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Title Page

“Development of muscle mass: how much is optimum for performance?”

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Abstract

Training for muscle hypertrophy can be expected to induce some increase in total body mass, and this can have positive or negative consequences for athletic performance. Positive effects may be increased strength, increased resistance to being pushed aside, and greater momentum when running, while possible negative effects may be reduced capacity to accelerate, decelerate, change direction, and jump. These possible effects of gaining muscle and total body mass suggest that strength and conditioning coaches should give thoughtful consideration to the amount of hypertrophy training prescribed throughout an athlete's development, and should be determined by the specific needs of the athlete.

Key Words

Muscle mass, Hypertrophy, Relative strength, Neural adaptations, Biomechanics

Introduction

Resistance training for the development of muscle mass (hypertrophy) is a common goal in strength and conditioning. Gaining muscle mass is considered desirable for increasing strength and power, as well as for increasing overall body mass in some sports (12). Although the most effective hypertrophy training methodology may be an ongoing pursuit for some strength and conditioning coaches, the objective of this article is not to explore this issue. Rather, the purpose of this discussion is to outline considerations for determining how much muscle and body mass is optimum for individual athletes in various sports.

It is well understood that increased muscle mass can contribute to strength gain, because larger individual muscle fibers are partly a result of synthesized contractile tissue containing actin and myosin proteins that are responsible for contractile force (strength) (16). Since hypertrophy involves morphological changes and increased tissue matter, muscle mass gains can be associated with an increase in overall body mass, providing other tissues such as fat are not proportionally catabolized (broken down). Using principles of biomechanics, the following discussion will explore the possible desirable and unwanted side-effects of increased muscle and body mass.

Advantages of increased muscle and body mass

Generally, there is a positive relationship between muscle cross-sectional area and absolute strength (8); that is, a larger muscle is a generally a stronger muscle. This relationship holds true especially when an increase in muscle mass is due to greater contractile tissue (myofibrillar hypertrophy), rather than increased substances that do not directly contribute to force production such as capillaries, sarcoplasm, and mitochondria (21). For example, when professional Australian football players are compared to elite U-18 players, the higher standard players possessed significantly more fat-free soft tissue mass and were also superior in measures of lower body power and upper body strength (3). Such observations may lead to a conclusion that the development of more muscle mass will always produce a better athletic performance.

Well-known principles of physics can be used to explore the relationships between force, mass and motion. Newton’s laws of motion are described in almost any biomechanics textbook (10). The first law of motion, the law of inertia, states that a body will maintain a state of rest or constant velocity unless acted on by an external

force. The greater the inertia of a body, the greater its reluctance to change its state of rest or motion. The inertia of a body is proportional to its mass. Therefore, the more mass in a body, the harder it is to change its state of rest or motion. This means that a basketball player with more body mass is harder to displace when preparing for a rebound under the ring, compared to a player with less mass. Likewise, a more massive wrestler is harder to push over, which is one reason combat sports generally use body weight divisions.

Another potential benefit of increased body mass is that it may allow an athlete to move with greater momentum. Since $\text{momentum} = \text{mass} \times \text{velocity}$, a more massive athlete running at a given velocity will possess greater momentum. A practical application of moving with greater momentum is that the athlete will have a greater effect in a collision. Using an analogy of a motor vehicle accident, if a car and truck are both moving towards each other at the same velocity, the more massive truck will have greater momentum, and will have a greater effect at impact and do more “damage” to the car. Likewise, in a collision of two American football or rugby players, the athlete with the greater momentum will likely have the advantage. Indeed, analysis of rugby union players performing head-on tackles in competition (11) indicated tackle outcome was more related to momentum than either mass or velocity in isolation. As a result, some coaches consider momentum rather than just velocity when conducting sprint tests with contact sport athletes (2). However, if an athlete gains body mass over time, running momentum will only increase if velocity doesn’t decrease enough to negate momentum. Therefore, the ability to run faster after gaining body mass may be challenging, and is discussed below.

Disadvantages of increased muscle and body mass

Newtons' second law of acceleration can easily be applied when described in the form of an equation.

Force (F) = mass (m) x acceleration (a) or, $F = ma$

Rearranged, $a = F/m$. This equation indicates the following:

1. If force (strength) increases more than mass, acceleration increases
2. If mass increases more than force, acceleration decreases
3. If changes in force and mass are proportional, acceleration remains constant

Changes to the capacity to accelerate have far-reaching consequences in sport. For example, the ability to jump for height requires a high vertical acceleration in order to achieve a high velocity at the instant of take-off. Horizontal acceleration is required for many sports involving sprinting, especially in relatively small playing areas where sprint distance is limited e.g. basketball or tennis court. Newton's second law equally applies to *deceleration*, so that the capacity to decelerate (e.g. rapid reduction in velocity or stopping hard) is important in sports such as soccer where an attacker wants to create space from a pursuing defender. The capacity to change direction laterally requires a deceleration in the original direction before accelerating in the new direction. Therefore, change-of-direction speed and agility movements are also influenced by the athlete's force (strength) and body mass characteristics.

