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The Acute and Chronic Effects of Superset Resistance Training Versus Traditional Resistance Training—A Narrative Review

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Abstract

Mang, ZA, Beam, JR, and Kravitz, L. The acute and chronic effects of superset resistance training versus traditional resistance training—A narrative review. *J Strength Cond Res* 39(11): 1216–1234, 2025—Resistance training (RT) leads to several health and performance benefits for a variety of people, including ball-sport athletes, occupational athletes, general population lifters, and elderly adults. Despite these well-established effects, a surprisingly high percentage of adults do not participate in consistent RT (~80%), and several cite "perceived lack of time" as their primary barrier to RT. Superset training, which involves performing 2 or more consecutive sets of different exercises separated by short rest intervals, presents a time-efficient RT modality that reduces session duration by ~50% compared with traditional RT (TRAD). Several applications of superset training exist, but this review focuses exclusively on the acute and chronic effects of agonist-antagonist paired sets (AAPS), reciprocal supersets (RSS), and total-body supersets (TBSS). The literature is particularly heterogeneous in its definitions, dependent variables, methodologies, and results, but acute data have generally demonstrated that muscle activation and training volume do not differ between supersets and TRAD. By contrast, power production is typically greater during TRAD, while training density, hormonal responses, blood lactate, energy expenditure, heart rate, oxygen consumption, and perceived exertion are greater during supersets. Exceptions exist, but chronic data generally indicate that supersets and TRAD lead to similar adaptations for endurance, hypertrophy, power, and strength. Considering the superior training density of AAPS, RSS, and TBSS, we tentatively conclude that superset programs deliver similar adaptations as TRAD in a more time-efficient manner.

Key Words: strength training, paired exercises, time-efficient sessions

Introduction

Resistance training (RT) is defined as a form of exercise during which muscular force is applied to overcome a variety of external loads such as barbells, dumbbells, elastic bands, kettlebells, and machines (59,81). Common adaptations to RT include increased muscular endurance, power, skeletal muscle hypertrophy, and strength (23,24,134). These adaptations improve performance outcomes for a range of populations. For example, RT benefits athletes by increasing acceleration, agility, change of direction, rate of force development, sprint speed, and vertical jump height (VJH) (85,144). From a clinical perspective, RT benefits elderly adults by improving functional task performance, gait speed, and sit-to-stand capability while decreasing risk for falls and fractures (8,90,147). Therefore, RT confers performance and functional benefits for athletes, healthy adults, and clinical populations.

In addition, RT positively impacts cardiovascular and metabolic health. Specifically, RT is reported to increase insulin sensitivity and resting metabolic rate and has been shown to decrease blood glucose concentration, blood insulin concentration, blood pressure, markers of dyslipidemia (e.g., abnormal levels of lipids in the bloodstream), and visceral fat mass (154,155). These positive effects contribute to reduced risk for type 2 diabetes, cancer, coronary artery disease, dementia, hypertension, stroke, and Alzheimer's disease (1,8). Collectively, these data help explain why participating in an RT program decreases the risk for all-cause mortality by ~10–20% (11,111,126). In addition, adults with greater muscular strength have a reduced risk for all-cause mortality compared with their weaker counterparts (40,68). In short, the act of participating in an RT program and the adaptations associated with RT lead to several positive health outcomes for men and women of all ages.

Despite the abovementioned health and performance effects, a surprisingly low number of adults participate in RT. To be specific, a recent review by Nuzzo et al. (103) highlighted that 80% of adults do not satisfy RT recommendations—total-body lifting at least 2 days per week—and 58% of adults do not perform RT at all. There are many reasons and factors why people fail to participate in an RT program, but "perceived lack of time" is most commonly cited (103). To address this issue, several recent review articles have highlighted minimum-effective-dose and time-efficient RT strategies such as drop-set, exercise-snack, rest-pause, single-set, and superset training (8,39,62,103). In brief, superset training involves performing 2 or more consecutive sets of different exercises separated by a minimal rest interval (RI)

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(e.g., 10 seconds) (62,71). Reducing RIs increases training density, meaning that more exercises, repetitions, and sets are completed in less time (62,86,119). There are many applications of superset training, such as agonist-agonist supersets (152,161), total-body supersets (TBSS) (41,110), agonist-antagonist paired sets (AAPS) (119), and reciprocal supersets (RSS) (115). This review will focus on the latter 3.

To the best of our knowledge, the RT literature is bereft of a current review that exclusively compares AAPS, RSS, and TBSS with traditional RT (TRAD). Two reviews have discussed superset training, but both provided brief summaries within sections of manuscripts more broadly focused on time-efficient (62) and advanced (71) training techniques. In a similar vein, Robbins et al. (119) thoroughly reviewed the AAPS literature, but RSS and TBSS studies were not included, and several AAPS studies have been completed since the article's publication in 2010. Later, Brendlokken et al. (12) reviewed the effects of RSS vs. TRAD, but AAPS and TBSS studies were not included, and the manuscript is a Bachelor's thesis that was not published in an academic journal. Moreover, the review by Brendlokken et al. (12) only included 8 studies that focused solely on hypertrophy, rating of perceived exertion (RPE), strength, time-efficiency (i.e., session duration), and training volume. Most recently, Zhang et al. (159) conducted a systematic review and meta-analysis of superset vs. TRAD configurations and concluded that supersets are a time-efficient training technique that effectively improves muscular fitness while resulting in greater physiological and psychological strain. The review by Zhang et al. (159) is important because it quantified acute and chronic effects of superset and TRAD protocols, but the article did not provide sufficient guidance for applying superset training in practice. Therefore, the purpose of this study is to provide a thorough and up-to-date review of studies that have compared AAPS, RSS, and/or TBSS with TRAD while emphasizing their application for strength and conditioning professionals.

Methods and Terminology

The superset training literature is heterogeneous as the applications (e.g., AAPS, RSS, TBSS), definitions, outcome measurements (e.g., blood pressure, energy expenditure [EE], hypertrophy), and training variables (e.g., number of exercises, relative intensity, RIs, set volume) differ greatly between studies. Therefore, we chose a narrative review to analyze this research instead of a meta-analysis or systematic review, which reflects the methodology of 2 recent minimum-dose RT reviews (8,103). Terminology and the specific definitions of the terminology vary between superset studies. Hence, the following definitions will be used for the 4 primary training techniques discussed in this review.

- TRAD: multiple sets are performed for the same exercise, separated by 60–300 seconds RIs, before advancing to the next exercise.
- AAPS: multiple sets are performed for paired agonist/antagonist exercises. Sets are completed in an alternating fashion and are separated by 45–120 seconds.
- RSS: multiple sets are performed for paired agonist/antagonist exercises. Sets of the paired exercises are performed consecutively, separated by minimal RIs (e.g., 10–30 seconds), before taking a 60–180 seconds RI.
- TBSS: similar description as RSS and AAPS, but exercises that target upper- and lower-body musculature are trained instead of agonist/antagonist pairings.

Historical Origins and Proposed Physiological Mechanisms

A search of the academic literature yielded no clear historical origin for superset training. However, it is generally accepted that Joe Weider, who is considered by some to be the father of body building, is responsible for introducing supersets to the world of RT. Supersets were listed in Weider's Training Principles, which is a collection of advanced training techniques (e.g., drop-sets and pyramid training) that Weider believed would lead to superior training outcomes (e.g., hypertrophy). Despite their arguably obscure origin story, supersets are a commonly applied advanced training method, as a survey of 127 competitive male bodybuilders revealed that 60.6% of respondents used supersets in their RT programs (50). There are many reasons why lifters may choose to adopt supersets, including increased training density, metabolic stress, and neuromuscular performance (135).

As previously mentioned, compared with TRAD, supersets involve performing similar training volume in significantly less time, which increases the training density of the session (16,62). The increase in training density leads to higher physiological and psychological stress which manifests as higher blood lactate concentration (BLC) (67), EE (115), heart rate [HR] (115), oxygen consumption (115), perceived effort (125), and perceived discomfort (3) when compared with TRAD. There are, however, potential benefits that stem from the stress imposed by higher training densities, such as increased aerobic fitness (101) and muscular buffering capacity (130). Hence, the time-efficient nature of supersets increases training density, which may improve one's work capacity.

Moreover, supersets typically lead to longer time under tension (TUT) per set, which causes greater local muscle energy turnover, reliance on anaerobic glycolysis, and, ultimately, metabolic stress (i.e., higher BLC) (84). Indeed, there is much debate surrounding the importance of metabolic stress for stimulating muscle hypertrophy, as affirmative (150) and negative (77) arguments are found in the RT literature. Even if metabolic stress does not directly stimulate muscle protein synthesis, and therefore eventual hypertrophy, some have posited that fatiguing metabolites (e.g., hydrogen ions) lead to greater recruitment of high-threshold motor units (26), which innervate fast-twitch muscle fibers that are more prone to hypertrophy (148). In addition, considering buffering capacity and improved local muscular endurance, it is theorized that sets of RT with longer TUT mimic the stress of aerobic exercise, which may lead to increased capillarization and mitochondrial density (84,160). However, these adaptations may only be pertinent to agonist-agonist supersets where the same muscle group is stressed consecutively (e.g., leg press + knee extension) (93).

Finally, superset training configurations that involve agonist/antagonist pairings, such as a bench press (BP) and seated row, may enhance neuromuscular performance compared with TRAD. Specifically, research has shown that contracting the antagonist muscle leads to increased force output (46) and higher repetition performance (105) by the agonist muscle, which may be driven by reduced antagonist inhibition and increased stored elastic energy in the muscle-tendon complex (16,119,121). Thus, the subsequent increased motor unit recruitment and neural drive to the agonist muscle may result in greater mechanical tension, a key stressor to elicit muscular adaptations such as hypertrophy (77,150).

Acute Effects of Agonist-Antagonist Paired Sets, Reciprocal Supersets, and Total-Body Supersets

Training Volume, Total Work, and Training Density

Training volume, which is colloquially described as the amount of RT work performed during an exercise, session, or week, has been associated with long-term increases for hypertrophy (132) and strength (113). Researchers have reported training volume as repetition performance (96), set volume (113,132), TUT (72), total work (18–20), and total volume load (sets × reps × external load; TVL) (54,55). The latter is arguably the most commonly used. To describe the efficiency of a training session, TVL is expressed relative to time, which is referred to as training density (TVL/time) (151). This section will discuss the effect of superset and TRAD configurations on total work, training volume, and training density.

