessions compared to the TP session.
Miranda *et al.*, (2022)	14 active men (29.3 ± 10.5 years)	**Traditional protocol**: no prior stretching; **PNF1 protocol**: 3 sets of 20-second stretches of the antagonist muscle; **PNF2 protocol**: 3 sets of 30-second stretches of the antagonist muscle.	The results showed a significant difference in the total number of repetitions for the PNF2 protocol compared to the Traditional protocol. No significant differences were observed between the PNF1 protocol and the Traditional protocol.
Pessoa *et al.*, (2023)	12 trained men (30.8 ± 4.8 years)	Four different protocols were randomly applied: quadriceps stretching (AG); hamstring stretching (AN); combined quadriceps and hamstring stretching (AGN); and a traditional control without stretching (RT).	The main finding of the study was a significant decrease in total training volume (TTV) for the AG protocol (4855.42 ± 1279.38 kg) compared to the AN (6002.08 ± 1805.18 kg),

		All protocols consisted of four sets of leg extension performed to maximal repetitions at a 10RM load, with 2-minute rest intervals between sets.	AGN (5977.50 ± 1778.49 kg), and TR (6206.04 ± 1796.15 kg) protocols.
Pisz *et al.*, (2023)	13 national-level female softball players (22.2 ± 3.1 years)	**Protocol:** medicine ball throw performed before and after the conditioning activity (CA). The CA consisted of bench press and bent-over row exercises, with 2 sets of 4 repetitions at 60% 1RM and 2 sets of 4 repetitions at 80% 1RM.	An increase in throwing distance was observed following the barbell row and push-up exercises, while an increase in throwing velocity was noted after the bench press and push-up exercises.

Table 7. Influence of the tri-set method on acute responses

Reference	Sample	Training protocol	Main Results
Brunelli *et al.*, (2013)	18 trained men (22.0 ± 1.8 years)	**Tri-set protocol**: consisted of two combinations of three exercises targeting the same muscle group, performed with loads of 6–8RM at 75% of 1RM and 3 minutes of rest between sets; **Control protocol**: no exercises were performed.	Significant increases in total leukocytes, monocytes, and neutrophils were observed post-exercise compared to pre-exercise values. No significant changes were found in plasma concentrations of TNF-α, IL-6, or cortisol across the measured time points. Compared to the control group, the tri-set protocol demonstrated very large effect sizes for total leukocytes, neutrophils, and monocytes 15 minutes post-exercise, as well as a reduction at 24 hours post-protocol.
Ribeiro *et al.*, (2013)	10 trained men (25.6 ± 5.7 years)	Two exercise sequences were employed: Sequence A consisted of the bench press, incline bench press, and peck deck; Sequence B followed the reverse order, beginning with the peck deck, followed by the incline bench press and bench press. The load used in both sequences corresponded to 80% of 1RM, allowing for 8 to 12 repetitions per exercise.	A significantly greater number of repetitions and higher total training volume were observed in Sequence B compared to Sequence A.

Faria *et al.,* (2015)	14 trained men (23.5 ± 5.4 years)	Two different exercise sequences were implemented: **Sequence A**: Smith machine squat, 45° leg press, and bilateral leg extension; **Sequence B**: bilateral leg extension, 45° leg press, and Smith machine squat. Participants performed three sets to voluntary fatigue in all exercises, using a load corresponding to 75% of 1RM.	Superiority was observed for Sequence B, which resulted in a significantly greater total number of repetitions and total training volume compared to Sequence A.
Weakley *et al.,* (2017b)	14 trained men – Rugby players (20.8 ± 1.2 years)	**Traditional Protocol (TRAD)**: Consisted of the execution of a single set of one exercise followed by a rest interval. **Superset Protocol (SS):** Involved the performance of two different exercises consecutively, without rest between them, followed by a rest interval. **Tri-set Protocol (TRI):** Comprised the execution of three different exercises in sequence, with no rest between sets, followed by a rest interval.	The SS and TRI protocols proved to be more time-efficient compared to the TRAD protocol. However, these gains in efficiency were accompanied by notable increases in perceived training intensity, muscle damage, and blood lactate concentrations during the sessions. The elevated metabolic demands were associated with reductions in neuromuscular performance 24 hours post-exercise, suggesting a greater fatigue response. Endocrine responses varied considerably between protocols, but the TRAD protocol consistently elicited a lower neuroendocrine stress response both immediately and 24 hours after training.
De Camargo *et al.*, (2022)	18 trained men (30.0 ± 5.6 years)	TRAD consisted of performing a single set of each exercise followed by a rest period. TRI involved performing one set of each exercise sequentially with minimal rest between sets (<10 seconds). Both protocols were performed for three sets using loads corresponding to the 10-repetition maximum (10RM).	Despite the lower training volume, greater swelling of the pectoralis major muscle, higher internal training load, and improved training efficiency were observed during the tri-set protocol compared to the traditional condition.

Table 8. Longitudinal Effects of the Combined Exercise Protocol.

