Post Activation Potentiation and Its Role in Complex Training

Megan Smith

University of Minnesota
Athletes are always looking for new ways to get bigger and stronger in an effort to be the best. In these efforts, many have turned to science to discover the best way to train. One of these scientific based training methods that has been recently gaining popularity is one known as complex or contrast training which, simplified, is alternating lifting heavy and light loads with the goal of improving power output. Russian sport scientist, Yuri Verhoshansky, is credited for the earliest work in this field dating back to 1973, although it is believed the Soviets may have been using this training method long before this. Several scientific studies have found this complex training method to be more beneficial for gains in strength in power compared to other more traditional training methods such as Olympic lifts and plyometrics. The physiological concept believed to describe why complex training works is known as post-activation potentiation. The theory behind this phenomenon is that a muscle has a greater explosive capacity after undergoing maximal or near maximal contractions (McGregor).

Post-activation potentiation is essentially the fooling of the nervous system. Docherty, Robbins, & Hodgson (2004) credit enhanced motor neuron excitability as the workings behind post-activation potentiation. This enhanced neuronal effect results from: enhanced motor unit recruitment, better motor unit synchronization, increased central input to the motor neuron, and less presynaptic inhibition.

Phosphorlation of the myosin light chain is another explanation for the occurrence of post-activation potentiation. The quantity of Ca2+ flowing into the sarcoplasmic reticulum is increased by heavy exercising. The Ca2+ activates the myosin light chain kinase which produces ATP to be used by the actin-myosin complex. This causes cross bridging between actin and myosin to occur at a faster rate. This phosphorlation makes myofilaments more sensitive to Ca2+. Power production is enhanced because more ATP is able to be produced as the level of
Ca2+ increases at the cellular level (Docherty et al., 2004). This theory is also supported by McBride, Nimphius, and Erickson (2005) and Gourgoulis, Kasimatis, Mavromatis, and Garas (2003). They add that there might be more neurotransmitters released in afferent nerves as a result of complex training. Several other articles reviewed by these authors found increased potentiation to be produced by fast-twitch dominant muscles (McGregor).

Ebben and Watts (1998), as referenced by McGregor, listed neuromuscular, hormonal, metabolic, myogenic, and psychomotor effects as factors that may contribute to post-activation potentiation, but did not describe any of these in detail other than the neuromuscular effects. McGregor references a study by Fees (1997), previously cited by Ebben and Watts, explaining post-activation potentiation found that stimulation of an agonist muscle causes inhibition around a joint to be reciprocal. The Golgi-tendon organ and Renshaw cell limit the maximal activation of motor units. There activation is believed to be reduced in reaction to a heavy stimulus applied to muscles thus allowing more motor units to be recruited which leads to increased power output. Baker (2003), as cited by McGregor, suggests this to be another explanation for the occurrence of post-activation potentiation. It is unknown though whether or not these theories explain why complex training is beneficial for more experienced lifters, since the inhibition occurring in the events described by Fees and Baker is known to occur within the first month of training performed by those new to weight training (McGregor).

All of these studies seem to agree that the main events underlying post-activation potentiation occur at the neuronal level and have to do with reduced inhibition and the excitability of the muscles being increased. The idea that there are muscle factors that also contribute to post-activation potentiation is acknowledged by majority of these authors as well,
but less literature exists in this area (McGregor). More research needs to be done in order to fully understand the underlying factors behind post-activation potentiation.

Some may wonder how knowledge of post-activation potentiation can be applied to the real world. As mentioned previously, post-activation potentiation is believed to be the underlying physiological cause of complex or contrast training which has been found in many studies to produce greater strength gains in power compared to other forms of training. With this being a relatively new topic, there is still a lot of debate over the exact definition of complex training with several people using the terms complex and contrast training interchangeably and others differentiating between the two. McGregor quotes Ebben and Watts’ (1998) expanded version of Verhoshansky’s definition of complex training as alternating “biomechanically comparable high-load weight training and plyometric exercises in the same workout.” Duthie, Young, & Aitken (2002) define complex training as “various sets of groups/complexes of exercises performed in a manner in which several sets of a heavy resistance exercise are followed by sets of a lighter resistance exercise.” They went on to differentiate between complex training and contrast loading which they defined as “the use of exercises of contrasting loads, that is, alternating heavy and light exercises set for set.” Docherty et al. (2004) went on to expand upon these previous definitions a bit by mentioning that the “biomechanically similar plyometric exercise” should be performed “relatively quickly” after the heavy resistance exercise. Docherty et al.’s definition of complex training is describing contrast training according to Duthie et al... Dodd and Alvar (2007) defined complex training as “performing a heavy resistance exercise immediately prior to a high-velocity/plyometric movement with a lighter resistance within each set.” This definition is also describing contrast training according to Duthie et al... Ebben (2002) also describes complex training in a similar way which would
also fall under Duthie et al.’s definition of contrast training. Smilios, Pilianidis, Sotiropolous, Antonakis, and Tokmakidis (2005) give contrast training a similar definition as Duthie et al. This paper will define complex training similar to Ebben, Dodd and Alvar, or the same ways as others describe contrast training.

