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Practical Application of Traditional and Cluster Set Configurations Within a Resistance Training Program

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ABSTRACT

Altering set configurations during a resistance training program can provide a novel training variation that can be used to modify the external and internal training loads that induce specific training outcomes. To design training programs that better target the defined goal(s) of a specific training phase, strength and conditioning professionals need to better understand how different set configurations affect the training adaptations that result from resistance training. Traditional and cluster set structures are commonly implemented by strength and conditioning professionals as part of an athlete's resistance training program. The purpose of this review is to offer examples of the practical implementation of traditional and cluster sets that can be integrated into a periodized resistance training program.

INTRODUCTION

The application of variation to specific aspects of a resistance training program, such as altering training intensity or volume, exercise selection, and order, as well as the length of the rest interval between sets (i.e., interset rest interval), can alter the physiological adaptations to resistance training (58). One of the training variations that is often overlooked, but has recently become more commonly used, is the manipulation of the set structure (38,52). In general, 2 types of set structures are implemented by strength and conditioning professionals as part of an athlete's resistance training program: a traditional set and a cluster set (35,36). Traditional sets can be defined as a set structure where repetitions are performed continuously (i.e., no intraset or inter-repetition rest interval) with a preplanned interset rest interval (52,117) (Figure 1). On the other hand, cluster sets are an extended set structure where repetitions are performed with intraset or inter-repetition rest intervals that are placed within the set (121) (Figure 1). To appropriately apply both types of set configurations, strength and conditioning professionals should contextualize the athlete's training goal and incorporate set manipulation strategies into their resistance training programs to target specific training outcomes that align with the specific goals outlined within the periodized training plan. As such, the purpose of this review is to offer examples of how to integrate traditional and cluster sets into a resistance training program and explain how to align the use of these set structures with key phases of a periodized training plan.

Although cluster sets are an effective method for maintaining movement velocity across a series of sets, one often noted issue with this programming strategy is that the total time of the session can be extended (119). Owing to the reality that the time allotted for strength training is often limited in many applied settings, several researchers have recommended an alternative that they refer to as the rest-redistribution method (117). The rest-redistribution method can be applied by (a) redistributing the rest time between sets to include the intraset or inter-repetition rest intervals and/or (b) reducing the number of repetitions per set and increasing the total number of sets while leaving the overall

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KEY WORDS:
set manipulation; training variation; rest interval; inter-repetition rest interval; intraset rest interval

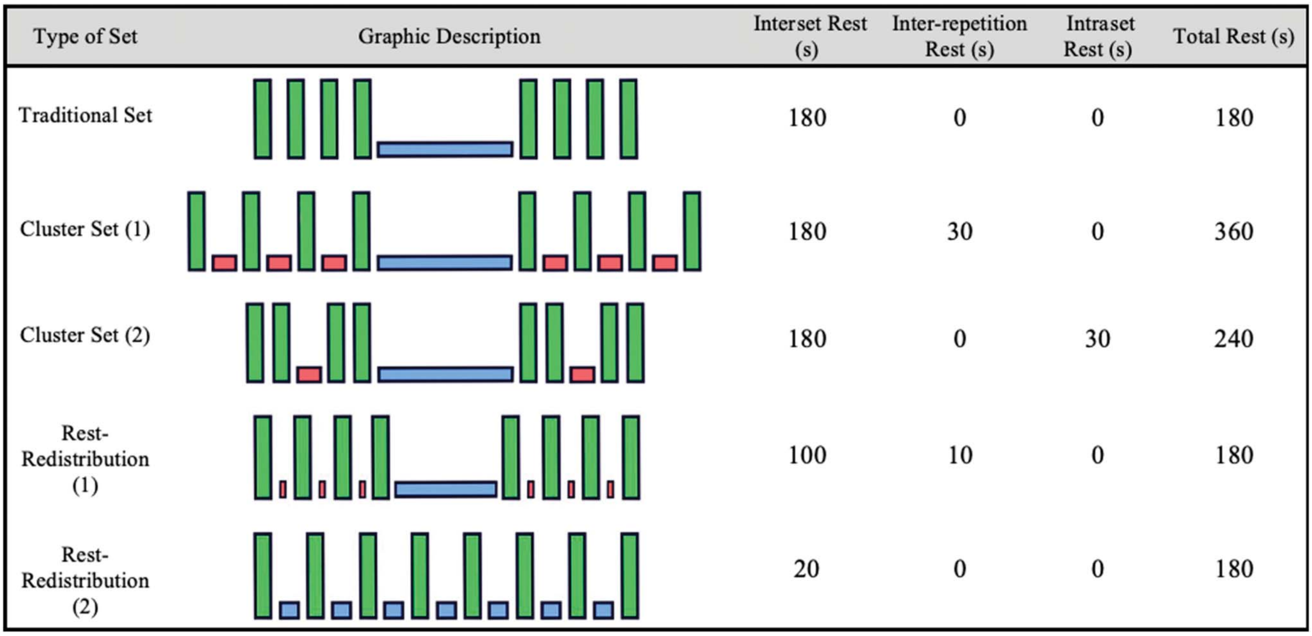

Figure 1. Two sets of 4 repetitions with 5 different set configurations. Green bars indicate repetitions performed in a set. Blue bars indicate interset rest intervals, whereas red bars indicate inter-repetition or intraset rest intervals.

rest unchanged (117) (Figure 1). Although rest-redistribution and cluster sets are often referred to interchangeably in the scientific literature (4,6,27,39,40,51,72,75,120,139), they should be used independently because of distinct differences in the total amount of rest placed within the set (Figure 1) and the impact that both set structures have on acute responses to resistance training (52). As such, the practical application of cluster sets, not rest-redistribution sets, within resistance training programs will be primarily discussed in this review.

