Advanced resistance training strategies for increasing muscle hypertrophy and maximal strength

Part 1: Accumulation methods

By **Louis Howe,** MSc, ASCC, *University of Cumbria*
and **Dr Mark Waldron**, *St Mary's University, Twickenham*

OVERVIEW

Training variation has been suggested as a primary principle in the pursuit of increasing muscle hypertrophy and maximal strength. Although variation may be achieved in a number of different manners within the training process, at the training session level advanced approaches to stimulating adaptations can be employed. At present, research is undecided on the benefits of these methods. Part 1 of this two-part article will review methods that may be employed to accumulate greater training volume through raising training density. Part 2 will discuss advance strategies that possess the potential to increase training intensity, while maintaining other acute exercise variables. The practical application of these methods will also be discussed, in the context of creating greater muscle cross-sectional area and developing maximal strength.

Introduction

In pursuing improvements in athletic performance, the development of maximal strength may be regarded as fundamental in underpinning the success for numerous sports skills.[38] Therefore, ensuring that an athlete is capable of developing high levels of force is a priority for many strength and conditioning (S&C) practitioners. In order to achieve high levels of maximal strength, structural and neurological adaptations can be obtained through resistance training protocols that provide a stimulus to the human organism.[9] As such, increases in force development may be obtained either directly via improvements in neuromuscular efficiency[13] or indirectly through increases in muscle cross-sectional area.[18]

During the early stages of strength development, providing an athlete with a novel stimulus is a simple task because the athlete has a low level of development and is likely to have had very little exposure to resistance training. However, as the athlete progresses in their physical development, more advanced strategies may need to be employed in order to create further adaptations.[37] In order to accomplish this, training variation should be employed strategically so as to attain a higher capacity in developing force.[33,37] This variation can be implemented at different levels within the training process in order to present a stimulus for overload.[33] At the training session level, this may be accomplished via the manipulation of any acute exercise variables.[37] However, intermediate and advanced athletes may be exposed to non-traditional training approaches that exist in order to provide overload within a training session that stimulates a new level of adaptation.[26,37]

Advanced approaches to training can be used to acutely increase either training volume or intensity by prolonging the duration of the set or allowing higher loads (intensities) to be lifted, respectively. Methods that aim to extend time under tension allow for an accumulation of training volume. This objective can be achieved by 1) reducing the intensity of the exercise as the athlete approaches momentary muscular fatigue (MMF)[34] or by 2) targeting a muscle group with a series of exercises, performed consecutively to fatigue.[15]

Accumulation methods include:

- Drop sets
- Forced repetitions
- Pre- and post-exhaustion

Methods that attempt to increase training intensity tend to do so by either diminishing fatigue,[25] reducing the work output through manipulating the distance a load is moved,[12] or by employing an alternate muscle contraction type.[4]

Intensification methods include:

- Cluster sets
- Partial range of movements exercises
- Eccentric training

The aim of this two-part article is to provide an overview of the underpinning tmechanisms for each of the advanced training methods, as well as an evidence-based review of their application in a strength and conditioning setting. This is viewed from the perspective of how each method may be used to increase either muscle hypertrophy or maximal strength. Part 1 focuses on accumulation methods, and part 2 discusses the efficacy of intensification methods to increasing training novelty for intermediate and advanced athletes.

Drop sets

Drop sets are one of the most popular methods for prolonging time under tension. Drop sets involve an athlete reaching a point of MMF (or at least approaching MMF) and reducing the load in order to increase the work completed and extend the set duration, resulting in greater fatigue. As high levels of fatigue (transient decrease in ability to produce voluntary force) correspond with metabolic stress and local ischaemia,[35] this technique provides a logical stimulus for muscle hypertrophy. Research seems to support this hypothesis, with drop sets being shown to increase the deoxygenation of a muscle, demonstrating that a mild hypoxic state may be achieved with this method.[24] Furthermore, as MMF is reached and surpassed with this technique,[16] motor unit activation may be maximised through Henneman's size principle:[7] as fatigue ensues, both lower and higher threshold motor units will be recruited to maintain force output for the duration of the set. By reducing the load following MMF, it has been hypothesised that fatigue will occur across a wider spectrum of motor units when compared to traditional sets, leading to greater adaptation.[16]

