



Resistance exercise and sports performance: The minority report

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ABSTRACT

Resistance exercise is typically performed to increase both muscle size and strength and is regularly incorporated into training programs for sports performance. Presumably, the exercise would be expected to increase the force producing capabilities of skeletal muscle, which may have subsequent influence on various sports related abilities. Interestingly, few studies are designed to examine sports related benefits of resistance exercise while including a proper control group to account for adaptations to simply performing the sports related task. Much of our knowledge on resistance exercise for sport is based off cross-sectional work showing that stronger athletes tend to perform at the highest level, along with cross-sectional work demonstrating that higher levels of strength are associated with various performance related parameters. Although there is a large body of cross-sectional literature providing a rationale for resistance exercise for sport, its implementation is largely based on the following: 1) An increase in muscle size will produce an increase in strength and 2) a stronger muscle will increase sports performance. However, there is a lack of evidence to support these assumptions. The weight of evidence suggests that resistance exercise may indirectly impact sports performance through injury prevention, as opposed to directly improving sport related abilities.

Introduction

Resistance exercise is typically performed with the intention of increasing both muscle size and strength. Given these expected outcomes, resistance exercise is regularly incorporated into training programs to improve sports performance [1]. Presumably, resistance exercise would be expected to increase the force producing capabilities of skeletal muscle, which may have subsequent influence on various sports related abilities. An early paper by Sutherland and Wiley [2] reported that all teams in the National Football League had strength and conditioning programs and that the majority of professional baseball, and basketball teams have full time strength and conditioning professionals on staff. Despite the widespread incorporation of resistance exercise across a wide variety of sports [3–7], the performance benefits are not entirely clear. Notably, few studies are specifically designed to examine sports related benefits of resistance exercise while including a proper control group to account for adaptations to simply performing the sports related tasks. It appears that much of our knowledge on resistance exercise for sport is based off cross-sectional work showing that stronger athletes tend to perform at the highest level [8], along with cross-sectional work demonstrating that higher levels of strength are associated with various performance related parameters [9]. Although there is a

large body of cross-sectional literature providing a rationale for resistance exercise for sport, its implementation is largely based on the following assumptions: 1) An increase in muscle size will produce an increase in muscle strength and 2) a stronger muscle will increase sports performance. These assumptions seem intuitive, but recent studies have brought up questions regarding the role of exercise induced muscle growth on exercise induced strength adaptation [10], as well as how important specificity is for strength adaptation [11,12]. Considering these suggestions, the role that resistance exercise has for sports performance may be largely based on cross-sectional derived intuition rather than experimental evidence. The purpose of this review is to examine the evidence behind these assumptions and to examine the experimental evidence suggesting that resistance exercise (lifting weights with the intention of increasing muscle size and strength) improves sports performance.

Assumption 1: An increase in muscle size will produce an increase in muscle strength

Within sport, resistance exercise is often implemented through a programming strategy known as periodization. Modern periodization techniques place a great focus on skeletal muscle hypertrophy

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(hypertrophy phase) under the assumption that skeletal muscle growth during this phase will play a role on subsequent strength adaptation [13,14]. Although it seems that prior to and independent of resistance exercise, a larger muscle is a stronger muscle [15], the influence that *exercise induced* increases in muscle size have on *exercise induced* increases in muscle strength has become an area of debate [16,17]. Indeed, our understanding of the role that muscle growth has on muscle strength is driven primarily by cross-sectional associations [15], as well as retrospective correlations [18–20]. In addition, recent experimental evidence from our laboratory has demonstrated that performing a resistance training protocol to increase both muscle size and strength does not result in greater strength gains than simply practicing a one-repetition maximum (i.e., the strength test) in both trained [21] and untrained individuals [12]. Although these studies do not completely rule out the possibility that exercise induced muscle growth can contribute to exercise induced strength, it does allow for renewed discussion on how influential muscle growth is upon this change in strength.

Despite a lack of strong experimental evidence that increasing muscle size is necessary or important for strength adaptation, cross-sectional data has demonstrated that athletes have greater amounts of lean mass compared to controls or non-athletes [22,23]. To many this may stress the importance of muscle mass in sport, underlying the importance of resistance exercise. However, considering the relatively small amount (compared to that gained during development) of muscle mass that an individual can gain as an adult [24], this more likely highlights inherent differences in individuals who are capable of excelling in sport. This suggests that an individual with higher levels of baseline muscle mass (independent of resistance exercise) may be predisposed for success in a given sport. In addition, skeletal muscle growth does not appear to be infinite [24], which may suggest that the majority of adult athletes will not gain a great deal of muscle mass beyond that of their first year of resistance training. Further, it appears that most of these athletes may be capable of maintaining those adaptations following the initial months of training with much lower volumes of exercise than it took to accrue them initially [25]. Following this logic, there may be some merit to resistance exercise for younger athletes (still growing/developing), as resistance exercise may help them to attain a higher baseline [26]; however, the resistance training focus can likely be drastically reduced into adulthood.

