

**Eccentric overload training: A viable strategy to enhance muscle hypertrophy?**

\*Brad Schoenfeld<sup>1</sup>

Jozo Grgic<sup>2</sup>

<sup>1</sup>Department of Health Sciences, Lehman College, Bronx, NY, USA

<sup>2</sup>Institute of Sport, Exercise and Active Living (ISEAL), Victoria University, Melbourne,  
Australia

\*Corresponding author

Brad Schoenfeld

Department of Health Sciences, Lehman College, Bronx, NY, USA

## Abstract

It has been postulated that eccentric actions have the greatest effect on muscle hypertrophy. The potential hypertrophic benefits to eccentric training raise the possibility that muscular growth could be enhanced by supplementing resistance training with eccentric overload training. Herein we examine whether this strategy is efficacious for enhancing muscle growth.

## Introduction

Resistance training (RT) can be carried out with 3 distinct types of muscle actions: concentric, eccentric, and isometric. Concentric actions occur when a muscle produces force as it shortens; eccentric actions occur when a muscle produces force as it forcibly elongates; and isometric actions occur when a muscle produces force without a change in its length (24). Of these actions, it has been postulated that eccentric actions are the most important from a hypertrophy standpoint. This hypothesis is supported by findings that eccentric actions elicit more rapid elevations in muscle protein synthesis and greater increases in intracellular anabolic signaling and gene expression versus concentric actions (6, 11, 19, 29). However, acute studies cannot necessarily be generalizable to long-term adaptations. Results from longitudinal studies examining muscle actions and hypertrophy adaptations are somewhat equivocal on the matter. While some studies show that eccentric actions promote greater muscle growth compared to concentric and isometric contractions (8, 13, 17, 20), others have failed to show significant hypertrophic differences between conditions (9, 11, 18).

A recent meta-analysis by Schoenfeld et al. (28) sought to provide clarity on this topic. Pooled analysis of 15 studies directly comparing hypertrophic changes between different

dynamic muscles actions showed a greater magnitude of effect for eccentric versus concentric RT, but results did not reach statistical significance. When quantified on a percentage basis, the average gain from eccentric actions corresponded to 10.0% compared to 6.8% for concentric actions, a finding that can be deemed potentially meaningful from a practical standpoint. A potential confounding issue with these findings is that a majority of studies matched the number of repetitions as opposed to total work. Given that strength capacity for eccentric actions exceeds that of concentric actions by as much as 50% (1), it cannot be ruled out that growth-related advantages favoring eccentric exercise resulted from the greater loads employed during training. Moreover, many of the studies were carried out using isokinetic dynamometry, and thus the results cannot necessarily be generalized to isoinertial training RT commonly performed in gym settings.

It has been proposed that an increase in muscle damage may at least partially account for the superior hypertrophic effects of eccentric actions (26). Although myodamage is seen with the performance of concentric and isometric training (4, 15), eccentric exercise causes the greatest damage to muscle tissue (7), purportedly due to heightened forces distributed among fewer active fibers (24). Muscle damage is considered to be one of the three primary mechanisms of exercise-induced muscle hypertrophy (25). Although the factors responsible for this phenomenon remain to be elucidated, current theory postulates that structural microtears to contractile elements and the extracellular matrix initiates anabolic processes to reinforce these tissues and thereby safeguard them from future injury (2). Intriguingly, there is some evidence that concentric and eccentric actions elicit regional-specific adaptive hypertrophic responses in the vastus lateralis, with greater distal growth from eccentric actions and greater growth in the mid-portion of the muscle from concentric actions (11). The reasons for these findings have yet to be

elucidated, but it has been speculated that they may result from regional muscle damage along the length of the fiber that in turn causes non-uniform alterations in muscle activation (16).

The potential hypertrophic benefits to eccentric training raise the possibility that muscular growth could be enhanced by supplementing RT with eccentric overload training (23). Such a strategy involves performing isolated eccentric actions with a load greater than the concentric 1 repetition maximum (RM), or, performing concentric actions at a given load, and increasing the load over the concentric 1RM on the eccentric part of the lift. Hypothetically, the greater magnitude of load used in this type of training may enhance the growth response by heightening stimulation of type II fibers and increasing structural perturbations to the working musculature. In addition, there may be beneficial effects on regional hypertrophic adaptations, particularly in the quadriceps femoris. Some studies also report that eccentric overload training might increase metabolite accumulation, specifically, blood lactate (32). Metabolite accumulation has also been hypothesized to be an important factor contributing to muscle hypertrophy (27).

