A Brief Review: How Much Rest between Sets?

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SUMMARY

RELATIVELY FEW STUDIES HAVE BEEN CONDUCTED TO DETERMINE THE EFFECT OF DIFFERENT REST INTERVALS BETWEEN RESISTANCE EXERCISE SETS. A REST INTERVAL IS ESSENTIAL TO RE-ESTABLISH INTRA MUSCULAR BLOOD FLOW AND OXYGEN DELIVERY THAT ALLOWS FOR THE REPLENISHMENT OF PHOSPHOCREATINE STORES, RESTORATION OF INTRAMUSCULAR PH, REMOVAL OF METABOLIC END PRODUCTS, AND RETURN OF MUSCLE MEMBRANE POTENTIAL TO RESTING LEVELS. GENERAL RECOMMENDATIONS FOR REST INTERVAL LENGTH HAVE BEEN BASED PRIMARILY ON THE TRAINING GOAL (E.G., POWER, STRENGTH, HYPERTROPHY, MUSCULAR ENDURANCE). HOWEVER, OTHER FACTORS RELATED TO THE WORKOUT AND INDIVIDUAL CHARACTERISTICS MAY SHORTEN OR LENGTHEN THESE GENERAL RECOMMENDATIONS.

INTRODUCTION

Resistance exercise has become very popular and is now considered an essential component of every athlete’s conditioning program. Part of what makes resistance exercise so popular and effective is the seemingly endless selection and variation of exercises. Several components make up the structure of a resistance exercise program. The most common component and most frequently studied is the workout volume (3,4). Several studies have compared neuromuscular adaptations resulting from different volumes of training (i.e., single versus multiple sets) (17). However, relatively few studies have been conducted to determine the effect of different rest intervals between sets (22,23).

A certain amount of rest between sets is essential. Because resistance exercise emphasizes anaerobic metabolism, the muscles reach fatigue relatively quickly. The time to fatigue is dependent on the training intensity or percentage of maximal strength that is lifted. Most resistance exercise programs are conducted at intensities that range from 30% to 100% of maximal strength (3,4). Since blood flow to the muscle is occluded at intensities as low as 20% of maximal strength, a rest period is essential to reestablish intramuscular blood flow and oxygen delivery that allows for the replenishment of phosphocreatine stores, restoration of intramuscular pH, removal of metabolic end products, and return of muscle membrane potential to resting levels (10,22,23).

A workout is commonly prescribed simply based on the load lifted per set, the number of sets per exercise, and the number repetitions per set (3,4). A rest period between sets is typically acknowledged, but might be undertaken carelessly or without thought concerning the specific length of time, or the impact of the time between sets on workout performance and subsequent physiological adaptations. The next set might be performed when the athlete feels ready or in some unfortunate cases when two athletes have a break in their conversation. A problem exists when idle conversation extends far beyond when full recovery has taken place. To help athletes achieve maximal results, the rest between sets must be considered just as important as any other component within a resistance exercise program.

A commonly used text on resistance exercise has made some general recommendations that are based on different training goals (3,4). For example, when training for muscular power and strength, longer rest intervals of 2 to 5 minutes have been recommended between sets. Conversely, shorter rest intervals of 30 seconds to 90 seconds have been recommended for muscular hypertrophy and less than 30 seconds for muscular endurance. These general recommendations provide an important baseline for resistance exercise prescription, but they also represent relatively broad ranges that may vary throughout a training cycle (23).

KEY WORDS:
recovery; energy systems; resistance exercise; exercise prescription; repetitions
The central factor that determines the baseline prescription of the rest interval might be the training goal (3, 4; see Figure 1). However, other factors related to the workout or individual characteristics may shorten or lengthen the rest interval (23). Therefore, the purpose of this article will be to discuss some of these factors in the context of different training goals that include: power, strength, hypertrophy, and muscular endurance. The goal of this article will be to take several research examples and determine how the findings can be applied in a practical manner.

MUSCULAR POWER

Muscular power represents a combination of strength and the speed of muscle action (3,4). Increases in either of these components may increase power output. However, continual increases in strength over time may not lead to increases in power. This is because sports skills are performed so rapidly (i.e. ≤ 250 ms) that the rate of force production may eventually become more important than absolute force production (7). For advanced lifters that possess high levels of strength, the most effective strategy to increase power might be to focus on lifts that involve higher velocities and rates of force production.

