MONTHLY

THE S&C RESEARCH REVIEW

By Chris Beardsley

SEPT 2019 EDITION

September 2019 Edition

Editorial by Chris Beardsley

Welcome to the September 2019 edition! This edition covers two or three of the most important studies published this year. The lead article covers a study that is the most detailed analysis of the determinants of strength gains after long-term strength training that has ever been done. While not without its limitations, it draws our attention to two points. Firstly, a large proportion of the strength gains that we record when measuring changes in 1RM are likely to be stability-specific, and are related to our ability to stabilize ourselves when doing the exercise. Secondly, the determinants of strength gains differ depending on the contraction mode of the test.

In the hypertrophy section, I reviewed an extremely exciting study in which the research team assessed the relative contributions of muscle fiber activation and muscle fiber mechanical tension on the anabolic signaling that leads to hypertrophy. They found that when mechanical tension is the same, both active contractions and passive stretching of the muscle cause the same anabolic signaling. In contrast, when muscle fiber activation is the same but mechanical tension is blocked from occurring, there is no anabolic signaling. This shows yet again that mechanical tension is the primary driver of muscle fiber growth. Naturally, this does not mean that only heavy weights cause muscle growth during strength training, because the proximity to failure is what determines bar speed (not the external load) and the force-velocity relationship is what determines muscle fiber mechanical tension during normal strength training.

In addition to these two landmark studies, there are many others covered in this edition that provide key insights into the effects of strength training for athletes and bodybuilders. Read on to learn more! See you next month.

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Mechanisms underlying the changes in isometric and dynamic strength

After conventional, heavy strength training, we observe increases in exercise 1RM, isometric strength, concentric strength, and eccentric strength. However, increases in exercise 1RM are usually greater than increases in the other strength measures. This may be due to stability requirements of the exercise 1RM test. Even so, the mechanisms that underpin gains in each type of strength are unknown. It is widely assumed that muscle size always contributes similarly to strength under all circumstances, but this may not be true.

