The Use of Specialized Training Techniques to Maximize Muscle Hypertrophy

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It is well accepted that progressive resistance training can bring about significant increases in muscle size. Enlargements in muscle cross sectional area (CSA) of approximately 10-15% have been reported after just 10–14 wk of dynamic heavy-resistance training (49; 58; 32). Muscle hypertrophy is limited during the initial weeks of training, with the majority of strength increases in untrained individuals attributed to neural and architectural adaptations (63). Thereafter, hypertrophy becomes increasingly evident, with the upper extremities tending to display growth before the lower extremities (52; 70). Although muscle hypertrophy is apparent in both Type I and Type II fibers, significantly greater gains are seen in Type II fibers (70; 42). Factors that mitigate the rate and absolute limits of muscular gains include genetics, age, and gender (43).

A significant number of those who lift weights do so to maximize muscular development. Hypertrophy is especially important to strength athletes (e.g. football linemen, shot putters, etc) given that a direct correlation exists between strength and muscle cross sectional area (29; 37), as well as bodybuilders, who are judged on the extent of their muscularity. A variety of specialized training techniques have been advocated as a means to heighten muscle growth. Forced repetitions, drop sets, supersets, and heavy negatives, in particular, have been purported to enhance the hypertrophic response to resistance exercise. Thus, the purpose of this paper will be to explore the potential role of these techniques in promoting muscle hypertrophy and to provide insight into possible applications to resistance training programs.

Mechanisms of Muscle Hypertrophy

Although the mechanisms of exercise-induced muscle hypertrophy have not been fully elucidated, current theory suggests that it is mediated by mechano-chemically stimulated intracellular signaling and involves a complex interaction of hormones, growth factors, myokines, and other signaling agents. These upstream regulators act on various myogenic pathways such as PI3K/Akt/mTOR (71; 39; 6), MAPK (44; 60), and calcium-signaling pathways (11; 12). Initiation of one or more of these pathways sets off an enzymatic cascade that ultimately increases protein synthetic rate and/or decreases the rate of proteolysis, leading to a greater accumulation of myofibrillar proteins (61).

Three basic factors have been implicated in promoting exercise-induced muscle hypertrophy: mechanical tension, muscle damage, and metabolic stress. Depending on the stimulus, these factors may work in tandem to produce a synergistic effect on muscle development (61). The following is a brief overview of these factors. For an in depth analysis of the topic, see the author's review article (61).

Mechanical tension is perhaps the most dominant mediator of muscle hypertrophy (18; 34; 73). It is believed that mechanical tension disturbs the integrity of skeletal muscle, causing mechano-chemically transduced molecular and cellular responses in myofibers and satellite cells (72). With respect to resistance training, the degree of mechanical tension is primarily a function of intensity (amount of load) and time under tension (duration of applied load). An optimal combination of these variables will maximize motor unit (MU) recruitment and rate coding, thereby bringing about the fatigue of a wide spectrum of MUs and thus a greater hypertrophic response (59).

Localized muscle damage caused by resistance training has also been implicated in mediating muscle growth (14; 31). The onset of myodamage initiates an inflammatory response involving neutrophils, macrophages and lymphocytes. This leads to the production of myokines, which are believed to potentiate the release of various growth factors that regulate satellite cell proliferation and differentiation (72; 74). Mechano growth factor (MGF), a splice variant of IGF-

1 that is locally expressed in muscle fibers, appears to be particularly sensitive to muscle damage (18; 5) and thus may be directly responsible for the increased satellite cell activity seen with myotrauma.

Finally, an emerging body of research indicates that exercise-induced metabolic stress can act as a potent hypertrophic stimulus (65; 59; 62; 66). Metabolic stress arises from the performance of resistance exercise that relies predominantly on anaerobic glycolysis for ATP production, which in turn results in the intramuscular accumulation of metabolites such as lactate, hydrogen ion, and inorganic phosphate (70; 67). Metabolic buildup is believed to promote positive alterations in anabolic milieu, conceivably modulated by a combination of hormonal factors (including IGF-1, testosterone, and growth hormone), cellular hydration, free radical production, and/or activity of growth-oriented transcription factors (22; 19; 68). Some researchers have speculated that the lower pH associated with fast glycolysis may further augment hypertrophic adaptation by stimulating sympathetic nerve activity and increasing fiber degradation (8).

Specialized Training Techniques for Muscle Hypertrophy

Forced repetitions, drop sets, supersets, and heavy negatives are popular training techniques for increasing muscle development. Although research is lacking as to their direct impact on muscle hypertrophy, a large body of implied data provide a sound theoretical rationale for a beneficial effect. The following sections explore the applicability of these techniques with respect to a hypertrophy-oriented routine.