To date, 3 studies have directly compared the effects of AAPS and TRAD on TVL and training density. Robbins et al. (120) had subjects perform heavy bench pulls (4 repetition maximum [RM]; BPull) and ballistic BP throws (40% of 1RM; BThrow) with AAPS and TRAD configurations. Volume was fixed for BThrow (4 reps), so TVL and training density were reported for BPull only. It was observed that TVL did not differ between conditions (1,034.7 vs. 1,094.3 kg), but training density was significantly greater for AAPS (103.5 vs. 54.7 $kg\cdot min^{-1}$). In a follow-up study, Robbins et al. (118) replicated their methodology, but 4RM loads were used for BPull and BP. As before, TVL did not differ between conditions for either exercise (BPull = 1,060.6 kg for AAPS and 1,105.5 kg for TRAD; BP = 1,039.6 kg for AAPS and 1,107.5 kg for TRAD), but training density was nearly 2 times greater for AAPS (106.1 vs. 55.3 $kg\cdot min^{-1}$ for BPull; 103.9 $kg\cdot min^{-1}$ vs. 55.4 $kg\cdot min^{-1}$ for BP). A primary limitation of both studies is that training duration was not matched (20 minutes for TRAD, 10 minutes for AAPS), which favored the AAPS condition for calculations of training density. Thus, in a third study, Robbins et al. (121) matched training duration between conditions (10 minutes) by equating RIs between AAPS and TRAD (120 seconds). Repetition performance decreased set-by-set for both conditions, but greater values were observed for AAPS. Because of this, TVL (BPull = 895.4 vs. 738.1 kg; BP = 930.4 vs. 731.3 kg) and training density (BPull = 89.5 vs. 73.8 $kg\cdot min^{-1}$; BP = 93.0 vs. 73.1 $kg\cdot min^{-1}$) were also significantly greater during AAPS compared with TRAD. Collectively, the research by Robbins et al. (118,120,121) suggests that higher TVL and training density can be achieved with AAPS configurations when compared with TRAD. Readers should note that these data were collected in young, previously trained male athletes and cannot be directly applied to female lifters or those with less training experience.

In a review article, Robbins et al. (119) theorized that several neuromuscular phenomena explain why AAPS acutely enhances repetition performance and TVL. In brief, the coactivation of agonist/antagonist musculature during AAPS may alter the triphasic pattern of ballistic contractions, prefatigued antagonist muscles result in decreased resistance of agonist movements, and/or agonist muscles are potentiated due to reciprocal innervation. These proposed mechanisms are logical, but they are speculative in nature, and direct evidence of their occurrence is lacking (119).

Two studies assessed the effects of RSS and TRAD on total work performed during lower-body exercise on an isokinetic dynamometer (i.e., BioDex). Of note, for these studies, total repetition performance was matched between conditions, and total work (J) was calculated for each set. Carregaro et al. (18) had subjects perform 3 sets of 10 repetitions for knee extension (KE) (i.e., TRAD) and 3 sets of 10 repetitions for knee flexion (KF) and KE (i.e., RSS). Both conditions were completed with slow ($60°\cdot s^{-1}$) and fast ($180°\cdot s^{-1}$) movement velocities. The results showed that total work decreased set-by-set for both conditions, but significant differences were not detected between RSS and TRAD. A primary limitation of this study is that sets of KF were not performed during the TRAD session. To address this limitation, Carregaro et al. (20) conducted a second study during which 4 sets of 10 repetitions were completed for KF and KE with RSS and TRAD configurations. As before, total work decreased set-by-set for both conditions, but significant differences were not found between them. Practitioners should be wary that these data were collected on isokinetic dynamometers, which may not reflect performance on isotonic resistance exercise modalities. In addition, the subjects were physically active individuals who had not partaken in RT for the prior 6 months, so the data are not applicable to higher-trained populations.

Several studies have directly compared the effect of RSS and TRAD on training volume. For example, Paz et al. (105) had subjects complete 1 set of seated row (SR; i.e., TRAD) and 1 set of chest press (CP) performed immediately before 1 set of SR (i.e., RSS). The results showed that repetition performance was significantly greater during RSS compared with TRAD (14 vs. 10 reps). Obvious limitations include that only 1 set was completed for each exercise, and the CP was not included in the TRAD protocol. Years later, the researchers replicated their design, but 3 sets of BP and SR were completed during TRAD and RSS (107). Repetition performance and TVL decreased set-by-set for both conditions, but significantly greater values were achieved during RSS for both variables. However, conflicting findings were achieved by Fink et al. (37), who reported that repetition performance and TVL did not differ between RSS and TRAD. Disparate outcomes between Paz et al. (107) and Fink et al. (37) can be explained by the fact that the latter study used single-joint exercises (biceps curl and triceps extension) on elastic bands with considerably high repetition volume (~20–60 reps/set). Differences in subjects should also be considered, as Fink et al. (37) studied untrained women and men, while Paz et al. (107) recruited well-trained male lifters. It is also noteworthy that both studies used 2 exercises, which do not reflect how most people train. With a more ecologically valid design, Bentes et al. (9) reported that TVL was significantly greater during TRAD (8,277.4 kg) compared with RSS (7,594.9 kg). These data were collected during training sessions that consisted of multiple sets (3 sets) for 6 total-body exercises. The conflicting findings from Bentes et al. (9), Fink et al. (37), and Paz et al. (107) likely stem from differences in total set volume (6 vs. 18). Perhaps RSS leads to greater residual fatigue, which affects TVL as more exercises are completed during a training session.

Three articles compared the effect of AAPS, RSS, and TRAD in the same study. De Souza et al. (29) had subjects perform 3 sets of SR and BP with AAPS, RSS, and TRAD configurations. Repetition performance was greater during AAPS compared with RSS and TRAD for both exercises. This outcome is likely explained by the fact that 240 seconds of rest was allotted between like exercises during AAPS, which was longer than RSS and TRAD. Conflicting results were reported by Paz et al. (109) when RSS led to significantly greater TVL than TRAD, but not AAPS. Training density did not differ between conditions. The same researchers later showed that AAPS (8,262.3 kg) and RSS (8,608.6 kg) led to significantly greater TVL than TRAD (7,527.5 kg), but no differences were found between the superset conditions (108). When only 2 exercises are completed, the literature generally suggests that AAPS is superior to RSS and TRAD for TVL. However, when several exercises are completed, AAPS and RSS may both be superior to TRAD for TVL, but this is not a universal finding (9). All 3 studies included only resistance-trained young men, making it unclear whether similar outcomes would be sustained in other populations (e.g., women, older).

Three studies have assessed the effect of TBSS vs. TRAD on training volume and efficiency. Weakley et al. (151) reported that TVL did not significantly differ between TBSS (11,599.2 kg) and TRAD (11,632.5 kg). However, because training duration was shorter during TBSS (24.0 vs. 42.3 minutes), training density was significantly greater during TBSS (483.3 kg·min^{-1}) compared with TRAD (275.0 kg·min^{-1}). Similar results were reported by Peña Garcia-Orea et al. (110). Although statistically significant differences were not found, it is noteworthy that absolute values for repetition performance during the squat (SQ) favored TRAD (30.3 vs. 24.4 reps). Once again, considering differences in training duration (23.3 vs. 42.2 minutes), training density was significantly greater for TBSS. Most recently, Neto et al. (102) reported that TVL was significantly greater for TBSS (2,676 kg) compared with TRAD (2,440 kg), but values for training duration and density were not reported. This study is primarily limited by the fact that subjects self-selected their RIs for both conditions, and the authors did not report these values (i.e., how long subjects rested for TBSS compared with TRAD). Other methodological differences may explain the conflicting outcomes reported by Neto et al. (102), as their subjects performed every set to momentary failure while Peña Garcia-Orea et al. (110) applied a 15–20% velocity loss threshold and Weakley et al. (151) matched training volume between conditions (3 × 10 reps). Together, these studies generally demonstrate that TVL does not differ between TBSS and TRAD, but the former is much more efficient. In addition, when self-selected RIs are applied, lifters may accrue greater TVL during TBSS.

In short, most studies have reported that superset training results in superior or similar training volume when compared with TRAD. Because superset sessions are typically much shorter than TRAD, training density is consistently greater during the former.

Acute Power Performance and Muscular Activation

Muscular power, which is the product of force and velocity, is an important component of physical fitness for a variety of populations (23,24). For instance, power has been correlated with superior athletic performance for ball-sport athletes (149) and occupational athletes (94). In addition, increasing power leads to better outcomes for functional task performance (58) and reduced fall risk in elderly adults (138). It is speculative, but training programs that elicit greater acute power production may lead to greater power acquisition over the course of time (44). Muscular activation, which is commonly measured with surface electromyography (EMG), may also provide insight for long-term adaptations, as greater EMG activity indicates greater neural drive and motor unit recruitment (34). Some researchers have used EMG to provide metrics for fatigue index (145), which may reflect the physiological strain imposed by RT sessions (157). This section will discuss the acute effects of supersets and TRAD on power and EMG indices.

Three studies have exclusively compared power and muscle activation between AAPS and TRAD. Baker and Newton (5) reported that 1 set of 8 BPull with 50% of 1RM acutely increased power on a subsequent set of BThrow (+22 W) (i.e., AAPS). By contrast, TRAD experienced a nonsignificant decrease in power during the BThrow (−3 W). Several limitations should be noted, including that both exercises were performed with low relative intensities, and subjects only performed 2 (TRAD) and 3 (AAPS) total sets. With an improved study design, Robbins et al. (120) had subjects perform 3 sets to momentary failure with a 4RM for BPull before 3 sets of 4 reps with 40% 1RM for BThrow with AAPS and TRAD configurations. Muscle activation, measured using EMG for pectoralis major, anterior deltoid, latissimus dorsi, and trapezius, did not differ between AAPS and TRAD. Likewise, acute power performance, measured as throw height, peak velocity, and peak power during sets of BThrow, did not differ between AAPS and TRAD. These outcomes were contrary to Baker and Newton (5) likely because multiple sets were executed (3 instead of 1), and the priming exercise (i.e., BPull) involved heavier loads that were lifted to momentary failure (i.e., 4RM vs. 50% 1RM). Later, the researchers replicated their study, but used heavy external loads for both exercises (4RM) and substituted BP for BThrow (118). As before, EMG data did not differ between AAPS and TRAD for pectoralis major, anterior deltoid, latissimus dorsi, and the trapezius. Unfortunately, acute power production was not measured during this study. Collectively, this research demonstrates that acute power production and muscle activation do not differ between AAPS and TRAD, especially when ecologically valid exercise routines are performed.

Several studies have exclusively compared RSS with TRAD for muscular power. For example, Carregaro et al. (18) assessed the effects of 3 sets of 10 repetitions of KE (i.e., TRAD) vs. 3 sets of 10 repetitions of KF + KE (i.e., RSS) with fast (180°·s^{-1}) and slow (60°·s^{-1}) movement velocities. Peak torque, which was used as a proxy measurement for power, did not differ between RSS and TRAD. This study was limited primarily by the lack of KF performance during the TRAD condition. To address this issue, the same authors compared the effects of 4 sets of 10 repetitions of KF and KE with TRAD and RSS configurations with slow movement velocities (60°·s^{-1}) (20). EMG data for the vastus medialis revealed that the fatigue index was significantly greater during RSS compared with TRAD. However, coactivation of the biceps femoris and peak torque did not differ between conditions. These data are interesting, but they were collected on isokinetic dynamometers and not isotonic resistance modalities that are typically used by fitness professionals. Future research can replicate these methods on more commonly used equipment and include more diverse samples, as both studies were conducted on untrained men.

