APPLICATION OF COMPLEX TRAINING WITHIN STRENGTH AND CONDITIONING PROGRAMMES

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Alternating a resistance exercise with a plyometric exercise is referred to as "complex training". Post-activation potentiation is the physiological rationale for complex training. This form of training is widely used to improve strength, power and stretch-shortening cycle (SSC) function. Enough is not known, however, on how this form of training can be optimised. Many factors such as the rest interval and the magnitude of the resistance exercise can have an influence on the efficiency of this training modality. More research is needed so that strength and conditioning coaches can best apply the principles of complex training to athletes' strength and power programmes.

KEYWORDS: jumping, stretch-shortening cycle, post-activation potentiation

INTRODUCTION & OVERVIEW: Complex training involves the completion of a resistance exercise prior to a plyometric exercise. A classic example is to perform vertical jumps or depth jumps after the completion of a back squat exercise. The term 'complex training' is credited to Verkhoshansky et al. (1973). It is postulated that the resistance exercise will have a performance enhancing effect on the plyometric activity (Ebben and Watts, 1998), resulting in increased power output, increased performance outcome and enhanced efficiency of the SSC behaviour.

Complex training is widely used in the practical setting and is a popular training modality. A number of reviews have been written on complex training (Docherty et al., 2004; Ebben, 2002; Ebben & Watts, 1998; Jeffreys, 2008). The conclusions regarding the effectiveness of complex training as an appropriate training modality are somewhat guarded and equivocal. Research has found the complex training can be beneficial to athletic performance (Comyns et al., 2007; Evans et al., 2000; Güllich and Schmidtbleicher, 1996; Young et al., 1998), while the opposite has also been reported (Jones & Less, 2003; Scott & Docherty, 2004). A possible explanation for this contradiction in findings is that many variables have an influence on the research outcomes and thus the efficiency of complex training, such as the magnitude and mode of the preload exercise as well as the rest interval between the preload and the plyometric components of complex training. In addition, the gender, training status, training age, strength levels of the participant may influence the potentiation benefits of complex training (Docherty et al., 2004; Robbins 2005).

Postactivation potentiation (PAP) is the physiological rationale for complex training (Docherty *et al.*, 2004). PAP results in an enhancement in the explosive capability of the muscle due to prior contractile activity (Docherty *et al.*, 2004; Robbins, 2005). Examples of contractile activity that have been used in PAP research include maximum voluntary contractions, (Güllich and Schmidtbleicher, 1996) and the execution of resistance exercises (Young et al., 1998; Evans et al., 2000). Two mechanisms have been put forward to explain the workings of PAP. Firstly the enhancement in plyometric performance after performing the contractile activity may be due to an increase in neural excitability (Güllich and Schmidtbleicher, 1996). Alternatively the phosphorylation of the myosin light chain has been proposed as a mechanism attributed to the PAP (Sale, 2002). Docherty et al. (2004) noted, however, that it is possible that PAP is the result of interactions between both the neural and muscular mechanisms.

The fitness-fatigue paradigm (Plisk & Stone 2003) provides a framework for explaining the potentiation effect associated with some complex training studies. Fitness is the term used to explain the positive response and adaptations that occur as a result of exposure to a training stimulus. Fatigue is a general term describing a loss of capability to generate force or an inability to sustain further exercise at the required level (Strojnik & Komi, 1998). Exposure to a training stimulus will result in both a fitness and fatigue response (Plisk & Stone, 2003). The fitness response is the desired response from the training stimulus, while the fatigue is the side effect. While the fitness and fatigue responses have similar traits in that they stem from the same source, co-exist (Rassier & MacIntosh, 2000), rise sharply after the training stimulus and dissipate thereafter, they exert opposite effects on the potential for potentiation and performance preparedness. The fitness-fatigue model, which is illustrated in figure 1, details the interplay between fitness and fatigue. This model can be used to explain the PAP effect related to complex training.