PRACTICAL APPLICATION OF DIFFERENT SET STRUCTURES

When integrating training variations into a resistance training program, the training goal(s) of the athlete should be contextualized and established to optimize physiological and performance adaptations (83). In doing so, the concept of periodization, which is defined as "the logical integration and sequencing of training factors into mutually dependent periods designed to optimize specific physiological and performance outcomes at predetermined time points" (33), should be understood and applied to introduce training variations into the training program in a systematic manner. Although a detailed discussion about periodization is beyond the scope of this review (See Stone et al. (101), Plisk and Stone (83), and Haff (34) for more detailed discussions), adopting a training model consisting of several training phases that are performed sequentially may be ideal for improving maximal strength and rapid force-generating capacity that underpins athletic performance (14,15,48,68,102,105,137). Thus, the practical application of different set configurations should be considered in the context of 3 different training phases, specifically the hypertrophy, basic strength, and strength-power phases (102,104) (Figure 2). In the following section, the theoretical platform by which strength and conditioning professionals can design resistance training programs that use traditional and cluster sets will be presented.

EXERCISE SELECTION

When cluster sets are used as part of a resistance training program, strength and conditioning professionals should consider which exercises are best suited for cluster sets and which exercises are not. Although several exercises can be used with cluster sets, it is generally recommended that not every exercise in a training program is performed using cluster sets (35,36). As a rule of thumb, using cluster sets for 1 or 2 of the most technical or fatiguing exercise(s), such as weightlifting movements and/or their derivatives, is recommended because this will minimize the potential time burden which may occur when cluster sets are integrated into a training program.

Using weightlifting movements (e.g., clean and snatch) and their derivatives (e.g., power clean and snatch) in resistance training programs may be an important training method as they stimulate greater physiological and performance adaptations when compared with other training modalities such as jumping (116), kettlebell (77), and powerlifting training (45). When weightlifting movements and their derivatives are used in a resistance training program, cluster sets can be used to maintain lifting technique and movement velocity. In support of this contention, Hardee et al. (42) reported that when recreational weightlifters performed power cleans with 3 sets of 6 repetitions at 80% 1RM, the

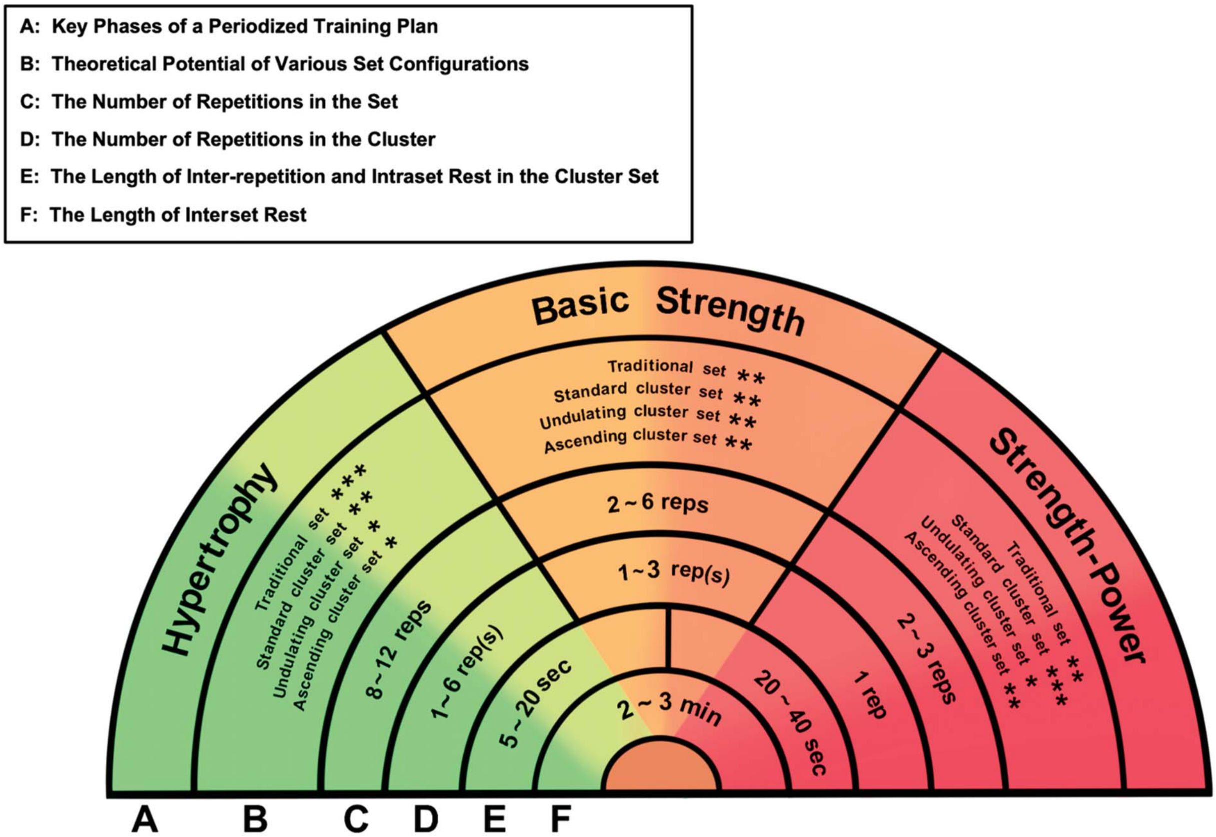

Figure 2. A theoretical framework of various training variations to design resistance training programs. *low potential; **moderate potential; ***high potential.

use of cluster sets with 20 and 40 seconds of inter-repetition rest maintained movement velocity across the sets. In addition, the authors reported that recreational weightlifters displayed a forward movement of the barbell during the first pull, which is considered to be a fatigue-induced technical breakdown (54,103). On the other hand, this fatigue-induced technical breakdown was not observed during cluster sets with 20 seconds of inter-repetition rest (41). Although this study provides useful data that support the use of cluster sets when performing weightlifting movements and their derivatives, it should be interpreted with caution. On closer inspection, Hardee et al. (41) evaluated lifting technique by comparing each data point within the barbell trajectory between the first and last repetition using a Student's *t* test. Given that barbell trajectory data are continuous, this statistical method is not appropriate and is likely to result in false positives (81). As such, more research on the effect of cluster sets on weightlifting technique analyzed with an appropriate statistical method is warranted.

