International Journal of Sports Physiology and Performance, 2013, 8, 677-681

INTERNATIONAL JOURNAL OF
SPORTS PHYSIOLOGY
AND PERFORMANCE
www.IJSPP-Journal.com
INVITED COMMENTARY

Preconditioning Strategies to Enhance Physical Performance on the Day of Competition

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Sports scientists and strength and conditioning professionals spend the majority of the competition season trying to ensure that their athletes' training and recovery strategies are appropriate to ensure optimal performance on competition day. However, there is an additional window on the day of competition where performance can be acutely enhanced with a number of preconditioning strategies. These strategies include appropriately designed warm-up, passive heat maintenance, postactivation potentiation, remote ischemic preconditioning, and, more recently, prior exercise and hormonal priming. The aim of this review was to explore the potential practical use of these strategies and propose a theoretical timeline outlining how they may be incorporated into athlete's precompetition routine to enhance performance. For the purpose of this review the discussion is confined to strategies that may enhance performance of short-duration, high-intensity sports (eg, sprinting, jumping, throwing).

***Keywords**:* postactivation potentiation, remote ischemic prior exercise, hormonal priming

Sports scientists and strength and conditioning professionals spend the majority of the competition season trying to ensure that their athletes' training and recovery strategies are appropriate to ensure optimal performance on competition day. However, there is an additional window on the day of competition where performance can be acutely enhanced with a number of preconditioning strategies. These strategies include appropriately designed warm-up, passive heat maintenance, postactivation potentiation (PAP), remote ischemic preconditioning, and, more recently, prior exercise and hormonal priming. The aim of this review is to explore the potential practical use of these strategies and propose a theoretical timeline outlining how they may be incorporated into athlete's precompetition routine to enhance performance. For the purpose of this review we are going to confine the discussion to strategies that may enhance performance of short-duration, high-intensity sports (eg, sprinting, jumping, throwing).

Warm-Up

Warm-up routines are a widely accepted practice before nearly every athletic competition that typically include bouts of exercise varying in intensity, dynamic stretching, and technical practice for the proceeding activity. A meta-analysis investigating the effects of warm-up practices on physical performance established that 79% of the studies reported improvements in performance after various warm-up protocols,[1] which are generally attributed to temperature-related mechanisms, although there are also a number of and non-temperature-related mechanisms.[2,3] Previous research has highlighted the importance of muscle temperature for performance by demonstrating a strong association between power output and muscle temperature (Tm), with an approximate 4% increase in power output per 1°C increase in Tm.[4] An active warm-up consisting of moderate-intensity exercise (80–100% of lactate threshold) produces rapid increases in Tm within 3 to 5 minutes, which reaches a relative equilibrium after approximately 10 to 20 minutes of exercise, with increases in Tm of approximately 3° to 4°C required for optimal warm-up effect.[5,6] It is important for sports scientists to consider the duration, intensity, and the recovery period between the cessation of the warm-up and the start of competition to maximize the warm-up's effectiveness. A recent study examining elite bob-skeleton athletes demonstrated that increasing typical warm-up intensity (~30% increase in load) and reducing the post-warm-up recovery time from 35 to 15 minutes resulted in substantially improved power output and 20-m sled-sprinting performance.[7]

Passive Heat Maintenance

In the competition environment, there is often a period of time between the end of the warm-up and start of competition when a physical warm-up can no longer be performed (eg, a prerace call room). During these periods

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of inactivity it has been demonstrated that Tm and core temperature (Tcore) show substantial decreases.[5,8] For example, a study by West et al[8] compared post-warm-up recovery periods of 45 and 20 minutes on 200-m freestyle performance in international-standard swimmers and found that Tcore had returned to baseline after 45 minutes but still remained elevated after 20 minutes. The 20-minute recovery period was also associated with an ~1.5% improved 200-m freestyle performance. Worthy of note, West and colleagues also demonstrated that of the rise in Tcore gained through the warm-up, 40% was lost by 20 minutes post-warm-up. These data demonstrate the importance of attenuating the decline in body temperature after the cessation of the warm-up.

One such method to offset the post-warm-up decline in body temperature is passive heat maintenance.[7,9] Passive heat maintenance involves the use of an external heat source such as heated clothing, outdoor survival jackets, and heating pads, which can be applied to the desired muscle groups to maintain post-warm-up muscle temperature and, thus, the temperature-mediated pathways that will aid performance.

For example, the aforementioned study of Cook et al[7] demonstrated a 65% greater tympanic temperature when an active warm-up was performed with an outdoor survival jacket; this was also associated with an improvement in 20-m sled-sprinting performance, compared with a control condition, in elite bob-skeleton athletes.