Key findings

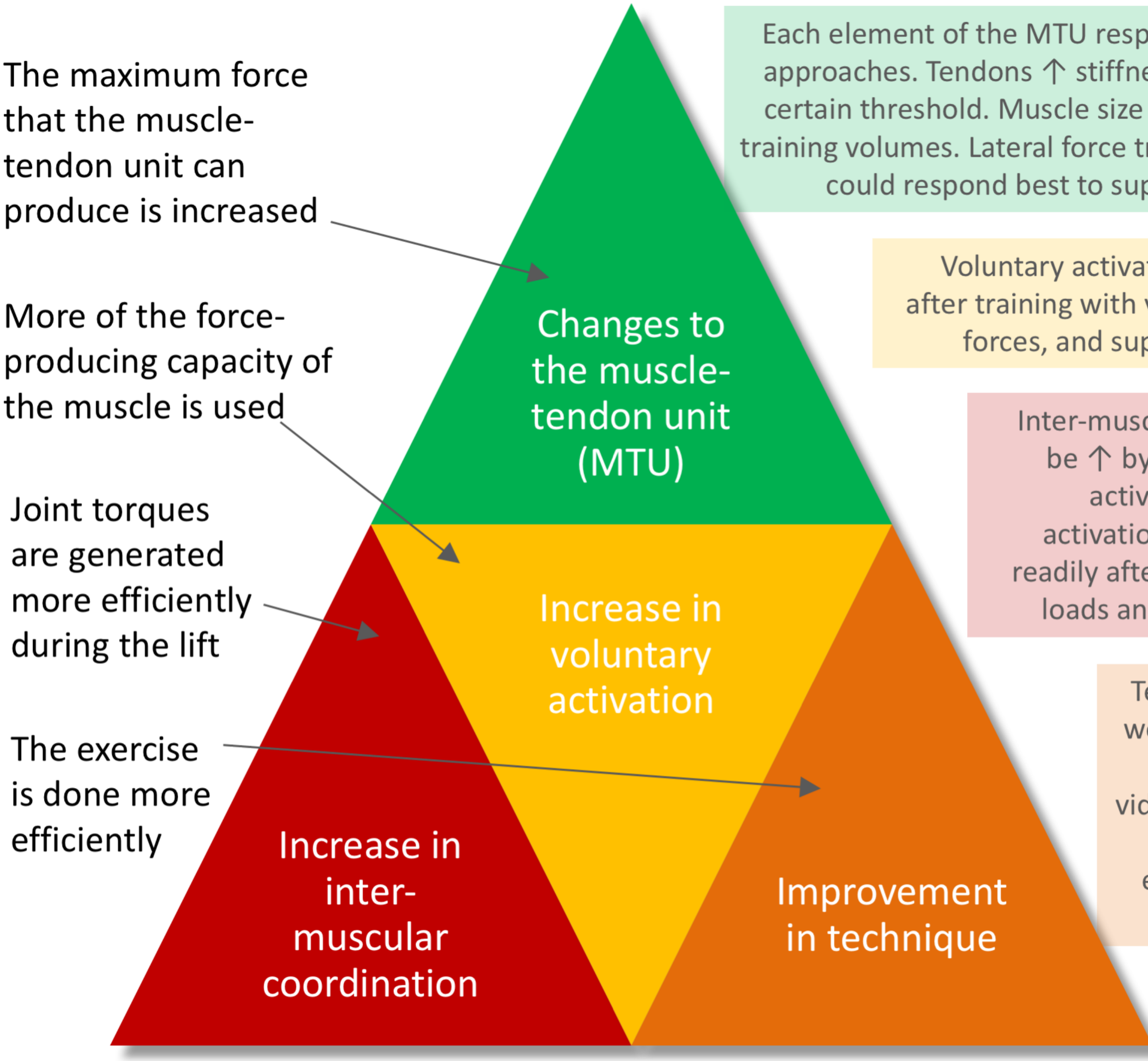
After untrained males completed a training program, gains in exercise 6RM were greater than (and unrelated to) the increases in maximum isometric, concentric, and eccentric strength. Increases in isometric strength were most closely related to the increases in muscle cross-sectional area and pennation angle. Increases in concentric and eccentric strength were most closely related to increases in muscle activation.

Practical implications

Although it is often assumed that increasing muscle size will enhance strength in many circumstances, hypertrophy likely plays a larger role in enhancing isometric strength than dynamic (concentric and eccentric) strength, where neural adaptations play a key role. This underscores the importance of using maximal efforts during strength training for athletes, since effort is closely related to motor unit recruitment in each rep.

Anatomical and Neuromuscular Determinants of Strength Change in Previously Untrained Men Following Heavy Strength Training. Trezise, J., & Blazevich, A. J. (2019). *Frontiers in Physiology*, 10, 1001.

We can increase one repetition-maximum (1RM) in four different ways, which can each be targeted with different training approaches



Each element of the MTU responds best to different approaches. Tendons ↑ stiffness once load is over a certain threshold. Muscle size responds best to high training volumes. Lateral force transmission capability could respond best to supramaximal eccentrics

Voluntary activation seems to ↑ most after training with very heavy loads, high forces, and supramaximal eccentrics

Inter-muscular coordination can be ↑ by ↓ antagonist muscle activation and ↑ synergist activation. This happens more readily after training with lighter loads and very fast bar speeds

Technique can be ↑ by working with a strength coach, by reviewing videos of your own 1RM lifts, and possibly by employing an external focus of attention

▶ 1RM can increase through improvements in technique, inter-muscular coordination (reductions in antagonist activation in favor of increased synergist activation), increases in voluntary activation, and changes in the properties of the muscle-tendon unit. Each of these changes can be targeted by different training methods.

Strength & Conditioning Research

OBJECTIVE

To assess the relationships between changes in maximum isometric, concentric, and eccentric strength and the changes in the mechanisms underlying these strength gains, in untrained males.