Cluster sets can also be useful when introducing weightlifting pulling derivatives into resistance training programs (109). The primary benefit of choosing weightlifting pulling derivatives is that a greater force overload stimuli can be imposed on the athlete by eliminating the catch phase (109). For example, the catch phase of a power clean requires an athlete to get under the barbell to receive it across their shoulders once the second pull phase is completed. With this in mind, eliminating the catch phase during weightlifting pulling derivatives (e.g., snatch and/or clean grip pull from floor, knee, and thigh) allows for greater training loads to be used (38,109). In support of this contention, Haff et al. (38) reported that cluster sets can maintain movement velocity and vertical barbell displacement during clean pulls from the floor with loads greater than the athlete's 1RM power clean. Thus, when introducing weightlifting pulling derivatives into resistance training programs, it is recommended that cluster sets be used if the goal is to ensure that movement velocity and vertical barbell displacement are maintained across a set. However, more research on how cluster sets affect kinetic and kinematic variables during various weightlifting pulling derivatives using varying loading paradigms is certainly warranted.

The hang derivatives of the weightlifting movement (e.g., hang clean and snatch) are often used to teach an athlete both the transition and second pull phases in the weightlifting movement before progressing to performing the full lifts (69). These exercises are typically initiated with the athlete holding the barbell in a hang position and then lowering it to above the knee and then lifting the barbell upward to receive it across their shoulders (53). To the best of the authors' knowledge, the effect of traditional and cluster sets on kinetic and kinematic variables during hang derivatives has not yet been investigated, and consequently, it may not be recommended to use cluster sets with these exercises. This is because excessive fatigue can be generated from having to return the barbell to the floor and then pick it up multiple times during the cluster set. If, however, the strength and conditioning professional decides to implement hang derivatives, it is recommended that lifting straps are used to help alleviate grip fatigue and ensure lifting technique is maintained.

It seems that the back squat and bench press are the most explored exercises in the recent scientific literature on cluster sets, presumably because of the simplicity of these exercises (25,59,118,119,130). A possible limitation of using cluster sets with these exercises is that the athlete has to place the barbell into a rack before every intraset and inter-repetition rest interval and remove the barbell from the rack after the rest interval, which may lead to the accumulation of additional fatigue (18). This fatigue can be minimized by using a monolift attachment that can minimize the horizontal movement required for racking and unracking the barbell. However, this equipment is not always available, especially in typical resistance training settings. In this case, the strength and conditioning professional should consider either extending the inter-repetition or intraset rest interval to better manage this possible increase in fatigue or using traditional sets.

Although some single-joint exercises (i.e., barbell biceps curls and knee extension) can be performed with cluster sets (47), several authors have questioned the addition of single-joint exercises to resistance training programs (7,8,19). For example, Barbalho et al. (8) compared the changes in muscular strength and muscle hypertrophy in resistance-trained women that completed 8 weeks of resistance training programs involving multijoint exercises or combination of multijoint and single-joint exercises. The authors in this study found no additional benefits from the addition of single-joint exercises to resistance training programs regarding muscle hypertrophy and muscular strength (8). Similar findings have been seen in other scientific literature (7,19). When taken collectively, adding single-joint exercises performed using cluster sets to resistance training programs may not maximize the development of muscle hypertrophy and/or muscular strength, especially with trained individuals. Although single-joint exercises performed using cluster sets may not be an effective training method for achieving these purposes, they may have a place as part of rehabilitation programs, such as those used for the hamstrings (62,114) and rotator cuff (26). As such, we recommend that single-joint exercises should be performed with traditional sets when integrated into a healthy athlete's resistance training program. A detailed proposal of the exercises that are best used when programming cluster sets is presented in Table 1.

TYPE OF SET CONFIGURATION IN THE CONTEXT OF TRAINING PHASES

HYPERTROPHY PHASE

The primary goals of the hypertrophy phase of training are to increase muscle size, increase work capacity, and prepare the athlete for higher intensity work that will occur in subsequent training phases (102,104). To achieve these goals, a hypertrophy training program generally involves low to moderate intensities and higher overall volumes (34,102,104). During this phase, traditional sets may be favorably used over cluster sets as previously published literature has demonstrated greater muscle activation, metabolic, and hormonal responses for traditional sets when compared with cluster sets (25,30,76). These acute physiological responses have been considered to be prerequisites for hypertrophy (57,87–89). This recommendation is supported by Goto et al. (30) who reported a significantly greater increase in the cross-sectional area of quadriceps femoris for a group of untrained men that trained with traditional sets when compared with a group who trained with cluster sets (i.e., 12.9 ± 1.3% versus 4.0 ± 1.2%), after 12 weeks of machine-based high-volume training programs (3–5 × 10 repetitions at 10RM). The authors in this study also reported that the traditional set group significantly increased body mass (i.e., Pre: 65.2 ± 3.0 kg, Post: 66.4 ± 2.8 kg) and decreased percentage body fat (i.e., pre: 20.3 ± 1.2 kg and post: 18.8 ± 1.3 kg), which was not observed for the cluster set group (30). It is important to note that the researchers equalized training loads between cluster and traditional sets (30). By equalizing the training load between groups, the main benefits of the cluster set may be obviated as cluster sets have been reported to allow for the use of the greater training loads and/or volumes (47,118), which can increase the time under tension and the mechanical strain that are associated with muscle hypertrophy (11,61,118). As such, more research into whether the chronic use of cluster sets with greater training loads and/or volumes results in greater muscle hypertrophy when compared with traditional sets is warranted.

