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Title: A comparison of different heat maintenance methods implemented during a simulated half-time period in professional Rugby Union players

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Title: A comparison of different heat maintenance methods implemented during a simulated half-time period in professional Rugby Union players

Running title: Comparing half-time heat maintenance methods

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Abstract

Objectives: In thermoneutral conditions, half-time is associated with reductions in body temperature that acutely impair performance. This laboratory-based study compared active, passive, and combined methods of half-time heat maintenance.

Design: Randomised, counterbalanced, cross-over

Methods: After a standardised warm-up (WU) and 15 min of rest, professional Rugby Union players (n=20) completed a repeated sprint test (RSSA1). Throughout a simulated half-time (temperature:

20.5±0.3°C; humidity: 53±5%), players then rested (Control) or wore a survival jacket (Passive) for 15 min, or performed a 7 min rewarm-up after either 8 min of rest (Active), or 8 min of wearing a survival jacket (Combined). A second RSSA (RSSA2) followed. Core temperature (T_{core}) and peak power output (PPO; during countermovement jumps; CMJ) were measured at baseline, post-RSSA1, pre-RSSA2.

Results: All half-time interventions attenuated reductions in T_{core} (0.62±0.28ºC) observed in Control (Passive: -0.23±0.09ºC; Active: -0.17±0.09ºC; Combined: -0.03±0.10ºC, all $p<0.001$) but Combined preserved T_{core} the most ($p<0.001$). All half-time interventions attenuated the 385±137 W reduction in Control PPO (Passive: -213±79 W; Active: -83±72 W; Combined: +10±52 W; all $p<0.001$); with best PPO maintenance in Combined ($p\leq0.001$). The fastest sprints occurred in RSSA2 in Combined (6.74±0.21 s; $p<0.001$) but Passive (6.82±0.04 s) and Active (6.80±0.05 s) sprints were 0.4% ($p=0.011$) and 0.8% ($p=0.002$) quicker than Control (6.85±0.04 s), respectively.

Conclusions: While the efficacy of passive and active heat maintenance methods was supported throughout a simulated half-time, a combined approach to attenuating heat losses appeared the most beneficial for T_{core} and subsequent PPO and sprint performance in professional Rugby Union players.

Key words: Temperature, intermittent, warm-up, rewarm-up, soccer

Introduction

In team sports it has been reported that tactical delivery dominates half-time practices [1]. However, comparable durations of inactivity (i.e., ~15 min) influence acid-base balance [2], glycaemia [3-5], and muscle (T_m) and core (T_{core}) temperatures [6-8]. Intermittent sports players also demonstrate reduced exercise intensities during the initial stages of the second half [9] and fail to recover eccentric hamstring strength over half-time [10]. Half-time therefore provides an opportunity to enhance subsequent performance [8, 11] but limited data exists profiling such potential interventions.

Attenuated losses of T_m protect subsequent physical performance [6, 12] and have been proposed to concomitantly reduce the elevated injury risk observed when muscle strength deficiencies occur over half-time [12]. The half-time maintenance of body temperature may therefore provide an ergogenic opportunity on match-day. Indeed, impaired countermovement jump (CMJ) and repeated sprint performance was observed following a simulated half-time in which T_{core} reduced [8]. Protection of temperature mediated pathways that benefit subsequent performance [7] have typically been achieved by either passive [8] or active [6, 12, 13] methods.

Passive heat maintenance requires the use of heated clothing, outdoor survival jackets, and/or heated pads [14]. An outdoor survival jacket worn over half-time attenuated a ~0.6°C (~1.5%) reduction in T_{core} and enhanced CMJ and sprint performance thereafter [8]. Alternatively, active heat maintenance uses 5-7 min of varying modes of exercise (i.e., small-sided games, resistance exercise, whole body vibration, multidirectional speed drills, running and other exercises) to rewarm players throughout half-time [6, 12, 13]. Although barriers may prevent active rewarm-ups being used in the applied setting [1], half-time active heat maintenance strategies appear beneficial [6, 12, 13].

While heat maintenance, be it from active or passive methods, appears superior to no heat maintenance at all, a systematic comparison in a single study design is currently lacking and the efficacy of a combined method (i.e., both passive and active heat maintenance in a single half-time strategy) remains unknown. Therefore, using a similar study design to previous literature [8], the aim of this study was to examine the influence of different heat maintenance strategies used during a simulated half-time period on markers of T_{core}, peak power output (PPO; during CMJ) and repeated sprint ability.

