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Post-warmup strategies to maintain body temperature and physical performance in professional rugby union players

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Abstract

We compared the effects of using passive-heat maintenance, explosive activity or a combination of both strategies during the post-warmup recovery time on physical performance. After a standardised warmup, 16 professional rugby union players, in a randomised design, completed a counter-movement jump (peak power output) before resting for 20 min and wearing normal-training attire (CON), wearing a passive heat maintenance (PHM) jacket, wearing normal attire and performing 3 × 5 CMJ (with a 20% body mass load) after 12 min of recovery (neuromuscular function, NMF), or combining PHM and NMF (COMB). After 20 min, participants completed further counter-movement jump and a repeated sprint protocol. Core temperature (T_{core}) was measured at baseline, post-warmup and post-20 min. After 20 min of recovery, T_{core} was significantly lower under CON and NMF, when compared with both PHM and COMB ($P < 0.05$); PHM and COMB were similar. Peak power output had declined from post-warmup under all conditions ($P < 0.001$); however, the drop was less in COMB versus all other conditions ($P < 0.05$). Repeated sprint performance was significantly better under COMB when compared to all other conditions. Combining PHM with NMF priming attenuates the post-warmup decline in T_{core} and can positively influence physical performance in professional rugby union players.

Keywords: *passive heat maintenance, core temperature, neuromuscular function, priming*

Introduction

Performing a warmup procedure has been well documented as integral to pre-competition preparation, e.g. (Bishop, 2003a, 2003b; Sargeant, 1987). A meta-analysis examining the influence of warmup on subsequent performance shows that ~79% of research has demonstrated positive effects of a warmup on physical performance (Fradkin, Zazryn, & Smoliga, 2010). There are numerous neurophysiological, metabolic and psychological benefits associated with warmup (for a review, see Bishop, 2003a; Kilduff, Finn, Baker, Cook, & West, 2013), and as such strategies that seek to optimise the pre-competition warmup have received considerable attention (Faulkner et al., 2013; Kilduff, West, Williams, & Cook, 2013; West, Dietzig, et al., 2013).

After the cessation of the warmup, body temperature (muscle and core) declines rapidly, and has been shown to decline to near baseline after 15–20 min of recovery (Faulkner et al., 2013; Kilduff, West, et al., 2013; West, Dietzig, et al., 2013). Passive heat maintenance and passive heating have been proven to be effective for protecting against post-warmup drops in body temperature (Faulkner et al., 2013; Kilduff, West, et al., 2013). We recently showed that applying a blizzard survival garment during the post-warmup recovery period (i.e. the period between the cessation of the warmup and subsequent physical performance) can offset the core temperature lost during this time by ~50% while improving lower body peak power output and repeated sprint ability, compared to a control condition, in professional rugby league players (Kilduff, West, et al., 2013). Additionally, Faulkner et al. (2013) demonstrated that wearing insulated athletic pants with an integrated heating element can improve sprint cycle peak power output by ~10%, when compared to a control trial. These data

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demonstrate the importance of maintaining body temperature during the post-warmup period for offsetting any temperature-related decrements in physical performance.

In addition to the maintenance of body temperature, additional avenues of research involve enhancing neuromuscular activity during the warmup procedure (e.g. Barnes, Hopkins, McGuigan, & Kilding, 2015; Bevan et al., 2010; Kilduff et al., 2013). For example, Barnes et al. (2015) found that the inclusion of 6 × 10 s strides with a weighted vest (20% of body mass) during a warmup procedure improved peak running speed, increased leg stiffness and improved running economy, when compared to a control trial without weighted vests, in 11 well-trained runners. This neuromuscular function priming effect has been demonstrated in other research with the inclusion of either heavy resistance (Bevan et al., 2010; Kilduff et al., 2007, 2011) or explosive exercise (Bergmann, Kramer, & Gruber, 2013; West, Cunningham, Bevan, et al., 2013; West, Cunningham, Crewther, Cook, & Kilduff, 2013) prior to physical performance.

However, there is scant data comparing pre-competition preparation strategies designed to minimise temperature loss (e.g. passive heat maintenance), maximise neuromuscular function activity or indeed a combination of both on physical performance in high-level athletes. Many sports have significant (e.g. 15–20 min) gaps between the cessation of the warmup and competition (e.g. soccer, rugby union), thus, we compared the effects of passive heat maintenance, explosive activity or both, performed after a standardised warmup on physical performance in professional rugby union players. We hypothesised that a combination of passive heat maintenance and explosive activity would offer the greatest benefit to post-warmup physical performance.