Reference	Sample	Training protocol	Main Results
Uchida *et al.*, (2006)	12 trained men (27.4 ± 4.8 years)	**Traditional Protocol**: Participants performed two exercises per muscle group, with 10 repetitions and a 90-second rest interval between sets. **Tri-set Protocol:** Participants performed three exercises per muscle group consecutively without rest between them, completing 10 repetitions per exercise. Both training programs lasted 8 weeks and had a training frequency of four sessions per week.	No significant changes were observed in morphofunctional parameters, except for improvements in squat performance. Regarding endocrine responses, the tri-set protocol induced a significant increase in cortisol levels immediately after the training session, both at the beginning and at the end of the eight-week intervention.
Cunha *et al.*, (2013)	33 untrained men (control group: 20.8 ± 1.9 years; traditional group: 20.5 ± 2.7 years and REC group 21.7 ± 2.1 years)	**Traditional protocol**: No preload; consisted of a single concentric knee extension exercise. **Control protocol:** No exercise was performed. **Reciprocal protocol:** Consisted of a knee flexion exercise immediately followed by a knee extension exercise. All training protocols were performed across three sessions.	A significant increase in peak torque was observed for both the REC and TRA protocols at 60°/s ($p < 0.05$), and for the REC protocol at 180°/s ($p < 0.05$). Intergroup analysis indicated that the REC protocol was more effective than the TRA protocol in promoting peak torque gains at both angular velocities.
Garcia *et al.*, (2014)	11 trained women (traditional group: 27.1 ± 8.2 years; tri-set group: 23.2 ± 2.2 years)	**Traditional protocol:** Training was structured as follows-Weeks 1–2: 3 sets of 12-14 RM; Weeks 3-4: 3 sets of 10-12 RM; Weeks 5-6: 3 sets of 6-8 RM. All sets were performed to failure. **Tri-set protocol:** In the TS method, participants performed three lower limb exercises consecutively without rest. A rest interval was provided only after completing all 3 exercises. This circuit was repeated 3 times per session.	Both resistance training protocols led to significant increases in strength, with no observed changes in body composition.

		The training intervention lasted for 12 weeks.	
Hadi *et al.*, (2018)	15 trained men (16-18 years)	The training groups were divided based on the execution of supersets using either machines or free weights. Training was conducted over a period of three months at an intensity of 70–80% of 1RM.	The results demonstrated that supersets performed with free weights elicited greater gains in muscular strength and hypertrophy compared to those performed using machines.
Merrigan *et al,.* (2019)	31 women trained (21.0 ± 2.0 years)	The training protocols included traditional, compound, and control conditions. In the compound sets, squats were performed immediately before leg presses, whereas during the traditional sets, a 1-minute rest interval separated the exercises. The control group did not practice any exercise. The training period lasted 12 weeks.	Both training groups (traditional and compound) produced similar improvements in strength, endurance, and muscle thickness.
Fink *et al.*, (2020)	23 athletes of both sexes (superset group: 19.8 ± 1.5 years; traditional group: 20.1 ± 1.4 years)	**Superset group**: A total of 3 supersets (each consisting of 2 exercises) were performed, with 60 seconds of rest between sets. **Traditional group:** The traditional group completed 3 sets of biceps curls followed by 3 sets of overhead triceps extensions, with 60 seconds of rest between sets and exercises. The training program lasted 8 weeks.	After 8 weeks of training, both groups demonstrated significant increases in biceps and triceps muscle size, with no differences observed between the groups. Improvements in one-repetition maximum (1RM) for the bench press and maximal voluntary contraction (MVC) of the arm extensors were observed exclusively in the traditional training group. Conversely, an increase in muscular endurance was observed only in the superset group.
Permatasari *et al.* (2021)	14 untrained men (18-40 years old)	**APS Group**: Performed reciprocal exercises involving the agonist and antagonist muscles of the knee, completing 3 sets with a 2-minute rest interval between sets.	The results showed a significant increase in single-leg hop distance in both training groups, with no statistically significant differences observed between them.

		Traditional Group: The exercises were performed in the traditional manner, with 3 sets and a 2-minute rest interval between each set. The training program lasted for 6 weeks.	
Pringga *et al.* (2021)	16 untrained men (APS group: 31.5 ± 3.9 years; traditional group: 34.7 ± 4.0 years)	**APS group**: 1 set of leg curls followed by 1 set of leg extensions. This sequence was repeated 3 times. **Traditional group:** Performed 3 sets of leg curls followed by 3 sets of leg extensions. The training program lasted 6 weeks.	Muscle thickness of the hamstrings and quadriceps femoris increased significantly from pre- to post-training in both groups, with no differences observed between them.
Dermitas *et al.* (2022)	33 male athletes (MGVT group: n= 11, 21.4 ± 2.4 years; superset group: n= 11, 22.4 ± 2.9 years; gian set group: n= 11 23.0 ± 4.3 years)	**Superset:** Two exercises performed consecutively without rest, for 4 sets of 10–12 repetitions; a 60-second rest was taken after completing each sequence. **Gianset:** Four exercises performed consecutively without rest, for 4 sets of 10–12 repetitions; a 60-second rest was taken after completing each sequence. **MGVT (Modified German Volume Training):** 5 sets of 10–12 repetitions, with a 90-second rest interval between sets. The training program lasted 6 weeks.	Significant increases in cross-sectional area and muscle thickness of the pectoralis major, deltoid, and latissimus dorsi were observed in all three groups, as well as improvements in strength for the bench press, barbell row, and shoulder press exercises. No differences were found between the training methods regarding strength gains and muscle hypertrophy.
García-Orea *et al.* (2023)	17 trained men (23.9 ± 5.3 years)	**Traditional protocol:** Performed all sets of the full squat (SQ) exercise before completing the bench press (BP) sets.	Both groups exhibited significant and comparable increases in muscular strength and countermovement jump (CMJ) performance. However, the alternating sets (AS) group showed greater improvements in muscular endurance for

	Alternating series protocol: The sets were performed in alternating order. The training program lasted 6 weeks.	the squat (SQ) exercise compared to the traditional series (TS) group. Additionally, the total training time per session was significantly shorter for the AS group than for the TS group.

