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The Effectiveness of Low Velocity (Superslow) Resistance Training

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summary

Superslow training, a form of low-velocity resistance training, is continuing to gain popularity in the U.S. This brief review examines the validity of the Superslow philosophy and its supposed benefits.

Superslow training, a form of low-velocity resistance training, has gained significant popularity in the last decade, with the lay press also demonstrating a profound interest in this unconventional type of physical training. However, a lack of research studies has resulted in the inability to confirm or disprove the many publicized benefits of Superslow training. Only recently have appropriate research designs emerged to test the efficacy of a Superslow program as compared with a traditional one (7, 10, 23, 25, 27, 42). The term traditional is used uniquely by each training study and therefore will be defined separately in the context of each individual study for the purposes of this brief review.

Superslow resistance training involves 10-second concentric contractions and 4- to 10-second eccentric contractions (26). Currently, the majority of Superslow-certified facilities use 10-second eccentric contractions. An exercise typically lasts for 80–160 seconds, the amount of time to complete approximately 4–8 repetitions. Although one can train at a higher frequency, it is claimed that benefits can be achieved through a single 15- to 30-minute session per week (26). According to the developer of Superslow training, this unique form of exercise offers a safer workout and superior benefits in terms of muscular fitness, cardiovascular health and fitness parameters, sport performance, and overall functionality as compared to more traditional forms of either resistance or aerobic training. In fact, the Superslow philosophy regards traditional aerobic training as a health risk related to musculoskeletal disorders and sees it as ineffective at reducing chronic disease risk (26).

Superslow advocates claim that their exercise regime is a high-intensity workout (26). If relative intensity is defined as a percentage of the 1 repetition maximum (1RM), it is clearly a low-intensity workout, as the average load is greatly lessened in comparison with traditional resistance training (25, 27). When comparing fast (2 seconds) and slow (10 seconds) eccentric protocols, the rates of perceived exertion (RPE) were 8.3 ± 2.1 and 5.4 ± 1.5 respectively (30). Therefore even if intensity is estimated by "perceived difficulty," which is relatively uncommon in resistance training research but has been recently validated (31), Superslow training should not be considered a high-intensity workout.

Muscular Strength and Endurance

Only 1 peer-reviewed study exists suggesting that a Superslow protocol may be more effective in developing total body strength than traditional resistance training. Westcott et al (42) trained 147 men and women for 8–10 weeks using either regular speed resistance training (2-second concentric phase, 1-second pause, and a 4-second eccentric phase) or Superslow training (10-second concentric phase and a 4-second eccentric phase). The regular-speed group completed 8–12 repetitions per set while the Superslow group completed 4–6 repetitions. The regular-speed and Superslow groups were tested for strength by a 10RM and a 5RM, respectively, at a speed consistent with their training.

Subjects in the Superslow group showed approximately a 50% greater increase in strength on several exercises from pre- to posttesting (42).

The choice of strength testing protocol in this study provokes controversy. Although other studies have used a 10RM to test strength, many would contend that it is not the best indicator of strength (as compared to a 1RM for example). More importantly, using a 5RM for the Superslow group at the speed described above (10- and 4-second contractions) has never been used in another peer-reviewed study, and therefore its validity as a measure of strength must be questioned. Clearly the Superslow group got better at performing their protocol than the regular-speed group, but this does not necessarily mean they got stronger.

A possible explanation for the greater improvements in the Superslow group is low neuromuscular coordination at baseline. The term "neuromuscular coordination" refers to motor unit recruitment, synchronization, rate coding, and antagonist inhibition. Few, if any, activities of daily living (ADLs) are purposely done at a slow speed. Subjects in the Superslow group may have had an initially low level of neuromuscular coordination at generating continuous force at such a slow speed, therefore making it easier to improve. Because speeds used for traditional resistance training more closely mimic ADLs, the traditional speed group may not have had this inherent advantage of a low baseline level. This point is further supported by studies showing significant increases in strength without significant increases in lean body mass after a period of Superslow training (10, 27). Ultimately, because of its questionable testing methods, the Westcott study does not indicate whether a traditional or Superslow training program is superior for producing strength gains.