For strength and power athletes (e.g., throwers and weightlifters), hypertrophy of type II muscle fibers should be emphasized as the greater type II/I fiber ratio has been reported to be strongly associated with their athletic performance (67,97,112). To change the type II/I fiber ratio, a training program that focuses on a muscle fiber transformation from type I to II fiber and an increase in type II muscle fiber content should be prescribed for strength and power athletes during the hypertrophy phase. Although the fiber transformation from type I to II fiber or vice versa is unlikely to occur (2,21), altering the hybrid fiber myosin heavy chain I/IIa to either I or

Table 1 Theoretical potential of resistance exercises to maximize benefits from the use of cluster sets		
High potential	**Moderate potential**	**Low potential**
Snatch/clean	Push jerk/press	Assistance exercises (single-joint exercises)
Power snatch/clean	Hang clean/snatch	
Snatch/clean grip pull from floor	Hang power clean/snatch	
Snatch/clean from the knee	Hang high pull	
Power snatch/clean from the knee	Jump shrug	
Snatch/clean grip pull from the knee	Back/front squat	
Snatch/clean from the thigh	Loaded countermovement jump	
Power snatch/clean from the thigh	Flat/incline bench press	
Snatch/clean grip pull from the thigh		
Deadlift		

Some exercises (e.g., back/front squat, flat/incline bench press, and loaded countermovement jumps) that have moderate potential may have high potential if specific equipment (e.g., monolift attachment and hexagonal barbell) are available.

IIa has been demonstrated by several articles (115,131,132), which potentially changes the overall type II/I muscle fiber ratio. However, it is uncertain whether altering myosin heavy chain I/IIa is possible among highly trained athletes after a period of high-volume resistance training. Thus, targeting an increase in type II muscle fiber content may be a realistic and feasible strategy to change the overall type II/I muscle fiber ratio (24). In doing so, manipulating training variations, specifically training volume and intensity, should be considered when designing a training program.

Although training volume has been considered a primary factor for muscle hypertrophy (87), to maximize type II muscle fiber hypertrophy, training intensity, especially the use of higher loads (e.g., ≥80% 1RM), seems to be important (24). However, when high training loads are used with traditional sets, lower repetitions schemes may be required (e.g., 6–8 repetitions) as it is not theoretically feasible to perform higher volume sets (9–12 repetitions) with loads ≥80% 1RM when performing multijoint large mass exercises. In addition, when performing multijoint exercises, it may not be possible to maintain movement velocity throughout a higher volume set without experiencing repetition failure before the prescribed number of repetitions is completed (86). These occurrences are problematic because a pronounced movement velocity loss during a set of resistance training that likely leads to repetition failure does not result in greater hypertrophy (78) and causes substantial exercise-induced fatigue (79,86,127). In this scenario, using cluster sets may be a viable choice as they can allow for the use of greater training loads (e.g., ≥80% 1RM) while maintaining movement velocity without repetition failure (118) and allowing for a higher volume load (i.e., sets × reps × load) to be completed (47).

In summary, traditional sets may be the primary option to be chosen for designing resistance training programs for the hypertrophy phase when considering the scientific literature that reports greater muscle hypertrophy after resistance training using traditional sets (30). However, not all longitudinal studies agree with this argument (5,138). Cluster sets may have the potential to induce greater muscle hypertrophy as they allow for the use of greater training loads. Using greater training loads can increase the time under tension and the mechanical strain (118), both of which are associated with increased rates of hypertrophy (11). Given this potential benefit of cluster sets, they may be most suited for power and strength athletes as higher training loads may induce a specific hypertrophy of type II fibers that is essential to these athletes to improve their performance. However, strength and conditioning professionals should still be aware of the additional time it may take to implement cluster sets as part of an athlete's resistance training program (118). Any extension in training time is dependent on the structure of the set, including the intraset and interrepetition rest intervals, along with the number of repetitions performed in each cluster. As such, using cluster sets with only 1 or 2 key exercises has often been suggested within the scientific literature (35,36). Figure 2 presents the theoretical potential of various set configurations, whereas Table 2 presents several examples of set manipulation during the hypertrophy phase of a periodized training plan.

BASIC STRENGTH PHASE

The primary goal of the basic strength phase of training is to increase maximal strength levels (31), which is often considered to be an essential factor

Table 2
Several examples of set manipulation during a hypertrophy phase of a periodized training plan

Type of set	Sets	Reps	Intensity (%) / Rep										Rest intervals between clusters (s)
Traditional	3	10	55–65 / 10										0
Standard cluster	3	10/1	65–75 / 1	65–75 / 1	65–75 / 1	65–75 / 1	65–75 / 1	65–75 / 1	65–75 / 1	65–75 / 1	65–75 / 1	65–75 / 1	5
	3	10/2	65–75 / 2	65–75 / 2	65–75 / 2	65–75 / 2	65–75 / 2						15
	3	10/5	65–75 / 5	65–75 / 5									30

10 = A total of 10 repetitions that are performed in a continuous manner without any rest interval within the set; 10/1 = A total of 10 repetitions with inter-repetition rest intervals; 10/2 = A total of 10 repetitions with intraset rest intervals placed between each 2 repetition; 10/5 = A total of 10 repetitions with an intraset rest interval placed between each 5 repetition. All training loads are determined based on 1 repetition maximum power clean. Strength and conditioning professionals should construct cluster sets based on the focus of the training session, training loads used, the exercise selected, and the athlete's level of development.

Source: Adapted from Haff et al. (35,36).

underpinning athletic performance (46,71,135). Although muscular adaptations tend to be a central aim of resistance training during the hypertrophy phase, increased neural drive that maximizes the expression of muscular strength is a desired training adaptation during this phase (21,34). To obtain this neural adaptation, a training program generally involves higher intensity (e.g., 80–90% 1RM) but lower volumes than what is used during the hypertrophy phase (34,102,104). For example, Schoenfeld et al. (90) have reported greater maximal strength gains, as indicated by an increase in 1RM back squat (i.e., ES = 1.12 versus 0.71), after resistance training with 3 sets of 2–4RM when compared with performing 3 sets of 8–12RM. This finding supports the contention that high-load training is important when targeting maximal strength gains, especially when working with stronger athletes (17).