Another application of the above equation relates to changes in body mass due to fat mass, rather than muscle mass. Let's assume an athlete has gained 3 kg fat mass with no increase in muscle mass or strength. Using hypothetical values, the detrimental change in acceleration can be easily observed:

Before fat gain: Force = 2000 N, mass = 70 kg. Therefore acceleration = $2000/70 = 28.6 \text{ m.s}^{-2}$

After fat gain: Force = 2000 N, mass = 73 kg. Therefore acceleration = $2000/73 = 27.4 \text{ m.s}^{-2}$

This example demonstrates that everything else being equal, an increase in body mass without an increase in the capacity to produce greater force can potentially impair jumping, acceleration, deceleration, change-of-direction and agility performance.

The same analysis can be conducted in relation to endurance performance. The gold standard measure of aerobic power is maximum oxygen uptake or $\text{VO}_2 \text{ max}$, which is expressed as $\text{ml. kg}^{-1}.\text{min}^{-1}$ (19). So if an athlete consumes $4000 \text{ ml.kg}^{-1}.\text{min}^{-1}$ with a 70 kg body mass, the $\text{VO}_2 \text{ max} = 57.1 \text{ ml. kg}^{-1}.\text{min}^{-1}$. However, if body mass increases to 73 kg (either from muscle or fat) with no improvement in O_2 uptake, $\text{VO}_2 \text{ max} = 54.8$, representing a 4 % decrease in endurance performance. Not only will the athlete be disadvantaged in running-based field sports (e.g. soccer), but the extra body mass may also be expected to result in increased ground reaction forces applied to the athlete while running. If the athlete is required to perform high running loads, repetitive ground reaction forces may increase the risk of overuse injuries (13). Older athletes may be especially vulnerable, and therefore limiting body mass as the athlete ages may be a useful strategy for achieving athletic longevity.

In the above examples, strength or endurance are simply divided by body mass. There are various alternative methods to normalize strength and compare individuals or predict athletic performance with more complex forms of allometric scaling (14, 15).

The example calculations above are only intended to illustrate the general influence of body mass changes.

Nevertheless, the above discussion reveals that body mass gains can be beneficial by possessing increased inertia, but in many cases, benefits are realized only when an increase in strength is proportionally greater. This means that for many sports that require force production against the resistance of the athlete's body, *relative* strength (strength/body mass) may be more important than the development of *absolute* strength (maximum strength capacity regardless of body mass). Indeed, most measures of lower body relative strength and power correlate more strongly with sprint performance than absolute measures (1). Therefore in these scenarios, the challenge is to identify the training methods that maximize strength gain with minimal hypertrophy and body mass gain.

Training to increase relative strength

It is generally accepted that relative strength is increased when strength gain is induced primarily by neural adaptations (4). Nervous system adaptations include intra-muscular factors such as increased motor unit recruitment, firing rate, synchronization, and reduced neural inhibitory mechanisms (18, 20, 21), as well as inter-muscular factors such as effective co-contraction of synergists (5). According to Zatsiorsky (21), lifting relatively heavy loads such as 90 % of maximum elicits strength gain via neural mechanisms, with minimal hypertrophy. A study that compared high-level bodybuilders, powerlifters and weightlifters (6) found that although the bodybuilders had slightly greater estimated thigh cross-sectional area than the other athletes, the power- and weightlifters had statistically significantly superior back squat strength. The authors speculated that neural adaptations were most likely induced by the higher intensity training, typically performed by the power- and weightlifters. It can be challenging to induce strength gains via neural

factors in well-trained athletes. However, a study of elite weightlifters showed that despite no meaningful changes in thigh girth or body mass over 12 months, a period of increased training intensity was associated with increases in quadriceps muscle activation and weightlifting performance (9). Although a wide range of resistance training loads can be effective for hypertrophy development (17), relatively heavy loads should be emphasized for maximizing strength gain (7, 17). It should also be acknowledge that increasing relative strength can have a positive effect on increasing relative power, since power output is the product of force (strength) and velocity.