Recently, Fisher and colleagues directly investigated the effects of coupling isoinertial eccentric overload training with traditional RT on measures of lean mass (10). A cohort of young, resistance-trained men and women were randomly assigned to one of three different groups: (i) a traditional training group that performed 8-12RM of combined concentric and eccentric actions twice per week; (ii) an eccentric training group that performed 1 traditional training session and 1 eccentric-only session per week, or (iii) an eccentric-only group that performed 2 weekly eccentric training sessions. Eccentric training was carried out at a load equating to 105% of the subject's 1RM, allowing muscular failure to occur in ~6 repetitions. At the conclusion of the 10-week study period, no significant differences in fat-free mass changes

were found between conditions. While these findings suggest there is no advantage to eccentric overload training, it should be noted that measures of fat-free mass were obtained by air displacement plethysmography, which includes all non-fat components of body composition and therefore is not specific to changes in muscle mass.

Brandenburg and Docherty (3) compared a group training at a load of 75% of 1RM for 4 sets of 10 repetitions to a group that used the same load for the concentric part of the lift but increased the load to ~115% of the concentric 1RM for the eccentric portion. In order to equate for volume load, the latter group performed 3 sets of 10 repetitions. The sample consisted of 18 young trained men and training was carried out using the preacher curl and supine elbow extension exercises. Magnetic resonance imaging (MRI) was used for the assessment of hypertrophy, which is considered to be the 'gold standard' measurement tool (21). Surprisingly, following nine weeks of the training intervention, no pre to post-changes in muscle cross sectional occurred in both groups. Of importance is the fact that two participants in the eccentric overload group dropped-out of the study because of forearm pain, which might have been caused by this type of training.

Walker et al. (31) compared the effects of accentuated eccentric loading (concentric load + 40%) to traditional RT methods. The eccentric load was added using weight-releasers for the leg press, while for the leg extension the researchers manually had to add and remove weight plates. Results showed that both groups increased quadriceps cross-sectional area from pre to post intervention, but no significant differences were noted between groups.

Based on these findings it seems that added eccentric loading does not contribute to additional muscle hypertrophy. However, both Brandenburg and Docherty (3) and Walker et al. (31) used *in vivo* measures of hypertrophy (MRI and ultrasound, respectively) which do not

detect changes at the muscle fiber level. Friedmann-Bette et al. (14) also reported that similar increases in muscle hypertrophy (as assessed by MRI) occurred between the traditional RT and the eccentric overload group. However, in addition to MRI, an *in vitro* method of hypertrophy (muscle biopsy sampling) was also performed. Muscle biopsy data showed that only the group that trained with added eccentric load experienced a significant increase in the cross-sectional area of type IIX muscle fibers. In both groups, no significant changes were noted for type I and type IIA muscle fibers. Such findings support the notion that eccentric overload training induces preferential type IIX muscle fiber hypertrophy.

There also is evidence that eccentric actions may promote different structural remodeling compared to concentric actions. Specifically, research indicates that eccentric training increases the addition of sarcomeres in series (11, 22). This can favorably alter the length-tension relationship, resulting in a greater maximum velocity of shortening of muscle fibers (12). The extent to which eccentric overload training can promote in series hypertrophy remains to be determined, but the potential for eliciting such adaptations provides a rationale for its inclusion in RT programs.

### **Practical Applications**

Despite a sound hypothetical rationale, there is insufficient direct research to draw causality as to whether eccentric overload training enhances muscle hypertrophy when combined with traditional RT. From a practical standpoint, it is important to highlight that in some cases, eccentric overload training requires special equipment (i.e. weight releasers) or assistance from a coach/personal trainer/training partner. In that regard, this type of training is somewhat more demanding than traditional RT. There is some evidence that eccentric overload training might enhance strength (such as maximal isokinetic concentric torque), power and speed performance

(5, 30, 31). As such, eccentric overload training might be of interest to athletes in various sports. However, the same advantage for muscle hypertrophy is not corroborated in the current body of evidence. Some studies (32) reported that rate of perceived exertion is greater when using eccentric overload training, which should be taken into account when working with RT naïve individuals. The limited body of evidence suggests that with eccentric overload training a potential preferential growth of type IIX muscle fibers and an increased number sarcomeres in series occurs; however, this remains preliminary due to the scarcity of evidence on this topic. There also is evidence that eccentric actions elicit selective distal hypertrophy in the quadriceps that conceivably would result in better symmetrical muscle development under overload conditions. There is no evidence that eccentric overload is an inferior method compared to traditional training. Thus, given the sound rationale for the strategy, it warrants experimentation in hypertrophy-oriented RT program design until research shows otherwise.