Elsewhere, Paz et al. (105) compared the effect of 1 set to failure with a 10RM load during a SR (i.e., TRAD) to 1 set to failure with a 10RM load of CP before 1 set to failure with a 10RM load of SR (i.e., RSS). EMG data revealed that muscle activation was significantly greater for biceps brachii and latissimus dorsi during RSS, but triceps brachii and pectoralis major activation did not differ between conditions. This study was limited by using only 1 set for each exercise. Building off their previous study, Paz et al. (107) compared the effects of RSS and TRAD on fatigue index, which was measured as EMG for the latissimus dorsi, pectoralis major, biceps brachii, and triceps brachii. Three sets were performed for BP and SR. The results showed that the fatigue index was significantly greater during RSS compared with TRAD, as reflected by greater activation for every muscle group measured. Years later, the same researchers reported that muscle activation for biceps brachii, latissimus dorsi, pectoralis major, and triceps brachii did not differ between RSS and TRAD (109). As previously discussed, this difference is likely explained by the fact that 6 exercises were used (18 total sets) instead of 2 exercises (6 total sets), suggesting that any observable potentiation effect may be minimized when multiple sets of multiple exercises are executed. In short, acute power production does not differ between RSS and TRAD, but muscle activation and fatigue index are consistently greater during RSS. For additional context, the research by Paz et al. (105,107,109) included young, active men with previous RT experience, which highlights that women and older lifters are generally understudied in the superset literature.

Four studies have compared TBSS with TRAD. First, Ciccone et al. (22) compared the effects of TBSS (SQ + BP + BPull) and TRAD (SQ only) on barbell metrics and ground reaction forces during the SQ. Data showed that ground reactive force and peak power did not differ between conditions. However, when volume was equated, TRAD elicited significantly greater average power than TBSS. The authors argued that TBSS led to more fatigue than TRAD, as ground reactive force and peak power reflect a "moment in time" for 1 repetition, while average power captures the entire repetition. Next, Weakley et al. (151) compared the effects of TBSS and TRAD on postexercise fatigue as measured by performance on a VJH test. Data revealed that TRAD led to greater decrements in VJH immediately after the session, but VJH performance completely recovered 24 hours post. By contrast, TBSS did not diminish VJH immediately after the session, but VJH was significantly lower when measured 24 hours post. Therefore, TBSS may lead to longer-lasting fatigue compared with TRAD. Later, Peña Garcia-Orea et al. (110) compared the effect of TBSS and TRAD on barbell velocity during BP and SQ. The fastest velocity recorded during each set did not differ between conditions. However, subjects completed more total repetitions with faster velocities during the SQ (0.9–1.1 $m \cdot s^{-1}$) and BP (0.8–0.9 $m \cdot s^{-1}$) during TRAD. This suggests that barbell velocity, and thereby acute power production, are slightly diminished during TBSS. In a more extensive study, Weakley et al. (152) compared AAPS (SR + BP), TBSS (SQ + BP), and TRAD (BP only) on power production during the BP exercise. Mean velocity and power decreased more during AAPS and TBSS compared with TRAD, but differences between the superset sessions were unclear. In summary, power production and barbell velocity are typically higher during TRAD compared with TBSS, and TBSS may lead to greater residual fatigue. Future research in this area can include subjects of different ages, biological sexes, and training statuses, as all 4 studies included young men with RT experience (22,110,151,152).

The collective findings of these studies are heterogeneous. In general, superset configurations lead to greater muscle activation and fatigue index compared with TRAD, but acute power production is typically greater during TRAD.

Cardiovascular Stress and Energy Expenditure

The EE during RT sessions may interest fitness professionals whose clients aim to use physical activity to facilitate the decrease of body fat and to improve body composition (80,143). Others may view RT as a substitute for aerobic training to potentially improve cardiovascular fitness and work capacity (84,140). Hence, the effect of superset and TRAD configurations on cardiovascular stress and EE is worth exploring.

To date, 2 studies have assessed the acute effects of RSS and TRAD on EE and markers of cardiovascular stress. Kelleher et al. (67) reported that total EE did not significantly differ between conditions (RSS = 1,009 kJ; TRAD = 954 kJ), but this can be explained by differences in training duration (RSS = 30 minutes; TRAD = 36 minutes). Thus, relative EE values were significantly higher for RSS (34.7 vs. 26.3 $kJ \cdot min^{-1}$). Similarly, postexercise oxygen consumption (EPOC) was 33% higher during RSS compared with TRAD (79.4 vs. 59.7 kJ). The authors concluded that RSS leads to greater relative EE and EPOC compared with TRAD, which can be explained by greater metabolic perturbations that stem from shorter recovery periods between exercises and higher training density. Realzola et al. (115) built upon the previous study by providing data for HR and oxygen consumption expressed relative to maximal-HR (HRmax) and maximal oxygen consumption ($\dot{V}O_2max$). They also included a mixed sample of female and male lifters. Data revealed that aerobic EE (31.8 vs. 23.0 $kJ \cdot min^{-1}$), anaerobic EE (1.86 vs. 0.65 $kJ \cdot min^{-1}$), HR (75.8 vs. 61.5% HRmax), EPOC (8.37 vs. 7.37 $kJ \cdot min^{-1}$), and oxygen consumption (40.9 vs. 29.7% $\dot{V}O_2max$) were significantly greater during RSS. These results support the findings of Kelleher et al. (67) as shorter training duration (RSS = 26.7 minutes; TRAD = 45.6 minutes) led to greater cardiovascular and metabolic stress when training volume was matched.

A collective limitation of these studies is the inclusion of young, physically active people with RT experience; therefore, the effects on other populations are unknown. In addition, the RSS sessions were always performed first to match TVL during the subsequent TRAD sessions. In other words, conditions were not randomized or counterbalanced, meaning that different outcomes may have been observed if subjects naturally accrued greater TVL during the TRAD sessions.

To that end, Brentano et al. (13) reported that agonist-agonist supersets and TBSS naturally led to similar TVL, which resulted in similar total EE between conditions. These data are interesting, but 2 superset conditions were compared, and a TRAD intervention was not included. Similarly, Enes et al. (32) found no differences between agonist-agonist supersets and TRAD for anaerobic EE under randomized and counterbalanced conditions. Readers should consider that Enes et al. (32) only applied 2 exercises, which differed from Brentano et al. (13) (4 exercises), Kelleher et al. (67) (6 exercises), and Realzola et al. (115) (6 exercises). Furthermore, Enes et al. (32) intentionally matched training volume between conditions (60 total repetitions), which potentially explains why anaerobic EE did not differ between supersets and TRAD in their study.

In short, cardiovascular stress and relative EE are greater during RSS compared with TRAD, which may be driven by a combination of shorter RIs, shorter session duration, and greater training density. However, EE and cardiovascular stress are influenced by the number of exercises used, training volume, and proximity to failure, which may explain variance between studies. Future research can modify the Kelleher et al. (67) and Realzola et al. (115) studies by randomizing the RSS and TRAD sessions.

Postexercise Blood Pressure and Heart Rate Variability

Resistance training sessions acutely decrease blood pressure, a phenomenon that is called postexercise hypotension (PEH) (21). The PEH response has been linked to long-term reductions in blood pressure (28) and overall risk for cardiovascular disease (31). Previous researchers have assessed the effect of RIs (73), relative intensity (21), and training volume (42) on PEH. It is therefore pertinent to discuss the effect of superset configurations on PEH compared with TRAD.

Bentes et al. (9) compared the effects of RSS and TRAD on PEH in 13 recreationally active young men. Data revealed that systolic blood pressure (SBP) and mean arterial pressure (MAP) were significantly lower following TRAD compared with RSS. However, postexercise diastolic blood pressure (DBP) did not differ between conditions or preexercise values. The authors concluded that TRAD led to a greater PEH response compared with RSS, confirming previous findings that shorter RIs cause greater increases in HR, SBP, and cardiac output (73). It is worth noting that TVL was significantly greater during TRAD (8,277 vs. 7,594.9 kg), which may have contributed to superior PEH (35).

Conflicting results were reported by Paz et al. (106) when RSS led to greater reductions in DBP and SBP compared with TRAD. Unlike Bentes et al. (9), significantly greater TVL was achieved for the seated row during RSS (1,625.1 vs. 1,493.7 kg), but TVL during the BP did not differ between conditions (1,435.8 vs. 1,373.6 kg). If combined, absolute TVL for both exercises was considerably higher during RSS (3,060.9 vs. 2,867.3 kg), which could explain the superior PEH response (35,42). Of note, Paz et al. (106) used only 2 exercises, while Bentes et al. (9) used 6 exercises, which may have contributed to their disparate findings. Perhaps, the potentially negative effect that RSS has on the PEH response is only observed when longer training sessions are performed (e.g., 18 vs. 6 total sets).

To our knowledge, 1 study has compared the effects of TBSS and TRAD on PEH. Neto et al. (102) reported no differences between conditions for postexercise DBP, but postexercise SBP was significantly lower following TRAD. TVL was slightly greater during TBSS (2,676 vs. 2,440 kg), which contradicts the hypothesis that training volume is the primary determinant of the PEH response. However, subjects self-selected their RIs during both conditions, and the specific durations of these RIs were not reported. Considering that RIs influence the cardiovascular response to RT sessions (73), it is unknown whether differences in RI duration influenced the data obtained by Neto et al. (102).

Heart rate variability (HRV) is also indicative of cardiovascular health (128) as it provides an indirect measure of autonomic nervous system regulation for the cardiovascular system (112). Paz et al. (108) compared the effects of AAPS, RSS, and TRAD on PEH and HRV in 13 resistance-trained men. Interestingly, TVL did not differ between RSS (8,608.6 kg) and AAPS (8,262.3 kg), but both were significantly greater than TRAD (7,527.5 kg). The results indicated that PEH and HRV did not differ between conditions, but larger effect sizes were observed during AAPS and RSS for DBP and MAP compared with TRAD. These outcomes support the hypothesis that higher training volumes result in greater PEH (35,42).

To summarize, the research that has compared the effect of supersets and TRAD on PEH and HRV is mixed, and outcomes are likely influenced by RI duration and TVL. Future studies can compare different levels of training volume and RIs with superset and TRAD configurations, or simply adjust the protocols to match TVL between conditions. Practitioners should note that these experiments were conducted on healthy, young, trained lifters with normal resting blood pressure values, so results should be cautiously applied to people with pre-hypertension and hypertension or who have different training statuses.

Blood Lactate Concentration

Blood lactate concentration is often used as a proxy measurement for metabolic stress incurred during RT sessions (84). In brief, when anaerobic glycolysis is relied upon during RT sets, hydrogen ions are combined with pyruvate molecules to form lactate through lactate dehydrogenase (96), and lactate is shuttled out of the muscle cell to serve as a substrate for neighboring muscle fibers and organ systems (14). The BLC response to superset training is intriguing because lactate has been proposed as an important signaling molecule for mitochondrial biogenesis (84) and skeletal muscle hypertrophy (75).

When studies have compared RSS with TRAD, it is consistently reported that BLC is significantly greater during the RSS condition (20,67,115,125). By contrast, Fink et al. (37) reported no significant differences between RSS and TRAD. This disparity can be explained by the fact that repetition performance did not differ between conditions, relatively short RIs were used (60 seconds), and subjects performed low-intensity training (20–60 reps/set) with elastic bands (37). In other words, the high-repetition, short-RI TRAD session from Fink et al. (37) provided a stronger metabolic stimulus than typically applied TRAD protocols in the literature. The subjects were also detrained/untrained (37), which may explain why there were no differences in metabolic stress stimulated by RSS and TRAD.