During the basic strength phase, traditional sets are often favored over cluster sets when creating training programs that are designed to maximize strength development. This contention is supported by Nicholson et al. (70) who reported that a group of resistance-trained men using traditional sets increased maximal strength slightly greater than a cluster set group (ES = 1.11 versus 0.69) after 6 weeks of high-load resistance training (4 × 6 repetitions at 85% 1RM). The authors in this study also compared a traditional set group with a cluster set group using greater training load (4 × 6 repetitions at 90% 1RM) and found no significant difference in maximal strength gains between these 2 groups (70). Although contemporary scientific literature can be interpreted as indicating that traditional sets are more appropriate for maximizing strength development, most research in this space has equalized training loads between cluster and traditional sets (5,30,84,138). It is important to note that cluster sets can allow for higher training loads to be used (47,118). As such, more research is warranted on whether cluster sets with higher training loads induce greater maximal strength gain.

For strength and power athletes, or highly trained athletes, it is well documented that greater training variation is necessary to induce muscle and neural adaptations when compared with novice and intermediate athletes (83). In this scenario, undulating and ascending cluster sets may likely be used as a method for adding variability to the resistance training program (Table 3). These advanced set configurations may induce a potentiation effect that can increase movement velocity within and between sets (20,106). This potentiation effect is most likely reserved for stronger individuals as they are more fatigue resistant and likely to display superior potentiation response to various training interventions when compared with weaker individuals (95,96,110).

In summary, during the basic strength phase, traditional sets are likely to provide equal or superior training adaptations to cluster sets when training loads are equalized after a period of high-intensity resistance training (80–90% 1RM). It should be noted that this may not be the case if greater training loads and volumes permitted by the use of cluster sets are incorporated into the resistance training program. Undulating and ascending cluster sets can be unique methods to add variability to a resistance training program and may be suited for strength and power athletes, or highly trained athletes. Table 3 presents several examples of set manipulation during the basic strength phase of a periodized training plan.

STRENGTH-POWER PHASE

The primary goal of the strength-power phase of training is to focus on the continued development of maximal strength, its translation into rapid force-generating capacity, and ultimately the improvement of an athlete's performance (34,102,104,108). It is recommended that training programs use loads and exercises which target various aspects of the force-velocity curve during this phase of training (37). In support of this recommendation, several researchers have suggested that resistance training programs focus on various aspects of the force-velocity curve, otherwise known as a mixed method approach (37), to better optimize the athlete's performance capacity in comparison with an unidirectional approach which only targets one aspect of the force-velocity curve (3,44,49,50). Generally, this phase involves low to very heavy training loads depending on the exercise performed (34). In the strength-power phase, using high training loads (≥80% 1RM) is considered to be integral especially with stronger athletes as training with only ballistic exercises using low training loads (≤30% 1RM) can neither improve nor maintain maximal strength levels (17). In addition, Comfort et al. (16) have reported significant increases in rapid force-generating capacity after 4 weeks of a moderate-to-high load training program (3 × 3 repetitions at 75–90% 1RM), whereas 4 weeks of a low-to-moderate load training program (3 × 5 repetitions at 60–82.5% 1RM) resulted in no improvements in rapid force-generating capacity. Furthermore, a combination of heavy resistance and ballistic exercises tends to result in superior athletic performance improvements when compared with a training program that only uses heavy resistance exercises or ballistic exercises (44). Based on these findings, to develop maximal and rapid force-generating capacity and improve an athlete's performance capacity during the strength-power phase, a mixed method training program using low to heavy loads is recommended (37).

Although a wide range of loads should be used to develop force-generating capacity across the entire force-velocity curve (37), training volume should be lower during the strength-power phase to minimize exercise-induced fatigue as neural adaptations to resistance training seem to be maximized during comparatively nonfatigued conditions (1,107). In addition, maintaining movement velocity across training sets has been shown to elicit greater maximal strength gains and athletic performance improvements (78,80). Cluster sets may be an effective method for ensuring that movement velocity is maintained during resistance training (42), while attenuating the accumulation of fatigue (52) to optimize neural adaptations that result from resistance training. For example, Zaras et al. (138) investigated the effects of 7 weeks of leg press training that was performed with cluster sets in untrained male physical education students. The authors reported that the participants who trained with cluster sets increased the rate of force development (RFD) during time bands such as 0–30 milliseconds (ES = 0.51 versus −0.21), 0–50 milliseconds (ES = 0.56 versus −0.25), and 0–80 milliseconds (ES = 0.54 versus −0.15), whereas the group that trained with traditional sets did not display improvements in RFD despite maximal strength increasing similarly for both groups (138). Although the authors in this study provide interesting data that support the use of cluster sets during the strength-power phase, it is still unknown whether trained athletes can gain the same benefits. In addition, Zaras et al. (138) used leg press as their training intervention, which has been reported to be less effective for improving jump performance (134) and maximal strength (85) than free-weight exercises for the lower body, such as the squat. As such, more research on whether other training modalities (e.g., weightlifting movement and their derivatives) using cluster sets elicit greater increases in rapid force-generating capacities and athletic performance in trained individuals is needed.

For strength and power development of highly trained athletes, introducing ascending cluster sets, which uses a different loading pattern to progressively increase the overall intensity of the set, may be a unique set modification to elevate maximal force-generating capacity (35,36). For example, where the athlete is performing 3 sets of 3 repetitions with the average load for each set corresponding to 81, 84, and 87% of 1RM, the 3 repetitions in the first set may be performed in a cluster format in which the load is increased (e.g., 78, 81, and 84% of 1RM). The next 3 repetitions in the

Table 3
Several examples of set manipulation during a basic strength phase of a periodized training plan

Type of set	Sets	Reps	Intensity (%)/rep					Rest intervals between clusters (s)
Traditional	3–5	5	70–80/5					0
	3–5	6	65–75/6					0
Standard cluster	3–5	5/1	75–85/1	75–85/1	75–85/1	75–85/1	75–85/1	20
	3–5	6/2	70–80/2	70–80/2	70–80/2			30
	3–5	6/3	70–80/3	70–80/3				40
Undulating cluster	3–5	5/1	72.5–82.5/1	75–85/1	80–90/1	75–85/1	72.5–82.5/1	30
	3–5	6/2	72.5–82.5/2	80–90/2	72.5–82.5/2			40
Ascending cluster	3–5	5/1	70–80/1	72.5–82.5/1	75–85/1	77.5–87.5/1	80–90/1	30
	3–5	6/2	70–80/2	75–85/2	80–90/2			40

5 = A total of 5 repetitions that are performed in a continuous manner without any rest interval within the set; 5/1 = A total of 5 repetitions with inter-repetition rest intervals; 6/2 = A total of 6 repetitions with intra-set rest intervals placed between each 2 repetition. All training loads are determined based upon one repetition maximum power clean. Strength and conditioning professionals should construct cluster sets based on the focus of the training session, training loads employed, the exercise selected, and the athlete's level of development.

