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Original research

The effect of warm-up on intermittent sprint performance and selected thermoregulatory parameters

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Abstract

Objectives: To investigate the effect of various warm-up intensities based upon individual lactate thresholds on subsequent intermittent sprint performance, as well as to determine which temperature (muscle; T_{mu}, rectal; T_{re} or body; T_b) best correlated with performance (total work, work and power output of the first sprint, and % work decrement).
Design: Nine male team-sport participants performed five 10-min warm-up protocols consisting of different exercise intensities on five separate occasions, separated by a week.
Methods: Each warm-up protocol was followed by a 6 × 4-s intermittent sprint test performed on a cycle ergometer with 21-s of recovery between sprints. T_{mu}, T_{re} and T_b were monitored throughout the test.
Results: There were no differences between warm-up conditions for total work (J kg^{-1}; $P = 0.442$), first sprint work (J kg^{-1}; $P = 0.769$), power output of the first sprint (W kg^{-1}; $P = 0.189$), or % work decrement ($P = 0.136$), respectively. Moderate to large effect sizes (>0.5; Cohen's *d*) suggested a tendency for improvement in every performance variable assessed following a warm-up performed at an intensity midway between lactate inflection and lactate threshold. While T_{mu}, T_{re}, T_b, heart rate, ratings of perceived exertion and plasma lactate increased significantly during the exercise protocols ($P < 0.05$), there were no significant correlations between T_{mu}, T_{re}, and T_b assessed immediately after each warm-up condition and any performance variable assessed.
Conclusions: Warm-up performed at an intensity midway between lactate inflection and lactate threshold resulted in optimal intermittent sprint performance. Significant increases in T_{mu}, T_{re} and T_b during the sprint test did not affect exercise performance between warm-up conditions.

Keywords: Muscle temperature; Lactate threshold; Lactate inflection

1. Introduction

Warm-up (WUP) is a well-accepted practice that is considered by many athletes and coaches to be an essential precursor to training sessions and competition, as well as a means to minimise sport-related injuries.[1] An active WUP is proposed to improve subsequent exercise performance through numerous temperature and non-temperature related benefits, which overall, prime the body for the ensuing exercise task.[2] Examples of these proposed benefits (described in detail in a review by Bishop[2]), are: increased nerve conduction rates, decreased joint and muscle resistance, speeding of metabolic reactions, increased blood flow to muscles, greater unloading of oxygen to working muscles, postactivation potentiation, as well as psychological effects.

While many researchers have reported improved exercise performance following an active WUP,[3,4] other researchers have found no benefit.[5,6] Lack of consensus regarding the effects of WUP on exercise performance may be due to heterogeneity of different exercise protocols, the lack of well-controlled studies, the recruitment of small cohorts, or the use of $\dot{V}O_{2max}$ to determine WUP intensity. Of relevance, Bishop et al.[7] noted that a WUP intensity of 80% $\dot{V}O_{2max}$

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was likely to be above the lactate threshold (LT: also known as 'anaerobic threshold') in some individuals (particularly if untrained) but below the LT in others (i.e. well trained athletes). Importantly, a WUP intensity that is greater than LT has been shown to result in high-energy phosphocreatine depletion (and the subsequent accumulation of phosphate), as well as an increase in metabolic acidemia, which can impair subsequent exercise performance.[7,8] While the role of intracellular acidosis on skeletal muscle fatigue has been challenged in recent years,[9] scientific opinion in this area is still equivocal. Overall, this suggests that WUP intensity should be based on lactate levels, rather than $\%\dot{V}O_{2max}$, with the ideal WUP intensity being able to raise body temperature to a point where benefits associated with WUP are achieved, without a concomitant detrimental increase in metabolic acidemia, the depletion of high-energy substrates, or the accumulation of phosphate.

Additionally, while a number of studies have investigated the effect of WUP intensity on single-sprint performance,[4,7,10] there is no published research to the authors' knowledge, describing the effects of WUP on intermittent sprint ability, where WUP intensity was based on lactate thresholds. This lack of research is surprising, as in many countries the most popular sports, are team sports, which require athletes to sprint repeatedly throughout the match.