The results have varied for studies that compared AAPS, RSS, and TRAD. For example, Miranda et al. (97) reported no differences between AAPS and TRAD, likely because repetition volume (10 reps/set) and relative intensity (85% of 10RM) were matched between conditions. However, Paz et al. (109) also found no differences between AAPS, RSS, and TRAD despite every set being performed to momentary failure. By contrast, De Souza et al. (29) concluded that BLC was significantly greater during RSS compared with AAPS and TRAD, while no significant differences were detected between AAPS and TRAD. The training sessions by De Souza et al. (29) involved considerably less training volume than Paz et al. (109) (6 vs. 18 total sets), which implies that the BLC response to AAPS, RSS, and TRAD may level out as more exercises and sets are added to a session. Elsewhere, Weakley et al. (151) reported that BLC was significantly greater during TBSS compared with TRAD. They also included a tri-set condition, which led to greater BLC compared with TBSS and TRAD, suggesting that training density could be the biggest driver for metabolic stress during RT.

Research in this area is generally mixed, but the majority of studies indicate that BLC is significantly greater during superset configurations compared with TRAD. Thus, the evidence suggests that higher training density leads to greater metabolic perturbations and reliance on anaerobic glycolysis, resulting in greater lactate accrual. Slight disparities between studies may be explained by a number of varying methodological factors. First, metabolic stress is influenced by TUT per set (84), which is determined by repetition volume (25), relative intensity (122), and repetition tempo (88). Second, the BLC response differs between upper- and lower-body lifts (96), implying that metabolic stress is influenced by exercise selection. Third, RIs between exercises influence how quickly lactate is accumulated and cleared during RT sessions (79,123). Thus, differences in these 3 factors may contribute to disparate BLC outcomes between studies. When applying superset configurations in practice, coaches should consider that the elevated BLC is associated with H+ ion accumulation and acid-base disruption due to a significant decrease in blood pH. This acute acid-base disruption can lead to symptoms such as nausea, dizziness, and/or lightheadedness, especially when TBSS are applied or when less-trained individuals are lifting. Thus, superset configurations should be reserved for exercises that target smaller muscle groups and for athletes/clients who have a higher training status and have demonstrated that they tolerate metabolic stress well.

Acute Hormonal Response and Muscle Damage

Some have postulated that RT programs with higher training density, such as superset training, lead to greater metabolic responses (i.e., BLC), which may lead to greater testosterone (TEST) secretion, cortisol (CORT) secretion, growth hormone (GH) secretion, and markers of muscle damage (i.e., creatine kinase; CK) (56,57,89). The acute hormonal response to superset and TRAD configurations is worth exploring because post-exercise changes to the abovementioned markers may influence long-term muscle remodeling (69). However, readers should note that this topic is hotly debated (15).

Weakley et al. (151) compared the effects of TBSS and TRAD on CK, CORT, and TEST. The results indicated that TBSS increased CK more than TRAD at the 24-hr-postexercise time point. Similarly, TBSS increased TEST immediately postexercise and 24-hr postexercise, while no change was observed for TRAD at either time point. Both interventions decreased CORT immediately postexercise, but CORT increased at the 24-hr post-exercise for TBSS only. The authors concluded that TBSS is more time-efficient and fatiguing than TRAD, which is why markers of muscle damage, anabolism, and catabolism were greater following the TBSS session. It is noteworthy that the changes to CK, CORT, and TEST were relatively small for both protocols, which may have stemmed from the low relative intensity used (65% 3RM), and the large variance in individual responses.

Conflicting results were reported by Paz et al. (109) as AAPS, RSS, and TRAD led to similar concentrations of CK and lactate dehydrogenase (i.e., both markers of muscle damage). Disparities between studies could be explained by exercise selection as Weakley et al. (151) used upper- and lower-body pairs while Paz et al. (109) used only upper-body pairs. The set end point should also be considered, as Weakley et al. (151) fixed training volume at 3 sets of 10 repetitions with 65% 3RM (i.e., effort was low and varied between subjects), while Paz et al. (109) had their subjects lift each set to momentary failure. Moreover, Paz et al. (109) noted that because BLC did not differ between protocols, it logically followed that markers of muscle damage did not differ because metabolic stress and muscle damage are often related (56). Finally, the subjects in their study had ≥3 years of RT experience, which may have limited the amount of muscle damage elicited by the protocols (92).

Similarly, Miranda et al. (97) assessed the effect of AAPS and TRAD on concentrations of CORT, GH, and TEST. Data showed no differences between conditions for any of the abovementioned endocrine markers, but GH and TEST increased above baseline levels for TRAD only. The authors concluded that despite the lack of statistically significant differences between protocols, TRAD caused a greater hormonal disruption than AAPS.

To summarize, the collective evidence is heterogeneous, but results generally indicate that markers of anabolism, catabolism, and exercise-induced muscle damage are higher following supersets compared with TRAD. However, the practical importance of these findings may be limited, as the acute hormonal response to RT likely does not contribute to long-term hypertrophic and strength adaptations (100,153).

Perceptual Measurements: Ratings of Perceived Exertion, Discomfort, and Enjoyment

A variety of perceptual scales have been used during RT sessions, including exercise enjoyment scales (EESs) (3), RPE (10), rating of perceived discomfort (RPD) (116), and session displeasure/pleasure (sPDF) (60). Measurements of RPE and RPD provide insight into proximity to momentary failure (53) and physiological stress (116), respectively. In addition, measurements of EES and sPDF may indicate potential for long-term exercise adherence (3,60). Thus, the perceptual responses to superset training are a worthy topic of discussion.

Perhaps the most comprehensive perceptual measures study was conducted by Andersen et al. (3), who compared the effects of TBSS and TRAD on session-RPE, RPD, sPDF, and EES in a mixed sample of previously trained lifters (15 women, 14 men). The results showed that session-RPE and RPD were significantly higher during TBSS compared with TRAD, while sPDF (i.e., more pleasure) trended to be higher during TBSS ($p = 0.059$). By contrast, EES did not differ between conditions. When asked which training session they preferred, 62% of subjects chose TBSS while 38% chose TRAD. In short, Andersen et al. (3) demonstrated that effort and discomfort are greater during TBSS, but the majority of lifters favored this style of training over TRAD. These findings were corroborated by Weakley et al. (151), who reported that session-RPE was significantly greater following TBSS (6.8 AU) compared with TRAD (4.4 AU). Years later, the same researchers demonstrated that session-RPE was greater following RSS and TBSS compared with TRAD, while no differences were observed between RSS and TBSS (152). Neto et al. (102) also reported significantly higher set-by-set RPE during TBSS compared with TRAD, but median values were 8–10 AU for each set under both conditions.

Elsewhere, the evidence is mixed in studies that compared RSS and TRAD. For example, Realzola et al. (115) used the 6–20 Borg Scale and reported that average RPE was significantly greater during RSS (12.1 AU) compared with TRAD (9.6 AU). These results echoed Sabido et al. (125), who used a 0–10 scale, and showed that session-RPE was significantly greater following RSS (8.4 AU) vs. TRAD (7.2 AU). Opposite outcomes were observed by Fink et al. (37), who reported that session-RPE did not differ between RSS and TRAD (values not reported). As previously noted, the combination of a high-repetition TRAD protocol (i.e., 20–60 reps/set) with short RIs (i.e., 60 seconds) and the inclusion of detrained/untrained lifters may explain why the data from Fink et al. (37) are consistently different from other RSS vs. TRAD studies.

Two studies provided set-by-set RPE data during AAPS, RSS, and TRAD. De Souza et al. (29) reported that RPE increased between sets 2 and 1, and sets 2 and 3, for BP and SR during AAPS, RSS, and TRAD. Data also revealed that RPE during SR was significantly greater for RSS compared with TRAD (set 2) and AAPS (set 3). No differences were observed between conditions for any set of BP. Conflicting results were achieved by Paz et al. (109), who concluded that set-RPE did not differ between AAPS, RSS, or TRAD for any set or exercise (i.e., 7–8 AU for all). Differences between these studies are likely explained by training volume and duration, as De Souza et al. (29) used 2 exercises while Paz et al. (109) used 6 exercises. Indeed, performing sets close to momentary failure, which took place in these studies, may result in higher RPE values irrespective of the selected training configuration.

In general, the literature indicates that perceived exertion is greater during RSS and TBSS when compared with TRAD, while differences are rarely found between AAPS and TRAD. However, it is difficult to provide a clear evidence-based recommendation because studies have varied in the type of scale used (e.g., 6–20 vs. 0–10 RPE), when the data were collected (e.g., immediately after a set, immediately after a session, 15 minutes after a session), set configurations compared (e.g., AAPS, RSS, TBSS, TRAD), and training parameters (e.g., number of exercises, proximity to failure, relative intensity).

The Effect of Rest Interval Duration During Superset Training

An RI is defined as the duration of time allotted between sets and exercises during an RT session (96). Acutely, RI duration impacts metabolic stress (123), repetition performance (144), TVL (54,55), and power production (114). Chronically, RI duration influences skeletal muscle hypertrophy (78) and strength (131). In the context of supersets, 2 RIs must be considered: the time between consecutive exercises during a superset, and the time between consecutive supersets.

To our knowledge, 2 studies have assessed the effect of RI duration between consecutive exercises during a superset. Maia et al. (82) compared the effects of several between-exercise RIs on KE performance during an RSS pairing of KF and KE. There were 6 experimental conditions: KE only, KF + KE with minimal rest, KF + KE with 30 seconds of rest, KF + KE with 60 seconds of rest, KF + KE with 180 seconds of rest, and KF + KE with 300 seconds of rest. It was discovered that minimal, 30-second, and 60-second RIs led to significantly greater repetition performance than 180- and 300-second RIs. Congruently, muscle activation, as measured by EMG, was greater for minimal and 30-second RIs compared with all other conditions. These results suggest that RSS pairings should be separated by 0–60 seconds to maximize repetition performance and muscle activation. However, this study used only 1 set for each exercise, which limits the ecological validity and applicability of the results.

Zhao et al. (161) compared the combined effect of between-exercise and between-superset RIs on bent-over row (BOR) and BP performance. For 1 condition, consecutive sets of BOR and BP were separated by 60 seconds, meaning that approximately 150 seconds of rest was provided before the execution of the same exercise (i.e., AAPS). During the other condition, consecutive sets of BOR and BP were performed back-to-back with minimal rest before taking a 120-second RI (i.e., RSS). Five supersets were performed during each condition for a total of 10 working sets. Data showed that BLC, fatigue index, repetition performance, and TVL did not differ between conditions, but RPE was significantly higher during RSS. The collective findings of Maia et al. (82) and Zhao et al. (161) suggest that between-exercise RIs should be 0–60 seconds during superset training. For context, both studies included young men with previous RT experience, so effects on other populations are currently unknown.

Three studies have fixed the between-exercise RI while comparing the effect of RIs between consecutive supersets. Maia et al. (83) had physically active men with RT experience complete sets of BP and SR with minimal rest before taking a 120- or 240-second RI between supersets. Three supersets were performed during each condition for a total of 6 working sets. The results indicated that repetition performance and set-by-set RPE (0–10 scale) did not differ between conditions for either exercise. By contrast, the fatigue index was significantly greater during the 120-second RI condition. The authors concluded that 120- and 240-second RIs are viable options for maximizing training volume, but fatigue may be higher during the former condition.

