The Application of Postactivation Potentiation to Elite Sport

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Recently there has been considerable interest and research into the functional significance of postactivation potentiation (PAP) on sport performance. The interest has evolved around the potential for enhancing acute performance or the long-term training effect, typically in the form of complex training. Complex training usually involves performing a weight-training exercise with high loads before executing a plyometric exercise with similar biomechanical demands. Despite a considerable amount of research in the past 10 years it would seem there is still much research to be done to fully determine whether PAP has a functional role and, if so, how to best exploit it. It is clear from the research that there are many factors that need to be considered when attempting to apply PAP to an athlete. It is possible that a well-conceived sport-specific warm-up might be as or more effective in enhancing acute performance and easier to apply in a practical setting. In addition, despite its current popularity, there has not been 1 study that has effectively examined the efficacy of complex training and whether it has any advantage over other forms of training that combine weight training and plyometrics but not in the same training session.

Key Words: weight training, plyometrics, complex training, explosive power

The contractile history of muscle has a profound effect on the ability of a muscle to generate force. One of the most apparent effects is a loss in the expected force-generating capabilities caused by fatigue from either high- or low-intensity muscle contractions. The contractile history can also result, however, in an enhanced contractile response, especially after high-intensity contractions, primarily because of elevated regulatory myosin light-chain phosphorylation, referred to as postactivation potentiation (PAP). In fact, fatigue and potentiation are considered to coexist, and the force a muscle is able to generate after prior contractile activity is the result of the net balance of fatigue and potentiation. The phenomenon of PAP has been clearly demonstrated using electrically induced twitch contractions. Although PAP seems to have little effect on peak force at high intensities, it has been found to increase the rate of force development, which has led some authors to predict that it might be advantageous in voluntary force production, especially in activities that require dynamic muscle contractions.
Background Information

A number of studies have examined the effect of PAP on acute athletic performance, as well as implying that PAP could be incorporated into training programs, referred to as complex training, to induce superior chronic neuromuscular adaptations. Complex training usually involves the execution of a high-intensity resistance exercise before doing some form of plyometric activity that involves the same muscle group. Previous reviews that examined the application of PAP in order to enhance acute voluntary explosive contractions concluded that the results were equivocal. In addition, no training study had been conducted that specifically examined the efficacy of applying PAP principles to training programs or determined that it was superior to other training methods. In addition to the equivocal findings it was also clear that there are many factors that can influence the efficacy of any enhanced-performance effect and need to be considered when applying the principles of PAP, such as the time between the preload activity and the performance measure, the fiber type of the individual, the load or intensity of the preload activity, the mode of the preload activity, and performance measures, as well as the training status of the individual.

PAP and Acute Performance

Since these reviews were done there have been a number of additional studies examining the efficacy of PAP to functional performance, but the situation would still seem to be equally equivocal and some other factors might have been introduced that need to be considered by anyone wishing to use PAP principles to enhance either acute performance or training. In addition, there is only 1 published study that actually examined the efficacy of using PAP in some form of training approach, such as complex training, but it lacked any comparison with other training methods and was limited to untrained, early-pubertal boys.

The important determining factors that affect the potential efficacy of PAP to either acute performance or training programs continue to present a challenge to practitioners. Individual variability is still one of the most important factors that need to be considered. The issue of the optimal time between the preload activity and the explosive movement, either for performance or training, has received additional attention but is still problematic, especially in regard to the ease of application. It is clear that there is probably an optimal time when the muscle has recovered from the fatigue induced during the preload activity but is still potentiated. It appears, however, that if there is an optimal time it is very individualized. If the performance or training activity is not done at the optimal time for the individual it could even result in a decrease in performance or training effect. It is, therefore, important to identify the optimal time for each individual when trying to capitalize on any potential effect of PAP on performance or training.

PAP has been attributed to elevated regulatory myosin light-chain phosphorylation induced by an increased sensitivity to calcium. It would appear, however, that not all individuals respond by an increase in regulatory myosin light-chain phosphorylation. Furthermore, regardless of whether individuals were considered positive or negative responders, there was no increase in any of the performance measures.
related to power, force, or velocity. Earlier studies suggested that individuals also needed to have a certain level of strength or training to be able to capitalize on the potential benefits of PAP. A more recent study, however, found that although overall a group of experienced weight lifters did not show any increase in vertical-jump height after high-intensity squat exercises, 5 of the 10 did show an improvement, but it was unrelated to their relative strength. Fiber composition has also been suggested as a determining factor in the use of PAP to enhance performance and might also be a factor in how quickly an individual returns to initial levels in the rate of force development. Individuals with predominantly myosin heavy-chain IIa fibers appeared to induce PAP, resulting in better restoration of neuromuscular performance. Although all individuals showed an initial impairment in performance, those with predominantly myosin heavy-chain IIa fibers were able to return to their initial levels of force production. Enhanced neuromuscular performance, however, was not demonstrated by either group.