Methods

Experimental approach to the problem

Participants. Following ethical approval from the university research ethics committee, fifteen male professional rugby union players (mean ± *s*, age: 28 ± 3 years; height: 1.88 ± 0.06 m; body mass: 99.1 ± 8.6 kg) participated in the study. All were informed of the potential risks associated with the study prior to giving their informed consent. All participants were following a detailed diet plan prescribed by the team's nutritionist, which was replicated between trials. The study was carried out during the final weeks of pre-season such that there was no influence of competition.

Procedures. The study followed a repeated measures design, with each participant completing a control trial and three experimental conditions, with each trial separated by 7 days and trials taking place at the same time of the day (~10:00 am) to limit any influence of circadian changes in body temperature (West, Cook, Beaven, & Kilduff, 2013). Trials were carried out in a temperature-controlled exercise physiology laboratory and adjacent indoor sprint track (sprint track: air temperature 21.4 ± 0.4°C; humidity 61.0 ± 2.0%). The order in which the trials were completed was randomised and counter-balanced.

Participants reported for the trials at 10:00 am after consuming their typical training day breakfasts (replicated across trials) and having refrained from caffeine and alcohol; moreover, participants had refrained from alcohol and strenuous exercise during the previous 24 h.

Upon arrival to the laboratory, participants were seated for 15 min to measure baseline T_{core} (CorTemp™ Ingestible Core Body Temperature Sensor, HQ Inc., USA). During this time they were familiarised with the trial procedures. Once baseline measures were collected at the sprint track, participants performed a standardised warmup, which was prescribed by the team coach.

After the warmup, T_{core} was measured and participants carried out three counter-movement jumps on a portable force platform (Type 92866AA, Kistler, Germany). After the completion of the warmup, there was a 20-min period before further testing took place. During this time participants remained at rest wearing normal training attire for the control trial (CON), wore a custom-made blizzard survival garment for passive heat maintenance (PHM) after the warmup, remained at rest in normal training attire and after 12 min (i.e. 8 min prior to subsequent performance measures (Kilduff et al., 2007, 2008; West, Cunningham, Crewther, et al., 2013) performed a neuromuscular function priming stimulus of three sets of five counter-movement jumps with 20% body mass load (Barnes et al., 2015) (neuromuscular function, NMF), or while wearing the blizzard survival garment, players completed the NMF priming stimulus protocol at 12 min (COMB; participants removed the blizzard survival jacket for the counter-movement jump protocol and immediately put it back on once completed).

After 20 min had elapsed, further T_{core} and counter-movement jump measures were collected and participants then performed a repeated sprint ability test (Kilduff, West, et al., 2013; Rampinini et al., 2007). All participants wore normal training attire for the performance tests. T_{core} was recorded at baseline, post-warmup and pre-performance tests. Counter-movement jumps were analysed for peak power output (PPO); repeated sprint data was analysed at an individual sprint level and also processed for quickest time, total sprint time and mean sprint time. All participants were highly familiar with the repeated sprint and counter-movement jump tests, these tests were carried out multiple times throughout the year as part of the teams' testing battery.

The warmup consisted of jogging, skipping and lateral bounding over ~40 m, repeated 5 times, before progressing to dynamic stretches over 30 m, repeated 4 times, with emphasis on the gluteals, quadriceps and hamstring muscle groups. Participants then progressed on to plyometric strides (40 m × 2), high-knee striding into maximal sprinting (40 m × 2) and rolling start sprinting, which progressively increased in intensity such that the final two repetitions were maximal (30 m × 5). The warmup procedure took ~25 min to complete.

The blizzard jacket (Blizzard Survival Jacket, Blizzard Protection Systems Ltd, UK) is made from ReflexCell^{TM}, which is designed to clinch the body, which reduces convection, and it traps warm, still air, providing insulation. The blizzard survival jacket also has a reflective surface that limits radiated heat loss (Allen, Salyer, Dubick, Holcomb, & Blackbourne, 2010). The blizzard survival jackets used in the current study were custom made for athletes; tailored with long sleeves and were of a below the knee length.

The repeated sprint test consisted of six 40 m (20 + 20 m) shuttle sprints separated by 20 s of passive recovery (Rampinini et al., 2007). The test is designed to measure both repeated sprint and change in direction abilities. The participants started from a line, where electronic timing gates were placed (Brower TC-System, Brower Timing Systems, USA), sprinted 20 m, touched a second line with a foot and returned to the start as quickly as possible.