INTERVENTION

Subjects did 2 workouts per week for 10 weeks. Each workout comprised the leg press, knee extension and leg curl exercises for 3 sets of 6RM each, with 2 minutes of rest between sets and 3 minutes of rest between exercises.

POPULATION

36 untrained males, aged 29.0 ± 5.1 years

MEASUREMENTS	RESULTS
Maximum strength in the trained exercises	Knee extension 6RM increased by 46%. Leg press 6RM increased by 114%. Leg curl 6RM increased by 48%.
Maximum isometric, concentric, and eccentric strength: By maximal voluntary isometric contraction (MVIC) knee extension torque and by maximal voluntary contraction concentric (MVCC) and eccentric (MVEC) knee extension torques at 60°/s in dynamometers.	MVIC knee extension torque increased by 17%. MVCC knee extension torque increased by 13%. MVEC knee extension torque increased by 16%. These increases were all significant. The changes in MVIC, MVCC, and MVEC knee extension torques were not significantly associated with the changes in knee extension 6RM.
Voluntary activation (VA): By interpolated twitches in an MVIC.	VA increased significantly by 4%.
Muscle activation: By electromyography (EMG) amplitudes of the quadriceps (normalized to M wave amplitudes) and hamstrings (normalized to levels in maximal knee flexion contractions).	Quadriceps EMG amplitudes significantly increased in MVICs (by 23%), MVCCS (by 19%), and MVECs (by 23%). Hamstrings EMG amplitudes did not change significantly. Increases in MVCC and MVEC were significantly associated with increases in quadriceps, rectus femoris, and vastus medialis EMG amplitudes.
Regional muscle size: By anatomical cross-sectional area (CSA) of the proximal, middle, and distal quadriceps using ultrasound.	Increases in MVIC were significantly associated with quadriceps proximal CSA, vastus lateralis proximal and middle CSA, and vastus intermedius distal CSA. Increases in MVCC were significantly associated with vastus lateralis proximal CSA only.
Muscle architecture: By quadriceps muscle pennation angle and fascicle length ultrasound.	Increases in MVIC were significantly associated with vastus lateralis proximal pennation angle. Increases in MVCC were significantly associated with vastus intermedius pennation angle in addition to vastus lateralis middle region fascicle length.

SUMMARY

After untrained males completed a training program, gains in exercise 6RM were greater than (and unrelated to) increases in maximum isometric, concentric, and eccentric strength. Increases in isometric strength were most closely related to the increases in muscle cross-sectional area and pennation angle. Increases in concentric and eccentric strength were most closely related to increases in muscle activation.