Many studies have been done focusing on the acute effects of complex training and have found it to be an effective way to train. Studying the acute effects of complex training has less practical application to the real world outside of its use as a warm-up activity since it may not be practical for athletes to go perform a complex training circuit immediately before a competition in order to improve vertical jump performance during the competition. It is unknown whether strength gains found in acute studies are long lasting. Duthie et al. (2002) found that contrast training, when compared to traditional and complex training, showed the greatest improvements in squat jumps performed within a training session only in athletes with a high level of strength to begin with. This study defined contrast training the way complex training is defined here. This study was performed by eleven female, international level hockey and softball players. External validity of this study was limited by the small sample size using all elite females in only two sports, leaving it unknown how other populations would perform. A study on twenty physically active men by Gourgoulis et al. (2003) found similar results with the subjects with greater maximum strength improving more at vertical jump immediately after performing half-squats than those with lower strength to begin with. This study was also limited by its male only population and its somewhat small sample size. The physical activity level or these males may have varied creating variability between subjects. Another study on complex training by Smilios et al. (2005) found a short term increase in counter jump movement performance from complex training. The counter movement jump test was performed before, during, and after the exercises.
Ten men who had participated in regional level sports teams were the subjects of this study. The all male group is a limitation to the external validity of this study as well as the fact that countermovement jump is not necessarily the most sports specific movement for team sports, so it is unknown if increasing this jump height will actually improve sports performance in team sports. Vertical jump is known to be an accurate measure of power though, so it is assumed that increased jump height indicates increased power that will lead to increased performance.

A few previous studies have examined the chronic effects of complex training on power and most have found that it produces superior results to plyometrics and traditional strength training programs in highly trained athletes. Studying the chronic effects of complex training is important to understand whether or not it can be used as an effective method of training to improve strength over time as opposed to being used as a warm-up activity. Using it as a training method, as opposed to a warm-up activity, seems to be a more practical way to apply this to the real world. A study by R. Rahimi, Arshadi, Behpur, Boroujerdi, and M. Rahimi (2006) comparing the effects of traditional, plyometric, and complex training programs completed over six weeks by forty-eight male college students found that the complex training group showed the greatest improvements in angular velocity in a cycling test from the baseline test before the training. Another study by Rahimi and Behper (2005) examining a similar group of participants and the same exercise protocols found that complex training led to greater improvement in vertical jump, 50-yard dash times, and max leg strength over a six week time period. The external validity of these studies was limited by the fact that the subjects were all college aged males, so it is not known if the same effects would be observed in different populations.
Not all studies have found complex training to be better than other methods. Dodd and Alvar (2007) performed a study where they had forty-five male Division II junior college baseball players each participate in three four week training protocols of traditional weight training, plyometrics, and complex training. All groups showed greater improvements in twenty, forty, and sixty yard sprints as well as standing long jump tests after undergoing the complex training protocol. However, they found that the plyometrics training program produced the greatest improvements in vertical jump height. Similar to others, the external validity of this study is limited by the all male Division II baseball player population used. Ebben (2002) references Faigenbaum et al. (1999) and Zepeda and Gonzalez (2000) as finding complex training in children and women to be equally effective as other training methods, but not superior, alluding once again to the idea that a high level or prerequisite maximum strength typically not found in women and children must be present in order for complex training to be superior to other methods.

Most of this research has found the application of post-activation potentiation theory to complex training to lead to increased gains in power compared to more traditional forms of training at both the acute and chronic levels. More research should be done in order to better understand the underlying factors that explain how post-activation potentiation works. Once a better understanding of post-activation potentiation is obtained, this knowledge can lead to a better understanding of why and how complex training works. This better understanding can be used to more effectively design and implement complex training programs and can help discover the most effective way to train for various athletic endeavors. More research also should be done studying the chronic effects of complex training, since that application of complex training can more easily be carried out in the real world.
References


