



## The Truth on Fitness: **Does Muscle Activation Determine Exercise Effectiveness?**

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## Does Muscle Activation Determine Exercise Effectiveness?

Recently, an interesting chat string appeared on a sports performance forum, wherein someone claimed to have identified the best exercises for developing the gluteal muscles. Making the posting especially fascinating, was the fact that the exercises were not selected for their ability to enhance hip joint movement or stability, but for their propensity to induce greater levels of muscle activation, as measured by electromyography. Apparently, a relatively new trend has emerged, whereby sports and fitness coaches use electromyography to validate training and fitness practices.

Electromyography (EMG) is an application which allows scientists to measure electrical activity in muscles during various states of contraction. That activity represents, in a way, the manner in which muscles are activated by the central nervous system (CNS). It has been fairly well established, for example, that higher EMG values, or amplitudes, are associated with more forceful muscle contractions (Bigland and Lippold, 1954; Gerdle, et al, 1988; Komi and Viitasalo, 1976; Milner-Brown and Stein, 1975; Moritani and Muro, 1987). Thus, in comparing two exercises, one might conclude that the one which produces the higher EMG amplitude also induces greater muscle tension, and therefore, is the exercise of choice.

At face value, this is a perfectly reasonable conclusion. After all, elevated muscle tension might be associated with increased strength gains, and potentially, enhanced function. On the other hand, rarely should a scientific application as complicated as EMG be taken at face value. For, as nearly a half century of research has demonstrated, there are multiple factors which influence and contribute to signal amplitude. Failing to account for these, makes any conclusion regarding the efficacy of strength training exercises highly questionable.

One simple characteristic of movement that could affect EMG amplitude is joint range of motion. Funk and colleagues (1987) examined electrical activity in the biceps during elbow flexion to various end points. The authors demonstrated that as the joint range of motion increased, the amplitude of the EMG signal increased as well. In practical terms, two movements, identical but for a slight deviation in range of motion, would be characterized as different because of the disparity in EMG amplitude.

Perhaps, the one involving the smaller range of motion would be considered less effective because of the lower EMG value. But what if the goal of the movement, for some reason, were to limit the range of motion? Wouldn't the higher EMG level point to the less preferred exercise?

Years earlier, Inman et al (1952) measured the amplitude of the EMG signal when muscles were stretched to different lengths, and discovered that the EMG signal diminished as muscles were stretched further. The authors reasoned that since a muscle on stretch had greater inherent tension-generating capacity, there was less of a demand for central stimulation, thus, the EMG signal was lower.

Similar results have been seen when comparing concentric to eccentric muscle contractions (Moritani et al, 1987; Sheehy et al, 1998), or alternatively, when distinguishing between agonist and antagonist muscle function (Shapiro et al, 2005). In either example, greater EMG amplitudes were associated with muscle shortening, and lower values resulted from lengthening contractions. Once again, since the muscles were more efficient during eccentric contractions, there was less of a need for stimulation from the CNS.

These discoveries present an interesting paradox. In this case, one might prefer an exercise that begins with the muscle under stretch, because of an exaggerated range of motion, or one which emphasizes eccentric loading, such as depth jumping. If EMG amplitude is the defining characteristic by which an exercise is deemed effective, then the lengthened or eccentric condition would be discarded, since it generates lower amplitudes. Would that be the correct decision?

Another condition that affects EMG amplitude is muscle fatigue. One would think that as muscles fatigue, the EMG signals that drive them would diminish as well. But this is exactly the opposite of what really occurs. According to Maton (1981), muscle fatigue was correlated with a significantly higher level of EMG activity. This stands to reason, for as muscles lose their ability to generate force, the CNS must drive them harder in order to sustain tension.

The practical implications of fatigue are fairly obvious. If a group of exercises is being compared to determine which is best for developing specific muscle groups, then the outcome could be influenced by the sequence in which they're tested. Those which come later in the sequence may exhibit higher EMG values, not because they are superior exercises, but because the muscles have reached a more extensive level of fatigue. Would that result provide an accurate determination of the most effective exercise?

Under the domain of practical influences, one of the most consistently reported findings is that EMG amplitude in agonist muscles increases linearly with the speed of movement (Bigland and Lippold, 1954; Freund and Budingen, 1978; Hagood et al, 1990; Solomonow et al, 1990). The explanation for this phenomenon is simple; as movement velocity increases, the need to recruit fast-twitch motor units also increases. Since fast-twitch muscle fibers exhibit higher EMG amplitudes, the overall level of muscle activation is subsequently increased. Studies using EMG to compare different exercises, therefore, should keep velocity constant, in order to ensure that the differences between exercises are not due to velocity itself.

Peckinpaugh and Guzell (2009) did this in their comparison of the effects of postural stability during a chest press exercise, on the activation of abdominal musculature. In order to ensure that movement velocity (even of the limbs in this case) did not influence the activity of the abdominal muscles, the authors employed a metronome to regulate the movement speed of all test conditions. Consequently, one could confidently argue that the results were not influenced by movement speed.

The regulation of conditions should also be extended to the amount of joint torque created by various exercise configurations, unless, of course, one were studying how torque influences EMG. Torque may be viewed as the impulse which produces rotation of the joints, and is the product of the magnitude of the external force acting on a body segment, and the distance from that force to the joint axis.

EMG amplitude has been shown to vary directly with torque loading in the elbow flexors (Funk et al, 1987) and in the plantar flexors (Gottlieb and Agarwal, 1971), in instances where the authors elected to evaluate the effects of torque on the EMG response. Unfortunately, this simple biomechanical construct is sometimes overlooked, leading researchers to arrive at potentially erroneous conclusions.