The selection of appropriate rest intervals becomes crucial to maintain high velocity, rate of force production, and power throughout a set. Set and repetition schemes that are structured to produce high levels of fatigue may be detrimental for power development due to lower velocities and lower rates of force production at the end of a set. To prevent high levels of fatigue, a typical set can be split up into blocks that range from singles (one repetition) to triples (three repetitions), with intra-set rest intervals between blocks. The goal would be to avoid performing a full repetition maximum (RM) set to failure.

Intra-set rest intervals allow for replenishment of phosphocreatine (PCr) stores that may result in higher velocities and rates of force production. According to Fleck and Kraemer (7), 90% of the ATP and PCr stores can be resynthesized in 1 minute by oxidative metabolism. Harris et al. (10) demonstrated that the time course of PCr resynthesis was biphasic, exhibiting fast (21–22 seconds) and slow (more than 170 seconds) recovery components. Therefore, to take advantage of the fast component of PCr resynthesis, an athlete could perform blocks of 1 to 3 repetitions with 20 second pauses between blocks; this strategy may provide a more effective stimulus for power development (15).

Lawton et al. (15) compared the power output per repetition for the bench press performed continuously with 6-RM load (to failure) versus three other conditions in which the set was split into blocks of singles, doubles, or triples. The singles condition involved 20 seconds of rest between each repetition, the doubles condition involved 50 seconds rest following repetitions 2 and 4, and the triples condition involved 100 seconds of rest following the third repetition. Greater percentage increases in power output per repetition were demonstrated for all conditions relative to the continuous condition. However, the total power output was greatest for the triples condition. Similarly, Abdessemed et al. (1) examined mean power output during 10 sets of 6 maximal effort bench press repetitions, performed at 70% of a 1-RM, and with 1, 3, or 5 minutes rest between sets. There was less of a decline in the mean power output per set when resting 3 or 5 minutes between sets versus 1 minute between sets.

When considered collectively, these studies indicate that when performing resistance exercises for the purpose of power development the greatest benefits might be gained by splitting sets into blocks of three repetitions (i.e., triples), with approximately 2 minutes rest between blocks, and 3 minutes rest between sets (1,15). This approach might be most effective during peaking phases or in-season training phases. Use of this approach may prevent excessive fatigue and leave greater energy reserves for sports skill practice.

Complex training and rest intervals. The previous studies evaluated power production in the context of a traditionally structured training program, in which resistance exercises were conducted on separate days from...
plyometric exercises. However, coaches may utilize complex training, in which high intensity resistance exercises are combined with plyometric exercises in the same training session. This approach is more time efficient and has been hypothesized to provide a superior stimulus for power development (6,11).

The rest interval between the high intensity resistance exercise and the plyometric exercise is crucial. On the one hand, the rest interval must be long enough to allow for replenishment of phosphocreatine stores and consistency in movement mechanics, but also short enough to take advantage of the heightened neural activation that may allow for greater power production (9). Selecting the appropriate rest interval can be a challenging task for a coach that is working with several athletes. Nevertheless, studies have demonstrated some general trends that can provide for a baseline prescription.

Jensen and Ebben (11) divided collegiate athletes from anaerobic sports (i.e., volleyball; wrestling; high and long jumps; and shot, discus, and hammer throws) into a higher strength group and a lower strength group according to their 1-RM back squat. Countermovement jump height was assessed prior to and at 10 seconds, 1 minute, 2 minutes, 3 minutes, and 4 minutes following 1 set of back squats with a 5-RM load. The higher strength group was able to exceed the pre-squat jump height, with the greatest mean increase of 7.4 cm occurring after 4 minutes of rest. However, the lower strength group did not respond as well with only a mean increase of 1.8 cm occurring after 4 minutes of rest.

In a similarly designed study, Comyns et al. (6) demonstrated varying responses for men versus women. Countermovement jumps were performed prior to and at 30 seconds, 2 minutes, 4 minutes, and 6 minutes following 1 set of back squats with a 5-RM load. The highest strength group was able to exceed the pre-squat jump height, with the greatest mean increase of 7.4 cm occurring after 4 minutes of rest. However, the lower strength group did not respond as well with only a mean increase of 1.8 cm occurring after 4 minutes of rest.

When considered collectively, these studies indicate that the greatest jump height is generally achieved at 2 minutes and at 4 minutes following the high intensity resistance exercise. Rest intervals of 30 seconds or less may not allow sufficient replenishment of phosphocreatine stores, and rest intervals 6 minutes or more may prevent the ability to take advantage of the heightened neural excitation (15). Complex training might be more beneficial for individuals near the peak of their strength development when increasing rate of force development becomes the primary focus (11).