With a sample of untrained male subjects, Cardoso et al. (17) fixed the between-exercise RI at 60 seconds and compared the effect of 0-second, 60-second, and 120-second RIs between consecutive supersets. Four supersets of KF and KE were completed (8 total working sets) during each condition. Muscle activation and fatigue index did not differ between RIs. However, total work and peak torque decreased during the 0-second and 60-second RI conditions, which was not observed when 120-second RIs were provided. The ecological validity of this study should be considered, as exercises were completed on an isokinetic dynamometer (i.e., BioDex), and it is unlikely that a strength coach would prescribe a between-superset RI that is shorter than a between-exercise RI (e.g., 0 vs. 60 seconds).

Behenck et al. (7) fixed the between-exercise RI at 10 seconds and evaluated the effects of 4 between-superset-RI conditions—60, 120, 180 seconds, and self-selected—in a sample of resistance-trained men. Three sets of 2 superset pairings were completed (BOR + BP; lat pulldown + shoulder press) for a total of 12 working sets. Repetition performance, session duration, and TVL followed a dose-response relationship in which 180 seconds > 120 seconds > 60 seconds. Self-selected RIs (avg = 146 seconds) were superior to 60-second RIs for repetition performance and TVL, but did not differ from 120-second and 180-second RIs. The self-selected RI session duration was longer than 60 seconds, shorter than 180 seconds, and did not differ from 120 seconds. To balance training volume and efficiency, the authors concluded that self-selected and 120-second RIs may be better options than 60-second and 180-second RIs. Taken together, the literature indicates that between-exercise RIs should be 0–60 seconds while between-superset RIs should be 120–150 seconds. As highlighted by Iversen et al. (63), longer RIs that resemble AAPS more than RSS can be applied to decrease the physiological and psychological strain for relatively untrained lifters or for those who simply do not tolerate metabolic stress well. Indeed, there is evidence that people can make marked hypertrophic and strength adaptations when RIs are systematically reduced over time (30), a strategy that could be applied to superset configurations (Table 1).

Chronic Effects of Agonist-Antagonist Paired Sets, Reciprocal Supersets, and Total-Body Supersets

Agonist-Antagonist Paired Sets Versus Traditional Resistance Training

Robbins et al. (117) randomly assigned 15 resistance-trained men to AAPS ($n = 8$) and TRAD ($n = 7$). The training programs took place 2 $d \cdot wk^{-1}$ for 8 weeks. Depending on the training session, subjects performed 3–6 sets with 3–6 RM loads for BP and BPull with an AAPS or TRAD configuration. Both groups also performed 1–4 sets of 4–6 BThrow with 40% of 1RM. After the intervention, the results indicated that both programs similarly increased BP 1RM (+4.5–5.1 kg), BPull 1RM (+2.6–4.5 kg), BP throw height (+2.7–8.6 cm), peak velocity (0.2–0.3 $m \cdot s^{-1}$), and peak power (+230–274 W). The AAPS sessions were much more efficient, as these subjects logged a total training duration of 4.5 hours compared with 10.1 hours for TRAD. This study provides evidence that AAPS configurations can be applied to athletes and general population clients who want to use superset configurations that are geared toward developing strength and power. Specifically, the utilization of heavier external loads (3–6 RM), a ballistic exercise (BP throw), and sufficient RIs (120 seconds between agonist/antagonist exercises; 240 seconds between agonist/agonist exercises) resembles power/strength training more than traditional bodybuilding. Readers should consider that these results were sustained in trained, male lifters, only 2 exercises were applied, and lower-body musculature was not trained

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Table 1

A brief description of the methodologies for studies that compared the acute effects of agonist-antagonist paired sets (AAPSs), reciprocal supersets (RSSs), total-body supersets (TBSSs), and traditional resistance training (TRAD).*

Study	Subjects	Training	Volume	Load	Rest intervals	Effort	Exercises
Andersen et al. (3)	Active women ($n = 15$) and men ($n = 14$) with >1 y of RT experience	TBSS; TRAD	3 × fail for each exercise	9RM	120 s	Momentary failure	DL, BP, SQ, BPull, CF, TE, RF, BC
Baker and Newton (5)	20 male rugby players with >1 y of RT experience	AAPS; TRAD	1 × 8 BPull; 2 × 5 BP	50% 1RM	180 s	Not specified	BPull, BP
Behenck et al. (7)	18 active men with >1 y of RT experience	RSS	3 × fail for each exercise	10RM	60, 120, 180 s, and self-selected	Momentary failure	BPull, BP, LPD, SP
Bentes et al. (9)	13 active men with >5 y of RT experience	RSS; TRAD	3 × fail for each exercise	10RM	120 s	Momentary failure	BP, LR, KE, KF, LPD, SP
Cardoso et al. (17)	50 active men w/o RT experience	RSS	4 × 10 for each exercise	Max effort at $60^{\circ}\cdot s^{-1}$ on isokinetic dynamometer	No rest, 60 s, and 120 s	Not specified	KE, KF
Carregaro et al. (18)	14 active men w/o RT experience	RSS; TRAD	3 × 10 for each exercise	Max effort at $60^{\circ}\cdot s^{-1}$ on isokinetic dynamometer	60 s	Not specified	KE, KF
Carregaro et al. (20)	24 active men w/o RT experience	RSS; TRAD	4 × 10 for each exercise	Max effort at $60^{\circ}\cdot s^{-1}$ on isokinetic dynamometer	60 s	Not specified	KE, KF
Ciccone et al. (22)	20 active men with >1 y of RT experience	TBSS; TRAD	3 × 4 for each exercise; 1 × fail for final set of each exercise	80% 1RM for each exercise	50 s for TBSS; 180 s for TRAD	Not specified for first 3 sets; momentary failure for 4th set	SQ, BP, BPull
De Souza et al. (29)	10 active men with >1 y of RT experience	AAPS; RSS; TRAD	3 × fail for each exercise	8RM	120 s for AAPS and TRAD; 180 s for RSS	Momentary failure	BP, SR
Fink et al. (37)	Active men ($n = 13$) and women ($n = 12$) w/o RT experience	RSS; TRAD	3 × fail for each exercise	30–40 RM; bands that corresponded w/~50% 1RM	60 s	Momentary failure	BC, TE
Peña Garcia-Orea et al. (110)	19 active men with >6 mo of RT experience	TBSS; TRAD	3 × 15–20% VL for each exercise	55–60–65–70% 1RM	45 s, 180 s	Not specified; controlled by VL	SQ, BP
Kelleher et al. (67)	10 active men with >6 mo of RT experience	RSS; TRAD	4 sets for each exercise	70% 1RM	60 s	Volitional fatigue	BP, BOR, BC, TE, KE, KF
Maia et al. (83)	14 active men with 3.5 y of RT experience	AAPS	3 sets for each exercise	8RM	120 and 240 s	Not specified	BP, SR
Maia et al. (82)	15 active men with 2.7 y of RT experience	RSS; TRAD	1 × fail for each exercise	10RM	None, 30, 60, 180, and 300 s	Momentary failure	KE, KF
Miranda et al. (97)	12 active men with >1 y of RT experience	AAPS; TRAD	3 × 10 for each exercise	85% of 10RM	120 s	Momentary failure	SR, BP
Neto et al. (102)	15 active men with 6.5 y of RT experience	TBSS; TRAD	5 × fail for each exercise	80% 1RM	Self-selected	Momentary failure	Smith-SQ, Smith-BP, SQBP
Paz et al. (108)	13 active men with >5 y of RT experience	AAPS; RSS; TRAD	3 sets for each exercise	10RM	90 s for AAPS and TRAD; 180 s for RSS	Not specified	BP, LPD, IBP, SR, TE, BC
Paz et al. (106)	15 active men with 4.5 y of RT experience	RSS; TRAD	3 × fail for each exercise	8RM	120 s	Momentary failure	BP, SR
Paz et al. (109)	22 active men with 6.2 y of RT experience	AAPS; RSS; TRAD	3 × fail for each exercise	10RM	90 s	Momentary failure	BP, LPD, IBP, SR, BC, TE
Paz et al. (107)	15 active men with 3.5 y of RT experience	RSS; TRAD	3 × fail for each exercise	10RM	120 s	Momentary failure	BP, SR
Paz et al. (105)	15 active men with 3.5 y of RT experience	RSS; TRAD	1 × fail for each exercise	10RM	None; only 1 set completed	Momentary failure	CP, SR
Realzola et al. (115)	Active women ($n = 9$) and men ($n = 9$) with >1 y of RT experience	RSS; TRAD	4 × 12–15 for each exercise	75–80% 10RM	60–120 s for RSS; 90 s for TRAD	Volitional fatigue	DL, LP, CP, SR, LPD, SP
Robbins et al. (120)	18 male athletes with >1 y of RT experience	AAPS; TRAD	3 × fail BPull; 3 × 4 BThrow	4RM BPull; 40% 1RM BThrow	120 s AAPS; 240 s TRAD	Momentary failure for BPull; not specified for BThrow	BPull, BThrow
Robbins et al. (121)	16 male athletes with >1 y of RT experience	AAPS; TRAD	3 × fail for each exercise	4RM	120 s	Momentary failure	BPull, BP
Robbins et al. (118)	16 male athletes with >1 y of RT experience	AAPS; TRAD	3 × fail for each exercise	4RM	120 s AAPS; 240 s TRAD	Momentary failure	BPull, BP
Sabido et al. (125)	17 active men with >2 y of RT experience	RSS; TRAD	6 × 10 for each exercise	70% 1RM	Not specified	Not specified	IBP, SR, LP, KF

Table 1
A brief description of the methodologies for studies that compared the acute effects of agonist-antagonist paired sets (AAPSs), reciprocal supersets (RSSs), total-body supersets (TBSSs), and traditional resistance training (TRAD).* *(Continued)*

Study	Subjects	Training	Volume	Load	Rest intervals	Effort	Exercises
Weakley et al. (151)	14 male rugby players with >6 mo of RT experience	TBSS; TRAD	3 × 10 for each exercise	65% of 3RM	120 s	Not specified	SQ, BP, RDL, SP, BOR, UR
Weakley et al. (152)	10 active men with >2 y of RT experience	AAPS; TRAD	3 × 10 for each exercise	65% of 3RM	120 s	Not specified	BP, SR
Zhao et al. (161)	11 active men with >2 y of RT experience	AAPS; RSS	5 × 8 for each exercise	80% of 1RM	60 s for AAPS; 120 s for RSS	Not specified	BP, SR

*BC = biceps curl; BP = bench press; BThrow = bench press throw; BOR = bent-over row; BPull = bench pull; CF = chest fly; CP = chest press; DL = deadlift; IBP = incline bench press; KE = knee extension; KF = knee flexion; LP = leg press; LPD = lat pulldown; LR = low row; mo = months; RDL = Romanian deadlift; RF = reverse fly; RM = repetition maximum; RT = resistance training; s = sec; SP = shoulder press; SQ = squat; SR = seated row; TE = triceps extension; UR = upright row; VL = velocity loss; y = year.

or assessed. In addition, measurements for hypertrophy and muscular endurance were not measured in this study, and future comparisons of AAPS and TRAD can address this limitation.