Take, for instance, the study by Santana and colleagues (2007), which asked the question, what is the difference in abdominal muscle activation between a supine bench press (fully supported) and a free-standing cable press (unsupported)? According to the authors, the exercise which elicited the greater levels of abdominal muscle activity would be the preferable exercise, for its enhanced ability to activate the core. Their findings revealed increased EMG activity in the left internal oblique muscles during the free-standing cable press, leading them to conclude that the unsupported exercise was the superior choice.

What the authors failed to account for, however, was that the free-standing cable exercise was done with only the right arm, while the supine bench press was performed using both arms. Consequently, the free-standing version created a rotational torque around the spine to the right – which was not present in the bilateral bench press – inducing a higher level of left internal oblique activity. In support of this explanation, one need only look at the EMG values of the right internal oblique muscles, which would not have been affected by the rotational loading around the spine. Those, coincidentally, exhibited the same level of EMG amplitude in both the supported and free-standing conditions.

Arguably, the difference in left internal oblique activity was the result of a one-arm movement versus a two-arm movement, and not the support conditions. Incidentally, although Santana and group noted that the exercises under examination were performed in a slow and controlled manner, they did not take any steps to ensure that the speed of movement was the same for both free standing and bench press conditions, thereby

further obscuring their results. Had the authors compared a velocity-regulated bilateral free-standing cable press with the supine bench press, they may very well have come to the same conclusion as Peckinpaugh and Guzell (2009); that there is no difference in abdominal muscle EMG amplitude between a free-standing or fully supported chest press.

Lastly, but perhaps most importantly, one needs to consider the context within which muscles are contracting. It is often stated that muscles have two functions; they can either provide motion or stability. This view, in actuality, is not altogether accurate. Muscles have but a single function, to exert a pulling force on the bones to which they attach. It is the responsibility of the central nervous system to determine whether those forces lead to movement or stability.

According to Hogan et al (1987) opposing muscles always create tension, regardless of whether the objective is motion or fixation. The purpose of this “co-contraction” is to control the forces acting around a joint in order to maintain joint integrity. The ratio of agonist to antagonist activity determines whether the outcome is movement or stabilization. In other words, if the activation level of the agonist is high, relative to the antagonist, then the result will be joint motion. As the differential between the muscles increases, the movement becomes faster.

On the other hand, if the ratio of activation between antagonistic muscle pairs is low, meaning that muscles on opposite sides of the joint are contracting at the same relative intensity, then the completely balanced force resulting from this level of co-contraction produces an immobile joint, or stability. This is, in fact, the manner by which joints are stabilized, and in many cases, produces high EMG levels in the muscles that are under control.

Herein lies the problem. Taken at face value, an exercise which produces higher levels of abdominal EMG activity may be labeled as the more effective exercise for the core. But if the EMG activity is associated with joint stabilization, then that exercise might not be as effective in enhancing spine motion.

As a case in point, Cowley and others (2009) required subjects to train with static abdominal exercises that elicited very high levels of muscle activation. When tested on a dynamic assessment of abdominal power, requiring significant trunk acceleration, the subjects performed poorly. Apparently, elevated levels of EMG, brought about by high co-contraction of muscles around the spine, did not contribute to improved function when evaluated in a dynamic motion context.

High levels of muscle activity, parenthetically, don't always guarantee improved movement performance, even when that activity is being measured during moving conditions. In one study, for example, subjects were

given two elbow flexion tasks, in which they had to move a normalized weight, over a fixed range of motion, to a target, as fast as possible (Juris, 1993).

The difference between the two conditions was in the pattern of resistance against which they were moving. In one, the resistance peaked earlier, allowing the agonist (biceps) to develop enough tension to accelerate the joint, and then relax in order to permit the antagonist (triceps) to efficiently decelerate the limb and stop at the target. In the other, peak resistance occurred much later, so that the biceps was required to contract maximally at virtually the same time that the triceps was attempting to decelerate the joint. The result was a high degree of co-contraction, which further increased biceps EMG activity, in order to produce the required motion.

Interestingly, the second condition produced the higher EMG levels in both the biceps and triceps. By that outcome, one might argue in favor of that condition, if EMG amplitude were taken at face value. But the first condition resulted in a significantly faster movement to target, even with lower EMG values, and thus, allowed for better performance under the requirements of the task. This may seem to contradict the studies correlating EMG amplitude to velocity, but the results stem from the fact that there was less co-contraction, meaning that there was less antagonist activity resisting the movement, and therefore, the agonist could effectively accelerate the limb.

Evidently, EMG amplitude does not always correlate with better performance. Furthermore, without controlling for range of motion, muscle length, contraction type, torque, fatigue, velocity, and movement context, EMG actually tells us very little at all.

The truth is that electromyography, or any technology for that matter, can be very useful, provided that one has a proper grounding in the fundamental science which underlies that application. The irony here is that the author of the post, which was cited at the outset of this article, argues that EMG ought to be left in the hands of casual practitioners, and not scientists.

Is this position limited just to those who wish to prove a point with EMG, or is it really indicative of a more pervasive attitude in which people are satisfied with a perfunctory understanding of scientific concepts, and never truly achieve a depth of knowledge in the areas in which they profess their own expertise?

The reason that scientists employ these technologies is to help provide answers to honest and legitimate questions that lead to understanding and enlightenment. Perhaps, if fitness and sports practitioners started asking more questions, rather than simply turning to technology to support their opinions, then we would all truly benefit from their efforts.

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