T_{core} was collected via the ingestion of a temperature sensor (CorTemp™ Ingestible Core Body Temperature Sensor, HQ Inc., USA), which transmitted a radio signal to an external sensor (CorTemp™ Data Recorder, HQ Inc., USA), which subsequently converted the signal into digital format. Participants ingested the sensor 3 h prior to the experimental trials (Byrne & Lim, 2007). The ingestible core temperature device has been demonstrated to be both reliable and valid (Byrne & Lim, 2007).

Peak power output was calculated from the counter-movement jumps as per West et al. (2011). The vertical component of the ground reaction force during performance of the counter-movement jump was used in conjunction with the participants' body mass to determine instantaneous velocity and displacement of his centre of gravity. Instantaneous power was determined using the following standard relationship:

Power (W) = vertical ground reaction force (N) × vertical velocity of centre of gravity ($m \cdot s^{-1}$).

Statistical analyses. Statistical analysis was performed using SPSS software (version 16; SPSS Inc., Chicago, IL), with significance set at $P \leq 0.05$. Within and between condition responses for T_{core} were examined using repeated measures ANOVA on two factors (condition × time). Where significant P-values were obtained for interaction effects (time × condition), an intervention was deemed to have influenced the response, and simple main effects analyses were performed. Partial-η^2 is presented for an estimate of the effect size; the reader should square root this value for correlation coefficients that can be compared with Hopkins et al. (Hopkins, Marshall, Batterham, & Hanin, 2009). Repeated sprint data and δ changes in T_{core} and peak power output were examined using one-way ANOVA with Bonferroni adjusted pairwise comparisons. Data are presented as mean ± s.

Results

There were significant time ($P < 0.001$; partial-$\eta^2 = 0.929$), condition ($P < 0.001$; partial-$\eta^2 = 0.478$) and time × condition interaction effects ($P < 0.001$; partial-$\eta^2 = 0.853$) in the T_{core} responses to the protocol. The warmup increased T_{core} similarly between all conditions ($P > 0.05$; Figure 1A), when compared with baseline; however, at post-20 min, T_{core} was significantly higher in PHM ($P < 0.001$) and COMB ($P < 0.001$) versus CON and NMF ($P = 0.143$). Additionally, T_{core} in NMF was lower than PHM (95% CI −0.34°C to −0.47°C; $P < 0.001$) and COMB (95% CI −0.35°C to −0.48°C; $P < 0.001$) whereas PHM and COMB were similar (95% CI −0.02°C to 0.04°C; $P = 0.934$; Figure 1A) at this time point. The δ change in T_{core} from post-warmup to post-20 min is presented in Figure 1B. The change in T_{core} was significantly less under both PHM (95% CI −0.16°C to −0.23°C) and COMB (95% CI −0.14°C to −0.24°C), when compared to CON (95% CI −0.62°C to −0.70°C) and NMF (95% CI −0.59°C to −0.71°C; Figure 1B), with PHM and COMB being similar ($P = 0.781$).

Of the temperature gained through the warmup procedure, −84.5 ± 21.5% and −88.0 ± 30.0% was lost for CON and NMF, respectively; with values being similar between conditions at post-20-min ($P = 0.591$). Conversely, T_{core} declined less ($P < 0.001$) with PHM (−29.4 ± 14.5% loss) and COMB (−29.7 ± 17% loss) and similar T_{core} values