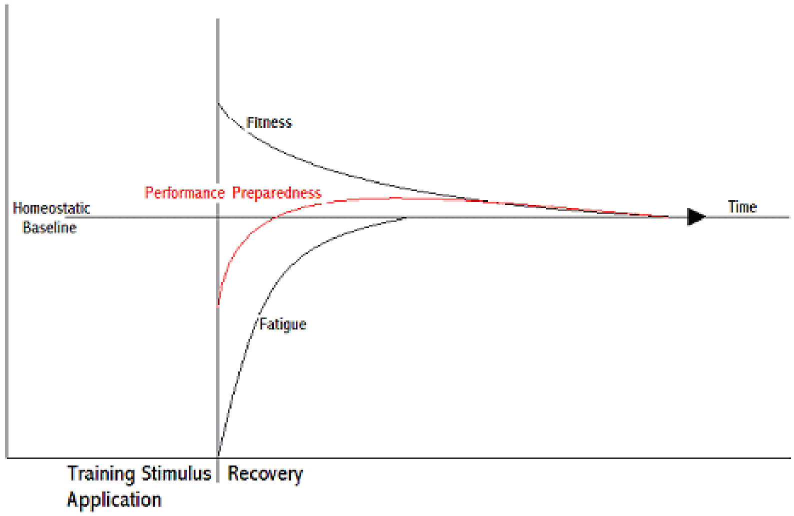

Figure 1. Fitness-fatigue model adapted from Plisk & Stone (2003:21)

An athlete's preparedness for performance and potentiation is defined as the summation of the two after-effects of training, i.e. fatigue and fitness. Preparedness, according to Plisk & Stone (2003), can be optimised with strategies that maximise the fitness response to training stimuli while minimising fatigue. Complex training is possibly one of these strategies that can result in realising this performance preparedness. Examples of research into how both the fitness and fatigue responses interplay as a result of complex training are outlined in this paper. Further research is needed, however, on the optimisation of potentiation and performance preparedness as a result of exposure to complex training protocols.

COMPLEX TRAINING REST INTERVAL: The rest interval between the resistance and plyometric components of complex training has been referred to as the intra-complex rest interval. In complex training research this rest interval has ranged from 10 seconds (Jensen & Ebben, 2003) up to 20 minutes (Jones & Lees, 2003). Research has indicated that 3 to 4 minutes may be optimum (Evans et al 2000; Güllich and Schmidtbleicher, 1996; Young et al., 1998). Jensen & Ebben (2003) investigated the effect of 5 repetition maximum (5RM) squat on countermovement jumps (CMJ) that were performed 10 seconds, and 1, 2, 3 and 4 minutes after the squat. Results revealed no significant difference in jump height from pre-squat to post-squat for any of the rest intervals. The jump performance, however, at the 10 seconds interval was reduced but not significantly. A nonstatistically significant trend of improvement in jump height occurred from 10 seconds up to 4 minutes. Jones and Lees (2003) adopted a similar approach to Jensen & Ebben (2003) by manipulating the length of the rest interval. They investigated the effect of 5RM back squatting on CMJs and drop jumps (DJs) that were performed immediately, 3, 10 and 20 minutes post-lifting. While no statistical significance was found, suggesting that complex training did not enhance plyometric performance, it was also noted that no adverse effects occurred. One possible reason for the above findings could be that the potentiation window may differ for individuals, as suggested by Docherty et al. (2004), and thus mask any ergogenic response at the different intervals. Comyns et al. (2006) addressed this issue in their optimum intracomplex rest interval study by analyzing the greatest improvement and reduction in the dependent variables' scores compared to the baseline scores regardless of when they occurred to assess if complex training had an ergogenic effect.