Source: Adapted from Haff et al. (35,36).

second set may also be performed in the same manner (e.g., 81, 84, and 87% of 1RM) followed by the last 3 repetitions in the final set (e.g., 84, 87, 90% of 1RM) (Table 4). This set configuration can potentially enhance maximal force-generating capacity and may be suited for weightlifting derivatives or weightlifting pulling derivatives because using this set configuration during full weightlifting movements may result in substantial fatigue that can cause repetition failure, which may increase the injury risk (35,36).

In summary, to enhance maximal and rapid force-generating capacity and optimize athletic performance, a mixed method training program using a wide range of training loads, while keeping training volumes low, can be the optimum training prescription during the strength-power phase. Cluster sets can be used to maintain movement velocity and mitigate fatigue accumulation during resistance training sessions, which can potentially optimize neural adaptations that result from resistance training. Ascending cluster sets with progressively increased loads across the sets may be a unique set alternation to potentially elevate maximal force-generating capacity. Table 4 presents several examples of set manipulation during the strength-power phase of a periodized training plan.

NUMBER OF REPETITIONS IN THE SET

The total number of repetitions in the set should be determined based on the athlete's training goal (99). When muscle hypertrophy is the primary resistance training goal, a moderate-to-high repetition scheme (e.g., 8–12 repetitions) is often recommended. This recommendation is supported by Schoenfeld et al. (90), who reported that resistance training with 3 sets of 8–12RM induced greater muscle hypertrophy when compared with 2–4RM. However, this study did not equalize the training volumes for both groups (90), which might affect the magnitude of muscle hypertrophy. In another study by Schoenfeld et al. (94), there were no differences in the magnitude of muscle hypertrophy after the volume-equated resistance training program with 3 sets of 10RM versus 7 sets of 3RM. Although a dose-response relationship between resistance training volume and increases in muscle hypertrophy seems to exist (92), a low repetition scheme with higher training loads necessitates more sets to provide enough training volume to maximize hypertrophic gains (94). Performing numerous sets with higher loads may not be the most efficient methodology for providing an appropriate hypertrophic stimulus because of the amount of time that would be required to complete the session. In the real world, this increased time commitment may be problematic as strength and conditioning professionals typically have time constraints when delivering training programs. Thus, from a practical standpoint, a moderate-to-high repetition scheme (i.e., 8–12 repetitions) is recommended when designing resistance training programs targeting muscle hypertrophy (Figure 2).

During a basic strength phase, an increase in maximal strength is the primary goal established for the athlete (31). To attain this goal, a low-to-moderate repetition scheme (e.g., 2–6 repetitions) with high training loads (e.g., ≥ 80% 1RM) is typically recommended (91,102,104). Unlike resistance training targeting muscle hypertrophy,

Table 4
Several examples of set manipulation during a strength-power phase of a periodized training plan

Type of set	Sets	Reps	Intensity (%)/rep			Rest intervals between clusters (s)
Traditional	3–5	3	80–90/3			0
Standard cluster	3–5	3/1	85–93/1	85–93/1	85–93/1	30
Ascending cluster	Set 1	3/1	78–81/1	81–84/1	84–87/1	30–40
	Set 2	3/1	81–84/1	84–87/1	87–90/1	30–40
	Set 3	3/1	84–87/1	87–90/1	90–93/1	30–40

3 = A total of 3 repetitions that are performed in a continuous manner without any rest interval within the set; 3/1 = A total of 3 repetitions with inter-repetition rest intervals. All training loads are determined based upon one repetition maximum power clean. Strength and conditioning professionals should construct cluster sets based on the focus of the training session, training loads employed, the exercise selected, and the athlete's level of development.

Source: Adapted from Haff et al. (35,36).

using higher training loads seems to be prerequisite for optimizing maximal strength (91). Several authors have reported greater maximal strength gains after resistance training with 2–5RM when compared with that with 8–12RM (13,61,90,94). As such, a low-to-moderate repetition scheme (i.e., 2–6 repetitions) that allows for higher training loads is recommended when designing resistance training programs targeting maximal strength gains (Figure 2).

In a strength-power phase, the development of maximal and rapid force-generating capacities and the improvement of an athlete's performance are the main goals for the athlete (34,102,104,108). Using the lower repetition scheme (e.g., 2–3 repetitions) may be recommended to attain these goals. This recommendation is supported by several studies showing that resistance training with a low repetition scheme increased maximal strength (129), rapid force-generating capacity (16), and vertical jump performance (102,129). These training adaptations may be more evident especially when the strength-power phase is preceded by a higher volume training program with lower training loads (e.g., a basic strength phase) (16,102,129). Thus, a low repetition scheme (i.e., 2–3 repetitions) is recommended when designing resistance training programs during the strength-power phase (Figure 2).

NUMBER OF REPETITIONS IN THE CLUSTER

The number of repetitions performed in the cluster should be modified based on the training phase. In a hypertrophy phase, given that the recommended number of repetitions in a set is high (i.e., 8–12 repetitions), the number of repetitions performed in the cluster can vary from 1 to 6 (Figure 2). For example, Tufano et al. (118) reported that when performing the back squat using sets of 12 repetitions, higher training loads (i.e., 75% 1RM versus 60% 1RM) can be used by dividing 12 repetitions into 3 clusters of 4 repetitions with 30 seconds intraset rest between clusters when compared with traditional sets. If weightlifting derivatives are performed using sets of 8 repetitions in the hypertrophy phase, 4 clusters of 2 repetitions with 20 seconds intraset rest between clusters can be used to potentially maintain movement velocity and lifting technique across the set (41,42). Ultimately, strength and conditioning professionals should determine the number of repetitions performed in the cluster based on the focus of the training session, training loads used, the exercise selected, and the athlete's level of development.