4. Discussion

The aim of this study was to review and synthesize results on the acute effects and longitudinal adaptations associated with the combined exercise training method. To the best of our knowledge, this is the first review to examine both acute and long-term adaptations of combined exercise training in the context of training variables. For clarity, the discussion was organized into two sections: acute responses and longitudinal adaptations.

4.1 Acute Effect Studies

4.1.1 Performance, Training Volume and Electromyography

Training volume is one of the main determining factors of physiological and metabolic responses, as well as strength gains and muscle hypertrophy (Ratamess *et al.,* 2009; Krieger 2010; Radaelli *et al.*, 2015; Schoenfeld *et al.*, 2019; Baz-Valle *et al.*, 2018; Brigatto *et al.*, 2019; Baz-Valle *et al.,* 2022). Studies show that protocols with higher training volume are associated with greater hormonal responses and superior outcomes concerning strength and muscle hypertrophy compared to reduced volumes (Ratamess *et al.*, 2005; Baz-Valle *et al.,* 2018; Brigatto *et al.*, 2019; Baz-Valle *et al.*, 2022). Thus, investigating methods that increase training volume is essential, especially in a society in which people have less and less time to train. In this context, the combined exercise method proves to be an efficient strategy.

For example, supersets (SS) or paired sets (PS) methods have been studied for their ability to optimize training time and maximize muscle stimuli. One of the pioneering studies in these analyses was that of Maynard and Ebben (2003), who explored the effects of hamstring pre-fatigue on variables such as torque, power and electromyographic (EMG) activity during knee extensions at different angular velocities. The results demonstrated significant reductions in quadriceps performance when the hamstrings were fatigued, mainly at slower speeds ($60°•s^{-1}$), with no changes in quadriceps electromyographic (EMG) activity.

The efficiency of paired sets compared to traditional training was also highlighted by Robbins *et al.*, (2010a, 2010b). Although the authors did not find significant differences in EMG activity, PS demonstrated greater efficiency in maintaining load volume and reducing training time, which makes them an effective alternative.

The influence of PS on training volume was also analyzed by Paz *et al.,* (2015), who found greater load volume and muscle fatigue indices under PS conditions compared to traditional strength training (TST). The EMG activity was also higher in the PS protocol, indicating a more efficient stimulus in less training time.

The differences between the studies by Robbins *et al.* (2010a, 2010b) and Paz et al. (2015) can perhaps be attributed to the training loads and rest intervals. While Robbins *et al.*, (2010a, 2010b) employed loads corresponding to 3-4 repetitions, the study by Paz *et al.*, (2015) applied 10RM loads without rest intervals between the combined exercises, which may have contributed to a higher training volume and increased muscle activation. One of the principles of the agonist-antagonist PS method is the neurological inhibition of antagonist muscles following pre-activation in the first exercise, which may lead to a reduction in muscle coactivation and an increase in neural activation and strength of the agonist muscles (Mackenzie *et al.,* 2010; Robbins *et al.,* 2010c).

Another relevant factor is execution speed. Antunes *et al.*, (2018) evaluated the pre-activation of antagonists at slow (90 bpm) and fast (60 bpm) speeds, observing that both were more efficient than TST in terms of training volume.

Furthermore, different muscles responded differently to the protocols, with the rectus femoris demonstrating more activation in the PS protocol and the vastus lateralis in the TST protocol.

The way exercises are combined also impacts performance. For example, Weakley *et al.,* (2017a) compared supersets based on similar biomechanical movements (SB) with the agonist-antagonist (AA) format. The SB protocol led to greater reductions in average speed, power, and peak force, while the AA protocol minimized these losses, demonstrating greater training efficiency.

Wallace *et al.*, (2018) reported that when performing two consecutive exercises for the same muscle group in an agonist-agonist superset format, the training volume was lower compared to TST and other evaluated methods. In opposition, alternating upper and lower body exercises in a superset has been shown to promote similar responses to TST, but in a significantly shorter duration (García-Orea *et al.,* 2022). The rest redistribution strategy (cluster sets) applied within upper and lower body supersets may help reduce fatigue during training sets. However, even with this approach, no improvements in mechanical performance were observed in subsequent sets of the training session (Janicijevic *et al.,* 2024). Andersen et al. (2022) found that alternating supersets between different muscle groups (such as lower limbs, upper limbs, and isolated upper limbs) resulted in 4% less training volume, a higher rate of perceived exertion, and shorter training duration. Additionally, the combined exercise session was perceived as more enjoyable compared to TST. Therefore, individuals with extensive training experience may benefit from this type of methodology.