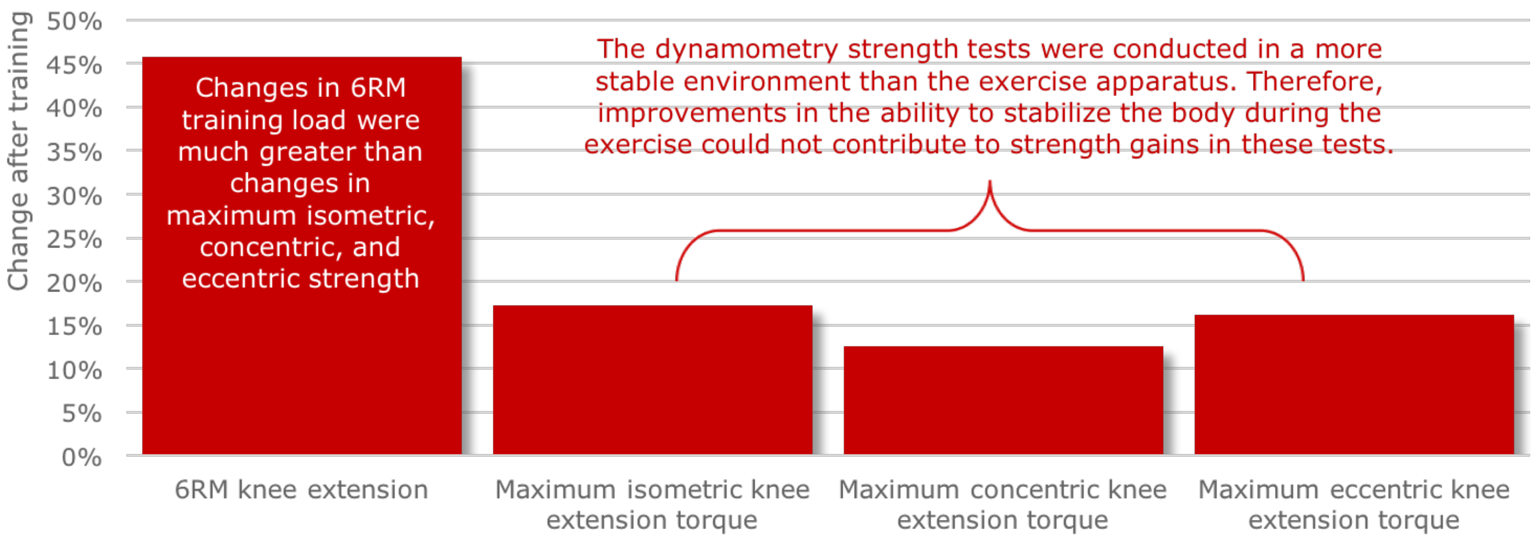
This study reported that after untrained males complete a strength training program, gains in exercise 6RM were substantially greater than (and unrelated to) the increases in maximum isometric, concentric, and eccentric strength.

It is possible that the greater gains in knee extension 6RM were achieved through improvements in the ability to stabilize the body during the exercise, because the exercise apparatus required the lifters to stabilize themselves more than the dynamometers (1). Indeed, research has shown that when training using unstable weights or surfaces, there are greater gains in strength when strength is measured in the unstable condition than in the stable condition (2,3,4), due in part to reductions in antagonist muscle activation and increases in synergist muscle activation (5).

Indeed, antagonist muscle activation is often greater in unstable exercise variations than in equivalent stable exercise variations when measured before a training program (6,7). Consequently, there is scope to cause a reduction in the braking force produced by the antagonist muscles as a result of training, by transferring the stabilizing role away from the antagonists and towards the synergist muscles.

Interestingly, this stability-related strength gain was far greater than the strength gain associated with coordinating the movement through a full, dynamic range of motion. Indeed, strength gains were greater when measured in the knee extension 6RM than in the dynamometry measurements, while the three dynamometry measurements did not differ substantially from one another, despite the different contraction modes.

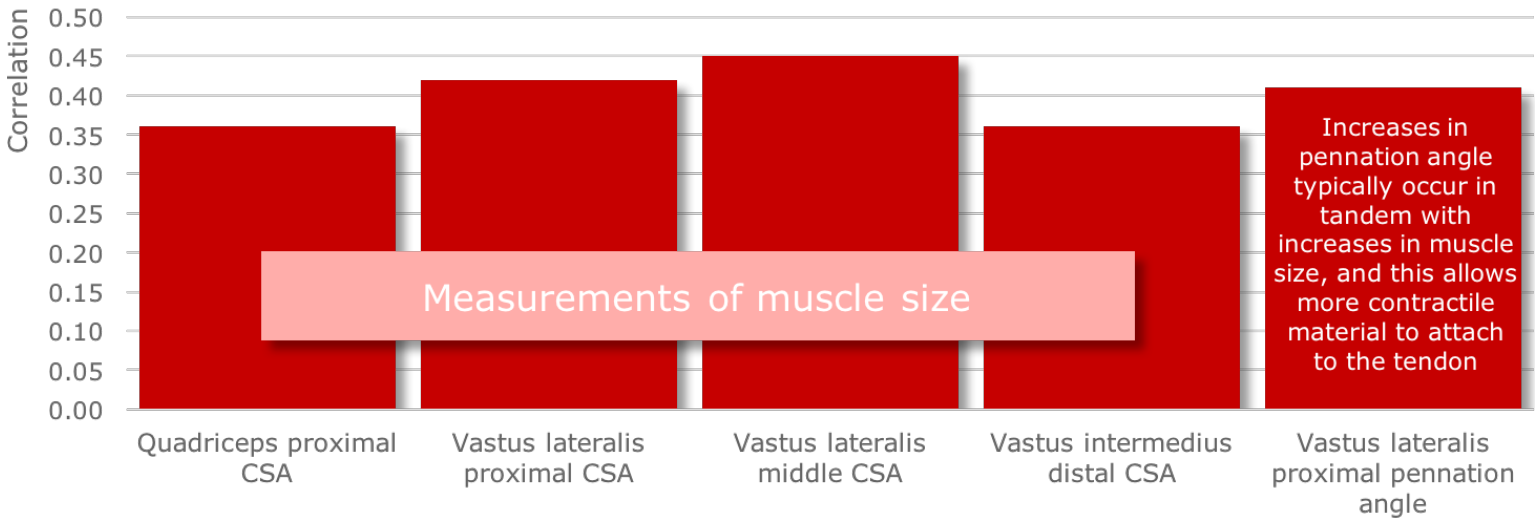
Changes in different measurements of maximum knee extension strength after 10 weeks of lower body strength training with 6RM loads, in untrained males