One issue that has not been previously addressed, but could certainly be a factor in assessing the impact of PAP protocols on performance, is the fact that the preload activity might have a warm-up rather than a potentiating effect as assumed. Most applied studies have not actually measured whether the muscles of interest have been potentiated using either measures of twitch potentiation or increases in neural excitability as reflected by the H reflex. Consequently, any change in performance might be the result of an increase in muscle temperature or some other mechanism associated with a warm-up. Recently a study attempted to compare the effects of different types of warm-ups on subsequent strength and power performance. The researchers used 6 warm-up protocols including variations of high-intensity (80–95% 1-RM parallel squat) and low-intensity loading (30% 1-RM parallel squat), as well as a volleyball-specific warm-up, on various measures of acute vertical-jump performance. They also examined the effects of the different protocols 6 hours later in the day after a more general, control warm-up. They found that the high-intensity warm-ups (those using 80–95% 1-RM) and the volleyball-specific warm-up produced similar improvements in explosive jump performance. It should be noted, however, that this study determined the squat loads for each individual that produced the highest power-output values for the preload activity, as well as the optimal drop-jump height and optimally loaded countermovement jump for the measurement outcomes. Such elaboration certainly enhances the internal validity of the study but makes it very difficult for practitioners to apply the results to their athletes. In addition, the volleyball-specific protocol concluded with slow stretching, which might have blunted the actual improvement found in the study for this protocol.

Even if PAP can provide some modest acute improvement in activities requiring explosive movements, it is difficult to see how it could be applied in an actual competitive situation. The window of opportunity is relatively brief (4–11 minutes) and dissipates over time. In most competitive situations it is probably not feasible to provide the time or equipment to perform maximal or near-maximal efforts to elicit PAP. One study suggested that it might be optimal at 1 minute, but that study used the adductor pollicis muscle, which might have a different fatigue and recovery profile than larger muscle groups. It would seem a more practical approach to use a sport-specific warm-up, including some dynamic flexibility exercises, given its relative effectiveness and ease of implementation.
PAP and Complex Training

PAP is usually applied to training through the use of complex-training strategies that are considered superior to other training methods for improving athletic performance involving explosive movement patterns. Unfortunately, despite its popularity among coaches and athletes, there has only been 1 published training study that has examined the efficacy of complex training, and this involved early-pubertal boys and only 1 training condition. The results showed that there were modest improvements in measures of power and large improvements in strength. It is not possible, however, to determine whether the findings were the result of the strength or plyometric part of the complex program or the combination, because these training approaches were not included as separate conditions. In addition, the format of the complex-training protocol was not described, so it is difficult to assess whether the study actually used common complex-training pairs and the order in which they were performed.

Several acute studies have failed to find any change in performance, either an increase or an impairment, and concluded that the application of PAP to training might be an efficient way to train for both strength and power. It is possible, however, that the athlete is not deriving the optimal training effects for either strength or explosive movement, and, therefore, the approach is not really very efficient. In addition, most of the acute studies that have attempted to apply their findings as a rationale for the efficacy of complex training have used only 1 set or sequence of the paired exercises. Normally, training programs involve multiple sets that might induce greater fatigue, which would affect the plyometric performance and perhaps limit any potential training effect. Only 1 recent acute study examined the effects of PAP over multiple sets (N = 3), and it found no enhanced plyometric performance for any of the sets and a tendency for an actual decrease in performance over the subsequent sets.

Conclusion

Given the equivocal findings in the current literature it would appear difficult to conclude that PAP can in fact enhance explosive performance or training, especially for all individuals. The situation is compounded by the many determining factors that affect the occurrence of PAP and the ability of individuals to use it for functional performance. There are a number of studies, however, that have found that combined strength and plyometric training, but not in the same training session, results in greater improvements in muscle power than using either approach by itself. More recently it was found that 2 sessions per week of weight training and plyometrics helped increase the club-head velocity and drive distance of 8 male golfers, although no other training protocols were used for comparison in that study. Not training strength and power in the same session alleviates many of the problems associated with complex training, especially finding the optimal time for recovery for each individual between the heavy-resistance and plyometric exercises, their optimal preload intensity, and whether they are positive responders.

Recently, meta-analysis was used to determine the effects of plyometric training on various measures of vertical-jump height. In addition to providing evidence
that plyometric training does in fact improve vertical-jump-height performance and possibly other athletic-performance measures of power, the study also offered a possible approach to assessing the efficacy of PAP in improving acute performance of explosive activities, with implications for assessing the efficacy of complex training. The approach is able to overcome the problem of small sample sizes and low statistical power of many studies, as well as account for some of the factors that might be responsible for the variability in the findings of the different studies. The author also used a PEDRO scale to assess the methodological quality of the studies, controlled for possible publication bias, and determined the overall effect size. It would seem to be an appropriate time to conduct a similar meta-analysis examining the effect of PAP on functional performance. There is also a need to conduct training studies to assess the validity of complex training, especially in comparison with other training techniques that have been proven to be effective in increasing muscle power.

References