Regarding power outputs, Baker and Newton (2005) found that pre-activation of antagonist muscles enhanced power performance in throwing tasks. However, in the study by Pisz *et al.*, (2023), no difference was found between exercises targeting antagonist and agonist muscles in medicine ball throws performed by national-level female softball athletes. The authors suggest that alternating between different types of exercises may be an effective strategy to enhance throwing distance and velocity.

In summary, the findings discussed are particularly relevant for the planning of training programs targeting individuals with limited time, as they allow for greater session efficiency without compromising the quality of muscular stimuli. Acutely, the combined exercise method (e.g., supersets, paired sets) demonstrated performance outcomes that were similar to, and in some cases superior to, those of the traditional set protocol, and may therefore be considered an effective training strategy. The best results were observed in agonist-antagonist configurations and in protocols alternating upper and lower limb exercises, compared to agonist-agonist configurations or those based on similar biomechanical movements. Therefore, this strategy may provide greater stimulation for individuals with strength training experience and can be considered an advanced training approach.

4.2 Influence of the Order of Exercises on the Combined Exercise Method

Exercise order is a crucial variable in resistance training design, as the sequence in which exercises are performed can affect training outcomes. The American College of Sports Medicine (ACSM) (Kraemer *et al.,* 2002; Ratamess *et al.,* 2009) recommends sequencing exercises from the largest to the smallest muscle groups. However, several studies have suggested that the order of exercises should adhere to the principle of priority (Simão *et al.*, 2012; Cardozo *et al.*, 2019; Nunes *et al.*, 2021; Cardozo *et al.*, 2021). One relevant question when applying combined exercise methods (e.g., supersets) is determining the optimal sequence of exercises. Should priority exercises or muscle groups be placed at the beginning or the end of the training session to leverage physiological effects such as reduced muscle coactivation? To address this, some studies have investigated the impacts of exercise order.

Carregaro *et al.*, (2011a) evaluated the effects of two different muscle activation configurations on performance and electromyographic activity of the knee extensors. Fifteen men completed two isokinetic muscle action protocols: (1) reciprocal contraction (RC), consisting of alternating antagonist/agonist concentric contractions (one repetition of knee flexion immediately followed by one of knee extension), and (2) superset, involving ten consecutive repetitions of knee flexion followed by ten of knee extension. All experimental sessions consisted of four sets, ten repetitions at 60° s^{-1} and one-minute rest intervals between sets. No statistically significant differences were found between the protocols in peak torque and total work. Nevertheless, the activation pattern was more regular in the reciprocal sets protocol, suggesting that the decline in muscle strength is not affected by different antagonist activation strategies. Nonetheless, the reciprocal sets protocol allowed for better maintenance

of training volume (Carregaro *et al.*, 2011a; Carregaro *et al.,* 2011b).

One of the limitations of studies investigating isokinetic actions is their practical applicability. Therefore, Balsamo *et al.*, (2012) analyzed the influence of the order of exercises in the superset method using traditional resistance training equipment. Thus, twelve trained men performed two different superset sequences: (1) quadriceps followed by hamstrings, and (2) the reverse order - hamstrings followed by quadriceps. Each training session consisted of three sets using a load corresponding to 10RM and 90 seconds rest between sets. The results demonstrated that the total training volume was greater in the hamstrings-quadriceps sequence, as well as a lower rate of perceived exertion compared to the reverse sequence (quadriceps-hamstrings). These results indicate that initiating the sequence with hamstring exercises may lead to a greater training volume and lower levels of perceived exertion. Corroborating these findings, Maia *et al.*, (2015a) reported that the upper limb exercise sequence of bench press followed by seated row resulted in greater training volume for the back muscles, higher total work, and increased posterior deltoid activation compared to the reverse order (seated row followed by bench press). Paz *et al.*, (2013) also verified an improvement in the performance of the repetition volume when the seated row exercise followed the bench press. One possible explanation, aside from the reduction in coactivation, could be that the back muscles, with their higher composition of type I fibers, are more resistant to fatigue accumulation, which may influence the preload adjustment of the antagonist (Robbins *et al.*, 2010b).

Although the literature on the order of exercises in the combined exercise method is still limited, it appears that placing hamstring exercises before quadriceps exercises or exercises targeting the pectoralis major before those for the latissimus dorsi, promotes a better response in training volume and antagonist muscle activation. It is important for future studies to investigate whether these acute responses would influence strength gains and muscle hypertrophy following a training period, as well as to examine other exercise orders.

4.3 Influence of Rest Interval on the Combined Exercise Method

Rest interval is a critical variable in strength training, as it directly influences physiological and performance responses, thereby impacting strength gains and muscle hypertrophy (Ratamess *et al.,* 2007; Ratamess *et al.*, 2009; Grgic *et al.*, 2017; Grgic *et al.,* 2018; Cardozo *et al.,* 2021; Cardozo *et al.,* 2024). The literature suggests that longer rest intervals favor greater ATP resynthesis, thereby enabling the execution of a greater training volume (Kraemer *et al.*, 2002; Ratamess *et al.*, 2009; Bompa and Haff, 2012; Cardozo *et al.*, 2021). Since training volume plays a fundamental role in the gains of strength and muscle hypertrophy, it is important to investigate the influence of the rest interval on the combined exercise method.