Complex training might provide a greater training advantage for men due to higher levels of absolute strength. However, women might be able to recover quicker following the high intensity resistance exercise, and so this approach represents a highly efficient training option for this population (6). Through careful observation and record keeping, a coach can eventually determine the optimal rest interval and pair athletes accordingly.

MUSCULAR STRENGTH

The rest interval guidelines when training for absolute strength are similar to those used when training for muscular power. However, in contrast to power training, greater increases in absolute strength might be achieved by occasionally performing full repetition maximum sets to failure (3,4). Research has demonstrated that when performing multiple sets to failure, there were differences in the repetitions completed per set, based on the rest interval between sets (25).

Willardson and Burkett (25) compared bench press repetitions over 5 sets with absolute loads of 50% versus 80% of a 1-RM, and 1, 2, or 3 minutes rest between sets (see Figure 2). A continual decline in repetitions occurred for all rest conditions between the second through fifth sets; however, the 3 minute rest condition resulted in less of a decline versus resting 1 or 2 minutes between sets. Since the total volume of training is an important stimulus for strength increases, the additional repetitions accomplished when resting 3 minutes between sets might be worth the extra recovery time.

Figure 2. Mean comparison repetitions with different loads and rest intervals. Note. 5 sets of bench press were performed to failure with absolute loads of 50% versus 80% of a 1-RM, and 1, 2, or 3 minutes rest between sets; columns depict the mean decline in repetitions over consecutive sets. Adapted from Willardson and Burkett (25). The effect of rest interval length on bench press performance with heavy versus light loads. J Strength Cond Res 20: 400–403, 2006. Reprinted by permission of the National Strength and Conditioning Association, Colorado Springs, CO.
This theory was supported in a study by Robinson et al. (18) that compared back squat strength increases following 5 weeks of resistance training with 30 seconds, 90 seconds, or 3 minutes rest between sets (see Figure 3). The greatest increases in strength were demonstrated by the 3 minute group, followed sequentially by the 90 and 30 second rest groups. The authors concluded the 3 minute rest intervals allowed for maintenance of training intensity, which led to greater strength increases.

Conversely, Willardson and Burkett (26) found no differences in back squat strength increases following 13 weeks of training in groups that rested 2 minutes versus 4 minutes between sets. However, the 4 minute group consistently performed greater repetitions per set during all barbell back squat workouts, despite the intensity being equated between groups. These results suggest that the extra repetitions did not make a difference in terms of the resulting strength increase. Ahtiainen et al. (2) suggested that after a certain threshold volume is achieved, the length of the rest period between sets does not make a systematic contribution to the neuromuscular response. Subjects may have reached the threshold volume necessary to gain a certain amount of strength (based on training age), which reduced the importance of including longer rest intervals between sets.

When considered collectively, these studies indicate that the rest interval between sets should be varied based on the training age of the individual (2,18,25,26). For continued increases in maximal strength, advanced lifters must perform increasingly higher volumes of training (3,4). To achieve a given volume goal, longer rest intervals (e.g., 4 to 5 minutes) might be prescribed initially, until an individual has adapted psychologically and physiologically, and is able to perform the same volume with shorter rest intervals between sets (e.g., 2 to 3 minutes). This approach may allow for maintenance of higher training intensities and repetitions over subsequent sets, which may ultimately lead to greater strength increases.

Muscle size and the role of synergists. The ability to recover between sets may depend on the type of muscle action being performed (21). Most sets performed by athletes involved both concentric and eccentric muscle actions of the prime movers. However, other muscles may function isometrically as stabilizers to position body segments properly to reduce the likelihood of injury.

High intensity ground-based movements such as the squat, deadlift, shrug, overhead press, and barbell curl all require isometric muscle actions from the core musculature and forearm flexors. The forearm flexors can be a weak link for movements like the deadlift and shrug. For example, athletes might not be able to work the prime movers (e.g., gluteus maximus, hamstrings, erector spinae, and trapezius) sufficiently if the forearm flexors have not recovered sufficiently to hold the resistance.

Stull and Clark (21) used a hand-grip device to compare the maximal strength recovery time of the forearm flexors consequent to dynamic versus isometric muscle actions. Recovery following the dynamic task (~2 minutes) occurred more rapidly versus recovery following the isometric task (~4 minutes). The authors hypothesized that longer rest intervals were necessary for the isometric condition due to slower reestablishment of intramuscular blood flow.

These results indicate that for high intensity deadlifts and shrugs, resting 4 minutes between sets might be advantageous, and may indirectly contribute to greater strength increases for the prime movers consequent to these movements. For baseball players and athletes from other sports (i.e., racquet sports), in which greater isometric grip strength might provide a performance advantage, longer rest intervals should be prescribed between sets to ensure adequate recovery and maximal force production on subsequent sets.