There are numerous ways to integrate eccentric overload training in the context of a carefully structured routine. That said, the supramaximal loads and damaging nature of the strategy merits a conservative approach. Initially, adding one or two eccentric overload sets per muscle group at ~120% of concentric 1RM is a feasible way to potentially enhance muscular development while minimizing the potential for undue complications. This approach can then be modified based on individual response over time by manipulating the volume, intensity and/or frequency of implementation.

## References

1. Bamman, MM, Shipp, JR, Jiang, J, Gower, BA, Hunter, GR, Goodman, A, McLafferty, CL, Jr, and Urban, RJ. Mechanical load increases muscle IGF-I and androgen receptor mRNA concentrations in humans. *Am. J. Physiol. Endocrinol. Metab.* 280: E383-90, 2001.
2. Barash, IA, Mathew, L, Ryan, AF, Chen, J, and Lieber, RL. Rapid muscle-specific gene expression changes after a single bout of eccentric contractions in the mouse. *Am. J. Physiol. Cell. Physiol.* 286: C355-64, 2004.
3. Brandenburg, JP, and Docherty, D. The effects of accentuated eccentric loading on strength, muscle hypertrophy, and neural adaptations in trained individuals. *J. Strength Cond Res.* 16: 25-32, 2002.
4. Clarkson, PM, Byrnes, WC, McCormick, KM, Turcotte, LP, and White, JS. Muscle soreness and serum creatine kinase activity following isometric, eccentric, and concentric exercise. *Int. J. Sports Med.* 7: 152-155, 1986.
5. Douglas, J, Pearson, S, Ross, A, and McGuigan, M. Chronic Adaptations to Eccentric Training: A Systematic Review. *Sports Med.* 47: 917-941, 2017.
6. Eliasson, J, Elfegoun, T, Nilsson, J, Kohnke, R, Ekblom, B, and Blomstrand, E. Maximal lengthening contractions increase p70 S6 kinase phosphorylation in human skeletal muscle in the absence of nutritional supply. *Am. J. Physiol. Endocrinol. Metab.* 291: 1197-1205, 2006.
7. Enoka, RM. Eccentric contractions require unique activation strategies by the nervous system. *J. Appl. Physiol.* 81: 2339-2346, 1996.
8. Farthing, JP, and Chilibeck, PD. The effects of eccentric and concentric training at different velocities on muscle hypertrophy. *Eur. J. Appl. Physiol.* 89: 578-586, 2003.
9. Farup, J, Rahbek, SK, Vendelbo, MH, Matzon, A, Hindhede, J, Bejder, A, Ringgard, S, and Vissing, K. Whey protein hydrolysate augments tendon and muscle hypertrophy independent of resistance exercise contraction mode. *Scand. J. Med. Sci. Sports* 24: 788-798, 2014.
10. Fisher, JP, Carlson, L, and Steele, J. The effects of muscle action, repetition duration and loading strategies of a whole-body, progressive resistance training programme on muscular performance and body composition in trained males and females. *Applied Physiology, Nutrition, and Metabolism* 10.1139/apnm-2016-0180, 2016.
11. Franchi, MV, Atherton, PJ, Reeves, ND, Fluck, M, Williams, J, Mitchell, WK, Selby, A, Beltran Valls, RM, and Narici, MV. Architectural, functional and molecular responses to concentric and eccentric loading in human skeletal muscle. *Acta Physiol. (Oxf)* 210: 642-654, 2014.
12. Franchi, MV, Reeves, ND, and Narici, MV. Skeletal Muscle Remodeling in Response to Eccentric vs. Concentric Loading: Morphological, Molecular, and Metabolic Adaptations. *Front. Physiol.* 8: 447, 2017.
13. Friedmann, B, Kinscherf, R, Vorwald, S, Muller, H, Kucera, K, Borisch, S, Richter, G, Bartsch, P, and Billeter, R. Muscular adaptations to computer-guided strength training with eccentric overload. *Acta Physiol. Scand.* 182: 77-88, 2004.