Maia *et al.,* (2014) analyzed the effect of different rest intervals (protocols: PMR – minimum rest, P30 – 30 seconds, P1 – 1 minute, P3 – 3 minutes, and P5 – 5 minutes) in PS of knee flexion and extension, compared to a traditional training protocol (without paired exercises). Knee extension (KE) repetitions were significantly higher during the PMR, P30, and P1 protocols compared to the traditional protocol, P3, and P5. EMG activity for the rectus femoris muscle was significantly higher in the KE exercise in the PMR and P30 protocols compared to the tradicional, P3, and P5 protocols, respectively. These results suggest that eliminating rest pauses or encouraging shorter rest intervals (30 seconds and 1 minute) among paired sets may be more effective in promoting increases in agonist muscle repetition performance and muscle activation.

In a subsequent study, Maia *et al.*, (2015b) found no statistical difference in training volume between the 2- and 4-minute rest protocols for PS involving the upper limbs (pectoralis major: bench press exercise, followed by dorsal muscle group: seated row exercise). However, the fatigue index was significantly higher for all muscles examined (posterior deltoid, biceps brachii, pectoralis major, and triceps brachii) compared to the 4-minute rest protocol. Therefore, due to the high level of fatigue observed in the P2 protocol, if the training sessions aim to promote velocity with high loads, a longer rest interval should be preferred. Corroborating these findings, Behenck *et al.,* (2020) observed that 2-minute self-suggested rest intervals resulted in a greater total training volume compared to 1-minute intervals in paired upper limb exercises (bench row followed by bench press and lat pulldown followed by shoulder press). Although the literature on this subject is still scarce, the available studies present interesting findings, such as the recommendation of short rest intervals for lower limb exercises (immediate, 30 seconds, or 1 minute) and rest intervals longer than 2 minutes or self-suggested for upper limb exercises. The composition of muscle fibers appears to influence

this context, as the lower limbs contain a greater proportion of type I (slow-twitch) fibers. Additionally, due to their more frequent involvement in daily activities compared to the upper limbs, they may exhibit greater resistance and faster recovery (Schantz *et al.,* 1983; Campos *et al.*, 2002; Folland *et al.,* 2007).

The literature also shows that self-suggested rest intervals are a viable alternative for trained individuals, as performances under these protocols are comparable to those of long rest intervals in terms of training volume, while preserving the time efficiency characteristic of shorter intervals (Goessler and Polito, 2013; Cardozo *et al.*, 2021).

4.4 Influence of the Combined Exercise Method on Hormonal and Metabolic Responses

Hormonal and metabolic responses are influenced by the interaction of methodological variables in strength training, such as exercise order, intensity, number of sets and repetitions, rest intervals, among others (Ratamess *et al.*, 2005; Bottaro *et al.*, 2009, 2011; Rahimi *et al.*, 2010; Rønnestad *et al.*, 2011). Thus, the systematic manipulation of these variables contributes to the development of strength training systems (Fleck and Kraemer, 2017). Understanding the internal physiological responses elicited by the combined exercise method is also essential for designing a more efficient training prescription.

Kelleher *et al.,* (2010) investigated the energy cost of superset training compared to traditional training during and after exercise. Although total energy expenditure did not differ between the protocols, when values were expressed relative to time, energy expenditure ($kJ \cdot min^{-1}$), blood lactate concentrations, and excess post-exercise oxygen consumption (EPOC) were significantly higher in the superset training format than in the TST protocol.

Carregaro *et al.,* (2013) highlighted the importance of organizing the training format, as the reciprocal sets protocol resulted in greater total work, while the superset protocol elicited higher blood lactate levels compared to the other protocols. The authors concluded that the reciprocal sets protocol for lower limbs is more neuromuscularly and metabolically efficient during the execution of the knee extension exercise.

In the study by Realzola *et al.*, (2021) the influence of superset on metabolic responses in men and women was investigated. The superset protocol involved 3 blocks: block 1) hexagonal bar deadlift with leg press; block 2) chest press with seated row and block 3) overhead dumbbell press with latissimus dorsi pull-downs. The exercises were performed with four sets and a 60-second interval within the block and 2 minutes between blocks. The traditional protocol performed the same exercises and sets, but the interval was 90 seconds between exercises. The results demonstrated that regardless of gender, the superset protocol provided significantly higher VO_2, heart rate, lactate levels, rating of perceived exertion (RPE), energy expenditure, and was completed in a shorter time compared to traditional training. When compared to women, men demonstrated greater EPOC, lactate, and energy expenditure during the superset. The results of this study suggest that a training session in the superset format was metabolically more demanding, promoting increases in physiological responses in a shorter training duration. Corroborating this, Enes *et al.,* (2024) also found that upper limb bi-set training (flat bench press and incline bench press) promoted greater aerobic energy expenditure and oxygen consumption than traditional training.