Practical applications

Optimizing the development of strength and changes in body mass can be a delicate balance that can influence sprinting, jumping, change-of-direction, and agility performance, as well as body contact scenarios in various sports. Increased muscle and total body mass can potentially have positive or negative effects on performance. Therefore, strength and conditioning coaches should carefully consider the consequences of changes in body composition (muscle and fat) as a result of resistance training and diet. Rather than assuming greater muscle or body mass is always better, coaches should determine what is *optimum*. Therefore, while increasing muscle and body mass may be effective for an athlete with a relatively low training age, there is likely to be a point in an athlete’s development where relative strength and power should become the focus, and hypertrophy training should be reduced, with neural factors emphasized for further strength and power gain. In team sports, this optimum should take into account the individual needs of athletes, depending on their playing position and role within the team.

REFERENCES

1. Baker, D, Nance, S. The relationship between running speed and measures of strength and power in professional rugby league players. *J Strength Cond Res* 13: 230 - 235, 1999.
2. Baker, D, Newton, R. Comparison of lower body strength, power, acceleration, speed, agility and sprint momentum to describe and compare playing rank among professional rugby league players. *J Strength Cond Res* 22: 153 - 158, 2008.
3. Bilsborough, J, Greenway, K, Opar, D, Livingstone, S, Cordy, J, Bird, S, and Coutts, A. Comparison of anthropometry, upper-body strength and lower-body power characteristics in different levels of Australian Football players. *J Strength Cond Res* 29: 826-834, 2015.
4. Bompa, T, Buzzichelli, CA. *Periodization Training for Sports*, 3rd ed. Champaign, IL: Human Kinetics, 25, 2015.
5. Bosch, F. *Strength Training and Coordination: An Integrative Approach*. Rotterdam, Uitgevers, 191-193, 2015.
6. Di Naso, J, Pritschet, B, Emmett, J, Owen, J, Willardson, J, Beck, T, DeFreitas J, and Fontana, F. Comparing thigh muscle cross-sectional area and squat strength among national class Olympic weightlifters, power lifters, and bodybuilders. *Int SportMed J* 13: 48-57, 2012.
7. Fry, A. The Role of Resistance Exercise Intensity on Muscle Fibre Adaptations. *Sports Med* 34: 663-679, 2004.

8. Hakkinen, K, Alen, M, and Komi, P. Neuromuscular, anaerobic, and aerobic performance characteristics of elite power athletes. *Eur J Appl Physiol* 53: 97-105, 1984.
9. Hakkinen, K, Komi, P, Alan, M, and Kauhanen H. EMG, muscle fibre and force production characteristics during a 1 year training period in elite weightlifters. *Eur J Appl Physiol* 56: 419-427, 1987.
10. Hall, SJ. *Basic Biomechanics*. 5th ed. New York, NY: McGraw-Hill, 388-389, 2007.
11. Hendricks, S, Karpul, D, and Lambert, M. Momentum and Kinetic Energy before the Tackle in Rugby Union. *J Sci Med Sport* 13: 557-563, 2014.
12. Howe, L, Read, P, and Waldron, M. Muscle hypertrophy: A narrative review on training principles for increasing muscle mass. *Strength Cond J* 39, 2017.
13. Hreljac, A. Impact and overuse injuries in runners. *Med Sci Sports Exerc* 36: 845-849, 2004.
14. Jacobson, B. A comparison of allometric scaling methods for normalizing strength, power, and speed in American football players. *J Sports Med Phys Fit* 55, 2015.
15. Oba, Y, Hetzier, R, Stickley, C, Tamura, K, Kimura, I, and Heffernan Jr T. Allometric scaling of strength scores in NCAA Division I-A football athletes. *J Strength Cond Res* 28: 3330-3337, 2014.
16. Schoenfeld, B. The mechanisms of muscle hypertrophy and their application to resistance training. *J Strength Cond Res* 24: 2857-2972, 2010.
17. Schoenfeld, B, Grgic, J, Ogbord, D, and Krieger, J. Strength and hypertrophy adaptations between low- vs. high-load resistance training: A systematic review and meta-analysis. *J Strength Cond Res* 31: 3508-3523, 2017.

18. Suchomel, T, Nimphius, S, Bellon, C, and Stone, M. The importance of muscular strength: Training considerations. *Sport Med*, 2018.
19. Withers, R, Gore, C, Gass, G, and Hahn A. Determination of maximal oxygen consumption or maximal aerobic power. In: *Physiological Tests for Elite Athletes*. Gore, CJ, ed. Champaign, IL: Human Kinetics, 114-127, 2000.
20. Young, W. Transfer of strength and power training to sports performance. *Int J Sports Physiol Perform* 1: 74-83, 2006.
21. Zatsiorsky, V. *Science and Practice of Strength Training*. Champaign, IL: Human Kinetics, 63, 100-101, 1995.