Reciprocal Supersets Versus Traditional Resistance Training

Fink et al. (37) recruited 23 young athletes (10 women, 13 men) who had not participated in RT for ≥6 months before enrolling in this study, and subjects were randomly assigned to RSS ($n = 12$) or TRAD ($n = 11$). Programs were performed 3 $d{\cdot}wk^{-1}$ for 8 weeks, and training parameters were matched between conditions: 3 sets to momentary failure for biceps curl and triceps extension, external loads were elastic bands that equated to ~50% 1RM, and 60-second RIs were taken between sets and exercises. Data showed that both groups significantly increased the cross-sectional area of their biceps (0.2–0.3 cm^2) and triceps (0.2–0.4 cm^2) with no difference between them. By contrast, only TRAD increased maximal voluntary isometric contraction (MVIC) for their triceps (+3 $N{\cdot}m^{-1}$) while neither group increased the MVIC for their biceps. Similarly, TRAD significantly improved their close-grip BP 1RM while RSS did not (+3.6 vs. 2.3 kg), and neither group improved their barbell curl 1RM. For muscular endurance, RSS significantly improved repetition performance for close-grip BP (+6.1 reps) and barbell curl (+8.8 reps), but TRAD did not improve either. Thus, for practitioners who use low-load RT, RSS and TRAD can both be used for stimulating hypertrophy, but an endurance-minded client should prioritize RSS over TRAD and vice versa for the strength-minded client. Coaches should note that the training programs used high repetitions (20–60 reps/set), elastic bands, and the exercises trained (elastic band biceps curl and triceps extension) did not match the exercises tested (close-grip BP and barbell curl). In addition, because the subjects were untrained/detrained, the outcomes may not be applicable to lifters with a higher training status.

With a more ecologically valid study design, Burke et al. (16) randomly assigned 50 resistance-trained women and men (consistently trained upper- and lower-body musculature ≥3 $d{\cdot}wk^{-1}$ for ≥12 months) to RSS ($n = 25$) or TRAD ($n = 25$). The specific number of female and male volunteers was not specified. Training took place 2 $d{\cdot}wk^{-1}$ for 8 weeks, and the following exercises were performed with RSS or TRAD configurations: lat pulldown, Smith-BP, seated KF, seated KE, dumbbell bicep curl, and cable triceps pushdown. Both groups completed 4 sets of 8–12 repetitions to momentary failure with a 2:1 second repetition tempo (2 seconds eccentric, 1 second concentric). Rest intervals were 120 seconds between sets and supersets for TRAD and RSS, respectively, and paired exercises were separated by ~20 seconds during RSS. The results indicated that both interventions increased upper- and lower-body muscle thickness (measured at several sites for the biceps, triceps, and quadriceps) and fat-free mass with no differences between RSS and TRAD. Similarly, both interventions improved vertical jump performance, isometric strength, dynamic strength, and muscular endurance. The authors also reported acute data, which demonstrated that TVL was not appreciably different between interventions (RSS = 8,075 kg; TRAD = 7,908 kg), but RSS resulted in greater session-RPE (8.1 vs. 7.2 AU) and shorter training duration (44.4 vs. 69.1 minutes). Thus, in trained lifters, Burke et al. (16) demonstrated that RSS and TRAD similarly improve endurance, hypertrophy, power, and strength. Importantly, RSS stimulated these adaptations with much shorter training sessions. Readers should consider that these results occurred in previously trained lifters, so this protocol should not be directly applied to people with less RT experience.

Total-Body Supersets Versus Traditional Resistance Training

Garcia-Orea et al. (41) recruited 17 resistance-trained men and randomly assigned them to TBSS ($n = 9$) or TRAD ($n = 8$) after pair-matching them based on relative strength. Both groups lifted 2 $d{\cdot}wk^{-1}$ for 6 weeks with matched training variables: exercises (SQ and BP), volume (3 sets), relative intensity (55–70% of 1RM), RIs between like exercises (180 seconds) and set end point (15–20% velocity loss). Both groups similarly improved their BP 1RM (+2.9–5.0 kg), SQ 1RM (+6.8–6.9 kg), and muscular endurance (measured as average velocity during a fatigue test) for BP (+0.05 $m{\cdot}s^{-1}$) with no differences between them. Although statistical significance was not achieved, both groups similarly improved their counter movement jump performance (+1.1–1.4 cm). By contrast, the TBSS group significantly improved muscular endurance for SQ (+0.09 $m{\cdot}s^{-1}$) while the TRAD group did not. Unsurprisingly, the TBSS sessions were significantly shorter than the TRAD sessions. These data indicate that both training styles are effective for increasing muscular strength and power, but TBSS delivers these adaptations in a more time-efficient manner. Coaches should note that the authors matched set end point using velocity loss thresholds, which requires technology that may not be available to every practitioner. In addition, only 2 exercises were used, which may not reflect how most training sessions are organized. Finally, because the subjects in this study were young, resistance-trained men, the outcomes may not be applicable to other populations.

In what may be considered a hybrid of RSS and TBSS, Iversen et al. (63) recruited 26 men ($n = 13$) and women ($n = 13$) between the ages of 18–41 years and randomly assigned them to TBSS (n = 13) or TRAD (n = 13). The subjects had not performed RT for the previous 6 months and were encouraged to live as they normally would while refraining from additional RT. Both groups trained 2 d·wk^{-1} for 8 weeks and performed 3 sets to momentary failure with either a 6RM (2/X s tempo) or 12RM (2/2 seconds tempo) load, depending on the day. The same exercises were performed throughout this study, and the order in which they were performed alternated between sessions (Order 1 = BP → SR → LP → LPD; Order 2 = LPD → LP → BP → SR). Traditional resistance training subjects rested for 150 seconds between each set and exercise, while the TBSS group was provided 150 seconds after the final repetition of the first exercise in the series to finish the second exercise and recover before the next set superset. The researchers reported that a maximum of 30 seconds was provided between the first and second set within each superset. Data revealed that both groups increased 1RM strength for every exercise that was trained/tested. Significant differences were not detected between groups for BP (+19.1–21.5%) and LP (+17.6–19.5%), but TRAD was superior to TBSS for SR (+24.3 vs. 16.5%) and LPD (+20.5–12.6%). Both groups significantly and similarly increased muscle mass (+1.0–1.8%) and decreased fat mass (−4.3 to 5.8%) as measured by bioelectrical impedance analysis (InBody 770). It is noteworthy that the TBSS sessions were completed in half the time of TRAD sessions (17 vs. 34 minutes), meaning that supersets delivered similar results for muscle mass, fat mass, BP 1RM, and LP 1RM in a time-efficient manner. Differences in 1RM for SR and LPD, for which TRAD was superior to TBSS, may be explained by the order in which they were completed within each superset and the training session (128). Together, the research by Garcia-Orea et al. (41) and Iversen et al. (63) suggests that TBSS configurations can improve body composition, local muscular endurance, power, and strength in a time-efficient manner. It is noteworthy that the combined outcomes from these studies indicate that supersets are effective for female and male lifters, both trained and untrained. However, coaches should use caution when applying these protocols to older populations (Table 2).

Applying Superset Training in Practice

Fitting Supersets into a Training Program

It is critical to note that the previously summarized longitudinal studies used supersets for every training session to isolate their potential effects compared with TRAD. However, for application, it is impractical for coaches and trainers to prescribe 6–8 consecutive weeks of superset training. Rather, superset configurations should be considered as a partial method to be applied during particular sessions within a training block for any given program. From a broad perspective, supersets should fit the primary training goals for a mesocycle within a periodized-RT plan. For example, moderate-load, higher-volume supersets, as executed by Burke et al. (16) and Iversen et al. (63), could be reserved for off-season training blocks when primary training goals are hypertrophy and tissue tolerance. By contrast, heavy-load, lower-volume supersets, as applied by Robbins et al. (117), may be used during preseason training blocks when strength and power acquisition become primary training goals. Finally, moderate-load, low-fatigue supersets, as studied by Garcia-Orea et al. (41), may be prescribed for in-season training blocks when athletes attempt to maintain power while having limited time to train. These general guidelines reflect a key recommendation of this review—coaches should perceive supersets as a tool to use within a training session, not as a foundation for an entire training session, especially for trained and/or athletic populations.

From a narrow perspective, superset programs can be used in conjunction with TRAD to serve as 1 piece of a larger training session. For example, an athlete could perform their main exercises with a TRAD configuration (e.g., BP and BOR) while applying RSS for their auxiliary exercises (e.g., bicep curl and triceps extension). As another example, during a total-body training session more broadly focused on strength and power, coaches could blend the concepts of AAPS and TBSS by pairing a lower-body pull (e.g., RDL) with an upper-body push (e.g., BP) while allowing 120 seconds between every set. To summarize, supersets should be perceived as a piece of a training program, not an entire training program unto itself.

Table 2

A brief description of the methodologies for studies that compared the chronic effects of agonist-antagonist paired sets (AAPSs), reciprocal supersets (RSSs), total-body supersets (TBSSs), and traditional resistance training (TRAD).*

Study	Subjects	Training	Volume	Load	Rest intervals	Effort	Exercises
Burke et al. (16)	50 active men and women with >1 y of RT experience	RSS; TRAD	4 × 8–12 reps for each exercise	8–12 RM	120 s	Momentary failure	Smith-BP, LPD, KE, KF, BCTE
Fink et al. (37)	Active men (n = 13) and women (n = 12) w/o RT experience	RSS; TRAD	3 × fail for each exercise	30–40 RM; bands that corresponded w/~50% 1RM	60 s	Momentary failure	BC, TE
Garcia-Orea et al. (41)	17 active men with >6 mo of RT experience	TBSS; TRAD	3 × 15–20% VL for each exercise	55–60–65–70% 1RM	45 s, 180 s	Not specified; controlled by VL	SQ, BP
Iversen et al. (63)	26 women (n = 13) and men (n = 13) with >6 mo of RT experience	TBSS; TRAD	3 × 6–12 reps for each exercise	6 and 12 RM	150 s	Momentary failure	BP, LP, LPD, SR
Robbins et al. (117)	15 active men with >1 y of RT experience	AAPS; TRAD	3–6 × 3–6 BPull; 3–6 × 3–6 BP; 1–4 × 3–6 BThrow	3–6 RM BPull; 3–6 RM BP; 40% 1RM BThrow	120 s AAPS; 240 s TRAD	Momentary failure for BPull and BP; not specified for BThrow	BPull, BP, BThrow

*BC = biceps curl; BP = bench press; BThrow = bench press throw; BPull = bench pull; KE = knee extension; KF = knee flexion; LP = leg press; LPD = lat pulldown; mo = months; RM = repetition maximum; RT = resistance training; s = seconds; SQ = squat; SR = seated row; TE = triceps extension; VL = velocity loss; y = year.