Comyns et al. (2006) investigated the effect of 5RM back squatting on CMJs that were performed at rest intervals of 30 seconds, and 2, 4 and 6 minutes post-lifting. Flight time and peak ground reaction force (GRF) were the dependent variables. Repeated measures ANOVA found a significant reduction in flight time at the 30 second and 6 minute interval ($p < 0.05$). No significant difference was found between men and women. Only the men showed an enhancement in jump performance after the 4 minute interval. The improvement window was different for each subject and an analysis of the greatest increase and decrease in flight time and peak ground reaction force was conducted, showing a significant decrease for men and women and a significant increase in flight time for men and peak ground reaction force for women. The results suggest that complex training can benefit and/ or inhibit countermovement jump performance depending on the rest interval. The individual determination of the intracomplex rest interval may be necessary in the practical setting.

Clearly the efficiency of complex training relies heavily on the rest interval. The current findings on the optimal complex training rest interval are ambiguous. Jeffreys (2008) highlighted this finding and noted that it is likely that optimal PAP will only be evident at a given window of opportunity and outside this performance may be impaired, have no impact on performance or show limited benefit. The results from Comyns et al. (2006) support this viewpoint. In addition, the optimal timeframe for this window of potentiation opportunity is individual so the identification of an optimal intracomplex rest interval for group situations is not appropriate.

COMPLEX TRAINING OPTIMAL LOAD: When squats are used as the preload component of complex training a key variable in determining the efficiency of the complex training protocol is the magnitude of the load. Ambiguity exists in complex training research about the optimal load that needs to be lifted in the resistance exercise to maximise the benefits of PAP. Jeffreys (2008) suggests that as PAP is associated with Type II muscle fibres, then the preload component has to stimulate an appropriate number of Type II fibres, whether through high resistance or high velocity. Consequently, a 5RM squatting protocol has been used in the majority of complex training studies. The results using this approach have been mixed. Some researchers have found that this resistive load had a significant effect on the performance of the plyometric exercise (Young et al., 1998; Evans et al., 2000). Others found the 5RM did not produce statistically significant results for the dependent variables associated with the plyometric exercise (Jensen & Ebben, 2003; Scott & Docherty, 2004).

Research into loads outside of this 5RM range is sparse. Baker (2003) investigated the effect of lifting six repetitions at 65% of 1RM for the bench press on an explosive bench press-style throw (plyometric exercise) and showed a significant increase of 4.5% in power output from pre- to post-test for the experimental group. This finding is important as it suggested that a relatively light load of 65% could produce an enhancement in performance in a subsequent plyometric exercise. However, Hanson et al. (2007) investigating the effects of squats at 40% 1RM and 80% 1RM on repeated CMJ performance, found no change suggesting that these loads were too light to provided a PAP effect.

Comyns et al. (2007) addressed the optimal load issue by examining the effect of a 65% 1RM, 80% 1RM and 93% 1RM back squat on the DJ performance. Flight time, ground contact time, peak ground reaction force, reactive strength index and leg stiffness were the dependent variables. Repeated measures ANOVA found that all resistive loads significantly reduced ($p < 0.01$) flight time, but lifting at the 93% load caused a significant improvement ($p < 0.05$) in ground contact time and leg stiffness. From a training perspective, the results indicate that the heavy lifting will encourage the DJs to be performed with a stiffer leg spring action, which in turn may benefit performance. Although the findings from complex training optimal load studies are somewhat contradictory, it would appear that PAP is greatest when heavy loads are utilised.

CONCLUSION: Many factors contribute to the effectiveness of complex training as a practical training modality. While PAP is a very real physiological phenomenon, attaining it through complex training protocols is very much dependent on the rest interval, magnitude and mode of the preload activity, and the training status, training age, gender and strength levels of the participant. While heavy loads appear to elicit a PAP effect compared to lighter loads the optimal rest interval would seem to be individual. The optimal rest interval depends on the interaction between potentiation and fatigue and the latter is related to the magnitude and mode of the preload activity as well as the individual's tolerance to fatigue, which may change over time. All of this needs to be taken into consideration when designing strength, power and plyometric programmes. Further research is still needed, especially on long term benefits of complex training programmes, to provide greater insight into the value of applying PAP training modalities to athletes' training programmes.

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