Other studies cast doubt upon the ability of a Superslow protocol to increase muscular strength as effectively as traditional weight training. Keeler et al (27) studied 14 healthy, untrained women for a 10-week period. Subjects trained 3 times per week, performing 1 set of 8–12 repetitions on 8 exercises. The subjects were divided between a traditional protocol (2-second concentric phase, 4-second eccentric phase) and a Superslow protocol (10-second concentric phase, 5-second eccentric phase). Time between exercises was controlled between groups, as this could have been a confounding factor regarding aerobic measures that were made (2, 6).

Even though both groups showed significant strength gains as measured by pre- and posttraining 1RM, the traditional group had greater improvement in 5 out of 8 exercises, as well as total weight lifted. Across all exercises, the Superslow group's strength improved by 15% above baseline, whereas the traditional group saw a 39% improvement (27). It is possible that the Superslow group may have shown greater improvements if tested at a speed specific to its training protocol. However, the 1RM is considered to be an appropriate test for strength (4).

In response to criticism that the study by Keeler et al. was not performed at a certified Superslow facility, researchers at Furman University organized 39 college-aged men to compare the benefits of a "traditional" workout versus the Superslow protocol (7, 10, 23). Subjects trained either at a college fitness facility according to the 1998 American College of Sports Medicine (ACSM) guidelines for cardiorespiratory and muscular fitness, at a local certified Superslow gym 1 day per week according to Superslow protocol, or they were placed in a control group. ACSM guidelines for muscular fitness involve performing 1 set of 8–12 repetitions on 8–10 exercises at a frequency of 2 times per week (3). The concentric phase was performed as quickly as the resistance allowed, while the eccentric phase was done in a controlled manner (but with no precise duration restrictions). It should be noted that the ACSM guidelines were not designed for athletic performance (15) and were chosen simply to represent a traditional workout regime. Cardiovascular exercise of progressively increased volume was included in the traditional group's workout in order to test the claim that Superslow training enhances cardiorespiratory fitness.

After a 16-week training period, all subjects were tested for upper and lower limb strength and endurance on a Kincom dynamometer (Chattecx, Chattanooga, TN). When compared with baseline data, Blount et al (7) found that muscle endurance for arm flexion and extension significantly improved (5.46% and 2.3% fatigue index respectively) as compared with the traditionally trained and control groups. Because this test was performed at a speed (180°/s) drastically different than Superslow speeds, these results suggest that the training would have carryover to external activities. A significant improvement (11.58 foot-pounds) in lower limb extensor strength (measured at 60°/s) was also observed in the Superslow group (7).

In contrast, no improvements in lower limb endurance, upper limb strength, or lower limb flexor strength were observed in either training group when compared with controls (7). The highly specific nature of isokinetic testing may account for the lack of measured strength gains in both groups. This is plausible, as a 1-set workout of traditional-speed resistance training has been demonstrated numerous times to effectively increase strength for untrained subjects (9, 16). There is also research to suggest that the use of multiple sets will confer additional benefit (38); a higher level of adaptation may have been needed in order to observe benefits by isokinetic testing. Yet another possibility is that strength gains were diminished due to the high volume of aerobic work performed by the traditionally trained group in the latter weeks of the training period. There is evidence to either support or refute this hypothesis (5, 11, 22, 32). Regardless, after the 16-week training period, the traditionally trained group had significantly gained lean body mass, whereas the Superslow and control groups did not show improvements (10).

Isokinetic Studies

During isokinetic work, maximal effort is made throughout the set against a resistance with a fixed velocity. This differs from Superslow training and certain isoinertial (i.e., the often misused term *isotonic*) protocols in which a submaximal effort is made (until the latter portions of the set) with a relatively fixed velocity as determined by the practitioner or subject (29). This also differs from other isoinertial circumstances in which maximal effort is made throughout the set and therefore the velocity is determined by the amount of resistance. Consequently, protocols used in isokinetic training studies do not fit under the formal definition for Superslow training. Although the applicability of isokinetic studies remains controversial, certain research provides good comparison between slower and faster protocols; they are therefore appropriate for this discussion with the caveat that results cannot be directly applied to any form of isoinertial training without some degree of debate. Considering that traditional isoinertial resistance training velocity does not frequently exceed 60°/s (36), only recent studies using a protocol velocity of 30°/s or less will be discussed.