14. Friedmann-Bette, B, Bauer, T, Kinscherf, R, Vorwald, S, Klute, K, Bischoff, D, Muller, H, Weber, MA, Metz, J, Kauczor, HU, Bartsch, P, and Billeter, R. Effects of strength training with eccentric overload on muscle adaptation in male athletes. *Eur. J. Appl. Physiol.* 108: 821-836, 2010.
15. Gibala, MJ, MacDougall, JD, Tarnopolsky, MA, Stauber, WT, and Elorriaga, A. Changes in human skeletal muscle ultrastructure and force production after acute resistance exercise. *J. Appl. Physiol.* 78: 702-708, 1995.
16. Hedayatpour, N, and Falla, D. Non-uniform muscle adaptations to eccentric exercise and the implications for training and sport. *J. Electromyogr. Kinesiol.* 22: 329-333, 2012.
17. Higbie, EJ, Cureton, KJ, Warren, GL, 3rd, and Prior, BM. Effects of concentric and eccentric training on muscle strength, cross-sectional area, and neural activation. *J. Appl. Physiol.* (1985) 81: 2173-2181, 1996.
18. Jones, DA, and Rutherford, OM. Human muscle strength training: the effects of three different regimens and the nature of the resultant changes. *J. Physiol. (Lond.)* 391: 1-11, 1987.
19. Moore, DR, Phillips, SM, Babraj, JA, Smith, K, and Rennie, MJ. Myofibrillar and collagen protein synthesis in human skeletal muscle in young men after maximal shortening and lengthening contractions. *Am. J. Physiol. Endocrinol. Metab.* 288: 1153-1159, 2005.
20. Norrbrand, L, Fluckey, JD, Pozzo, M, and Tesch, PA. Resistance training using eccentric overload induces early adaptations in skeletal muscle size. *Eur. J. Appl. Physiol.* 102: 271-281, 2008.
21. Reeves, ND, Maganaris, CN, and Narici, MV. Ultrasonographic assessment of human skeletal muscle size. *Eur. J. Appl. Physiol.* 91: 116-118, 2004.
22. Reeves, ND, Maganaris, CN, Longo, S, and Narici, MV. Differential adaptations to eccentric versus conventional resistance training in older humans. *Exp. Physiol.* 94: 825-833, 2009.
23. Schoenfeld, B. The use of specialized training techniques to maximize muscle hypertrophy. *Strength Cond J* 33: 60-65, 2011.
24. Schoenfeld, BJ. *Science and Development of Muscle Hypertrophy*. Champaign, IL; Human Kinetics, 2016.
25. Schoenfeld, BJ. The mechanisms of muscle hypertrophy and their application to resistance training. *J. Strength Cond Res.* 24: 2857-2872, 2010.
26. Schoenfeld, BJ. Does exercise-induced muscle damage play a role in skeletal muscle hypertrophy? *J. Strength Cond Res.* 26: 1441-1453, 2012.
27. Schoenfeld, BJ. Potential mechanisms for a role of metabolic stress in hypertrophic adaptations to resistance training. *Sports Med.* 43: 179-194, 2013.
28. Schoenfeld, BJ, Ogborn, DI, Vigotsky, AD, Franchi, MV, and Krieger, JW. Hypertrophic Effects of Concentric vs. Eccentric Muscle Actions: A Systematic Review and Meta-analysis. *J. Strength Cond Res.* 31: 2599-2608, 2017.

29. Shepstone, TN, Tang, JE, Dallaire, S, Schuenke, MD, Staron, RS, and Phillips, SM. Short-term high- vs. low-velocity isokinetic lengthening training results in greater hypertrophy of the elbow flexors in young men. *J. Appl. Physiol.* (1985) 98: 1768-1776, 2005.
30. Wagle, JP, Taber, CB, Cunanan, AJ, Bingham, GE, Carroll, KM, DeWeese, BH, Sato, K, and Stone, MH. Accentuated Eccentric Loading for Training and Performance: A Review. *Sports Med.* , 2017.
31. Walker, S, Blazevich, AJ, Haff, GG, Tufano, JJ, Newton, RU, and Hakkinen, K. Greater Strength Gains after Training with Accentuated Eccentric than Traditional Isoinertial Loads in Already Strength-Trained Men. *Front. Physiol.* 7: 149, 2016.
32. Yarrow, JF, Borsa, PA, Borst, SE, Sitren, HS, Stevens, BR, and White, LJ. Neuroendocrine responses to an acute bout of eccentric-enhanced resistance exercise. *Med. Sci. Sports Exerc.* 39: 941-947, 2007.

ACCEPTED