A recent study by Kilduff et al[9] demonstrated that repeated-sprint performance and lower-body peak power output were greater when applying a blizzard survival garment during a 15-minute post-warm-up recovery period than in a control condition in professional rugby league players. In addition, Kilduff and colleagues showed that the decline in Tcore after the warm-up is related to the decline in lower-body peak power output ($r = .71$).

It is evident that maintaining body temperature during the post-warm-up recovery period is vital to prevent decrements in subsequent performance. For athletes who are unable to perform further active warm-up closer to the start of competition, passive heat maintenance offers an effective method for preserving body temperature, and helping combat the decrements in performance that may occur through the loss of Tm.

PAP

A large body of research has demonstrated that muscle performance can be acutely enhanced after a preloading stimulus, due to the induction of PAP. After a preload stimulus, mechanisms of muscle potentiation and fatigue coexist, and any resulting performance benefits depend on the balance between these 2 factors. The mechanisms by which PAP induces improvements in physical performance are suggested to be through an increase in the sensitivity of the actin-myosin myofilaments to Ca^{2+}, enhanced motor-neuron recruitment, and an increase in central input to the motor neurons.[10] A number of factors may influence an athlete's ability to harness PAP, and these include initial strength level, timing between the preload stimulus and subsequent muscle performance, and intensity and volume of the preload stimulus.

PAP has traditionally been induced through the use of heavy resistance exercise of intensities of approximately 75% to 95% 1RM in elite-level athletes with optimal recovery periods of 8 to 12 minutes.[11] However, other methods to induce PAP include maximal isometric contractions[12] and the use of ballistic movements.[13]

The application of performing moderate- or heavy-intensity resistance exercise before competition is limited; however, if PAP can be induced through the use of more practical methods, the benefits to performance may be harnessed during competition. Ballistic activities such as weighted jumps are associated with the preferential recruitment of type II motor units[14] and therefore may be used as a PAP stimulus. Previous research has reported that depth jumps are able to increase strength[15] and high-velocity performance,[16] and some studies have investigated the use of ballistic activities as part of a warm-up protocol. For example, Faigenbaum et al[17] reported improvements in jumping performance 2 minutes after jumps with 2% body weight (via a weighted vest) included during a dynamic warm-up. In addition, Chen et al[18] reported improvements in countermovement-jump height after multiple sets of depth jumps, the effects of which dissipated after 6 minutes. Another study by West et al[13] reported improvements in upper-body power output after 3×3 ballistic bench throws at 30% 1RM and 3×3 bench press at 87% 1RM, with no differences between the improvements in power output at 8 minutes post-conditioning contraction. The interactions of these mechanisms and application of PAP to the competition environment is still unclear. However, if it is possible to harness PAP through the use of explosive plyometric exercise, this strategy may have application for the precompetition environment.

Remote Ischemic Preconditioning

Recent observations have revealed that muscle function can be acutely enhanced through the use of ischemic preconditioning (IPC). This involves the use of repeated bouts of ischemia induced in skeletal muscle through the use of a cuff or tourniquet, interspersed with periods of reperfusion. Suggested mechanisms are that IPC increases muscle blood flow through increases in intramuscular ATP-sensitive potassium channels and adenosine levels. Increased blood flow improves oxygen delivery and speeds the clearance of various metabolites, including the potential up-regulation of intracellular and extracellular movement. In addition, IPC may improve muscle force and contractility via increased efficiency of excitation-contraction coupling. Enhanced efficiency of muscle contraction augments mitochondrial capacity, subsequently improving the balance between metabolic accumulation and removal. A recent study by Bailey et al[19] reported significant reductions in blood lactate accumulation and a subsequent 34-second improvement in 5000-m-run performance in a group of healthy males. This protocol involved 4 × 5-minute bouts of bilateral occlusion at 220 mmHg before a standardized warm-up. Another study by Jean-St-Michel et al[20] reported a 0.7-second improvement in 100-m-swim time after 4 × 5-minute bouts of upper-limb IPC through the use of an occlusion cuff inflated to a pressure of 15 mmHg greater than measured systolic arterial pressure, which finished immediately before starting the warm-up (approximately 45 min to performance testing).

Morning Exercise

The influence of circadian rhythms on anaerobic performance has received considerable attention, with evidence of an early-morning nadir and a subsequent peak in the late afternoon. Of practical importance is the potential influence of early-morning physical activity on subsequent competition performed later in the day. Testosterone and cortisol have been implicated in mediating performance in elite athletes[21] and show circadian rhythmicity with an early morning peak followed by a transient decline through the day. Some exercise is known to raise testosterone, which may be useful in offsetting the circadian decline in testosterone on days when athletes are required to compete. Some research has investigated the effects of prior and morning exercise on performance later in the day.