Isokinetic training at 180°/s was shown to be superior to 30°/s in regards to developing both muscular power and endurance more than 20 years ago (1); recent studies confirm this finding. Paddon-Jones et al (33) assigned 20 untrained subjects to 1 of 3 isokinetic training programs: 180°/s, 30°/s, or control (no training). After 10 weeks of training, the 180°/s group showed a decrease (13%) in the percentage of type I fibers and an increase (7%) in type IIb fiber percentage. In addition, increases in concentric and eccentric torque at 180°/s, isometric torque, and eccentric torque at 30°/s were observed in the faster trained group. Neither the 30°/s velocity nor control group demonstrated a significant improvement in torque production or changes in muscle fiber type (33).

Farthing and Chilibeck (14) placed 24 untrained subjects in either a 180°/s velocity training group or a 30°/s group. The subjects trained 1 arm eccentrically for 8 weeks and then trained the opposite arm concentrically for the same duration. Faster eccentric training conferred the largest increases in peak concentric and eccentric torque across all testing velocities. Faster eccentric training resulted in greater hypertrophy (as determined by sonography) than both 30°/s and 180°/s concentric groups, but not the slower eccentric group. The slower eccentric group showed a greater hypertrophic response than a control group only. According to the results of this study, eccentric training at 180°/s is a better route for inducing hypertrophy and maximizing strength in elbow flexor muscles than slower eccentric training or concentric training at either velocity used (14).

Observations from a study by Shepstone et al confirm these findings (40). In this study 9 subjects trained 1 arm on an isokinetic dynamometer at a velocity of 210°/s and the opposite arm at 20°/s. After training 3 times per week for 8 weeks, type II muscle fiber (IIx, IIa/x, IIa) hypertrophy was greater in the 210°/s velocity trained arm (31 ± 5%, 22 ± 5%, and 17 ± 5%, respectively) than the 20°/second velocity trained arm (9 ± 5%, 10 ± 3%, and 5 ± 2%, respectively). Type I fiber showed significant increase as well; however no difference was seen between the faster and slower protocols (40). Ultimately these isokinetic studies indicate that performing resistance training at slow velocities may be less effective in developing strength and hypertrophic gains when compared with faster velocities (1, 14, 33, 40).

Cardiorespiratory and Metabolic Effects

As previously mentioned, Superslow advocates claim that the training provides cardiovascular, as well as muscular, benefits (26). Although Superslow sets are not long enough in duration to reach a true steady-state metabolism and therefore be considered aerobic, the protocol is essentially a form of (low-intensity) circuit weight training (CWT). Research has demonstrated that CWT can modestly improve measures of cardiorespiratory fitness (2, 6, 19, 20). Caterisano et al (10), reporting from the same experiment as Blount et al (7), showed that after the 16 weeks of training $\dot{V}O_2$max and anaerobic threshold were unchanged in the Superslow group. As expected, the traditional group realized significant increases in both measures (5.57 mL/kg/min and 10.32% $\dot{V}O_2$max, respectively). Furthermore, Keeler et al report that after 10 weeks of a Superslow protocol, aerobic capacity and ventilatory threshold went unchanged (27).

A study by Hunter et al (25) further suggests that Superslow training does not provide a significant cardiovascular stress. When comparing a Superslow training session with a more "traditional" resistance training session, the Superslow session resulted in lower exercise heart rates and postexercise lactate levels. Combining energy expenditure values during work and the 15-minute recovery period, the traditionally trained group spent approximately 48% more kilocalories (172 ± 29 vs. 116 ± 22) in the same time period (25). Furthermore, because favorable changes in blood lipid profiles appear to be dependent on the caloric volume of exercise (12, 44, 45), Superslow training is an unlikely candidate for reducing this cardiovascular disease risk parameter.

Because kilocalories are an estimate of work, it is not surprising that Superslow training does not provide a metabolic stimulus equivalent to traditional training. Work is the product of force and distance; the distance that the weight moves will obviously be similar between the different training velocities. However, the force exerted is much lower in Superslow training because a lower resistance is used (25, 27). Therefore, less total work is done, and consequently fewer calories are burned as compared to traditional training. The premise that Superslow training would not be effective in controlling body weight/body fat is further supported by an unchanged body fat percentage after 16 weeks of Superslow training. The traditionally trained group, following the ACSM guidelines for the same time period, showed a 5.51% decrease in body fat percentage (10).

