By Adam Thompson

Introduction

Core training receives a lot of attention. Magazines, websites and fitness professionals all extol the virtues of having a strong core. Turn back the clock a couple of decades and core training was unheard of. Today we have exercises such as the plank, sidebridge and superman which specifically target these unseen and until recently, unappreciated muscles. Why the sudden emphasis on core training? Have athletes of the past been at a disadvantage for not targeting their core? Are we building bigger, stronger and more powerful bodies by training our core? Is core training just another fitness fad or is it an essential part of an athlete's training? Do you even need to train your core? With so many questions surrounding this apparently vital muscle group it is worth looking at what the evidence says.

What is your core?

Your core is more than just the abdominal muscles. It has been described as a muscular box with the abdominals in the front, paraspinals and gluteals in the back, the diaphragm as the roof, and the pelvic floor and hip musculature as the bottom[1]. This muscular box contains 29 pairs of muscles which work together to stabilise the spine, pelvis and hips during functional movements[2]. Without these muscles the spine would be mechanically unstable and could not support the weight of the upper body[1].

Why is a strong core important?

Core stability is defined as the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segments[3]. This simply means a stable core is needed

for postural control over the body so that power can be generated and transferred to the extremities in a controlled manner.

It is not possible to say whether certain core muscles are more important than others. This is because the 29 pairs of muscles work together to stabilise the core. There is some evidence that weakness in three particular muscles, the lumbar multifidus, transverse abdominis and quadrates lumborum, is associated with low back pain and lower body injury in both athlete's and non-athletes but this is not definitive[4].

Many muscles are trained in the gym for aesthetics. The muscles that make up your core have limited aesthetic value but their functional importance should not be underestimated. The core is an integral link in the kinetic chain[2]. The kinetic chain is a biomechanical term that describes the system of interdependent parts working in sequence to produce and transfer energy throughout the body[2,5].

One way to think of your core is as a junction with 4 pipes (representing your arms and legs) running into it. If the junction (your core) is strong then water can be moved at high pressure through one pipe into another without losing any of the pressure. If the junction has a structural weakness however, maximum pressure cannot be transferred throughout the system. This is analogous to strength being generated and transferred to the extremities of the body. As an integral part of the kinetic chain a weak and unstable core may limit the amount of strength and power that can be generated and moved around the body, regardless of the strength in the extremities[6,7].

A correlation exists between the strength of an athlete's core muscles and strength in the bench press, squat and power clean[7,8]. You probably think the strength required to perform upper body exercises comes solely from the upper body. This assumption is wrong however. In response to rapid arm movements, muscle activation patterns actually begin in the lower extremities and proceed upwards through the trunk and then to the arms[9,10]. Even before you consciously perform your first repetition of an upper body exercise the muscles of the lower body and core are activated in order to stabilise the body[10,11]. Your core therefore plays a vital role in every exercise you perform in the gym.

If your core muscles are weak then postural stabilisation and the transfer of power from the lower body to the extremities will be compromised[2,7,12]. This will limit optimum physical performance and may make an athlete more susceptible to injury as the impaired force production results in other body segments compensating the lack of core strength and postural control[2].

Training your core muscles

If you are to believe what you read in the media your core muscles should be treated just like any other muscle group and require their own dedicated training.

While there is no doubt that certain exercises and postural positions do activate the core stabiliser muscles the necessity of core-specific training for weight training athletes has to be questioned.

Arguments favouring core-specific exercises typically fail to acknowledge that the core musculature is bought into play during many common resistance exercises. A training load of 80% 1 repetition maximum (1RM) in the squat and deadlift can elicit greater activation of the core stabiliser muscles compared to core-specific exercises such as the sidebridge and superman[13].

Nuzzo et al. demonstrated that performing squats and deadlifts at 50% to 100% 1RM elicited significantly greater core muscle activity compared to performing core exercises on a stability ball[14].

Colado et al. compared muscle activity in the paraspinals during deadlifts and a number of different isometric core stabilising exercises such as the supine bridge. It was found deadlifts with 70% 1RM elicited on average 3 times more activity in the paraspinals compared to the core stabilising exercises[15].

The role of instability

Given that the role of the core muscles is to stabilise the body so that optimum force can be generated and transferred to the extremities it makes sense to adopt exercises that include this function. Unfortunately we all too often intentionally perform many exercises in the gym in such a way as to minimise the use of our core muscles. This is done by performing exercises in a seated position and by using a back rest to provide artificial stabilisation.

Adding instability to a movement enhances activation of the core musculature. Core muscle activity is increased by performing exercises standing as opposed to seated. Performing exercises unilaterally further increases the stress on the core musculature[16].

Building instability into a training program enhances core muscle activation but if the goal is maximum strength and hypertrophy it may limit training adaptations. Performing Squats and deadlifts in an unstable position such as on a BOSU ball increases the stress on the core musculature compared to a stable position with the same intensity[17,18] but reduces muscle activity and power output of the lower body compared to the stable position on the floor[18-21]. This suggests the additional resistance that that can be applied when training in a stable position provides a greater stimulus to the working muscles than does the instability provided by an unstable surface. Optimum strength and hypertrophy adaptations are therefore more likely to be achieved by performing ground-based exercises in a stable position.

Training the upper body on an unstable surface also increases core muscle activity[22-24] but reduces muscle power

ouput[25]. Anderson and Behm reported that muscle power output was reduced by 60% when performing bench presses on a balance ball compared to a stable bench[26].

