© National Strength & Conditioning Association
Volume 22, Number 6, page 67–69

Repetitions and Muscle Hypertrophy

Brad Schoenfeld, CSCS
Personal Training Center for Women
Scarsdale, New York

Keywords: repetitions; muscular mass.

MANY EXERCISE-RELATED factors influence muscular mass. Among them is repetition range—the amount of repetitions performed during a set. Unfortunately, this is one of the most misunderstood aspects of training.

Most people realize that the use of a high number of repetitions (in excess of 15 per set) is suboptimal for increasing muscular mass. The reason for this is simple: during a high-repetition set, the weights used aren't heavy enough to innervate the highest threshold motor units. These motor units control the fast-twitch, type IIB fibers—the ones that have the greatest potential for growth. Rather, the majority of work is accomplished by slow-twitch type I fibers, which are fatigue resistant but have a limited ability to hypertrophy. Thus, although high-repetition training is an excellent approach for heightening local muscular endurance and improving the quality of muscle tissue, it produces only minimal gains in muscular size.

On the other hand, there is a prevailing misconception that in order to get big, one needs to train like a powerlifter, using extremely heavy weights and low repetitions (less than 5 per set). It is common to witness an aspiring bodybuilder load up the bar and perform sets of squats or bench presses at or near his or her 1-repetition maximum. This approach, however, is contrary to established principles of exercise physiology. For a variety of reasons, a moderate-repetition scheme (approximately 8 to 10 repetitions per set) is the decidedly better choice for achieving optimal gains in muscular mass.

First, training in a moderate-repetition range stimulates the activation of a maximum number of muscle fibers. This is because of the size principle of muscle recruitment, which dictates that motor units are innervated in an orderly fashion. Smaller motor units are activated first. As a set becomes more intense, larger motor units are progressively brought into play until all available fibers are recruited. This is the general pattern of recruitment seen during moderate-repetition training, and it allows the full spectrum of fibers to exert force.

Alternatively, because low-repetition training requires an explosive concentric effort, the size principle can be short circuited. There is evidence that in a ballistic lift, synaptic-input systems cause the preferential recruitment of high-threshold motor units while inhibiting lower threshold motor units (15). Accordingly, smaller fibers are bypassed in favor of those with greater force potential. Although small fibers don't have the ultimate growth potential of larger fibers, they do, to a certain extent, contribute to muscle hypertrophy. Therefore, because of a reduced involvement of low-threshold neurons, the potential for muscular development is ultimately diminished.

Second, the secretion of endogenous, anabolic hormones is highest after a moderate-repetition set (8). After a muscle has been subjected to intense stress, these hormones help to instigate the growth process. As a rule, the greater the amount of circulating anabolic hormones, the greater the potential for increases in muscular hypertrophy.

It is theorized that lactic acid plays a central role in exercise-related hormonal excitation (11). Although many people tend think of lactic acid as an impediment to exercise, it is actually a potent anabolic facilitator. Lactic acid is generated as a byproduct of glycolysis, the energy system that is the primary fuel source used during moderate-repetition training. When lactic acid accumulates in large amounts, there is a corresponding surge in anabolic hormone levels. Conversely, because low-repetition training predominantly relies on the short-term phosphocreatine system for energy—not on glycolysis—only a limited amount of lactic acid is produced. Hence, the secretion of endogenous hormones is somewhat blunted.

Testosterone levels, for example, are significantly higher after a 10-repetition set when compared with the case after a 1-repetition maximum (3). Although the exact mechanism is still unclear, lactic acid somehow potentiates the release of cyclic adenosine monophosphate (cAMP)—a chemical messenger that acts a catalyst in cellular function. cAMP, in turn, promotes the secretion of testosterone, which then directly acts on the muscle cell to stimulate growth (9).

In addition, lactate has a significant impact on growth hormone (GH) secretion. A 10-repetition set has been shown to produce large increases in circulating GH—much greater than in a lower-repetition protocol (6). Moreover, these effects are fairly well sustained; they are seen for more than an hour after the workout (7). And the benefits of this are twofold: not only is GH itself a powerful stimulator of muscular growth, but it also mediates the release of insulin-like growth factor (specifically, IGF-1), perhaps the most potent of all anabolic hormones.

Third, moderate-repetition training augments myofibrilar hydration (14). During training, the veins taking blood out of working muscles collapse. However, the arteries continue to deliver blood into the muscles, creating an increased concentration of intramuscular blood plasma. This causes plasma to seep out of the capillaries and into the interstitial spaces (the area between muscle cells and blood vessels). The buildup of fluid in the interstitial spaces causes an extracellular pressure gradient, which causes a flow of plasma back into the muscle. The net result: blood pools in your muscles, causing the phenomenon commonly referred to as a "pump."