One of the rationales for the (publicized) superiority of Superslow training is that, because momentum is lessened, the muscle is forced to work harder throughout the lift. However, Westing et al. demonstrated that, with increasing contraction velocity, concentric torque decreases but eccentric force increases (43). Regardless, momentum can be controlled to reasonable levels without adhering to a program as extreme as the Superslow protocol. Consequently, it is unlikely that force output differs greatly between traditional training velocities and the Superslow protocol if using the same resistance. Therefore, the point previously mentioned regarding lower force output and its consequences is validated.

Athletic Performance

Superslow training has also been touted as an effective way to train athletes (26). This claim is unlikely, as the vast majority of sports benefit from hypertrophy of fast-twitch fibers or high-threshold motor units and, consequently, the development of strength, power, and speed (17, 18). Because the intensity used during a Superslow workout is approximately 25–50% of the 1RM (25, 27), higher threshold motor units will not be trained effectively (18, 24, 47). Strength gains as a result of resistance training are greatest at the approximate velocity that the training was performed when maximal effort is made (13, 46), although there is some evidence that does not support velocity specificity (34). Regardless, the majority of sports require force production at high velocities, and therefore training at a low velocity without maximum effort, as in Superslow training, would probably not be optimally beneficial. In addition, vertical jump, upper and lower limb power as measured by dynamometry, and grip strength were not improved over 16 weeks of Superslow training (7). Traditional exercise did not improve these variables either, as the ACSM guidelines were not designed to improve athletic performance (15).

Safety Issues

Although no studies exist testing the claim that training at a low velocity is safer, the absence of ballistic movements suggest that traumatic injury risk may be lower (26). However, Surakka et al (41) observed that a supervised program of "power-type strength training" (i.e., a program incorporating ballistic movements/activities) did not result in elevated injury rates for untrained middle-aged individuals. Because the muscle-tendon unit is under tension for considerably more time during Superslow training, there is a theoretical greater risk for overuse injuries, although as of yet there has been no research investigating this parameter. Most Superslow-certified facilities are machine based, which is generally (anecdotally) considered a safer mode of exercise. However, research has indicated that there is no practical difference in injury rates between using machines or free weights in healthy adult individuals (37).

There have been concerns that, due to the nature of training, elevations in blood pressure during exercise may be extreme, even though the Valsalva maneuver is discouraged (26). To this point, no known studies exist reporting blood pressure during a low-velocity contraction. Although there is a body of research indicating that resistance training has minimal chronic effects on resting blood pressure in normotensive individuals (8, 21, 39), Kelley's meta-analysis (28) found a treatment effect of 3% and 4% decreases in resting systolic and diastolic blood pressure, respectively. After 4 months of Superslow training, resting blood pressure values were not significantly changed, although the trend was toward a slight rise in diastolic pressure (3.81 mm Hg; 23).

Conclusion

More research needs to be performed concerning low-velocity resistance training before formal conclusions can be drawn. The available evidence demonstrates that it may be effective in developing muscular endurance as well as muscular strength when exerted at a velocity similar to the training (which is of extremely limited use in performing ADLs or in most athletic events). Traditional benefits associated with cardiorespiratory training are not seen with this type of training. Although no formal conclusions can yet be drawn regarding training velocity (35), it is highly questionable whether low velocity resistance training will find an appropriate place in the adult fitness model or as a rehabilitation modality. ♦

References

1. Adeyanju, K., T. Crews, and W. Meadors. Effects of two speeds of isokinetic training on muscular strength, power and endurance. *J. Sports Med.* 23:352–356. 1983.
2. Allen, T., R. Byrd, and D. Smith. Hemodynamic consequences of circuit weight training. *Res. Q.* 47:299–306. 1976.
3. American College of Sports Medicine. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Med. Sci. Sports Exerc.* 30:975–991. 1998.
4. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription* (6th ed.). Philadelphia: Lippincott, Williams & Wilkins, 2000. pp. 81–83.