In establishing the effectiveness of drop sets, early work by Goto et al[21] showed that the addition of a drop set using 50% 1RM following a high intensity training protocol resulted in significantly greater increases in acute growth hormone response. Although the hormone hypothesis has been questioned as it relates to muscle hypertrophy adaptations,[39] these findings do suggest a modified physiological response following the supplementation of traditional training with a low intensity drop set.

Further work by Goto et al[22] compared a traditional strength protocol of five sets at 90%1RM to the same training regime with the addition of a drop set using a 25-35 RM load following the fifth set. Following a four-week training programme using the leg press and leg extension exercises, the intervention group achieved significantly greater levels of leg strength and muscular endurance[22] when compared to a traditional loading scheme. Although not significant ($p = 0.08$), an increase in muscle cross-sectional area was also observed in the intervention group incorporating the drop set protocol.[22]

These results are similar to that of Giessing et al,[20] who found that in recreationally trained subjects, a drop set protocol led to favourable results when compared to a traditional loading scheme following a 10-week intervention. Increases in performance during sub-maximal strength tests (10RM) and non-significant, yet positive increases in whole body muscle mass (effect size = 0.27 vs. -0.34) support the use of drop sets over traditional loading schemes.

Although these results appear to be in favour of the use of drop sets, issues around study design make the findings difficult to interpret. As Goto et al[22] and Giessing et al[20] did not control for training volume, it may be that the addition of a drop set led to an increase in training volumes across the intervention and, therefore, the positive results may be a consequence of participants completing more total work.[34;16] As such, this evidence is unable to demonstrate whether the additional training volume or mechanisms associated with the drop set explain the results. Regardless, these findings do suggest that when logistical factors constrain training time, increases in training density through the incorporation of drop sets may allow for increased training efficiency relative to time.

When total training volume has been matched, the benefits of drop sets appear to dissipate. Angleri et al[2] showed that 12 weeks of drop sets performed unilaterally, with 6-12 repetitions at 75% 1RM, followed by up to two drops of 20% load reductions, produced no better gains in leg extensor strength or muscle cross-sectional area – when compared to a traditional routine completing the same total training volume on the contralateral extremity. These results are similar to that of Fisher et al.[16] Of interest, Angleri et al[2] recruited 32 well-trained male subjects, with resistance training experience of 6.4 ± 2.0 years. To the authors' knowledge, this is one of the few studies that has recruited experienced lifters to investigate the efficacy of drop sets.

In the same study, Angleri and co-authors[2] increased total training volume by 7% every six workouts for each protocol. Therefore, it is possible that progressive overload was sufficiently applied for each loading scheme and, therefore, the addition of drop sets did not offer any benefit. In this sense, it is likely that each training condition allowed the athlete to stimulate muscle protein synthesis by crossing the required volume threshold in order to achieve adaptation. Therefore, it appears that the addition of drop sets provides no added benefit beyond increasing training volume. As previously stated, this provides the S&C practitioner with a useful tool. With training volume being shown to be a prerequisite for increasing maximal strength[30] and muscle hypertrophy,[31] in circumstances where time is constrained, coaches may use drop sets to increase total training volume and therefore, overcome the volume threshold in order to stimulate adaptations.

In support of this notion, Fink et al[14] recently demonstrated that following a six-week intervention, triceps brachii cross-sectional area increased significantly following a drop set protocol. Although the increases in muscle mass did not surpass that of a traditional loading scheme significantly, the effect sizes were larger for the drop set group (0.47 vs. 0.25).[14] Of interest in this study was the drop set protocol, which involved only a single working set, versus the traditional training protocol that performed three working sets.[14] These findings support the notion that when time limitations exist, a drop set protocol can be employed in order to increase the efficiency of the training session when seeking to increase muscle mass.