Therefore, the aim of this study was to investigate the impact of varying WUP intensities (based on individual lactate accumulation) on intermittent sprint ability so to determine which intensity results in better subsequent exercise performance. A second aim of this study was to investigate whether muscle, body and rectal temperature (T_{mu}, T_b or T_{re}, respectively) induced by the various WUP protocols, were correlated with exercise performance. It was hypothesised that a WUP intensity performed mid-way between lactate inflection (LI) and LT would result in better intermittent sprint performance, as this intensity would produce an increase in body temperatures, while at the same time avoid a large increase in metabolic acidemia.

2. Methods

Nine male participants (mean ± SD age: 26.1 ± 4.4 years, body mass: 86.9 ± 11.4 kg, $\dot{V}O_{2max}$: 49.6 ± 6.1 mL kg^{-1} min^{-1}) were recruited from The University of Western Australia (UWA). All participants played in team-sports (rugby, AFL football and soccer) and trained three days per week (7.6 ± 2.7 h week^{-1} per week) with competition occurring once a week. The Research Ethics committee of UWA granted approval for the study's procedures and all participants provided written informed consent.

Participants were required to complete three preliminary sessions and five experimental trials over a seven-week period. During the first visit, participants performed a familiarisation session of both the graded exercise test (GXT) and the intermittent sprint test. Height was also determined using a stadiometer, while body-mass was measured using Sauter scales (model ED3300, Ebingen, West Germany). The GXT was performed on the second visit to determine the participant's LI, LT and $\dot{V}O_{2max}$. On the third visit, participants performed a second familiarisation of the intermittent sprint test. Participants then performed each of the five experimental trials over a five week period. Participants were asked to maintain their normal diet and training throughout the study and were required to consume no food or beverages (other than water) during the 2-h period prior to testing. Participants were requested to keep a diary of their food and drink intake during the 48-h period prior to exercise and to replicate this intake prior to each exercise trial. Additionally, participants were asked not to consume alcohol or perform vigorous exercise in the 24-h prior to testing.

All exercise tests were performed on a calibrated, front-access, cycle ergometer (Model EX-10, Repco, Australia) that was interfaced with a computer system for data collection (Cyclemax, UWA, Australia). Before testing, the ergometer was calibrated on a mechanical rig (Western Australia Institute of Sport, Perth, Australia) across a range of power outputs (100–2000 W).

The GXT consisted of an intermittent protocol (1-min rest between stages) performed on the same cycle ergometer described earlier. The test commenced at 70 W, with intensity increased every 3 min by 30 W until the participant could no longer maintain the required power output (volitional exhaustion). Lactate thresholds and $\dot{V}O_{2max}$ were determined from data collected during the GXT. The sum of the four highest consecutive 15-s of oxygen values was recorded as the participant's $\dot{V}O_{2max}$, while the LT was calculated using the modified Dmax method.[11] This is determined by the point on the polynomial regression curve that yields the maximal perpendicular distance to the straight line connecting the first increase in lactate concentration of more than 0.4 mM above the resting level (lactate inflection[12]) and the final lactate point. During the GXT, expired air was continuously analysed for O_2 and CO_2 concentrations using Ametek gas analysers (Applied Electrochemistry, SOV S-3 A/1 and COV CD-3A, Pittsburgh, PA), while ventilation was recorded every 15-s using a turbine ventilometer (Morgan, 225A, Kent, England). The gas analysers were calibrated immediately before and verified after each test using three certified gravimetric gas mixtures (BOC Gases, Chatswood, Australia), while the ventilometer was calibrated pre-exercise and verified post-exercise using a 1 L syringe in accordance with the manufacturer's instructions. Capillary plasma lactate samples were taken at rest and immediately following each 3-min stage of the GXT. Plasma lactate concentrations were determined using a blood-gas analyser (ABL625, Radiometer, Copenhagen), which was regularly calibrated using precision standards.

Participants were then allocated to one of five groups, with each group performing a different experimental trial each