Methods

Following ethical approval, 20 male professional Rugby Union players (age: 24 ± 5 years; height: 1.85 ± 0.1 m; body mass: 97.5 ± 7.8 kg) competing on behalf of a French top tier professional club volunteered to participate in this study. All players were informed of the potential risks associated with the study prior to providing informed consent. Players were following a detailed diet plan which remained consistent between trials as recommended by the team's nutritionist.

Trials were performed at the same time of the day (~10:00 h) with players wearing normal training kit and followed a randomised and counterbalanced repeated measures design. Each player completed a control and three interventions (each separated by 7 days). Trials were carried out in a temperature controlled indoor sprint track (temperature: 20.5±0.3°C; humidity: 53±5%). Players reported for the trials after consuming their typical training day breakfasts (replicated across trials) and having refrained from caffeine, alcohol and strenuous exercise in the 24 h preceding each trial. Upon arrival, players remained seated for 15 min while baseline T_{core} was measured and procedures were verbally reiterated. After the warm-up (WU), a 15 min rest period was required (to represent match-day practices) before the first repeated shuttle sprint ability (RSSA) test [15] was performed. Repeated sprint ability has been associated with activity rates during Rugby Union match-play [16]. Lower body explosive ability (i.e., during CMJ) was assessed three times before and after the half-time intervention (i.e., post-RSSA1 and pre-RSSA2) before players repeated a second RSSA test (RSSA2).

All players were highly familiar with the RSSA and CMJ tests as these were regularly implemented as part of the team's testing battery. The standardised WU (~25 min) consisted of five repeats of ~40 m jogging, skipping and lateral bounding, before four repeats of ~30 m dynamic stretches (focusing on the gluteals, quadriceps and hamstring muscle groups). Plyometric strides (40 m x 2), high-knee striding into maximal sprinting (40 m x 2) and rolling start sprinting which progressively increased in intensity such that the final two repetitions were maximal (30 m x 5) were then performed.

In agreement with the manufacturer's instructions, an ingestible temperature sensor (CorTemp™, HQ Inc, USA) was consumed 3 h before trials commenced and allowed T_{core} measurement at three time-points (i.e., baseline, post-RSSA1, pre-RSSA2). The sensor transmitted a radio signal to an external receiver device (CorTemp™ Data Recorder, HQ Inc, USA); a method previously demonstrated to be valid and reliable [17].

A portable force platform (Type 92866AA, Kistler, Germany) and methods described previously [18] were used to determine PPO during CMJ's. The participants' body mass and vertical component of the ground reaction force (GRF) elicited during the CMJ was used to determine the instantaneous velocity and displacement of the participant's centre of gravity [19]. Instantaneous power output was determined using Equation 1 and PPO was classed as the highest instantaneous value produced.

Eq'n 1: Power (W) = vertical GRF (N) x Vertical velocity of centre of gravity ($m.s^{-1}$)

The RSSA test consisted of six 40 m (20 + 20 m separated by a 180° turn) shuttle sprints each separated by 20 s of passive recovery [15]. From a stationary start, the players started the test 0.3 m behind a pair of electronic timing gates (Brower TC-System, Brower Timing Systems, USA). Upon instruction, players sprinted 20 m and touched a second line with their foot before returning to the start line as quickly as possible. RSSA best was calculated as the fastest 40 m sprint time within each half [15].

During the simulated half-time, players wore their normal kit and remained at rest (15 min; Control), or wore a survival jacket (15 min; Passive), or performed a 7 min rewarm-up after 8 min of rest (Active), or wore a survival jacket for 8 min before performing a 7 min rewarm-up (Combined). Each trial requiring the survival jacket used a garment designed to clinch the body, reduce convection, and trap warm, still air (Blizzard Survival Jacket, Blizzard Protection Systems Ltd, UK). The jacket also had a reflective surface which limited radiated heat loss [20]. The survival jackets used in the current study were similar to those used previously [7, 8, 14] and were tailored with long sleeves and were of a below-the-knee length. Trials requiring the ~7 min rewarm-up consisted of 3-4 min of low intensity jogging (over a 20 m distance) and simple ball skills (i.e., passing between team mates) which were followed by 3-4 min of medium intensity jogging and multi-directional ball skills. Mean HR during the ~7 min activity was 136 ± 4 $beats \cdot min^{-1}$.