Periodization Considerations for Superset Training

According to Stone et al. (141), periodization is defined as a "logical, sequential, phasic method of manipulating fitness and recovery phases to increase the potential for achieving specific performance goals while minimizing the potential for nonfunctional overreaching, overtraining, and injury." Periodization should not be mistaken for programming, as the former essentially sets the stage for the latter (4,142). In other words, periodization provides macromanagement for training phases and timelines while programming deals with the micromanagement of training variables (e.g., exercise selection, intensity, volume) to build specific physical capacities (4,142). Several applications exist, but the most commonly studied periodization models in the RT literature are block, linear (i.e., traditional), reverse-linear, and undulating (4). Indeed, there is evidence that periodized and nonperiodized training programs similarly increase hypertrophy, but periodized training programs typically yield better outcomes for long-term strength acquisition, especially in previously trained lifters (99). Thus, practitioners should strongly consider periodization when designing RT programs.

Rather than belaboring the nuances of various periodization models, which is outside of the scope of the current review, we will highlight how superset configurations can be included within generalized phases of training that can be applied to any desired periodization model. For example, during the early phases of a general preparatory period, where increasing work capacity is a primary goal, strength coaches can use TBSS to achieve higher training densities. Later in the general preparatory period, where hypertrophy and tissue tolerance are desired outcomes, coaches can apply RSS to maximize metabolic stress while maintaining training volume. When the program transitions to a specific preparatory period and strength becomes a primary goal, coaches can prescribe AAPS to utilize moderately heavy external loads while allowing sufficient RIs between sets. However, during precompetitive and competitive periods, where strength and power become primary training goals, coaches can apply TRAD for primary lifts (e.g., BP) while reserving supersets for accessory movements (e.g., face pulls and lateral raises). This recommendation highlights that when external loads are very heavy (>90% 1RM), supersets may be unsuitable because the demand on the neuromuscular system requires more recovery between sets.

Considerations for Specific Populations

Younger Versus Older. Rest intervals—To our knowledge, superset configurations have not been studied in older populations (i.e., >60 years old), so to make an evidence-based recommendation, we will discuss data from TRAD studies that have compared different RIs. Acute data in older lifters suggest that longer RIs (180 seconds) led to superior repetition performance and TVL compared with shorter RIs (60 seconds) (36), which echoes research conducted in younger lifters (96). However, neuromuscular fatigue may be greater when longer RIs are applied due to greater TUT and TVL completed during the session (65). Interestingly, a training study in older lifters provided evidence that short (60 seconds) and long (180 seconds) RIs led to similar increases in dynamic and isometric muscular strength, likely because TVL was matched between conditions (64). To that end, a recent study in younger lifters demonstrated similar hypertrophy and strength between 60- and 180-second RIs when TVL was matched by increasing set volume in the former condition (78). Collectively, acute and chronic data from TRAD studies indicate that RI durations similarly affect younger and older lifters. Thus, when applied to superset configurations, RIs should be dictated by an individual's preference and tolerance to metabolic stress with the aim to minimize discomfort and maximize program adherence.

Recovery—There is evidence that older lifters experience greater delayed onset muscle soreness than their younger counterparts, but the physiological mechanisms are unclear. Moreover, it remains ambiguous whether older lifters experience greater decrements in physical function during the days following an acute bout of RT, and data that have compared markers of exercise-induced muscle damage between older and younger lifters are conflicting (52).

Others have reported age-related differences in recovery from RT wherein older lifters have diminished recovery capacity compared with younger lifters. The proposed mechanisms are speculative, but it is possible that reduced satellite cell proliferation, decreased collagen turnover in the extracellular matrix, increased oxidative stress, increased inflammation, and deficient specialized pro-resolving lipid mediators explain why older lifters have diminished recovery capabilities (76). With this information at hand, it seems that superset configurations should be used sparingly for older lifters, especially when their experience with RT is limited. Indeed, an abundance of evidence indicates that single-set and multiple-set TRAD programs increase functional task performance, hypertrophy, power, and strength in older populations (38), so the application of supersets to them may be unnecessarily challenging. However, if coaches wish to use superset configurations with their older clientele, it is prudent to begin with lower external loads, longer RIs between paired exercises, and fewer working sets. If the client responds well to these initial sessions, external load and training volume can be systematically increased while RIs can be systematically decreased over time.

Trained Versus Untrained. Windows for adaptation should be considered, as untrained lifters make larger improvements in hypertrophy and strength compared with trained lifters following TRAD interventions (2). Thus, for the untrained or novice lifter, advanced training techniques, like supersets, may be superfluous, as simple, single-set TRAD programs have improved body composition, hypertrophy, power, and strength in these populations (6,61). However, it should be noted that superset training programs have stimulated increased hypertrophy and strength in trained (16) and untrained (63) populations, providing evidence that advanced training paradigms can be applied to people with lesser training histories. So, for those who wish to use superset paradigms with untrained-to-moderately trained clients, several common-sense adjustments can be implemented: lower set volume, longer RIs within supersets and between supersets, and terminating sets shy of momentary failure. External loads can be manipulated and progressed as well, but using relative intensities that lead to 8–12 reps/set seems sufficient. As the untrained-to-moderately trained client adapts to these initial sessions, strength coaches can provide overload by increasing set volume and relative intensity while decreasing RIs within and between supersets. They can also encourage the client to push their sets closer to momentary failure. By contrast, trained lifters may be able to tolerate higher external loads and training volume while pushing sets near momentary failure with shorter RIs. However, even for higher-trained individuals, it is best practice to reserve superset configurations for auxiliary exercises that are more localized (e.g., KE + KF; biceps curl + triceps extension).

Female Versus Male. Sex differences may also be considered when choosing set configurations that lead to greater metabolic stress. In general, women tolerate metabolic stress better than their male counterparts. This can be explained by their higher type I muscle fiber ratios, larger type I muscle fibers, and reduced glycogen utilization during high-intensity activity (96). In line with these physiological differences, there is evidence that women produced lower BLC values compared with men during an acute-circuit-training intervention (86), but it is unclear whether this was driven by differences in anaerobic metabolism, body mass, or fat-free mass. Similarly, Millender et al. (96) reported that female lifters sustained significantly higher repetition volume with 180-second RIs compared with 60-second RIs during repeated sets of CP and LP. This finding echoes RI studies conducted on men and casts doubt on the assumption that female lifters would outperform male lifters when faced with shorter RIs imposed by supersets.

From an acute standpoint, data from Realzola et al. (115) are most germane because they compared the physiological stress of RSS vs. TRAD in female and male subjects. In short, men had significantly greater aerobic EE, anaerobic EE, BLC, and EPOC than women during the RSS condition (115). However, RPE did not differ between sexes, which suggests that the perceived difficulty of the session was not influenced by differences in physiological stress (115). Because the research in this area is sparse, we are reluctant to advise strength coaches to select any particular training configuration based solely on an athlete's sex. Prior training experience may be a better guide, as a man who consistently performs circuit training may tolerate supersets better than a female powerlifter, and vice versa. From a chronic perspective, readers should also consider that training studies with mixed samples of women and men have reported that RSS (16,37) and TBSS (63) significantly increased endurance, hypertrophy, power, and strength.

Exercise Selection

Multiple-joint and single-joint exercises are effective for hypertrophy (124) and strength (43), and both could be included in superset training sessions. It has not been studied directly in the literature, but practitioners could pair a multiple-joint exercise (e.g., leg press) with a single-joint exercise (e.g., prone KF) to reduce the metabolic load of each individual superset (63). Similarly, coaches could instruct their athletes to perform multiple-joint exercises with a TRAD configuration (e.g., back squat and BP) while supersetting the single-joint exercises (e.g., calf raise and bicep curl) within the same session. This specific recommendation reflects that supersets are not appropriate for heavy, bilateral, compound lifts—such as squats, deadlifts, and Olympic movements—due to safety and fatigue concerns. When developing a training session, we recommend reserving supersets for accessory and/or isolation exercises that target smaller muscle groups (e.g., biceps curl and triceps extension) or trunk musculature (e.g., ab wheel rollouts and back extension).

In addition, unilateral and bilateral exercises lead to similar muscular adaptations (158) and should be selected based on time constraints (65) and desired transference to athletic performance (85). When applying supersets to unilateral training, lifters could perform a push with the right arm (e.g., landmine press) followed immediately by a pull with the left arm (e.g., dumbbell row) before taking a longer RI (e.g., 60–120 seconds) and repeating the exercises on the opposite side. Finally, machine- and free-weight exercises are both effective for hypertrophy, strength, and power (51) and should be chosen based on comfort, experience, and desired transfer to performance (85). However, machine exercises may lead to less physiological strain than free-weight exercises (136), thus presenting a potentially more tolerable option for supersets. Conceivably, coaches could prescribe free-weight exercises with a TRAD configuration and machine-based exercises as supersets within the same session. However, from a practical perspective, it may be difficult for a general population client to claim multiple machines in a crowded gym at once, so convenience should also be considered.

Exercise Order

Practitioners must consider 2 levels of exercise order when prescribing supersets: the order of supersets within the training session and the order of exercises within each individual superset. Muscular adaptations are superior for the exercises performed earliest in the training session, likely because their execution is enhanced due to lower levels of cumulative fatigue (137). In addition, as postulated by Burke et al. (16), any perceivable potentiation effect of superset training (i.e., pre-fatiguing the antagonist musculature to increase agonist force production) may be nullified when multiple superset pairings are completed in the same training session. Therefore, for application, the most important exercises should be performed first in the training session, the amount of supersets per session should be limited, and perhaps supersets should be performed later in the training session to serve as a metabolic finisher to the workout (i.e., TRAD configuration for exercises performed first/early in the session). Pertaining to the order in which exercises are completed within 1 superset, it is possible that the first exercise potentiates performance in the second exercise (119), but this is not a universal finding (9), and only applies to AAPS and RSS configurations. Regardless, to balance the opportunity for potentiation, coaches can simply flip the order of exercises within supersets between sessions (e.g., BP + SR and SR + BP). In contrast to potentiation, it is also possible that performance in the second exercise within the superset is diminished by an accumulation of central fatigue during the first exercise (22,157). Thus, coaches may also consider placing the most important exercise first in a series when supersets are performed.

Frequency

Hypertrophy and strength increase with training frequencies that range from 1 to 3+ d·wk^{-1} (48,133), and weekly training volume may have a greater effect than training frequency (133). This implies that the particular training split (e.g., upper/lower or push/pull/legs) should be decided by preference and time constraints. Pertaining to programs that have explicitly applied supersets, studies reviewed in this article effectively stimulated endurance, hypertrophy, power, and strength with training frequencies of 2–3 d·wk^{-1}. Considering the physiological demand of these sessions, practitioners may take caution by programming supersets 1 d·wk^{-1}, and emphasizing TRAD for the remainder of their client's weekly training sessions.

Volume

Multiple-set programs are consistently more effective than single-set programs (70), and there are dose-response relationships between weekly set volume and hypertrophy (132) and strength (113). The training studies reviewed in this article stimulated a variety of neuromuscular adaptations with 3–6 working sets for each superset pairing, so this may serve as a sufficient starting point for practitioners to apply. As a general recommendation, hypertrophic and strength adaptations may be maximized when each major muscle group is stimulated by ≥10 sets/week, but sets should be prescribed based on each individual's current weekly set volume. The individualized-volume approach to provide systematic overload has proven effective in 2 recent studies (33,127).