It should be noted, however, that Fink et al[14] established a difference in maximal strength following the intervention. Gains in maximal strength for the traditional loading protocol surpassed that of the drop set group (effect size = 0.88 versus 1.34).14 Although this finding did not reach a significant level,[14] this difference may be due to the average reduction in training intensity for the drop set intervention group. As training intensity is imperative for increasing maximal strength,[32] drop sets are therefore potentially an inferior method for increasing force output if volume is equated.

However, when drop sets are employed with heavier loads, they have been shown to increase maximal strength beyond traditional loading schemes.

Table 1. Example four-week training block aimed at developing functional hypertrophy in the upper body. Note that the interset recoveries displayed in brackets represent the rest period prior to the completion of the drop set. *perform one drop set; **perform two drop sets; AMAP = as many reps as possible

A1: MID GRIP FLAT BARBELL BENCH PRESS					
WEEK	**SETS**	**REPS**	**LOAD**	**DROP SET REPS AND LOAD**	**INTERSET RECOVERY**
1	4	8, 8, 6, 6*	75-80% 1RM	AMAP with 60% 1RM	120s (10s)
2	4	8, 8, 6, 6**	75-80% 1RM	AMAP with 60% and 45% 1RM	120s (10s)
3	5	8, 8, 6, 6, 6**	75-80% 1RM	AMAP with 60% and 45% 1RM	120s (10s)
4	3	6	75% 1RM	-	120s
A2: SINGLE ARM DUMBBELL ROW					
WEEK	**SETS**	**REPS**	**LOAD**	**DROP SET REPS AND LOAD**	**INTERSET RECOVERY**
1	4	8, 8, 6, 6*	75-80% 1RM	AMAP with 60% 1RM	120s (10s)
2	4	8, 8, 6, 6**	75-80% 1RM	AMAP with 60% and 45% 1RM	120s (10s)
3	5	8, 8, 6, 6, 6**	75-80% 1RM	AMAP with 60% and 45% 1RM	120s (10s)
4	3	6	75% 1RM	-	120s
B1: DUMBBELL INCLINE BENCH PRESS					
WEEK	**SETS**	**REPS**	**LOAD**	**DROP SET REPS AND LOAD**	**INTERSET RECOVERY**
1	2	10, 8*	70-75%	AMAP with 50% 1RM	120s (10s)
2	2	10, 8*	70-75%	AMAP with 50% 1RM	120s (10s)
3	3	10, 8, 8*	70-75%	AMAP with 50% 1RM	120s (10s)
4	2	8	70-75%	-	120s
B1: DUMBBELL INCLINE BENCH PRESS					
WEEK	**SETS**	**REPS**	**LOAD**	**DROP SET REPS AND LOAD**	**INTERSET RECOVERY**
1	2	10, 8*	70-75%	AMAP with 50% 1RM	120s (10s)
2	2	10, 8*	70-75%	AMAP with 50% 1RM	120s (10s)
3	3	10, 8, 8*	70-75%	AMAP with 50% 1RM	120s (10s)
4	2	8	70-75%	-	120s

Berger and Hardage[5] demonstrated that when repetitions are equated, a drop set protocol – whereby participants begin with a 1RM and reduced resistance in order to perform 10 repetitions – produced superior strength gains in comparison to performing a single set with a 10RM resistance. This is probably due to higher average intensity prescription.[32] Although such results are desirable, coaches should use this type of protocol with caution, as the fatigue incurred is probably high.[10]

With the nature of drop sets requiring that athletes repetitively reach the point of MMF, non-functional overreaching may occur, with a reduced anabolic environment potentially negating any positive benefits.[27]

Table 1 (on previous page) provides an example of how drop sets may be employed during a phase of training focused on increasing functional hypertrophy for the upper extremity. Note the progressive incorporation of drop sets across the initial three weeks within the training block. For example, with the mid grip flat barbell bench press exercise, the athlete in week one performs 2 sets of 8 repetitions and 2 sets of 6 repetitions, with a single drop set following the fourth set using 60% 1RM. This is progressed in the third week with the athlete performing 5 total sets, with the final set followed immediately by a double drop set, using 60% and then 45% 1RM loads.