Statistical analyses were performed using SPSS software (Version 21; SPSS Inc., Chicago, IL) and data are presented as mean ± SD. All RSSA data represents an *n*=20 whereas CMJ and T_{core} responses represent an *n*=16. Significance was set at $p \leq 0.05$. Two-way repeated measures analysis of variance (ANOVA; within-subject factors: trial x time) were used where data contained multiple time points. Mauchly's test was consulted and Greenhouse–Geisser correction was applied if sphericity was violated. Where significant p-values were identified for interaction effects (trial x time), trial was deemed to have influenced the response and simple main effect analyses were performed. Significant main effects of time were further investigated using pairwise comparisons with least significant differences (LSD) confidence-interval adjustment.

Results

Trial (time x trial: p<0.001, partial-eta^2=0.658) and time (p<0.001, partial-eta^2=0.875) influenced T_{core} (Figure 1). Baseline T_{core} (36.78±0.22ºC) was comparable (p=0.228) and T_{core} increased equally (p=0.190) at the post-RSSA1 time-point (+0.96±0.33ºC, +0.95±0.32ºC, +0.94±0.36ºC, +0.90±0.33ºC for Control, Passive, Active and Combined, respectively, being 37.71±0.40ºC). Although the 0.62±0.28ºC reduction in T_{core} observed in Control was attenuated by all half-time interventions (Passive: -0.23±0.09ºC, p=0.001; Active: -0.17±0.09ºC, p<0.001; Combined: -0.03±0.10ºC, p<0.001), T_{core} in Combined exceeded both Passive (p=0.009) and Active (p=0.018) at pre-RSSA2. The magnitude of T_{core} loss was smallest in Combined versus both the Passive (p<0.001) and Active (p<0.001) trials which were comparable to each other (p=0.508).

***** INSERT FIGURE 1 HERE *****

Trial (time x trial: p<0.001, partial-eta^2=0.823) and time (p<0.001, partial-eta^2=0.905) influenced PPO (Figure 2). Compared to post-RSSA1, PPO reduced by 385±137 W in Control at the pre-RSSA2 time-point; a reduction which was attenuated by all interventions (-213±79 W; -83±72 W; +10±52 W for Passive, Active and Combined, respectively, all p<0.002; Figure 2). At pre-RSSA2, PPO in Combined was greater than all other trials (all p<0.001) whereas Passive and Active (p=0.262) were comparable. The half-time reduction in PPO in Combined was significantly less than Active (p=0.014) and Passive (p<0.001). The drop in PPO in Active was significantly lower than Passive (p<0.001).

***** INSERT FIGURE 2 HERE *****

Figure 3 illustrates the sprint data throughout each trial. Sprint performance in RSSA2 was influenced by trial (time x trial: $p<0.001$, partial-eta^2=0.226) and time ($p<0.001$, partial-eta^2=0.904) with Combined improving performance versus all other trials. Relative to Control, sprints in RSSA2 were ~1.7% (sprints 7-9: all $p<0.001$) and ~0.8% (sprints 10-12: all $p<0.002$) faster in Combined. Versus Control, sprint times were also improved in Passive ($p<0.02$) and Active ($p<0.002$) in the initial two sprints of RSSA2. For RSSA1, no differences existed between trials (all $p>0.05$) but sprints 2-6 were slower (all $p<0.001$) than sprint 1.

***** INSERT FIGURE 3 HERE *****

The fastest sprint time throughout each RSSA test was influenced by both trial (time x trial: $p<0.001$, partial-eta^2=0.464) and time ($p<0.001$, partial-eta^2=0.573). No between-trial differences were observed in RSSA1 (6.72 ± 0.15 s; p=0.254). In RSSA2, Combined (6.74 ± 0.21 s) elicited the fastest sprint times relative to all other trials (all $p<0.001$) with a 1.7% improvement being observed in Combined versus Control (6.85 ± 0.04 s). For Passive (6.82 ± 0.04 s) and Active (6.80 ± 0.05 s), the best sprint times in RSSA2 were 0.4% (p=0.011) and 0.8% (p=0.002) quicker than Control, respectively; with no differences between these two trials (p=0.058).