The superiority of training in the superset or biset format in energy expenditure can be attributed to the characteristic of the method in performing the exercises consecutively without a rest interval. It is plausible, therefore, that minimal rest periods promote an environment of greater hypoxia, increased ventilatory compensation, and limited resynthesis of energy substrates (Binzen *et al.*, 2001; Allen *et al.*, 2008; Kelleher *et al.*, 2010; Fink *et al.*, 2018).

Regarding hormonal responses, Miranda *et al.*, (2018) found that the agonist-antagonist superset format targeting the upper limbs (seated row and bench press) did not differ from the TST protocol in terms of testosterone, growth hormone, cortisol, lactate levels, and RPE. It is important to highlight that this study investigated only two exercises; therefore, the physiological responses may vary across a complete training session. Nevertheless, based on the available literature, incorporating this training method may be beneficial for individuals seeking to increase caloric expenditure, stimulate an anabolic environment, and optimize training time.

4.5 Influence of the Combined Exercise Method on the Hypotensive Effect

Strength training has been recommended by important health entities such as the American College

of Sports Medicine and the American Heart Association as an important form of physical training in maintaining health (Pescatello *et al.*, 2004; Paluch *et al.*, 2024). Regarding blood pressure, the literature shows that a single training session can generate an acute reduction in blood pressure (Melo *et al.,* 2006; Cardozo, 2022) and long-term practice can help control blood pressure values (Moraes *et al.,* 2012; Mota *et al.*, 2013; Cardozo *et al.*, 2020).

Regarding superset training, Bentes *et al.,* (2017) subjected 13 men experienced in strength training to two experimental sessions: the traditional session consisted of the bench press (BP), low row (LR), leg extension (LE), leg curl (LC), pull-down (PD), and shoulder press (SP) exercises. The superset session required participants to complete the same exercises, but the exercises were combined in a way that allowed them to be worked in an agonist-antagonist format. Blood pressure (BP) was measured before and every 10 minutes for one hour after training. The traditional session resulted in a significant reduction in systolic and mean blood pressure (at 30º and 40º minutes post-exercise), while the superset session did not result in a hypotensive effect. According to the authors, training volume may have a significant role, as traditional training provided a greater total training volume than superset.

In the study by Paz *et al.*, (2017) it was observed that both the PS method and the agonist-antagonist superset promoted a greater training volume than the TST, however, no significant differences were observed between the training protocols in the hypotensive effect and heart rate variability (HRV). The authors also observed a tendency for a longer duration of the hypotensive effect in the superset and PS protocols, both of which can be considered options to the TST method to achieve a greater training volume and a more prolonged hypotensive response.

Recently, Corso *et al.*, (2024) analyzed the effect of the traditional method, superset and triset on the hypotensive effect and HRV. The results of this study demonstrated that the traditional method promoted a prolonged hypotensive effect compared to the superset and triset, with the combined exercise methods (superset and triset) being more efficient in the training sessions and the triset providing greater cardiac stress in the post-exercise period. The literature shows that a greater volume of training can prolong the hypotensive effect in both normotensive and hypertensive individuals (Mediano *et al.*, 2005; Simão *et al.*, 2005; Figueiredo *et al.*, 2015). Thus, as observed in the studies, TST promoted a longer duration of the hypotensive effect due to the greater time spent in the training sessions. Even when efficiency is better in the superset or triset methods, the trainer needs to consider the individual's health condition, as those with cardiovascular complications may find it prudent to organize training in the traditional format and safely progress the training as adaptations occur. It is important for further studies to be conducted on this topic, with a particular focus on the hypertensive population.

4.6 Influence of Stretching and Other Muscle Activation Methods on the Combined Exercise Format

Stretching is an effective method for increasing or maintaining the elastic capacity of muscles (Powers and Howley 2017). Several techniques can be used to improve muscle flexibility, including ballistic stretching, static stretching, and the Proprioceptive Neuromuscular Facilitation (PNF) technique (Powers and Howley 2017). However, evidence suggests that performing stretching before strength exercises may impair force production capacity, thereby negatively affecting performance (McBride *et al.,* 2007; Junior *et al.*, 2017). For instance, McBride *et al.,* (2007) reported that pre-exercise quadriceps stretching significantly reduced peak isometric force when compared to a control session without stretching. Junior *et al.*, (2017) found that flexibility training performed before training promoted a lower number of repetitions, total work volume and muscle hypertrophy. Thus, it is clear that stretching the agonist muscle before strength training can be harmful.

However, the question arises: what if the stretching is applied to the antagonist muscle? Could this generate a different response and be beneficial? With this perspective, Miranda *et al.*, (2015) investigated the effect of two acute training protocols in trained men: a) passive recovery (PR) which consisted of three sets to failure with a 2-minute rest between sets in the seated row exercise and; b) antagonist stretching (AS) protocol which was performed with 40 seconds of stretching of pectoralis major before each set of the seated row exercise. The results demonstrated that the AS protocol significantly increased the number of repetitions and muscle activity of the latissimus dorsi and biceps brachii, suggesting that stretching the antagonist during rest intervals may improve the performance and muscle activation of the agonists acutely (Miranda *et al.,* 2022). Corroborating these findings, Paz *et al.*, (2013) found significant

increases in EMG activity and training volume when using pre-activation with resistance exercises and static stretching in the antagonist muscles. Pessoa *et al.,* (2023) found that stretching the lower limbs, when applied only to the antagonist muscle or combining agonist-antagonist muscles, maximized training volume compared to stretching the agonist muscle. These results suggest that pre-activation, through stretching, can increase performance compared to traditional sets, mainly in exercises performed to muscle failure.