During this phase, overload is achieved through the gradual accumulation of training volume over the initial three weeks. As fatigue is accumulated, the fourth week is designed as a de-load week with drop sets omitted from the session, so as to allow the athlete to experience a supercompensation effect.

Forced repetitions

Forced repetitions require the athlete to achieve concentric failure on a given exercise; then, with the assistance of a training partner or coach, additional repetitions are performed as the 'spotter' aids the lifter with achieving additional volume. In this sense, forced repetitions are very similar to drop sets, whereby as the athlete reaches MMF, the reduction in load allows the athlete to attain a higher level of fatigue.[1] As such, superior gains in strength or hypertrophy are likely to be a result of increased training volume.

Acute elevations in hormonal responses have been shown following the performance of forced repetitions, exceeding that of traditional training. Ahtiainen et al[1] found that following sets of 12 repetitions, where a load above 12RM was used and forced repetitions were required, hormonal responses in both cortisol and growth hormone exceeded a protocol of traditional loading. Although total repetitions were matched between loading schemes, total training volume was not equated. Therefore, these findings – if relevant – could be due to increase total volume load via the use of higher intensities.

Studies investigating the chronic effect of forced repetitions on muscle hypertrophy and maximal strength are lacking. Drinkwater et al[11] had both elite basketball and volleyball players participate in a six-week intervention, whereby three groups performed either a 12x3, 4x6 or 8x3 set-rep scheme, all with a 6RM load. Although each group performed forced repetitions at varying amounts as required in order to complete the set-rep scheme prescribed, the 4x6 group performed significantly more forced repetitions than both the 12x3 and 8x3 group.[11] However, no difference was found in muscle hypertrophy or maximal strength between the groups following the training intervention.[11] Readers should be aware that anthropometric data were taken using chest circumference and skinfold measurement in order to estimate changes in muscle mass.[11] Such techniques have been shown to lack sensitivity when establishing changes in muscle hypertrophy.[8] However, these results do indicate that, in a similar way to research investigating the effects of drop sets, when the volume and intensity threshold is met, advanced techniques should not be viewed as a superior method to that of traditional loading schemes.

As forced repetitions may allow for increases in training density via the addition of training volume per unit of time, coaches have the option of employing forced repetitions when a time restriction exists in the planning of training sessions. Limitations to this technique exist, however, with the need of assistance being required. As such, the level of support during the forced repetitions is difficult to control and prescribe for during each repetition. Therefore, if coaches seek to ensure progressive overload is achieved throughout the training cycle, consideration should be given to this concern.

Table 2 demonstrates how forced repetitions may be incorporated into a training programme seeking to increase hypertrophy for the thigh musculature across a four-week training block. Similar to the previous example, forced repetitions are gradually introduced within the initial three weeks, and then removed in the fourth to allow for recovery before proceeding into the next phase of training. It is recommended that the same spotter be used across the training block in order to provide consistency between sessions. Each spotter should be well trained on how to aid the athlete in performing the additional repetitions, ensuring the athlete achieves MMF.

Pre-exhaustion

Pre-exhaustion techniques are suggested to work on a similar premise to drop sets and forced repetitions, whereby fatiguing a muscle with a single joint exercise before a multi-joint movement has the potential to increase the level fatigue to which a muscle is exposed.[17] The resultant fatigue would, therefore, theoretically lead to greater recruitment of higher threshold motor units during the second movement,[7] as well as increasing the metabolic stress within the target muscle. An example of a pre-fatigue method would be for an athlete to perform a seated leg extension to MMF in order to pre-fatigue the quadriceps, immediately followed by the barbell back squat. This method of inducing greater fatigue ostensibly increases the neuromuscular recruitment of the target muscle by allowing non-fatigued muscles to support in the performance of the compound movement.[28]