5. Bell, G., D. Syrotuik, T. Martin, R. Burnham, and H. Quinney. Effect of concurrent strength and endurance training on skeletal muscle properties and hormone concentrations in humans. *Eur. J. Appl. Physiol.* 81:418–427. 2000.
6. Blessing, D., H. Willford, J. Barksdale, and F. Smith. Alterations in lipids and cardiorespiratory function after weight training. *J. Hum. Movement Stud.* 14:75–83. 1988.
7. Blount, P., A. Caterisano, B. Greer, B. Fletcher, J. Farmer, P. Stewart, and J. Norton. The effect of Superslow training on strength parameters in college aged males. *Med. Sci. Sports Exerc.* 35(Suppl. 5):S373. 2003.
8. Blumenthal, J., W. Siegel, and M. Appelbaum. Failure of exercise to reduce blood pressure in patients with mild hypertension. Results of a randomized controlled trial. *JAMA.* 266:2098–2104. 1991.
9. Carpinelli, R., and R. Otto. Strength training: single versus multiple sets. *Sports Med.* 26:73–84. 1998.
10. Caterisano, A., P. Blount, B. Greer, B. Fletcher, J. Farmer, D. Kyriakos, and P. Stewart. The effect of Superslow training on aerobic capacity and body composition in college-age males. *Med. Sci. Sports Exerc.* 35(Suppl. 5): 373. 2003.
11. Craig, B., J. Lucas, R. Pohlman, and H. Sterling. The effects of running, weightlifting and a combination of both on growth hormone release. *J. Appl. Sport Sci. Res.* 5:198–203. 1991.
12. Durstine, J., P. Grandjean, P. Davis, M. Ferguson, N. Alderson, and K. DuBose. Blood lipid and lipoprotein adaptations to exercise. A quantitative analysis. *Sports Med.* 31:1033–1062. 2001.
13. Ewing, J., D. Wolfe, M. Rogers, M. Amundson, and G. Stull. Effects of velocity of isokinetic training on strength, power, and quadriceps muscle fibre characteristics. *Eur. J. Appl. Physiol.* 61:159–162. 1990.
14. Farthing, J., and P. Chilibeck. The effects of eccentric and concentric training at different velocities on muscle hypertrophy. *Eur. J. Appl. Physiol.* 89: 578–586. 2003.
15. Feigenbaum, M. Rationale and review of current guidelines. In: *Resistance Training for Health and Rehabilitation*. J. Graves and B. Franklin, eds. Champaign, IL: Human Kinetics, 2001. pp. 13–32.
16. Feigenbaum, M., and M. Pollack. Prescription of resistance training for health and disease. *Med. Sci. Sports Exerc.* 31:38–45. 1999.
17. Fleck, S., and W. Kraemer. *Designing Resistance Training Programs* (2nd ed.). Champaign, IL: Human Kinetics, 1997. pp. 21-27.
18. Gentry, M., and T. Caterisano. *A Chance to Win: A Complete Guide to Physical Training for Football*. Greenville, SC: The Iron Palace Co., 2003. pp. 11–21.
19. Gettman, L., J. Ayres, M. Pollock, and A. Jackson. The effect of circuit weight training on strength, cardiorespiratory function, and body composition of adult men. *Med. Sci. Sports Exerc.* 10:171–176. 1978.
20. Gettman, L., and M. Pollock. Circuit weight training: A critical review of its physiological benefits. *Phys. Sportsmed.* 9:44–60. 1981.
21. Gilders, R., E. Malicky, J. Falkel, R. Staron, and G. Dudley. The effect of resistance training on blood pressure in normotensive women. *Clin. Physiol.* 11:307–314. 1991.
22. Gravelle, B., and D. Blessing. Physiological adaptation in women concurrently training for strength and endurance. *J. Strength Cond. Res.* 14:5–13. 2000.
23. Greer, B., P. Blount, A. Caterisano, K. Karinshak, D. Shelby, and L. Valez. The effect of Superslow^{TM} training on resting blood pressure in college-age males. *Med. Sci. Sports Exerc.* 35(Suppl. 5):S373. 2003.
24. Henneman, E., G. Somjen, and D. Carpenter. Functional significance of cell size in spinal motoneurons. *J. Neurophysiol.* 28:560–580. 1965.
25. Hunter, G., D. Seelhorst, and S. Snyder. Comparison of metabolic and heart rate responses to super slow vs. traditional resistance training. *J. Strength Cond. Res.* 17:76–81. 2003.
26. Hutchins, K. *Superslow: The Ultimate Exercise Protocol* (2nd ed.). Casselberry, FL: Media Support, 1992.
27. Keeler, L., L. Finkelstein, W. Miller, and B. Fernhall. Early-phase adaptations of traditional speed vs. superslow resistance training on strength and aerobic capacity in sedentary individuals. *J. Strength Cond. Res.* 15:309–314. 2001.
28. Kelley, G. Dynamic resistance exercise and resting blood pressure in adults: A meta-analysis. *J. Appl. Physiol.* 82:1559–1565. 1997.
29. Kroemer, K.H. An isoinertial technique to assess individual lifting capability. *Hum Factors.* 225(5):493–506. 1983.
30. Kulig, K., C. Powers, F. Shellock, and M. Terk. The effects of eccentric velocity on activation of elbow flexors: evaluation by magnetic resonance imaging. *Med. Sci. Sports Exerc.* 33:196–200. 2001.
31. Lagally, K., S. McCaw, G. Young, H. Medema, and D. Thomas. Ratings of perceived exertion and muscle activity during the bench press exercise in recreational and novice lifters. *J. Strength Cond. Res.* 18:359–364. 2004.
32. Nelson, A., D. Arnall, S. Loy, L. Silvester, and R. Conlee. Consequences of combining strength and endurance training regimens. *Phys. Ther.* 70:287–294. 1990.
33. Paddon-Jones, D., M. Leveritt, A. Lonergan, and P. Abernethy. Adaptation to chronic eccentric exercise in humans: the influence of contraction velocity. *Eur. J. Appl. Physiol.* 85:466–471. 2001.
34. Pereira, M., and P. Gomes. Effects of two movement velocities of isotonic exercise on gains in strength and muscular endurance. *Med. Sci. Sports Exerc.* 34 (Suppl. 5):S289. 2002.
35. Pereira, M., and P. Gomes. Movement velocity in resistance training. *Sports Med.* 33:427–438. 2003.
36. Pipes, T., and J. Wilmore. Isokinetic vs.