Unlike the hypertrophy phase, the recommended number of repetitions performed in a set is low to moderate in a basic strength phase (e.g., 2–6 repetitions). In this phase, cluster sets may not provide greater maximal strength gains than traditional sets based on several studies (5,30,70,138). However, cluster sets with 1 to 3 repetitions in each cluster can be used for maintaining movement velocity and lifting technique (Figure 2). Several authors reported that using an inter-repetition rest interval can maintain movement velocity (42,70) and lifting technique (41) during resistance exercises when using high training loads (e.g., 80–90% 1RM) (38,42,59,70). In addition, Lawton et al. (60) reported that using intraset rest intervals placed between every 2 repetitions or every 3 repetitions maintained power output when performing 6 repetitions of bench press with 6RM load. In this study, the reduction in power output resulted from a decline in movement velocity as force production did not change during exercise because of the use of consistent loads throughout the set. It is recommended that longer intraset rest intervals be provided when using multiple repetitions in clusters (2–3 repetitions) (Table 3).

During a strength-power phase, one of the primary resistance training goals is to develop rapid force-generating capacity that translates into the improvement of an athlete's performance (34,102,104,108). Wagle et al. (124) reported that cluster sets with inter-repetition rest maintained rapid force-generating capacity throughout each set when performing back squat with 3 sets of 5 repetitions at 80% of 1RM. On the other hand, when using traditional sets, rapid force-generating capacity decreased toward the end of each set (124). Given that the recommended number of repetitions in a set during the strength-power phase is low (i.e., 2–3 repetitions), it is recommended that cluster sets with inter-repetition rest should only be used for the most technical or fatiguing exercise(s), such as weightlifting movements and/or their derivatives, whereas other exercises should be performed with traditional sets (Figure 2).

LENGTH OF INTER-REPETITION AND INTRASET REST IN THE CLUSTER SET

The alignment of the inter-repetition and intraset recovery times to the various training phases and goals is facilitated by considering the time course of adenosine triphosphate (ATP) and phosphocreatine (PCr) resynthesis. When longer inter-repetitions and intraset rest intervals are provided, more complete resynthesis of these 2 substrates occurs and, therefore, allows for more rapid muscular contractions (29). Conversely, if the rest interval is shortened, there would be incomplete ATP resynthesis and proportionally greater levels of fatigue (35,36,107). If the training goal is to stimulate gains in muscle hypertrophy, it has often been suggested that traditional sets should be implemented instead of cluster sets (30). However, based on more recent evidence from Tufano et al. (118), if higher loads are used with cluster sets, time under tension is increased and may in turn increase the hypertrophic stimulus. In addition, if cluster sets are implemented with higher training loads, a moderate-to-high repetition training set (i.e., 8–12 repetitions) with shorter rest intervals between individual repetitions (e.g., 5–10 seconds) or clusters (e.g., 15–30 seconds) may be a viable option. When this is performed, the provided recovery will facilitate the maintenance of performance, allow for the use of higher training loads (47,118), and still provide some degree of fatigue that may provide a stimulus that facilitates hypertrophy (25,28,118) (Figure 2). On the other hand, if the training goal is to improve rapid force-generating capacity, rest periods between individual repetitions or clusters may be longer (e.g., 30–40 seconds) to ensure greater recovery provided, especially when full weightlifting movements are incorporated into the resistance training program.

LENGTH OF INTERSET REST

Traditionally, the length of interset rest interval has been manipulated based on the training goal (99). In a high-volume resistance training program that targets muscle hypertrophy, short interset rest intervals (e.g., 30–60 seconds) are often used (56,113) as resistance training with short interset rest produces greater serum testosterone and growth hormone concentrations when compared with longer interset rest (55), both of which have often been suggested to affect the magnitude of muscle hypertrophy (87,88). On the other hand, long interset rest intervals (e.g., ≥3 minutes) are typically recommended in a low volume but high-intensity training program that targets strength development (128). However, several authors have reported greater changes in the cross-sectional area and regional muscle thickness after resistance training with longer interset rest (2.5–3 minutes) when compared with shorter interset rest (1 minute), whereas equal or greater maximal strength gains were observed for the longer interset rest training protocol (12,93). The potential explanation for these contradictory findings is that the high hormonal responses may not directly affect muscle protein synthesis that is directly related to muscle hypertrophy (10,82). McKendry et al. (64) reported a greater increase in myofibrillar protein synthesis after resistance training with 5 minutes of interset rest than that with 1 minute of interset rest, albeit no greater serum testosterone and growth hormone concentrations observed following the longer interset rest training protocol. Another important consideration is that the longer interset rest can allow for greater resynthesis of ATP and PCr to occur and more repetitions to be completed, especially when performing repetitions to muscular failure (29,93). As such, regardless of the training goal, a sufficient amount of rest intervals between sets (e.g., 2–3 minutes) is recommended during resistance training (Figure 2).

ADDITIONAL CONSIDERATIONS WHEN USING CLUSTER SETS

FEEDBACK

For strength and conditioning professionals, providing the athlete with feedback about the movement pattern of the exercise performed plays a significant role in the acquisition of motor skill (100). During a set of resistance training, the use of cluster sets can also allow the coach to provide the athlete with immediate feedback during the inter-repetition or intraset rest interval (109). When providing feedback within a set, the frequency of the feedback should be considered, as more frequent feedback does not always contribute to enhancement of skill acquisition (133). However, this may not be the case when the athlete is required to acquire a complex movement pattern as frequent feedback has been demonstrated to be beneficial for the learning of complex movement patterns (136). Thus, if the athlete is required to learn a highly technical exercise such as weightlifting movements, the use of cluster sets in this manner allows for frequent feedback and can be beneficial to facilitate motor learning.