However, studies analysing the electromyography (EMG) of the prime mover have failed to show increases in muscle activity during the multi-joint movement following a pre-fatigue exercise.[3,19] In fact, Augustsson et al[3] demonstrated that during the leg press exercise, the rectus femoris and vastus lateralis EMG activity significantly decreased following the pre-fatigue technique, induced via the seated leg extension exercise. Subjects also were able to perform significantly less reps on the multi-joint leg press exercise following the seated leg extension exercise.[3] As a result of these findings, the authors suggest that pre-fatiguing a muscle is unlikely to lead to greater gains in muscle hypertrophy or maximal strength.[3] This is also likely to be the case for increasing maximal strength during the compound movement, due to lower intensities being handled in order to complete a given repetition number.

These results are supported by studies investigating muscle activation strategies in the upper extremity during the bench press movement.[6,19] When either the pec deck[19] or dumbbell flyes[6] exercises were used to pre-exhaust the pectoralis major prior to a pressing exercise, pectoralis major activation reduced significantly. Therefore, the relevant body of literature disputes the notion that a pre-exhausting technique leads to greater muscle activation during the multi-joint movement.

Interestingly, the triceps brachii muscle activity has been shown to significantly increase during horizontal pressing exercises, following the pre-exhaustion of pectoralis major.[6,19] This suggests that when a target muscle is pre-fatigued, synergistic muscle activation is up-regulated in order to compensate during multi-joint movements. The strength and conditioning practitioner may use this finding to increase the muscle recruitment of down-regulated muscles (secondary to inhibition). For example, if a coach wanted an athlete to improve their gluteal recruitment during the squat, it may be that pre-fatiguing the quadriceps demands increased muscle activity of the gluteals as a compensatory mechanism. This counterintuitive thought process requires further investigation, but the theoretical mechanism has potential. Furthermore, the long-term effects of this strategy on synergistic muscle activity should also be established.

For both Gentil et al[19] and Brennecke et al,[6] the pre-fatiguing stimulus (ie, the isolation exercise) was performed to MMF. However, Júnior et al[29] showed that when the isolation exercise was not carried out to MMF, muscle activation was higher in the target muscle during the subsequent multi-joint exercise. This finding provides the rationale for why many coaches choose to include isolated hip extensor work in their dynamic warm up routines. This same strategy may, therefore, be employed in resistance training sessions, whereby a target muscle is stimulated acutely in order to enhance its activation during a compound exercise. Ensuring the isolation exercise is not carried out to MMF will likely accomplish this increase in muscle activation.

Table 2. Example four-week training block for increasing hypertrophy in the thigh musculature using forced repetitions. Note that '+ 2-3 FR' indicates the number of forced repetitions that should be performed with assistance from a spotter

A1: BARBELL BACK SQUAT				
WEEK	SETS	REPS	LOAD	INTERSET RECOVERY
1	4	6	75-80% 1RM	180s
2	5	5	77-82% 1RM	180s
3	6	4	80-85% 1RM	180s
4	3	6	75-80% 1RM	180s
B1: SEATED LEG PRESS				
WEEK	SETS	REPS	LOAD	INTERSET RECOVERY
1	2	8 + 2-3 FR	72-75% 1RM	180s
2	3	8 + 2-3 FR	72-75% 1RM	180s
3	3	8 + 2-3 FR	75-77% 1RM	180s
4	2	8	75-77% 1RM	180s
C1: ROMANIAN DEADLIFT				
WEEK	SETS	REPS	LOAD	INTERSET RECOVERY
1	3	8-10	70-75%	120s
2	3	8-10	70-75%	120s
3	4	6-8	72-77%	120s
4	2	6-8	72-77%	120s

Table 3 provides an example training session that may be employed to increase gluteal recruitment during squatting.