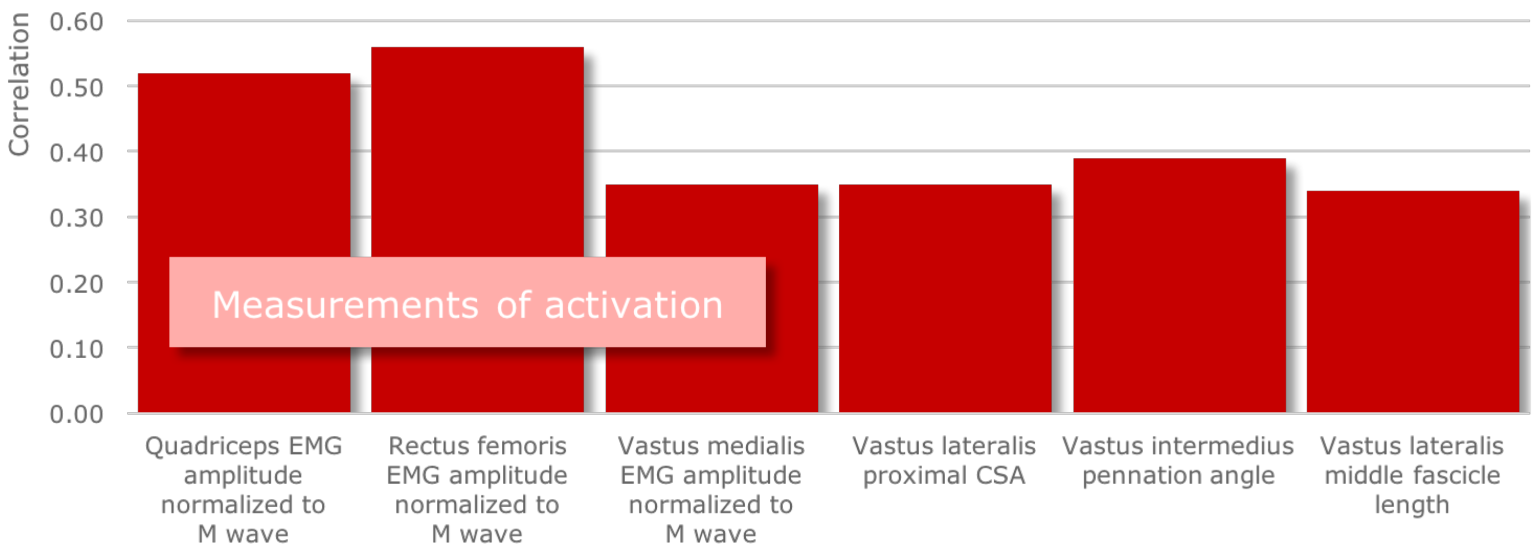
This study found that changes in isometric strength were most closely linked to measures of muscle size, and one measure of pennation angle. Previous research has found that isometric strength is related to muscle size in cross-sectional (8 – 11) and training studies (12,13).