Another approach to activating muscles is the use of foam rolling (Macdonald *et al.*, 2013; Healey *et al.,* 2014; Lastova *et al.*, 2018). This self-massage technique applies pressure to the target myofascial regions using body weight (Peacock *et al.*, 2014; Cheatham *et al.*, 2015). Santana *et al.*, (2021) investigated the effect of foam rolling on agonist (quadriceps) and antagonist (hamstrings) muscles, assessing repetition performance, fatigue index, and muscle soreness. The results indicated that using foam rolling between sets, for both the agonist and antagonist muscles or for either, increased repetition performance, reduced fatigue, and decreased the perception of acute muscle soreness compared to traditional training, proving to be an efficient and viable option.

To sum up, static stretching of the agonist muscle before exercise can acutely reduce torque and repetition performance, impacting total training volume. The literature indicates a reduction of 2.8% in peak torque (Marek *et al.*, 2005) and up to 36.7% in repetition performance (Gomes *et al.*, 2011). In contrast, stretching the antagonist can increase performance by 12 to 15% in repetitions (value valid specifically for the exercise investigated in the study: seated row) (Miranda *et al.*, 2015).

Hypotheses for the reduction in strength in agonist muscles after stretching include: reduction in muscle stiffness, increase in sarcomere length, alteration in the length-tension relationship, and neural factors, such as decreased muscle recruitment or reflex sensitivity (Evetovich *et al.,* 2003; Herda *et al.,* 2008).

On the contrary, the benefit of stretching the antagonist muscle may be related to the reduction of muscle coactivation and the increase in elastic energy within the agonist muscles, enhancing performance (Paz *et al.,* 2012).

Although these mechanisms are acceptable, a detailed understanding of the processes involved in agonist muscle activation is still limited, indicating the need for further studies to elucidate these physiological responses.

4.7 Influence of the Tri-set Combined Exercise Method on Acute Responses

The tri-set training method is based on the execution of three successive exercises for the same or different body segments (Fleck and Kraemer, 2017). This training method is demanding due to the sequence of exercises worked with the minimal possible interval. For this reason, knowing the influence of this training method on physiological and performance responses is important for a more accurate training prescription. In this sense, Brunelli *et al.*, (2013) analyzed the tri-set protocol in two sequences: 1) bench press followed by incline bench press and dumbbell fly, and 2) EZ bar curl followed by dumbbell biceps curl and scott machine. All sequences were performed in three sets, 6-8 repetitions, intensity of 75% 1RM and rest of 3 minutes at the end of the combinations. The results demonstrated significant increases in the total leukocytes, monocytes and neutrophils between the post and pre-training moments. There were no significant differences in plasma concentrations of TNF-a, IL-6 and cortisol across the time points measured. These results suggest that the use of the tri-set method did not exacerbate the acute inflammatory response and may be a good way to implement variation in training sessions for trained individuals.

Regarding the sequence of exercises, Ribeiro *et al.*, (2013) investigated the order of execution of exercises in the tri-set format and found that when the exercises are directed to the pectoralis major muscle group, starting the sequence with an isolated exercise and progressing to the compound exercises was better for generating a greater number of repetitions and training volume compared to the opposite sequence. Corroborating these data, de Faria *et al.*, (2015) also observed that when the training session begins with an isolated exercise and progresses to compound exercises, the number of repetitions and total training volume were significantly greater. In this study, the analyses were directed to the lower limbs in the exercises squat on guided bar, leg press 45º and leg extension.

Regarding physiological responses, Weakley *et al.*, (2017b) found that the tri-set training method was more efficient than the traditional training method. However, this efficiency is accompanied by significant changes in perceived exertion, testosterone, cortisol, muscle damage, and lactate concentrations during the

training session. Traditional training protocols promoted lower neuroendocrine stress and allowed for faster recovery in the countermovement jump (CMJ). Thus, the tri-set method can be applied as a form of metabolic conditioning when improvement in overall training capacity is desired, due to the large metabolic responses (lactate concentrations) that occurred. However, the trainer must consider that, although it is efficient, this type of training requires more recovery time. The study by De Camargo *et al.,* (2022) observed that tri-set training (three exercises in sequence for the pectoralis major) resulted in a lower training volume, but still promoted a higher rate of perceived effort, muscle swelling, internal load, and training efficiency.

In summary, tri-set is an effective training method that can be implemented in periodized training programs, mainly when greater training efficiency, hormonal responses, metabolic responses and muscle swelling are desired. It is important for the trainer to consider when this method will be applied, as it can be directed toward athletes who have limited time for training due to other specific sport demands and/or even individuals who don't have time to train because of heavy workloads, but always with individualized progression and periodization.