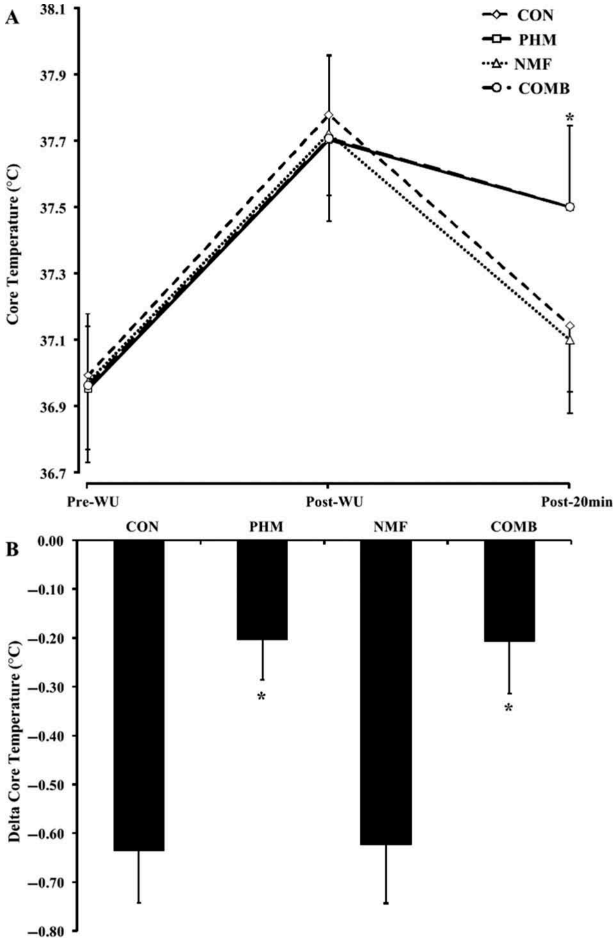

Figure 1. Time-course change in core temperature during the protocol (A) and δ change in core temperature from post-warmup to 20 min. *COMB and PHM are different from CON and NMF ($P < 0.05$).

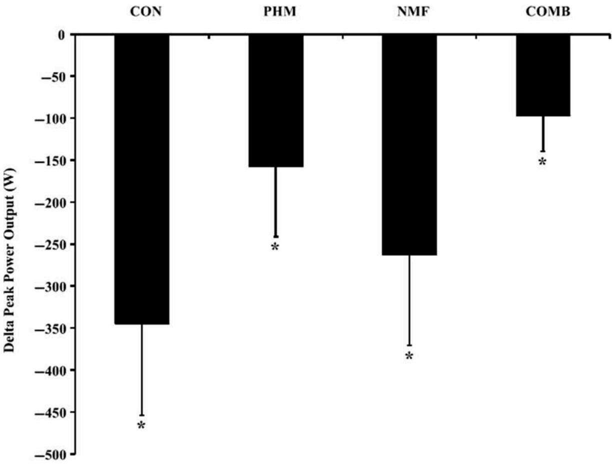

Figure 2. The δ change in peak power output from post-warmup to warmup to post-20-min. *Different from all other conditions ($P < 0.05$).

Table I. Player mean, total sprint and fastest sprint times.

	Mean (s)	Total (s)	Fastest (s)
CON	6.87 ± 0.15^{a}	41.23 ± 0.92^{a}	6.60 ± 0.16
PHM	6.83 ± 0.13^{a}	41.00 ± 0.81^{a}	6.54 ± 0.14$^{b\ c}$
NMF	6.88 ± 0.15^{a}	41.31 ± 0.90^{a}	6.58 ± 0.14
COMB	6.81 ± 0.13^{a}	40.89 ± 0.79^{a}	6.47 ± 0.14^{a}

Notes: CON, control; PHM, passive heat maintenance; NMF, neuromuscular function; COMB, combination of PHM and NMF. ^{a}Different from all other conditions; ^{b}different from control; ^{c}different from NMF. $P < 0.05$.

were observed between PHM and COMB at post-20-min ($P = 0.904$).

There was a significant time ($P < 0.001$; partial-$\eta^2 = 0.922$), condition ($P < 0.001$; partial-$\eta^2 = 0.594$) and time × condition interaction effect ($P < 0.001$; partial-$\eta^2 = 0.712$) in the peak power output responses to the protocol. Post-warmup peak power output was similar across conditions (CON 5567 ± 408; PHM 5548 ± 399; NMF 5543 ± 403; COMB 5566 ± 406 W, $P = 0.302$); however, despite peak power output declining under all conditions at post-20 min, and the δ change in peak power output being significantly different between all conditions ($P < 0.001$; Figure 2), peak power output dropped the least under COMB versus all other trials (Figure 2). PHM resulted in less of a drop in peak power output when compared to NMF (Figure 2).

There was a significant time ($P < 0.001$; partial-$\eta^2 = 0.919$), condition ($P < 0.001$; partial-$\eta^2 = 0.715$) and time × condition interaction effect ($P < 0.001$; partial-$\eta^2 = 0.459$) in player sprint times. When examining the repeated sprint data as mean, total and fastest sprint times, performance improved significantly under COMB when compared to all other conditions (Table I).