Discussion

In professional Rugby Union players, the effects of different half-time heat maintenance strategies (including passive, active and combined methods) implemented throughout a 15 min period that separated repeated sprint bouts were examined. T_{core} was best preserved in Combined when compared to both Passive and Active. Notably, versus Control, all interventions improved PPO and initial sprint performance in subsequent exercise; but the greatest effects occurred in Combined. While supporting the use of half-time heat maintenance strategies for team sports players competing in thermoneutral environments (i.e., ~21°C), our findings also highlight that additive effects may result from the combination of both passive and active methods. These findings offer practitioners and players a number of alternative strategies that can be implemented dependent on preference. Differences in the degree of half-time T_{core} maintenance suggests that a better preservation of temperature-related mechanisms likely explains the performance changes observed between the isolated versus combined strategies.

In support of previous studies that have used a single heat maintenance method [6, 8], the 1.6% (0.6±0.3°C) drop in T_{core} over half-time was reduced in both Passive (0.6%; 0.2±0.1°C) and Active (0.5%; 0.2±0.1°C). For the first time, we also demonstrate the additive effects of a combined strategy as the half-time T_{core} reduction was lowest when 8 min of passive heat maintenance was followed by 7 min of active re-warm up (i.e., -0.1%; -0.03±0.1°C). Although the rationale for implementing either a passive or active heat maintenance method in isolation during half-time is further substantiated, a strategy that combines both methods (e.g., through the use of survival jackets and active rewarm-ups) elicited additive effects on T_{core} and thus warrants consideration as a match-day performance-enhancing strategy.

Competitive actions that require sprinting and acceleration may be improved throughout the early stages of the second half when half-time heat maintenance methods are used as all interventions improved sprint performance at some point throughout RSSA2; but more so for Combined (Figure 3). Improvements in muscular contraction speed (with concomitant decreases in both the time to peak tension and half relaxation time) and enhanced neural transmission rates are observed under conditions of elevated body temperature [21-23]. Additionally, whole body temperature increases facilitate phosphocreatine hydrolysis and glycolytic rates [24], via up-regulation of key glycolytic enzymes (e.g. phosphofructokinase and lactate dehydrogenase; [25]), which improves the capacity for ATP resynthesis and cross-bridge cycling [24, 26]. The improved performance observed during the initial stages of RSSA2 in Combined may plausibly reflect a superior effect of these temperature-related changes when compared to Active and Passive. In support of this, the change in T_{core} over half-time was least for Combined when compared to both Passive and Active (Figure 1).

All interventions attenuated the 6.5% (385±137 W) reduction in PPO that occurred over half-time in Control (Figure 2); however, the magnitude of this response differed according to trial and the best preservation of CMJ performance occurred in Combined (+0.2±0.9%, +10±52 W). Every 1°C loss in T_m has been shown to result in a 3% decrease in leg muscle power [27] and higher T_m (~39°C) augments physical performance [6]. Unfortunately, T_m was not directly measured in this study, but we propose that the interventions used would likely have influenced T_m responses as Mohr et al. [6] showed that comparable durations of half-time activity (yielding a similar heart rate response to that reported here) elevated T_m at the start of the second half. Therefore, we propose that better maintenance of body temperature over half-time in Combined (Figure 1) facilitated performance to a greater extent when compared to the use of a single heat maintenance method alone (i.e., Passive or Active).

Previous authors have investigated the efficacy of active re-warm up strategies using between 3 and 7 min of varying modes of activity, including: moderate intensity running, intermittent agility exercise, whole body vibration, small sided games and lower body resistance exercises [6, 12, 13]. Notably, the current study highlights the comparability of body temperature and selected performance responses to passive and active heat maintenance methods when used at half-time, albeit in an indoor testing environment. However, such responses occurred in the context of differing durations of exposure to each intervention. The active rewarm-up was performed for 7 min following 8 min of rest whereas the passive heat maintenance strategy was employed for the full duration of half-time (i.e., 15 min). Thus, an active rewarm-up may present a time-efficient method of attenuating a half-time drop in T_{core}; especially in the context of a better maintenance of PPO in Active (-1.4±1.2%, -83±72 W) versus Passive (-3.7±1.5%, -213±79 W) seen over half-time. That said, in scenarios where active rewarm-ups are not possible, specific heat maintenance garments may offer an alternative method of maintaining body heat which has less of a disruptive effect on current half-time practices.