4.8 Longitudinal Studies

4.8.1 Strength Gains and Hypertrophy

Muscular strength is a fundamental physical attribute that contributes to the performance of daily activities, enhances sports performance, and improves overall health parameters (Rhea *et al.,* 2016; Fragala *et* al., 2019; Cardozo *et al.*, 2019; Tøien *et al.*, 2025). Resistance training is the ideal modality for developing muscle strength and hypertrophy. Therefore, understanding how combined exercise methods influence strength increase and muscle hypertrophy is essential for designing more efficient training protocols.

In the context of isokinetic training, Cunha *et al.*, (2013) found that only three sessions were sufficient to increase peak torque in the knee extensors, with the reciprocal actions method (a knee flexion movement immediately followed by a knee extension movement) proving to be more effective than the traditional format (three sets of knee extensions). However, as previously discussed, isokinetic training is not commonly available in most training centers, with the majority of studies conducted using machines and free weights. Thus, regarding the use of supersets with free weights versus machines, Hadi *et al.,* (2018) verified that training with free weights led to greater increases in lower limb muscular strength after three months of training. The literature indicates that free weights can stimulate greater levels of balance and coordination, as well as require increased muscle recruitment and hormone responses, among other effects (Schwanbeck *et al.,* 2009; Clark *et al.,* 2012; Shaner *et al.*, 2014). Thus, the use of free weights may be advantageous at certain stages of training, while machines can serve as a safety tool for more intense sessions.

Merrigan *et al.*, (2019) verified the influence of 12 weeks of lower limb superset training in recreationally active women. The results of this study demonstrated that the superset (squat followed by leg press) promoted gains in strength, endurance and quadriceps muscle thickness in a manner comparable to traditional training in young women. Fink *et al.*, (2020) observed the efficiency of superset training in hypertrophy and endurance muscular, however the method did not promoted significant changes in muscular strength. Perhaps the divergence in the results regarding strength gains may be due to the training characteristics and the sample profile, since in the study by Merrigan *et al.,* (2019) the sample was characterized as untrained and the exercises targeted the lower limbs (squats and leg press), whereas in the study by Fink *et al.*, (2020) the sample investigated was composed of men and women trained and single-joint upper limb exercises (biceps curl and triceps curl).

Regarding triset training, Uchida *et al.*, (2006) reported that this method induces a more stressful physiological response compared to traditional training, as higher cortisol levels and reduced glutamine levels were observed after eight weeks of training. Although hormonal and immunological changes were observed in the triset group, the morphofunctional parameters (body composition, 1RM and maximum repetition tests) did not differ between the TST and triset groups. Garcia *et al.,* (2014) found that the triset method promoted increases in muscle strength similar to those achieved with TST. Thus, the results indicate that the triset method does not lead to significant differences in muscle strength or body composition in trained individuals, regardless of gender.

In general, combined exercise training has shown comparable results to TST in terms of muscle thickness (Pringga *et al.*, 2021), strength gains (Pringa *et al.*, 2021; García-Orea *et al.*, 2023), jumping performance (Permatasari *et al.*, 2021; García-Orea *et al.,* 2023), as well as other advanced training methods (Demirtas *et al.*, 2022). Nonetheless, combined exercise methods may be considered superior, as all studies have

shown that combining exercises offers the advantage of promoting significant adaptations in a relatively shorter training time, with sessions being considered highly efficient.

Future studies could examine the inclusion of other types of antagonists preactivation in the longitudinal effects of training, such as the use of foam rollers, resistance bands, and stretching. Furthermore, more research is needed to deepen the understanding of the triset method. Most studies have evaluated muscle strength and thickness, primarily in the quadriceps. Therefore, it is recommended that future research explore additional variables, such as sport-specific performance and functional outcomes, to broaden the understanding of the potential benefits of this training method.

4.9 Limitations

Among the main limitations, the wide heterogeneity of the sample stands out and should be ackowledged. Previous experience with strength training ranged from 6 months to 5 years, and the participants' training status was not clearly described in most studies. Furthermore, some studies did not report whether the training sessions were managed by experienced professionals in the field, nor whether food intake was controlled during the experimental protocols. These methodological gaps hinder the comparison of results.

Another relevant point concerns the nomenclature used to describe the training method. Some studies have adopted the terms supersets, paired sets, or bi-sets as interchangeable, without clear standardization, especially regarding the combination of agonist-antagonist exercises. Future studies should aim for greater uniformity in the description of participants, control of intervening variables, and the terminology used. This measure would allow for better comparability, interpretability and replication of the findings.

6. Conclusion

Based on the evidence presented, the combined exercise method appears to be a valid approach in prescribing resistance training. This strategy demonstrated potential to induce more pronounced acute physiological responses, both metabolic and neuromuscular, in addition to promoting chronic adaptations (such as strength gains, hypertrophy and jumping performance) equivalent to those obtained with traditional training. However, it had a clear practical advantage: it produced more pronounced acute responses and chronic effects similar to those of the traditional method, but with shorter training sessions. These findings are especially relevant for athletes seeking more effective and shorter workouts, as well as for individuals with more extensive work routines, in which available time is a limiting factor. The best results were observed in agonist-antagonist configurations and in alternating between different body segments (such as lower and upper limbs). Therefore, its application can be particularly useful for strength and conditioning professionals who aim to optimize training time without compromising results, adapting to different practitioner profiles and intervention contexts.

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The author declare that there was no conflict of interest.

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