People tend to think of a pump as a temporary condition that is strictly cosmetic. However, this belief is shortsighted. Numerous studies have demonstrated that a hydrated cell stimulates protein synthesis and inhibits proteolysis (protein breakdown; 4, 10, 13). In this way, muscles are provided with the raw materials to lay down new contractile proteins—the basis for muscle tissue growth. Unfortunately, during low-repetition training, the time under tension simply isn't sufficient to generate a pump. Consequently, cell volume is relatively constant, and the impetus for protein synthesis is thereby reduced.

Fourth, by increasing time under tension, a moderate-repetition set maximizes muscle damage—a fact that has been shown to be imperative to increases in muscular hypertrophy (2). Theoretically, the longer that cross-bridge formation is maintained during training, the greater the potential for damage to the tissue. Because the duration of cross-bridge formation is shorter in a low-repetition set than in a moderate-repetition set, there is less time for myofilamental damage to take place.

It is important to note that these concepts are predicated on the overload principle, which states that a muscle must be taxed beyond its present capacity for growth to occur (5). Hence, all sets (excluding warm-ups) should be performed at a high level of intensity. This is an essential factor for promoting gains in size and strength (1, 12). Clearly, without muscular overload, results will be compromised.

In final analysis, there is substantial evidence that training in a moderate-repetition range is the superior method for building muscular mass. As discussed, it optimizes fiber recruitment, increases hormonal response, enhances cellular hydration, and heightens myofilamental damage. These factors work synergistically, combining to stimulate muscular growth. But does this mean that lower repetitions should never be employed in a mass-building program? Certainly not. Low-repetition sets can help to improve neuromuscular response, which in turn can translate into the ability to use heavier weights. Similarly, some high-repetition sets can also be employed to refine muscular endurance and raise lactate threshold. Still, if mass is your goal, the majority of training should be performed in a glycolytic mode, keeping repetitions between 8 to 10 per set. ▲

■ References

1. Atha, J. Strengthening muscle. *Exerc. Sport Sci. Rev.* 9:1–73. 1981.
2. Evans, W.J., et al. The metabolic effects of exercise-induced muscle damage. *Exerc. Sport Sci. Rev.* 19(-HD-):99–125. 1991.
3. Hakkinen, K., et al. Acute hormonal responses to two different fatiguing heavy-resistance protocols in male athletes. *J. Appl. Physiol.* 74(2):882–887. 1993.
4. Häussinger, D., et al. Cellular hydration state: An important determinant of protein catabolism in health and disease. *Lancet.* 341(8856): 1330–1332. 1993.
5. Hellebrandt, F.A., et al. Mechanisms of muscle training in man: Experimental demonstration of the overload principle. *Phys. Ther. Rev.* 36:371–383. 1956.
6. Kraemer, W.J., et al. Hormonal and growth factor responses to heavy resistance exercise protocols. *J. Appl. Physiol.* 69(4):1442–1450. 1990.
7. Kraemer, W.J. et al. Endogenous anabolic hormonal and growth factor responses to heavy resistance exercise in males and females. *Int. J. Sports Med.* 12(2):228–235. 1991.
8. Kraemer, W.J. et al. Changes in hormonal concentrations after different heavy-resistance exercise protocols in women. *J. Appl. Physiol.* 75(2):594–604. 1993.
9. Lu, S.S., et al. Lactate and the effects of exercise on testosterone secretion: Evidence for the involvement of a cAMP-mediated mechanism. *Med. Sci. Sports Exerc.* 29(8):1048–1054. 1997.
10. Millar, I.D., et al. Mammary protein synthesis is acutely regulated by the cellular hydration state. *Biochem. Biophys. Res. Commun.* 230(2): 351–355. 1997.
11. Roemmich, J.N. et al. Exercise and growth hormone: Does one affect the other? *J. Pediatr.* 131(1 Pt 2):S75–S80. 1997.
12. Rooney, et al. Fatigue contributes to the strength training stimulus. *Med. Sci. Sports Exer.* 26(9):1160–1164. 1994.
13. Waldegger, S., et al. Effect of cellular hydration on protein metabolism. *Miner. Electrolyte Metab.* 23(3–6):201–205. 1997.
14. Wilmore, J.H., et al. *Physiology of Sport and Exercise* (2nd ed.). Champaign, IL: Human Kinetics, 1999.
15. Zehr, E.P., et al. Ballistic movement: Muscle activation and neuromuscular adaptation. *Can. J. Appl. Physiol.* 19(4):363–378. 1994.

Schoenfeld

Brad Schoenfeld, CSCS, is the owner and founder of the Personal Training Center for Women in Scarsdale, NY. He is author of the book, *Sculpting Her Body Perfect.*