MUSCULAR HYPERTROPHY
This characteristic is probably the most sought after by recreational lifters, especially young males. However, increasing muscular size can also benefit certain athletes, and might be the primary focus of training during the

Figure 3  Mean comparison back squat strength gains with different rest intervals. Note. Mean barbell back squat strength prior to (red) and following (yellow) 5 weeks of resistance training with 30 seconds, 90 seconds, or 3 minutes rest intervals between sets. Adapted from Robinson et al. (18). Effects of different weight training exercise/rest intervals on strength, power, and high intensity exercise endurance. J Strength Cond Res 9: 216–221, 1995. Reprinted by permission of the National Strength and Conditioning Association, Colorado Springs, CO.
off-season for some sport positions (e.g., football lineman). Selection of the appropriate rest interval between sets is highly important to get the maximum hypertrophic response.

Studies have compared hormonal responses following protocols that involved varying repetitions per set and rest intervals between sets. Kraemer et al. (12) demonstrated that a hypertrophy type protocol that involved three sets of eight exercises, performed with a 10-RM load, and 1 minute rest between sets produced greater acute increases in growth hormone (GH) versus a strength type protocol that involved five sets of five exercises, performed with a 5-RM load, and 3 minutes rest between sets.

Likewise, Goto et al. (8) demonstrated that acute increases in growth hormone were highest following a hypertrophy type protocol versus a strength type protocol. The hypertrophy type protocol involved 3 sets each of the leg extension and leg press, with 30 seconds rest between sets; the resistance was progressively lowered so that 10 to 15 repetitions could be completed on each set. Conversely, the strength type protocol involved 5 sets each of the leg extension and leg press, with 3 minutes rest between sets, and 3 to 5 repetitions per set.

When considered collectively, these studies indicate that exercise prescription for muscular hypertrophy should involve a combination of moderately intense loads (i.e. 10 to 15-RM) combined with relatively short rest intervals between sets (i.e. 30 seconds to 1 minute) (5,8,12). A key point is that subsequent sets should be commenced prior to when full recovery has taken place. Therefore, the emphasis is on stressing the glycolytic energy system, as evidenced by the build-up of lactate in the muscles to buffer metabolic acids. Due to the relatively short rest intervals between sets, there might be difficulty in maintaining the absolute intensity level over subsequent sets. In such cases, the resistance should be lowered so that repetitions do not drop below the 10 to 15-RM zone.

Another key point is that repetitions should be performed to the point of reaching muscular failure. Linnamo et al. (16) demonstrated greater acute increases in growth hormone and testosterone for a protocol in which subjects trained to failure with a 10-RM load versus a protocol in which subjects did not train to failure with 70% of the 10-RM load. Each protocol involved 5 sets of the sit-up, bench press, and leg press with 2 minute rest intervals between sets. However, a word of caution is warranted here, in that training to failure should not be practiced repeatedly over long periods of time due to the potential for overtraining and psychological burnout.

A coach should allow an athlete time to adapt gradually to the demands of performing workouts with shorter rest intervals between sets. These adaptations may involve both psychological (i.e., perceptions of fatigue) and physiological (i.e., increases in capillary and mitochondrial density and buffering capacity) adjustments. Kraemer et al. (13) found that long-term bodybuilding style training created greater resistance to fatigue, which allowed subjects to maintain significantly higher mean intensities during performances of bench press and leg press exercises with 10 seconds rest between sets. During hypertrophy phases coaches may begin by allowing athletes 2 minutes rest between sets and then gradually lowering to 1 minute or less between sets.

**MUSCULAR ENDURANCE**

Training for muscular endurance is similar to training for hypertrophy in that the emphasis is on achieving high levels of fatigue through shorter rest intervals between sets. Because muscular endurance is defined as the ability to maintain submaximal muscle actions, the principle of specificity would dictate that training should involve short rest intervals between sets (3,4). Muscular endurance can be measured in both absolute (repetitions performed with a given mass) and relative (repetitions performed with a % of 1-RM) terms. Increasing maximal strength has been shown to have a greater effect on absolute muscular endurance versus relative muscular endurance. Improvements in relative muscular endurance require higher repetitions per set (i.e. >12) combined with shorter rest intervals between sets (i.e. ≤ 30 seconds). Because of the shorter rest intervals, maintaining higher repetitions per set is not possible without lowering the load over consecutive sets. If the load is not lowered, then a workout may not provide the optimal stimulus because the repetitions tend to drop into repetition zones more conducive to muscular strength and hypertrophy (5).