To date, very few longitudinal studies have been conducted in order to establish the long-term benefits of the pre-exhaustion method. Fisher et al[16] investigated the effects of a 12-week intervention programme using the pre-exhaustion technique, finding no significant differences in upper and lower extremity strength or changes in body composition in comparison to a traditional training group. Effect sizes for both groups also did not differ.[16] Therefore, it appears that employing the pre-exhaustion training method does not lead to superior gains in muscle hypertrophy or maximal strength when training exposure is controlled.

Practical applications

High training volume is a key determinant in stimulating muscle hypertrophy,[36] likely to be caused through the raised metabolic stress.[23,24] As such, strategies that extend time under tension and therefore increase training volume, may be predominantly used to target increases in muscle cross-sectional area. These methods may be particularly useful when a time constraint exists and coaches need to increase training density in order to drive a hypertrophic response.

However, in situations where time is not limited, these accumulation methods appear to be unable to increase muscle hypertrophy beyond what traditional training methods offer as long as progressive overload is achieved. As training volume for muscle hypertrophy appears to be subject to the law of diminishing returns,[36] these methods are probably inadequate at stimulating further increases in muscle hypertrophy as long as a volume threshold is met within the training cycle. Furthermore, with techniques such as drop sets and forced repetitions requiring an athlete to tachieve MMF, the accumulation of fatigue may be problematic as it increases the potential for non-functional overreaching.[27]

Accumulation methods, such as drop sets and the pre-exhaustion technique, may be inferior in increasing maximal strength due to the average training intensity being reduced when volume is equated. As training intensity is a crucial factor for consideration when developing force output capacity,[32] incorporating methods that reduce training intensity at the expense of increasing training density may be insufficient for developing maximal strength. However, at times of the year where maximal strength is the focus and muscle mass is to be maintained, incorporating a drop set or forced repetitions at the end of a strength routine may allow for a hypertrophy stimulus to be present, without excessive time being required.[22]

Lastly, the pre-exhaustion technique may be used to manipulate the organisation of muscle activation strategies. With reduced activation of the fatigued muscle and increased recruitment of synergistic prime movers,[3,6,19] coaches may use the pre-exhaustion method to emphasise the activation of certain muscles during multi-joint movements. Furthermore, by not taking the target muscle to MMF, coaches may increase the activation of potentially inefficient muscles during compound exercises, in order to improve the athlete's movement quality.[29]

Conclusion

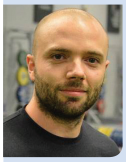
Advanced approaches can be employed that allow coaches to raise training volume through elevating training density. Drop sets, forced repetitions and pre-exhaustion methods all have the potential to increase total work completed per unit of time. The resultant fatigue induced has the potential to act as a stimulus for structural adaptations. Thus, increases in muscle hypertrophy and maximal strength may be observed following these methods, although the present body of evidence suggests that they are no more superior than traditional training methods as long as training volume is equated and progressive overload is present.

Part 2 of this article will discuss the mechanisms and potential benefits of intensification methods. Following this discussion, the practical application of intensification methods will be discussed.

Table 3. Example training session for increasing gluteal recruitment during the barbell back squat

ORDER	EXERCISE	SETS	REPETITIONS	LOAD	INTERSET REST
A1	Barbell hip thrusts	4	5	50% 1RM	60s
A2	Barbell back squat	4	4-5	80-85% 1RM	120s
B1	Romanian deadlifts	4	6-8	75% 1RM	120s
C1	Barbell reverse lunge	3	6-8 each leg	75% 1RM	120s

AUTHORS' BIOGRAPHIES



LOUIS P HOWE, MSC, ASCC

Louis has been coaching international level athletes for over ten years. He is currently a lecturer at the University of Cumbria, in both the Sport Rehabilitation and Sport and Exercise Science undergraduate degrees. Academically, he is currently completing his PhD, investigating the variability of compensatory movement strategies derived from ankle dorsiflexion range of motion deficits.

DR MARK WALDRON,

Mark is a senior lecturer in exercise physiology at St Mary's University, Twickenham.

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