Forced Repetitions

Forced repetitions (i.e. assisted repetitions) involve the use of a spotter who assists the lifter in the performance of additional repetitions after concentric failure is reached, often to help move the weight past a "sticking point." It is theorized that forced repetitions may enhance the hypertrophic stimulus by augmenting MU fatigue and/or metabolic stress.

Ahtiainen et al. (1) investigated the effects of forced repetitions on acute growth hormone (GH) secretion following performance of four sets of 12 repetitions of the leg press and two sets of 12 repetitions for the squat and leg extension. A maximum repetition (MR) group performed all sets at their 12 RM, while a forced repetition (FR) group utilized a load higher than MR so that the subjects required assistance to complete 12 repetitions. After 30 minutes post-workout, GH levels were significantly greater in the FR group compared to those who did not perform forced reps. Volume (as measured by total repetitions performed) was equated between groups, implying that elevated hormonal concentrations were attributable to the use of forced reps.

There is some disagreement among researchers as to whether GH actually is involved in the anabolic response to exercise. However, studies indicate that an exercise-induced increase in GH is in fact highly correlated with the magnitude of both type I and type II muscle fiber hypertrophy as well as strength-related muscular adaptations (48; 26). Evidence suggests that this may be related to GH's ability to potentiate the upregulation of the IGF-1 gene in muscle so that more IGF-1Ea is spliced toward the MGF isoform (27; 36). Additional research is needed to elucidate what, if any, role exercise-induced elevations in GH play in the hypertrophic process and whether this is a benefit to employing forced reps in a muscle building program.

Drop Sets

Similar to forced repetitions, drop sets (a.k.a. descending sets) involve performing a set to muscular failure with a given load and then immediately reducing the load and continuing to train until subsequent failure. It is believed that this technique can stimulate greater muscular growth by inducing greater MU fatigue (75). The increased time under tension associated with drop sets would likely also heighten metabolic stress and ischemia, enhancing anabolic milieu. Multiple drops can be performed in the same set to elicit even greater levels of fatigue and metabolic stress.

There is some evidence that drop sets can indeed enhance the body's anabolic environment following resistance exercise. Goto et al. (20) assessed the inclusion of a low intensity set (50% of 1RM) immediately following performance of a high-intensity set. Results showed a significant spike in GH levels associated with the additional low-intensity drop set. Follow up work by Goto et al. (21) showed that the addition of a drop set to a standard strength training protocol resulted in a significant increase in muscle CSA as opposed to the strength training protocol alone. Neither of these studies controlled for total training volume, however, leaving open the possibility that the elevated hormonal response and associated muscle protein accretion was caused by an increased volume.

As opposed to forced reps, drop sets do not necessarily require the presence of a spotter. This allows for greater independence when training as well as affording lifters with greater control over the intensities employed.

Given that forced reps and drop sets both involve training to muscular failure, caution must be utilized when integrating these techniques into a hypertrophy-oriented program. Repeatedly training to muscle failure over time has been shown to increase the potential for overtraining and psychological burnout (17), and may lead to reductions in resting IGF-1 concentrations and a blunting of resting testosterone levels (38). Hence, a general recommendation is to employ forced reps and drop sets sparingly in the context of a periodized routine. It is usually prudent to limit their use to a select few sets in a given microcycle, making sure to intersperse periods of unloading to allow for necessary recuperation. That said, recuperative abilities are highly dependent on the individual and are impacted by nutritional supplementation, the use of anabolic steroids, and other factors which may allow for more frequent use of these techniques.

Supersets

Supersets (a.k.a. paired sets) can be defined as two exercises performed in succession without rest (56). Although supersets have long been employed in bodybuilding routines, a search of the literature failed to reveal any studies directly investigating whether their use facilitates increases in muscular growth. However, it is conceivable that the reduced rest between sets increases muscular fatigue and metabolic stress, which may enhance hypertrophy.

Hypothetically, any two exercises can be combined to form a superset. Perhaps the most common superset technique involves the performance of exercises that share an agonist/antagonist relationship, sometimes called agonist-antagonist paired set (APS) training. Multiple studies have shown that contracting an antagonist muscle increases force output during subsequent contractions of the agonist (9; 23; 24; 40). This has been attributed to reduced antagonist inhibition and/or an increase in stored elastic energy in the muscle-tendon complex (40; 4). The greater mechanical tension generated by the agonist could potentially lead to increases in muscular growth. There is some evidence that the benefits associated with precontractions may be limited to faster movements (47), suggesting that hypertrophy would be optimized by performing concentric repetitions explosively during the second exercise in a superset.