This was reflected in a study by Willardson and Burkett (24) that compared bench press repetitions versus squat repetitions over 5 sets with an absolute 15-RM load, and 30 seconds, 1 minute, or 2 minutes rest between sets (see Figure 4). For all rest conditions, subjects were able to perform more repetitions for the squat versus the bench press. However, none of the subjects were able to complete 15 repetitions on all sets. For example, when resting 30 seconds between sets, by the fifth set, the mean repetitions had declined to approximately 6 for the squat and 2 for the bench press. Therefore, productive muscular endurance training should place primary emphasis on maintaining repetitions within the zone conducive to this training goal.

Studies that have examined increases in muscular endurance following resistance training have found conflicting results. Robinson et al. (18) demonstrated greater increases in high intensity cycle endurance consequent to 5 weeks of resistance training that involved 30 seconds versus 90 seconds or 3 minutes between sets (see Figure 5). Conversely, Kulling et al. (14) found greater increases in bench press muscular endurance following 12 weeks of resistance training that involved 90 seconds versus 30 seconds rest between sets.

The difference in results between these studies might be attributed...
different levels of training; moderately trained men in the study by Robinson et al. (18) and untrained men and women in the study by Kullinge et al. (14). When considered collectively, these studies indicate that untrained individuals may respond better to longer rest intervals (≥90 seconds) that allow for lower levels of metabolic acids and less potential psychological distress, whereas trained individuals may require shorter rest (≤30 seconds) intervals for continued progression.

**CONCLUSION**

The rest interval between sets is a highly important workout component that should receive greater attention in resistance exercise prescription. Manipulation of this component can determine the degree to which an athlete will achieve adaptations related to power, strength, hypertrophy, and muscular endurance. However, proper prescription of the rest interval must occur in conjunction with proper prescription of other components such as intensity and repetition zones.

Coaches have an enormous responsibility of keeping records and prescribing exercises for large numbers of athletes. One suggestion for monitoring the rest interval between sets might be to purchase several large digital clocks with count-down timers. These could be placed adjacent to squat racks or lifting platforms. In this manner athletes would have responsibility for setting the clock and performing the next set in a timely manner.

The research presented in this article supports the general recommendations for prescription of the rest interval between sets. Generally, longer rest intervals (i.e., 2 to 5 minutes) are prescribed when training for power and strength. This allows for greater recovery and maintenance of force production and rate of force development. Conversely, shorter rest intervals (i.e., 30 seconds to 90 seconds) are prescribed when training for hypertrophy and muscular endurance. This allows for a high level of muscular fatigue that stimulates high acute levels of anabolic hormones and increases in buffering capacity. However, these general recommendations can vary based on several factors (see Figure 1). Coaches can use the information presented in this article to adjust the rest interval between sets based on workout characteristics and individual needs.

An important topic for future research would be to examine the order of exercises performed within a workout and the interaction with the rest interval between sets. The length of the rest interval between sets may

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**Figure 4** Mean comparison bench press repetitions versus squat repetitions. Note. 5 sets of bench press (BP) and squat (SQ) were performed to failure with an absolute 15-RM load, and with 30 seconds, 1 minute, or 2 minutes rest between sets; columns depict the mean decline in repetitions over consecutive sets. Adapted from Willardson and Burkett (24). The effect of rest interval length on the sustainability of squat and bench press repetitions. *J Strength Cond Res* 20: 396–399, 2006. Reprinted by permission of the National Strength and Conditioning Association, Colorado Springs, CO.

**Figure 5** Mean comparison muscular endurance with different rest intervals. Note. Mean high intensity cycle endurance prior to (red) and following (yellow) 5 weeks of resistance training with 30 seconds, 90 seconds, or 3 minutes rest intervals between sets. Adapted from Robinson et al. (18). Effects of different weight training exercise/rest intervals on strength, power, and high intensity exercise endurance. *J Strength Cond Res* 9: 216–221, 1995. Reprinted by permission of the National Strength and Conditioning Association, Colorado Springs, CO.
depend on whether an exercise is performed at the beginning or end of a workout. Sforzo and Touey (19) demonstrated a 22% decline in total work (resistance × repetitions) on the first set of squats when preceded by leg curls and leg extensions. Similarly, Spreuwenberg et al. (20) demonstrated a 32% decline in total repetitions on the first set of squats when preceded by stiff-leg deadlift, and hang pull.

Future research might find that including longer rest intervals at the end of a workout is advantageous to maintaining the intensity and the repetitions performed per set as fatigue accumulates.

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REFERENCES