Relative Intensity

Recent evidence has indicated that hypertrophy increases at relative intensities of ~30–90% 1RM, which corresponds with ~3–35 reps/set (134). Higher relative loads (>80% 1RM) are generally superior for strength, while moderate relative loads (40–70% 1RM) are generally superior for power (146). Muscular endurance increases at a variety of relative intensities (e.g., 30 and 80% 1RM) and may be specific to the external load and repetition range that is trained (98). The majority of studies discussed in this review applied relative loads that resulted in 4–15 reps/set, but specific loads and repetition ranges can be selected based on goals for a particular training block (99). For example, training studies reviewed in this article demonstrated that strength and power increased with 3–6 RM loads (117), hypertrophy increased with 8–12 RM loads (16), and endurance increased with loads that corresponded with 20–60 reps/set (37). This provides flexibility for practitioners to incorporate heavy, moderate, and light days into a microcycle or mesocycle of training. However, when coaches are designing strength/power programs with very-heavy loads (e.g., >90% 1RM), superset configurations are not recommended due to greater recovery demands between consecutive sets.

Repetition Duration and Tempo

Meta-analytical data indicate that hypertrophy increases with repetition durations of 0.5–8 seconds (129) while strength increases with fast (<2 seconds), moderate (2–4 seconds), and slow (>4 seconds) durations (27). For power, 1 study demonstrated that maximal-intent concentric phases are more effective than smooth concentric phases (44), but another study reported that slower concentric phases (e.g., 2 seconds) are also effective (95). To address hypertrophy, power, and strength in the same session, practitioners could instruct their clients to control the eccentric phase for 2–3 seconds and perform the concentric phase with maximal intent (87).

Rest Intervals

Research has suggested that hypertrophy and strength increase with a variety of RIs (e.g., 30–240 seconds) (47,54), but moderate RIs (e.g., 60–120 seconds) are also effective (139), and will shorten session duration (62). Thus, when hypertrophy and strength are the primary training goals, practitioners could separate consecutive exercises during a superset by a minimal to 60 seconds and allow 120 seconds RIs between consecutive supersets, but self-selected RIs between supersets should also be considered. Longer RIs (>180 seconds) may be beneficial when practitioners are programming for power training (156). Under these circumstances, the AAPS configuration by Robbins et al. (117) may be the best solution, where 120 seconds of rest is allotted between every set, so 240 seconds of rest is taken between sets of the same exercise. In line with our recommendation for training with very-heavy loads (>90% 1RM), it is likely best to use TRAD configurations, which would include the application of longer RIs (>180 seconds) between consecutive sets of the same exercise.

Set End Point

Failure and nonfailure training are both effective for hypertrophy and strength (49), and recent evidence has shown that training 1–3 repetitions shy of failure leads to similar hypertrophy and strength as failure training (127). When hypertrophy and strength are the desired adaptations, effort should be high (e.g., an RPE of 8), but instruct clients to leave 1–3 repetitions in reserve during superset training. By contrast, training to failure may be detrimental to long-term power acquisition (66), and VL research has shown that lifters can increase their power with considerably modest VL (e.g., 15–25%) (104). When power is the primary goal, the training study by Garcia-Orea et al. (41) is informative, because subjects increased upper- and lower-body power by performing TBSS with VL thresholds of 15–20%. Depending on the relative intensity that is used, this corresponds with leaving ~50–70% of total repetitions in reserve (45). In other words, significant adaptations can occur despite terminating sets well before momentary failure.

Safety Considerations

As previously discussed, supersets impose greater physiological stress than TRAD, and coaches should be wary of the potential for adverse events such as nausea, overtraining syndrome, and rhabdomyolysis. For example, Burke et al. (16) reported that several subjects in the RSS group experienced symptoms of nausea ($n = 17$) and vomiting ($n = 3$) during/after training sessions. These findings reflect that symptoms of acute overload generally include nausea, vomiting, dizziness, confusion, or loss of coordination. If a lifter is demonstrating these symptoms, the coach should stop the session and modify training to reduce the physiological stress imposed by the RT session. In their discussion, Burke et al. (16) provided several recommendations to improve a lifter's tolerance to superset configurations, including training at higher repetitions in reserve, reducing set volume, performing fewer exercises, and lengthening RIs between supersets and each exercise within the superset. These guidelines may be most critical for those with minimal training experience and those who are relatively new to superset training.

Coaches should also beware of nonfunctional overreaching—intense training that leads to stagnation and sustained performance decline—and overtraining syndrome—a prolonged maladaptation that disrupts hormonal, biological, and neurological regulatory mechanisms—when prescribing supersets (91). Common signs and symptoms of overtraining include, but are not limited to, declining performance, persistent fatigue, apathy, excessive soreness, insomnia, lack of mental concentration, and decreased body mass (91). Of note, markers of nonfunctional overreaching and overtraining syndrome have not been directly studied in the superset literature, but coaches can take several precautions to prevent them from occurring with their clients. Simple lifestyle strategies may include promoting the importance of sleep, adequate hydration, and consuming a well-balanced diet, especially ingesting carbohydrates and protein before and after training sessions (91). From a training perspective, coaches can apply the abovementioned adjustments for preventing nausea/vomiting (e.g., training at higher repetitions in reserve), reduce the frequency at which supersets are performed, and allow 48–72 hours of recovery between sessions that include supersets.

Finally, exertional rhabdomyolysis (ER)—the breakdown of striated muscle from performing exercise—leads to elevated levels of muscle proteins in the blood (i.e., myoglobin), which may lead to potentially life-threatening conditions such as acute renal failure, blood clotting, and hyperkalemia (74). Typical risk factors for developing ER appear to be low baseline fitness levels combined with repetitive movements that involve eccentric contractions (e.g., pushups or squat jumps) performed beyond a point of fatigue that would compel an individual to naturally stop exercise (74). Moreover, the triad of ER symptoms includes reddish brown urine, muscular pain, and weakness (74). To our knowledge, ER has not been reported or studied in the superset literature, but the risk for ER is higher under high-density loading schemes, such as superset training, that involve training larger muscle groups (e.g., squats, deadlifts, and lunges). Therefore, coaches can take several common-sense approaches to avoid causing ER with their clients that include avoiding training to failure, reducing set volume, decreasing external loads, reserving supersets for smaller muscle groups, and prolonging RIs between sets and exercises. Above all, to avoid exposing a lifter to unaccustomed training loads that may lead to ER, it is advisable to identify how much RT your client is currently doing and prescribe training frequencies and volumes to gradually provide overload. Much like the recommendations for avoiding overtraining, it is important for coaches to encourage their athletes to hydrate before, during, and after training sessions.

Limitations and Directions for Future Research

The primary limitation of this article is that a narrative review was conducted in lieu of a systematic review or meta-analysis. In a similar vein, the snowballing technique used to gather references makes it possible that some pertinent studies to the topic may have been unintentionally missed. In addition, we chose to review AAPS, RSS, and TBSS studies and excluded other superset (e.g., agonist-agonist) and high-training-density modalities (e.g., tri-sets and circuits). However, this allowed for the study to be narrowly focused on a particular area of the literature, leading to specific insights for practitioners and researchers. Based on our review of this literature, the acute response to AAPS, RSS, and TBSS has been well researched, but the overwhelming majority of studies have been conducted on young, trained, male lifters. Future acute studies could expand their scope to include older, less-trained, and female subjects. In fact, comparisons between sexes and across age groups are underexplored in the superset literature and present several opportunities for novel research.

There are, however, several opportunities for training studies. For instance, to date, there is only 1 published AAPS training study, and it only implemented 2 exercises for the upper body. Future AAPS studies could include 4–6 exercises that concurrently target upper- and lower-body musculature, thus presenting a hybrid of AAPS and TBSS. In addition, training studies for AAPS, RSS, and TBSS have applied an "all out" approach when comparing these set configurations to TRAD. Future studies can compare a combination of supersets + TRAD to TRAD, whether the combination is within the same session (e.g., TRAD for main lifts, supersets for auxiliary lifts) or within the same week (e.g., TRAD on Monday, supersets on Thursday). Furthermore, minimum-effective RT sessions and dose-response relationships between set volume and neuromuscular adaptations are commonly studied in the RT literature, but such research has not been applied to supersets. A future training study could compare the effects of different volumes of superset training (e.g., 1 vs. 2 vs. 4 supersets) on hypertrophy, power, and strength. The health benefits of TRAD, which include reduced hypertension and improved insulin sensitivity, are well-established (154,155), but the long-term health effects of superset configurations are unknown. Therefore, researchers could evaluate the longitudinal effects of superset training on people with chronic diseases such as dyslipidemia, hypertension, and type 2 diabetes. Finally, and similar to gaps in the acute data literature, future superset training studies can target populations that are generally underrepresented, such as female athletes, or compare longitudinal outcomes between younger (e.g., 18–35 year old) and older (e.g., >60 year old) lifters.

In conclusion, RT confers a variety of health and fitness benefits, but the overwhelming majority of adults do not consistently include RT sessions in their exercise routines. Several barriers to RT exist, but the perceived lack of time is often cited. Superset configurations, such as AAPS, RSS, and TBSS, offer time-efficient alternatives to TRAD. The research in this area is vast and mixed, but acute data have generally demonstrated that muscle activation and training volume do not differ between supersets and TRAD. Exceptions do exist, but power production is typically greater during TRAD while training density, hormonal responses, BLC, EE, HR, and oxygen consumption are typically greater during supersets. Longitudinal studies have shown that supersets and TRAD lead to similar and significant adaptations for endurance, hypertrophy, strength, and power. When training density is considered, we tentatively conclude that supersets deliver similar adaptations as TRAD in a more time-efficient manner. Practitioners have several effective superset programs to choose from when prescribing RT for their athletes and clientele, but supersets should be used as a tool within a training session rather than an entire training session or program unto itself.

Practical Applications

Superset configurations offer a time-saving alternative to TRAD without compromising volume, and the resulting increase in training density leads to greater physiological (e.g., BLC, HR, $\dot{V}O_2$) and psychological stress (e.g., RPE, RPD). Thus, strength and conditioning professionals should be aware of the metabolic cost of superset training sessions and take special precautions when prescribing them to their clients and athletes. For example, reducing set volume, decreasing the number of exercises, terminating sets with higher repetitions in reserve, and increasing RI duration may reduce the stress imposed by superset training. These adjustments could be most critical for less-experienced trainees or for those who are new to superset training. Longitudinal studies suggest that superset configurations stimulate similar increases in endurance, hypertrophy, power, and strength as TRAD, but strength and conditioning professionals should consider the external validity of these findings. Specifically, an entire training session, microcycle, or mesocycle of training will likely not be comprised of supersets, so practitioners should view supersets as a tool to employ within the fabric of a larger training program. This can be accomplished in many ways, such as performing 1 superset during an otherwise TRAD training session, or periodically programming multiple supersets within a training session, provided that it serves the primary goal of that particular training block. Above all, it seems that superset training is best suited for moderate-load, endurance-focused training, and TRAD should predominate when very-heavy loads are used (>90% 1RM), and maximizing strength is the primary goal. For best practice, we encourage coaches to reserve superset configurations for auxiliary exercises that target smaller muscle groups after main strength and power exercises have been completed.

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