Researchers have also found that hypertrophy is more closely related to gains in isometric strength than in dynamic strength (14,15). Indeed, in this study, the gains in maximum concentric strength were partly related to increases in muscle activation and partly to hypertrophy.

Significant correlations between the changes in various mechanisms that underpin strength gains and the changes in **maximum isometric strength** after training, in untrained subjects



Significant correlations between the changes in various mechanisms that underpin strength gains and the changes in **maximum concentric strength** after training, in untrained subjects



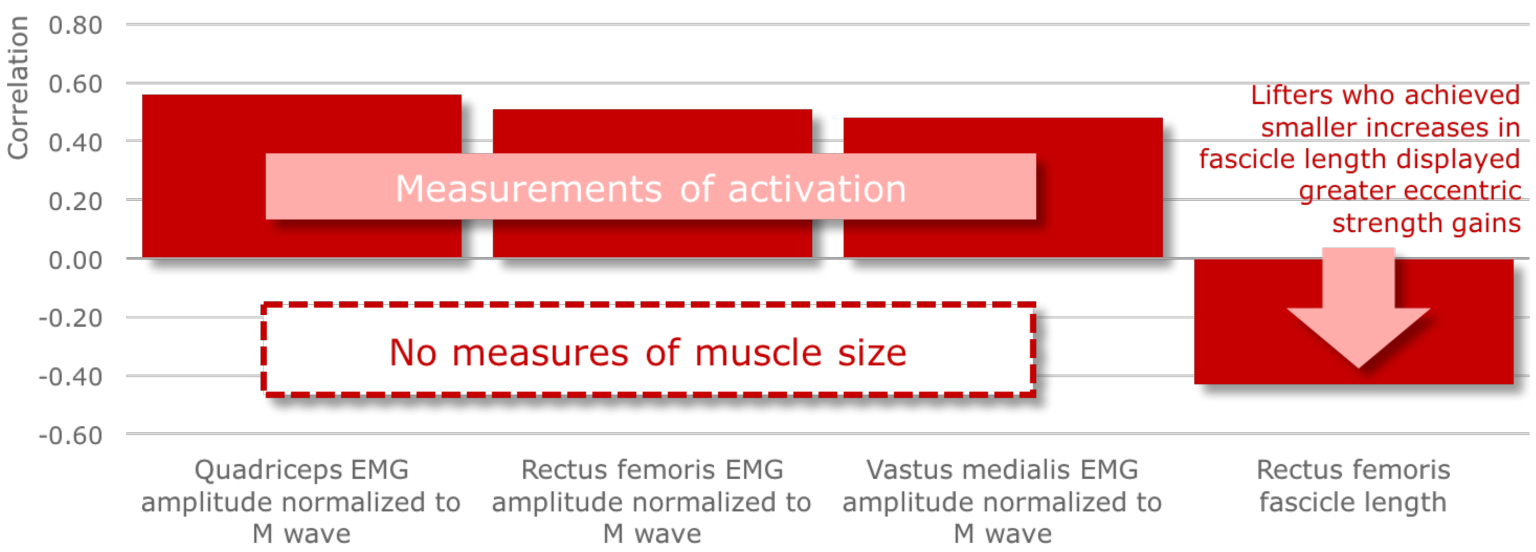
Gains in eccentric strength in this study were similarly most closely related to increases in muscle activation, and were not associated with hypertrophy. Indeed, there was no significant association between the changes in any measure of muscle cross-sectional area and the gains in maximal eccentric strength. Moreover, the relationship between increases in fascicle length and eccentric strength was actually negative, indicating that those subjects who achieved smaller increases in fascicle length after training achieved greater gains in maximum eccentric strength.