Table 5
Practical integrations of standard cluster set into accentuated eccentric load training programs during key phases of a periodized training plan

Training variation	Hypertrophy	Basic strength	Strength-power
Eccentric load (%1RM)	80–120	100–120	≥120
Concentric load (%1RM)	60–70	70–80	≥80
Number of reps in a set	8–12	2–6	2–3
Number of reps in a cluster	3–6	1–3	1
Number of rest intervals between clusters	1–2	1–2	1–2
Length of rest intervals between clusters (s)	20	30	30–40

All concentric and eccentric training loads are determined based on 1 repetition maximum back squat in articles published by Wagle et al. (123,124) and Merrigan et al. (65) and the book by Verkhoshansky (122). For example, if an athlete performs 10 repetitions of back squats with a 120% 1RM eccentric load and a 65% 1RM concentric load, 10 repetitions can be broken into 2 clusters of 5 repetitions and a 30-s intraset rest interval can be added between clusters. In this case, supramaximal eccentric loads (120% 1RM) are imposed on the athlete at the first and sixth repetition of the set of back squats.

ACCENTUATED ECCENTRIC LOADING

It is well documented that the force produced by a muscle during eccentric muscle actions is larger than what can be developed during isometric and concentric muscle actions (63). As such, traditional training prescriptions that use equal absolute loads for both the concentric and eccentric muscle actions during a resistance exercise do not maximize the force-generating capacity during the eccentric muscle actions (125). Accentuated eccentric loading (AEL) refers to a novel training modality in which the eccentric load is programmed at a higher load compared with the load used during the concentric muscle action within a specific resistance exercise (111,125). For example, the eccentric phase of the selected exercise is programmed with a higher load, and then some of the load is removed by using a weight releaser before the transition from the eccentric to concentric phase of the lift (122). The use of AEL can result in the potential enhancement of type II fiber recruitment as well as the hypertrophy of type II fibers (22,23), a greater increase in maximal strength (9,43,126), and greater improvements in vertical jump performance (23,98) (For more detail on AEL, the reader is directed to the review paper by Wagle et al. (125)).

Two common methods to use AEL with the use of the weight releaser are to (a) accentuate the eccentric phase of the first repetition and then perform the rest of the set without applying greater loads to the eccentric phase of the lift (59,65,66,123,124) and (b) accentuate the eccentric phase of every single repetition or the first repetition of every single cluster (59,123,124). The second method necessitates time between individual and clusters of repetitions to reload the eccentric phase of the selected exercise. This form of AEL has an inherent cluster-like set configuration that may contribute to the training benefits associated with AEL. If AEL is introduced into training programs that target hypertrophy and an increase in work capacity, short rest intervals between individual repetitions or clusters may be selected (e.g., 20 seconds). On the other hand, if training

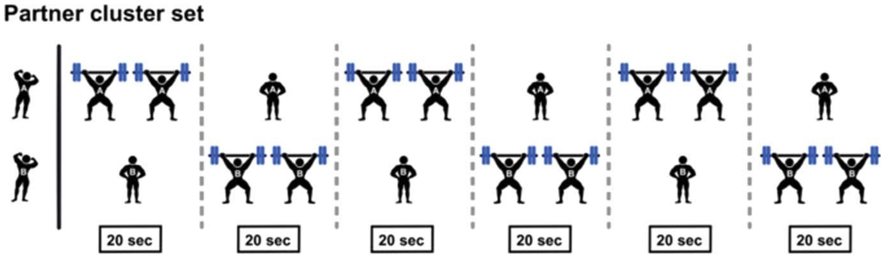

Figure 3. A partner cluster set. In this set configuration, athletes (A and B) take turns performing 3 clusters of 2 power snatches with intraset rest intervals. When the athlete (A) rests, the athlete (B) performs 2 repetitions of power snatches, and vice versa. The length of rest intervals is determined based on training loads, an exercise performed, the targeted goal of the training plan, and the athlete's level of development (e.g., In this example, 20 seconds of intraset rest intervals are used).

programs that target the development of force-generating capacity involve AEL, longer rest intervals between individual repetitions or clusters may be chosen (e.g., 30–40 seconds). Table 5 presents a detailed recommendation on how AEL with cluster sets may potentially be applied into resistance training programs in key training phases.

PARTNER CLUSTER SETS

A partner cluster set is a unique training method that was first presented at the NSCA National Conference in 2016 (32). This method of using cluster sets uses multiple athletes (e.g., 2–3) that use similar or the same training loads and take turns performing the repetitions or clusters of repetitions prescribed for the set. In this training method, although one athlete rests during an inter-repetition or intraset rest interval, the other athlete is performing one repetition or cluster of repetitions (Figure 3). When one partner finishes their repetitions, they will rest while the other partner performs their repetitions. If longer rest intervals are programed, then additional partners can be added, thus increasing the time between each athlete's repetitions. An additional benefit of this methodology is that it possibly serves as a team building activity that facilitates the ability of the athletes to work together, especially if loads need to be changed between individuals (32).

CONCLUSIONS

Altering set configurations during resistance training programs can be a novel training variation that can be used to modify the external and internal training loads that result in specific training outcomes. Strength and conditioning professionals need to understand how different set configurations affect the training adaptations that result from resistance training. If appropriately used, traditional and cluster sets can be incorporated into resistance training programs in different training phases to optimize muscle hypertrophy, as well as an athlete's maximal and rapid force-generating capacity, all of which potentially underpin their athletic performance. In addition, cluster sets can be responsible for the efficacies of several training strategies such as accentuated eccentric loading and weightlifting derivatives. Collectively, this review has provided strength and conditioning professionals with comprehensive insight into the addition of set manipulation for resistance training programs and the potential enhancement of athletic performance.

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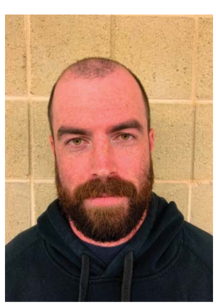

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