The reduction in muscle power output and increase in core muscle activity appears to be most pronounced at intensities exceeding 50% 1RM[21,23,27]. At intensities of 50% 1RM or lower core muscle activity and muscle power output may be equivalent between exercises performed in stable and unstable positions. Body weight exercises such as push ups produce greater activity in the core and the upper body when performed in an unstable position[28].

As well as providing a significantly greater stimulus to the muscles being trained, high-intensity ground-based exercises provide a sufficiently unstable environment to condition the core musculature. The *Canadian Society for Exercise Physiology* recommends that athletes training for maximum strength, power and velocity of movement should emphasise higher-intensity ground-based lifts such as Olympic lifts, squats and deadlifts for conditioning the core musculature. Lower intensity core-specific exercises should not be a major component of training for these athletes[12].

Core training may not be suitable for everyone

Experienced weight training athletes, especially those who regularly train with high-intensity ground-based exercises, will likely already possess highly conditioned core stabiliser muscles. Training programs that incorporate an instability component such as a sling or balance ball may not provide a sufficient stimulus to effectively work the core in these athletes[27,29].

Transference and specificity

The rationale behind core training is that the strength developed through core-specific exercises can be transferred to other movements that require strong core stabiliser muscles, thereby enhancing those movements. While logical, this belief ignores the accepted training principle of specificity which states that adaptations are specific to the nature of the training stimulus[30]. This means the vast majority of training-induced adaptations occur only in those muscle fibres that have been recruited during the specific exercise, with little or no adaptive changes occurring in untrained muscles[31].

The principle of specificity predicts that the closer the training routine is to the requirements of the desired outcome, the better the outcome will be[31]. Optimum performance therefore requires a training regimen that incorporates training specificity[13]. In other words if you want to get strong in the squat, deadlift or bench press you need to train with those specific exercises.

Core training emphasises different muscles and requires different neuromuscular coordination compared to resistance exercises performed in the

gym. The adaptations that occur in response to the stimulus of core training will be different than those required to support optimum performance in resistance exercise such as the squat, deadlift or bench press.

The problem with core training is that many of the exercises are performed as an isometric contraction in a prone position while the majority of resistance exercises are performed in an upright position using eccentric contractions. Due to the different demands placed on the body in a prone position, conditioning of the core musculature through core-specific exercises may not transfer to improved physical performance during exercises performed in an upright position[13]. This makes core-specific training a poor choice for athletes looking to maximise strength and hypertrophic adaptations through resistance exercise.

Neuromuscular coordination

Core stability is not determined solely by strength of the core muscles. Motor control also plays an important role. When performing a specific movement there is constant feedback between the muscles and the central nervous system. This feedback coordinates muscle activity to stabilise the body and allow for the efficient execution of the movement[1]. Deficits in neuromuscular coordination of the core are a significant risk factor for knee injuries in athletes. This risk factor is more pronounced in females than males[32].

Different exercises will place different neuromuscular demands on the body. Specificity explains why core training utilising core-specific exercises does not necessarily translate into improved physical performance during complex tasks[33].

The principle of specificity is not completely rigid as different exercise that follow a similar pattern of movement can produce transference of strength from one resistance exercise to another[34,35]. There is insufficient evidence to support the use of exercises that use different patterns of movement.

Developing core strength – the right way

As previously mentioned a correlation exists between core muscle strength and strength in the squat, bench press and power clean[7,8]. One way to interpret this data is that if you develop a strong core through core training then your strength in these exercises will also improve. While logical, this runs contrary to the accepted principles of specificity and transference. There is also no evidence to support this. Another more accurate interpretation is that athletes who are strong in the squat, bench press and power clean have strong core muscles due to the strength they have developed by training in these exercises. Their strong core is merely a by-product of their training.

The advantage of using high-intensity ground-based exercises for conditioning the core musculature is that the core muscles are trained to specifically

complement the exercise being performed. This means the core muscles will be strengthened in a manner that provides maximum support and stabilisation during those specific exercises. This will result in optimum exercise performance and training adaptations.

Does core training have any role?

When interpreting data relating to core muscle activity it is tempting to apply a qualitative answer that describes the core musculature as being worked either more or less during various exercises. Given the core consists of 29 pairs of muscles it is naive to assume they are all subject to the same level of stress during physical activity. There is no single exercise that optimally stresses all the core muscles; a variety of exercises are therefore needed to ensure the entire core musculature is effectively conditioned[36]. Core training utilising techniques such as instability should not form the basis of training for strength and power athletes but may be a useful addition to a periodized training program during high-volume low intensity phases[12].

Conclusion

The core stabiliser muscles play a vital role in generating and transferring muscle power throughout the body. A strong core is therefore critical for optimum athletic performance. Weakness in the core musculature will limit an athlete's strength and power and may make them more susceptible to injury. Weight training athletes should emphasise high-intensity ground-based exercises as the foundation of their core conditioning. This provides both training specificity and optimum stimulation of the muscles being trained. High-intensity ground-based exercises also provide a sufficiently unstable environment to effectively condition the core musculature in such a way as to complement the exercise being performed. The benefit of core-specific training for athletes engaged in resistance exercise has yet to be established. Despite the lack of evidence core training may be a useful addition to periodized training programs during high volume low intensity phases however it should not be a major part of an athlete's training.

Conflict of interests

The author declares no conflict of interests in the publication of this review.

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