Robbins et al. (57) demonstrated that APS training allows for a greater number of repetitions to be performed per given unit of time without significantly reducing intensity or total training volume. This increased “training density” is achieved through acute improvements in training efficiency, which necessarily heightens the extent of fatigue. The elevated levels of fatigue, in turn, may contribute to the hypertrophic stimulus (59). Although markers of metabolic stress were not studied, an increased training density would conceivably require a greater reliance on anaerobic glycolysis, enhancing anabolic milieu.

Heavy Negatives

Heavy negatives (supramaximal loaded eccentric actions) involve the performance of eccentric contractions at a weight greater than concentric 1 RM. This usually requires a spotter to help raise the weight concentrically after the lifter performs the eccentric repetition. The lifter may perform multiple repetitions depending on training intensity. Given that a muscle is not fully fatigued during concentric training (75), the use of heavy negatives may elicit greater MU fatigue and thus provide an additional hypertrophic stimulus.

A significant body of research shows that eccentric exercise elicits greater gains in lean muscle compared to concentric and isometric contractions (15; 30; 54; 16). Hather et al. (28) found that maximal muscle hypertrophy in response to resistance exercise is not attained unless eccentric muscle actions are performed. To this end, eccentric actions are associated with a more rapid rise in protein synthesis (51) greater increases in IGF-1 mRNA expression (64), and more pronounced elevations in $p70^{S6k}$ (13) when compared with other types of contractions.

Several explanations have been proposed to account for the hypertrophic superiority of eccentric exercise. For one, it is associated with greater muscle damage which, as previously noted, has been shown to mediate a hypertrophic response (14; 31). Damage to muscle manifests as Z-line streaming, which current research suggests is indicative of myofibrillar remodeling (10; 76). Z-bands are critical sites for mechanotransduction and localized trauma is believed to facilitate hypertrophic signaling (33). c-Jun NH_2–terminal kinase (JNK), a signaling module of

MAPK, appears to be particularly sensitive to eccentrically-induced muscle damage (7). The activation of JNK by eccentric contractions is coupled with significant elevations in mRNA of transcription factors involved in cell proliferation and DNA-mediated tissue repair (2; 3; 7).

Eccentric exercise also has been shown to provoke a preferential recruitment of fast-twitch muscle fibers (64; 69; 53) and possibly elicit recruitment of previously inactive motor units (50; 53). Increased high threshold MU recruitment occurs in conjunction with a reduced activation of slow twitch fibers, resulting in a greater amount of stress per motor unit (25; 45). The net result is increased mechanical tension in Type II fibers which, because of their anaerobic phenotype, have the greatest potential for muscle growth (70; 42). This was demonstrated by Hortobagyi et al. (35) who investigated the effects of eccentric contractions versus concentric contractions on muscle CSA in the quadriceps. After 12 weeks, type 1 fiber diameter was not significantly different between groups, but eccentric exercise resulted in a tenfold increase in diameter compared to concentric exercise.

Finally, eccentric training is associated with increased metabolic stress. Ojasto, & Häkkinen (55) reported an elevated lactate buildup and a corresponding spike in anabolic hormonal levels following accentuated eccentric training, with the greatest increases noted when training at higher eccentric intensities.

Given that eccentric strength is approximately 20-50% greater than concentric strength (5), a general recommendation is to perform heavy negatives with a load between 105 to 125% of concentric 1RM. This will allow the lifter to complete multiple repetitions at a supramaximal intensity. A 2 to 3 second eccentric tempo is hypothesized to be ideal for maximizing a hypertrophic response (61).

As with forced repetitions, a downside of heavy negatives is that a spotter is required for performance and, in instances where free weights are used, two spotters may be required if the loads are sufficiently heavy. Moreover, forced reps also overtax the neuromuscular system and therefore can hasten the onset of overtraining. Moderation is therefore required when integrating this technique into hypertrophy-oriented programs.

Conclusion

Evidence suggests a beneficial effect for selectively including forced reps, drop sets, supersets, and heavy negatives in a hypertrophy-oriented resistance training routine. The lack of direct research examining the hypertrophic effect of these techniques makes it difficult to provide specific guidelines for volume and frequency. However, their fatiguing nature increases the risk for overreaching and overtraining, and it is generally prudent to limit their use to no more than a few microcycles over the course of a periodized program. That said, people have differing recuperative abilities and experimentation is therefore necessary to determine an appropriate volume and frequency for the individual. Potential signs of overtraining should be continually monitored to optimize results.

Moreover, these techniques should be considered advanced training strategies. Their use has a taxing effect on the neuromuscular system that is likely to exceed a beginner's capacity for adaptation. Based on the author's experience, a minimum of several months of regimented training is warranted before integrating the techniques into a routine.

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