Assumption 2: A stronger muscle will increase sports performance

Skeletal muscle hypertrophy may not be necessary or important for strength adaptation; however, resistance exercise may still be efficacious for sport if it could improve performance by augmenting strength. The idea that resistance exercise will increase sports performance is generally accepted [9,27]; however, it appears that this assumption is largely based off cross-sectional data demonstrating that strength is associated with being a starter or non-starter [8], as well as with various tasks related to performance [9]. For example, Iguchi et al. [8] found that Japanese football starters had greater bench press and back squat strength compared to non-starters. In addition, Fry and Kremer [27] found that bench press, power clean and vertical jump could differentiate between starters and non-starters in 5 of 6 different positions in American collegiate football. In addition to being associated with a higher level of athletic ability, strength is also associated with higher task performance in skills that are believed to be important for sports performance. For example, performance measures such as rate of force development, external mechanical power, and sports related skills such as jumping, and sprinting are associated with strength [9,28]. For the purposes of this review, we will discuss the impact of resistance exercise on rate of force development, jumping abilities, as well as “sports specific” abilities. In addition we will discuss the reliance on cross sectional data in our understanding of strength and how it applies to sports performance.

Rate of force (torque) development

Rate of force development is also known as “explosive muscle strength” and is defined as the rate of rise in contractile force at the onset of contraction [29]. Although rate of force development has been shown to increase following resistance exercise [30,31], the reason increases in rate of force development are believed important for athletes appears to be largely based off a body of cross-sectional literature which suggests that starters have greater rates of force development compared to non-starters [32]. In addition, it has been shown that greater rates of force development are positively associated with other factors such as vertical jump [33] and muscle cross-sectional area [34]. Andersen and Aagaard [35] found that maximal strength may account for up to 80% of the shared variance in rate of force development further underscoring the importance for resistance exercise. Although these cross-sectional associations certainly create a case that rate of force development might be an important factor for sports performance, it does not appear that there are any studies designed to show that *increasing* the rate of force development through resistance exercise improves actual sports performance. Meaning, rate of force development may be associated with high sports performance, but this does not necessarily mean that increasing this in a laboratory test through resistance exercise will reflect any meaningful change in sports performance. This is an important distinction, as there are countless associations within the literature, which may drive many of our presumptions regarding the influence of resistance exercise on sport (in this case through rate of force development). In order to better answer the question, interventions should be designed to elicit a change in rate of force development and compare changes in sports outcomes to individuals practicing their sport related skills.

Jumping Abilities

Vertical jump is often used as a surrogate for sports performance. Cross-sectional literature has demonstrated that stronger individuals are able to jump higher than weaker individuals [36]. Suchomel et al [9] examined correlations amongst 116 different studies, finding that 91 (78%) of the studies displayed a greater than moderate correlation between jumping ability and strength. Experimentally, Cormie et al. [37] observed increased jump performance following 10-weeks of either heavy resistance training or ballistic power training. Lamont et al. [38] found that 6-weeks of periodized resistance training (with or without the application of whole body vibration) could improve 30-cm depth jumps and 20-kg squat jump performance. Thus, it appears that jumping performance can be improved through resistance exercise. This may provide some efficacy to resistance exercise for sports performance, as the ability to jump is important across a wide variety of sports and sporting events. However, it is still unclear if a laboratory measure of jumping performance will actually translate to jumping performance in the sports setting. Fatouros et al. [39] found that vertical jump increased approximately 5–8 cm following 12 weeks of either plyometric training, weight training or a combination of both in untrained individuals. The authors conclude that “combination” training may be an effective strategy for athletes to improve explosiveness, but we must consider that vertical jump was executed from a “2-footed standing position without a step into the jump”. If we use American football as an example, it is unclear how this increase would apply to a wide receiver running down the football field in full gear prior to jumping. An athlete is very skilled in the execution of their sports specific jumps/movements; however, they are likely much less skilled at a laboratory test of vertical jump. Any increase in vertical jump for an athlete may simply reflect the acquisition and improvement of a new skill in which they were not already efficient. Such laboratory based skills may have more meaning for sports such as volleyball, where the sports specific jumps may more closely mimic the laboratory test [40,41]. Nonetheless, no study to our knowledge has examined the

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