Exactly why hypertrophy contributes most to gains in isometric strength, moderately to concentric strength gains, and little to eccentric strength gains among untrained lifters is not entirely clear.

It seems likely that the very low level of voluntary activation that can be attained in maximal eccentric contractions by untrained lifters is one important contributory factor (16). The low level of voluntary activation that untrained lifters can attain during eccentric contractions means that strength training can cause large increases in eccentric strength by increasing the number of motor units that can be recruited in maximal eccentric contractions (17).

Additionally, it is noteworthy that maximal eccentric strength can be enhanced by increases in the stiffness of passive structures, which do not cause large increases in muscle size (18). Thus, gains in muscle size will likely contribute proportionally less to eccentric strength after training, since there are other factors that can play a large role.

Significant correlations between the changes in various mechanisms that underpin strength gains and the changes in **maximum eccentric strength** after training, in untrained subjects



The greater contributions of increased muscle activation to gains in maximal concentric strength (MVCC) than to maximal isometric strength (MVIC) are less easy to explain. Two key differences between concentric and isometric contraction modes are probably relevant.

Firstly, there is a smaller amount of time available during concentrics to exert force. This means that the rate of force development (RFD) could play a greater role in MVCC than in MVIC. Consequently, adaptations that influence RFD may cause a greater impact on MVCC than on MVIC. It is widely accepted that RFD is influenced strongly by neural adaptations such as increased motor unit firing rates (19). Thus, changes in muscle activation might reasonably be expected to enhance MVCC to a greater extent than MVIC.

Secondly, the force-velocity relationship applies to a greater extent in concentric contractions than in isometric contractions. The force-velocity relationship is produced by the detachment rates of actin-myosin crossbridges. These rates increase with increasing shortening velocity (20). When the detachment rates are high, they can be compensated for by faster motor unit firing rates. When they are slow, this is not necessary. Thus, improvements in motor unit firing rates are likely to have a greater influence on MVCC than on MVIC.

Researchers and other strength training experts often debate the relationship between hypertrophy and gains in strength, but they rarely specify the type of strength that is being measured. Yet, this is very important, because athletic performances frequently rely upon the ability to exert force while muscles are lengthening and shortening dynamically, often quickly.

Most previous studies that have examined the relationships between muscle size and strength (or hypertrophy and strength gains) have used isometric strength tests (8 – 13). Yet, this study shows that such isometric strength tests will very likely produce a much stronger relationship with hypertrophy than concentric strength tests, which rely more on the ability to recruit motor units and the ability to produce faster motor unit firing rates (21). Thus, we probably overestimate the importance of muscle fiber hypertrophy in mediating strength gains in exercises and in sporting movements after strength training, and underestimate the importance of adaptations that affect the control of motor units.

Even so, that is not to say that increases in muscle fiber size do not contribute to increases in strength in many situations. An increase in the number of myofibrils in parallel will allow more crossbridges to form between actin and myosin myofilaments, which will increase muscle force.

Finally, it is important to note that the correlations reported in this study between the underlying adaptations and the strength gains were only moderate (and the models that were created were only able to explain a small proportion of the strength gains in each test). This may be partly because several variables (such as lateral force transmission for all contraction modes and titin-based stiffness for eccentric contractions) were not measured.

Similarly, the contributory effects of motor learning are unclear. While coordination is often stated to be a key determinant of strength in an exercise, and motor learning is similarly claimed to be a key determinant of gains in strength, alterations in coordination after a training program are rarely (if ever) measured. Thus, their true contribution to strength gains is completely unknown, and may be small or substantial.

Conclusions

After untrained males completed a training program, gains in exercise 6RM were greater than (and unrelated to) increases in maximum isometric, concentric, and eccentric strength. Increases in isometric strength were most closely related to the increases in muscle cross-sectional area and pennation angle. Increases in concentric and eccentric strength were most closely related to increases in muscle activation.

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