isotonic strength training in adult men. *Med. Sci. Sports Exerc*. 7:262–274. 1975.
37. Requa, R., L. DeAvilla, and J. Garrick. Injuries in recreational adult fitness activities. *Am. J. Sports Med*. 21:461–467. 1993.
38. Rhea, M., B. Alvar, L. Burkett, and S. Ball. A meta-analysis to determine the dose response for strength development. *Med. Sci. Sports Exerc.* 35:456–464. 2003.
39. Schwartz, R., and V. Hirth. The effects of endurance and resistance training on blood pressure. *Int. J. Obes. Relat. Metab. Disord*. 19 (Suppl. 4):52–57. 1995.
40. Shepstone, T., S. Dallaire, C. Correia, J. Tang, and S. Phillips. Effect of velocity on elbow flexor hypertrophy following eccentric high-resistance training in young males. *Med. Sci. Sports Exerc*. 35 (Suppl. 5):S386. 2003.
41. Surakka, J., S. Aunola, T. Nordblad, S. Karppi, and E. Alanen. Feasibility of power-type strength training for middle aged men and women: self perception, musculoskeletal symptoms, and injury rates. *Br. J. Sports Med.* 37: 131. 2003.
42. Westcott, W., R. Winett, E. Anderson, J. Wojcik, R. Loud, E. Cleggett, and S. Glover. Effects of regular and slow speed resistance training on muscle strength. *J. Sports Med. Phys. Fitness* 41:154–158. 2001.
43. Westing, S., A. Cresswell, and A. Thorstensson. Muscle activation during maximal voluntary eccentric and concentric knee extension. *Eur. J. Appl. Physiol. Occup. Physiol.* 62:104–108. 1991.
44. Williams, P. Relationship of distance run per week to coronary heart disease risk factors in 8283 male runners: The National Runner's Health Study. *Arch. Intern. Med*. 157:191–198. 1997.
45. Williams, P. Relationships of heart disease risk factors to exercise quantity and intensity. *Arch. Intern. Med*. 158:237–245. 1998.
46. Wilson, G., R. Newton, A. Murphy, and B. Humphries. The optimal training load for the development of dynamic athletic performance. *Med. Sci. Sports Exerc*. 25:1279–1286. 1993.
47. Zatsiorsky, V. *Science and Practice of Strength Training*. Champaign, IL: Human Kinetics, 1995. pp. 92–96.

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