Discussion

We sought to examine and compare the effects of incorporating PHM, explosive NMF priming activity, or both (COMB), after a standardised warmup on physical performance in professional rugby union players. Here we show that combining PHM with NMF during the post-warmup recovery period results in maintenance of T_{core} and consequently limits the post-warmup decline in peak power output, and improves repeated sprint ability, to a greater extent than using either strategy in isolation.

After the cessation of the warmup, T_{core} declined under all conditions, but the greatest decline occurred with the Control and NMF conditions, where ~85% of the temperature gained through warmup was lost, whereas this was limited to ~30% with PHM and COMB strategies. These findings are similar to previously reported data examining the use of PHM (Kilduff, West, et al., 2013). The blizzard survival jacket is designed to trap warm, still air, thus providing insulation; it has a reflective surface that limits radiated heat loss, and its elastic properties reduce heat loss via convection (Allen et al., 2010; Kilduff, West, et al., 2013). This preservation of temperature may have contributed to improving physical performance with PHM and COMB and is in agreement with prior literature in the area (Cook, Holdcroft, Drawer, & Kilduff, 2013; Faulkner et al., 2013; Kilduff, West, et al., 2013).

In accordance with earlier research (Faulkner et al., 2013; Kilduff, West, et al., 2013), the incorporation of PHM improved peak power output and repeated sprint ability in our participants. However, peak power output was greater with COMB by 60–247 W (1.5–6.2%) across conditions and participants also demonstrated better performance during the repeated sprint test with this strategy. To our knowledge, we are the first to demonstrate that combing PHM with NMF priming activity can enhance physical performance, to a greater extent than employing either strategy alone, in a group of professional athletes. Prior research has demonstrated the importance of an elevated core (West Dietzig, et al., 2013) and muscle (Sargeant, 1987) temperature on physical performance. Sergeant (Sargeant, 1987), demonstrated a 4% increase in leg muscle power per 1°C increase in muscle temperature, but more importantly, every 1°C decrease in muscle temperature resulted in a 3% decrease in leg muscle power. Although muscle temperature was not measured in the current study due to the examination of professional athletes (muscle temperature measures were not permitted by the team management), it is reasonable to suggest that using a PHM strategy would have also lessened the decline in muscle temperature after the cessation of the warmup. Notably, both core and muscle temperature demonstrate similar time course changes during and after exercise (Mohr, Krustrup, Nybo, Nielsen, & Bangsbo, 2004).

The elevated muscle temperature may help maintain neural pathways heightened by the warmup, such as increased neural transmission rate, in both peripheral and central nerves (Hill, 1972), and increased speed of muscle contractions and decreases in both the time to peak tension and half relaxation time (Bennett, 1984; Davies & Young, 1983). As well as increased phosphocreatine hydrolysis and glycolytic rate subsequently improving the capacity for ATP re-synthesis, and increased cross-bridge cycling rate (Edwards et al., 1972). However, we can only speculate as to what additional mechanisms underpin the augmented performance demonstrated with COMB, in comparison to PHM alone. Potentially this strategy harnessed the benefits of a higher muscle temperature (as previously described), along with 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 neuron (Hodgson, Docherty, & Robbins, 2005); mechanisms traditionally associated with post-activation potentiation and the improved physical performance after an explosive preloading stimulus (Turner, Bellhouse, Kilduff, & Russell, 2015).

A surprising finding in our data set was that players performed comparably during the repeated sprint test under NMF, when compared to CON, and lower body peak power output was just ~1% greater under NMF. Speculatively, a potential explanation may lie in an up-regulation of neuromuscular pathways associated with performing the explosive exercise, but a simultaneous down-regulation of temperature-mediated pathways during the post-warmup recovery period may have resulted in players demonstrating increased capacity for single explosive efforts, evidence by an improved fastest sprint time and counter-movement jump peak power output, but the loss of temperature may have compromised repeated sprint ability. Furthermore, there may be potential role of an observer/placebo effect in these data. Future research should seek to identify the mechanisms, whether physiological or psychological, underpinning this finding.

In conclusion, the effects of PHM, neuromuscular priming and a combination of both were assessed in a group of professional rugby union players. Our data demonstrate that PHM combined with a neuromuscular priming activity helps maintain an elevated core temperature during the post-warmup recovery period, and helps to reduce the subsequent decline in lower body peak power output and repeated sprint ability, to a greater extent than if either strategy were implemented in isolation.

Disclosure statement

No potential conflict of interest was reported by the authors.

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