For example, a recent study by Ingham et al[22] reported substantial improvements in 800-m time-trial performance when preceded by 200-m repetitions 3 hours before the time trial. Further research has demonstrated that morning resistance exercise can positively affect afternoon performances in elite-level athletes. For example, a study by Ekstrand et al[23] reported that a morning resistance-training session improved throwing performance in the afternoon; the authors suggested there is a 6-hour window that could potentially influence performance in an afternoon competition. Furthermore, a recent study by Cook et al[24] reported that morning strength training was associated with improvements in countermovement-jump peak power output, 400-m-sprint times, and 3RM bench and squat performance performed 6 hours later in rugby union players. Cook and colleagues also reported morning strength training to offset the circadian decline in testosterone; however, it is unclear whether these hormonal changes are causal in the improvements in performance shown or are simply a reflective marker.

Irrespective of the mechanisms responsible, early evidence suggests that a bout of morning exercise may provide a priming effect, which may improve performance later in the day.

Hormonal Priming

In addition to the benefits of elevated testosterone to physical performance (eg, positive correlation between baseline testosterone levels and ability to produce power), recent literature has identified a potential link between endogenous testosterone and aspects of athletic behavior related to motivation and confidence to compete.[21] These behaviors may in part be related to the effects of endogenous testosterone on the brain. For example, in sports such as judo, free testosterone concentrations have been positively associated with a number of offensive behaviors, as well as links to higher testosterone in winners in both physical and nonphysical tasks. Coaches often engage athletes in prematch talks with the aim to outline tactical practices (<2 h before competition), as well as motivate and instill confidence in athletes through the use of verbal persuasion (<1 h before competition), with these strategies reinforced through the warm-up and final 20 minutes before competition. To our knowledge, only 1 study has quantified the effects of different types of coach feedback and video clips on free testosterone and subsequent match performance. That study, by Cook et al,[21] suggested that the most effective strategy for promoting the highest pregame testosterone and best performance ratings involved watching successful skill execution by the athlete, reinforced with positive coach feedback. However, videos of successful skill execution by an opposing player, accompanied with cautionary coach feedback produced larger cortisol responses and worse performance ratings. In addition, Cook and Crewther[25] demonstrated that presenting highly trained males with aggressive or intense training videos acutely raised testosterone, which was associated with improved 3RM back-squat performance.

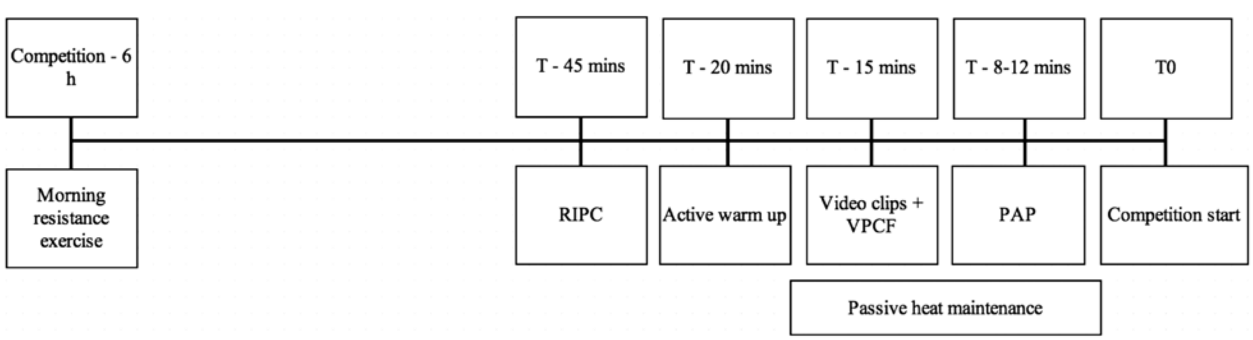

Figure 1 — Theoretical timeline for preconditioning strategies to improve performance on the day of competition. Abbreviations: RIPC, remote ischemic preconditioning; VPCF, verbal positive coach feedback; PAP, postactivation potentiation.

Conclusions

To date the majority of available research would suggest that a well-structured warm-up (with the addition of passive heat maintenance in the period between the end of warm-up and start of competition), PAP, ischemic preconditioning, morning exercise, and hormonal priming (through the use of videos) lead to performance benefits in sports that require short-duration explosive-type activity, and therefore sports scientists and strength and conditioning coaches should consider incorporating these strategies into their athletes' precompetitive preparation. Currently no research has examined trying to combine a number of these strategies on a preevent timeline (Figure 1) to further enhance muscle performance.

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