Attainment of a critical core temperature has been proposed as a candidate mechanism of fatigue [28, 29]. Although this study was performed in a thermoneutral environment, the omission of a period of temperature recovery over half-time may indeed impair exercise performances elicited in hyperthermic conditions as initial body temperature is inversely associated with subsequent exercise capacity performed in the heat [28]. It is therefore possible that our findings are indeed specific to the context in which these measurements were taken. The influence of half-time heat maintenance methods upon exercise performed in hyperthermic conditions warrants further investigation.

The absence of T_m could be viewed as a limitation of this study. Although the pattern of response to work and rest appears similar between T_{core} and T_m throughout soccer-specific exercise [6], the magnitude of these changes likely differs between methods of temperature assessment. Unfortunately, the top tier professional athletes recruited here precluded the invasive measurement of T_m. While previous authors have measured T_m in team sports athletes [6, 12], differences should be noted in the playing standard versus the level of participants reported presently. Nevertheless, T_{core} presents a valuable insight into the body temperature response and the level of participant used in this study enhances the ecological validity of the findings for the population where the interventions likely have the most value. Likewise, the use of the RSSA test instead of a longer duration exercise simulation may also be questioned. In defence, repeated sprint ability is associated with activity rates during actual match-play in Rugby Union players [16] and the use of such a protocol standardises the physiological demands elicited between repeated trials making the effects of exercise repeatable (demonstrated by the pre-intervention responses to RSSA1). Nevertheless, heat maintenance strategies (especially those which combine both passive and active methods to reduce half-time losses of body temperature) may impact positively on subsequent exercise performed in thermoneutral conditions and should be considered by practitioners.

Conclusion

Although active rewarm-ups and passive heat maintenance methods proved beneficial in a thermoneutral environment, a combined method (i.e., 8 min of wearing a survival jacket followed by 7 min of an active rewarm-up) used during half-time elicited additive performance effects in a group of professional Rugby Union players. Such findings are likely due to minimised losses in body temperature occurring during the recovery period that separated the two consecutive bouts of exercise.

Practical implications

- Reductions in body temperature during a 15-min half time impaired subsequent sprint performance.
- Half-time heat maintenance strategies, such as passive and active methods, reduced the drop in T_{core} and protected subsequent countermovement jump and repeated sprint performance at the start of the second half.
- In a controlled, laboratory orientated protocol, a combined half-time strategy incorporating passive and active heat maintenance methods, elicited greater physiological and performance effects compared to either passive or active methods used in isolation.

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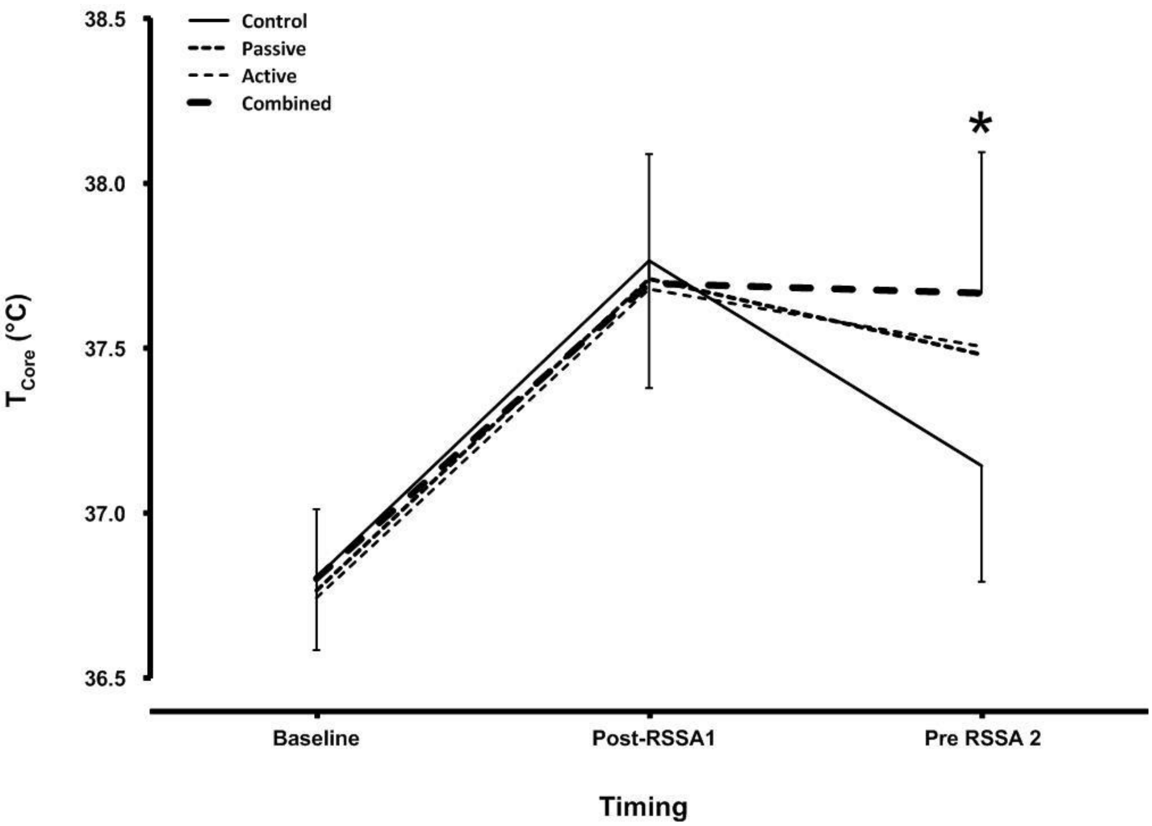
Figure legends

Figure 1: Core temperature (T_{core}) responses throughout the Control, Passive, Active and Combined trials. * represents significant between-trial difference ($p<0.05$) at the corresponding time-point. For clarity, data is mean ± SD for the Control and Combined trials only. RSSA represents repeated shuttle sprint ability.

Figure 2: Mean ± SD peak power output (PPO) throughout the Control, Passive, Active and Combined trials. * represents significant difference ($p<0.05$) from Control at the corresponding time-point. X represents significant difference ($p<0.05$) from Combined at the corresponding time-point. RSSA represents repeated shuttle sprint ability.

Figure 3: Sprint times (40 m) throughout the Control, Passive, Active and Combined trials. * represents significant between-trial difference ($p<0.05$) at the corresponding time-point. For clarity, data is mean ± SD for the Control and Combined trials only. Shaded region represents RSSA2.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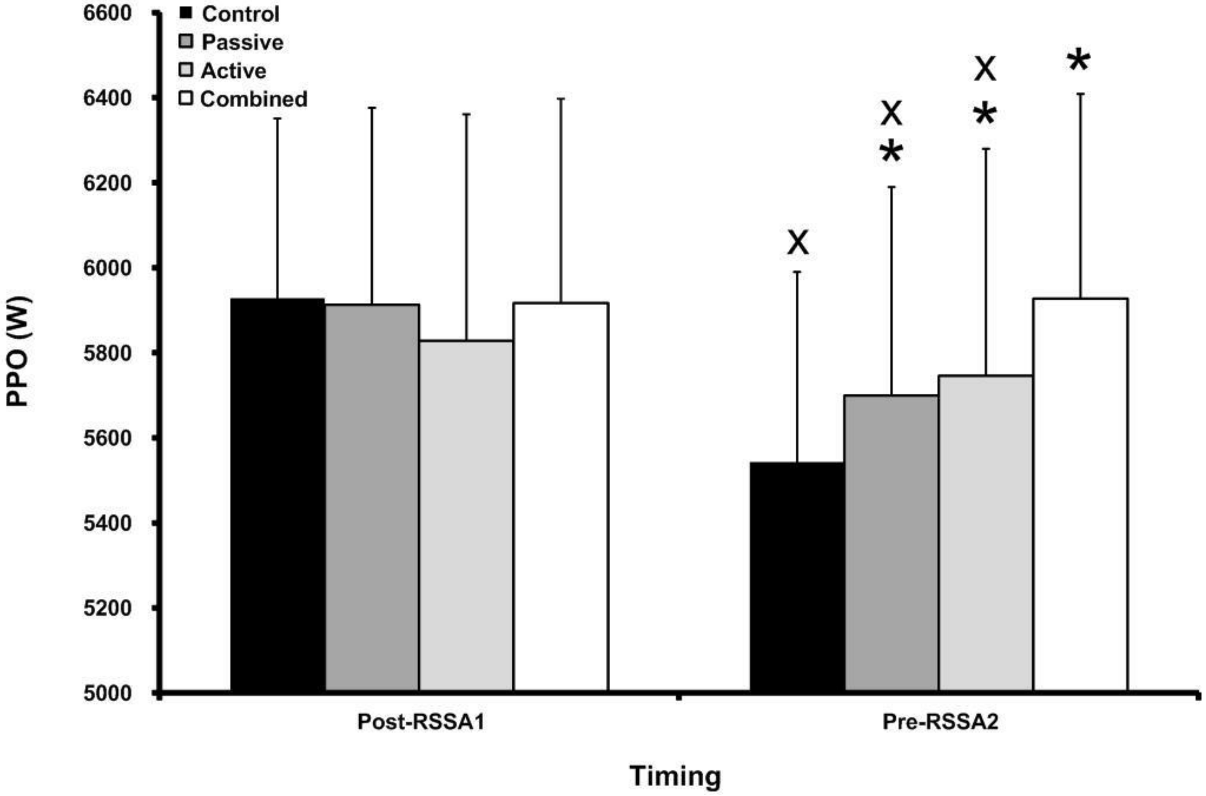
Timing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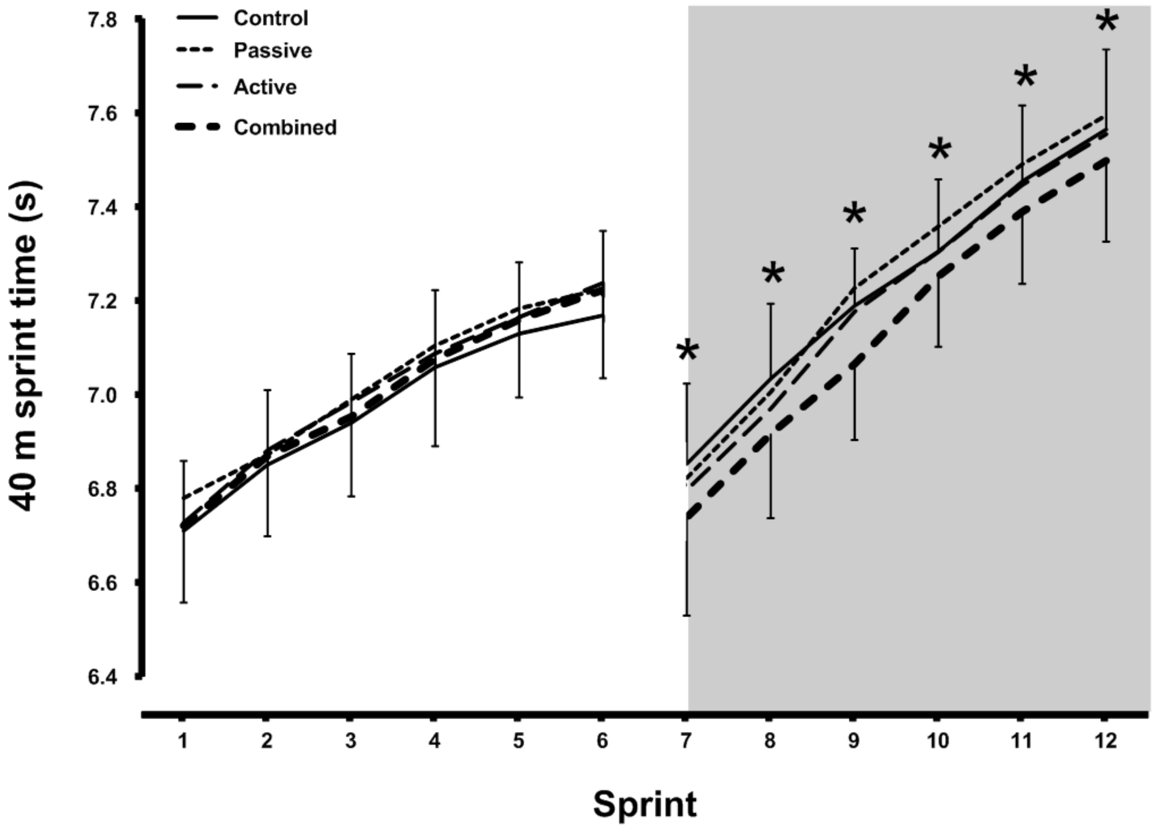
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