Journal of Science and Medicine in Sport 20 (2017) 1024–1028

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Original research

Effect of a moderate caffeine dose on endurance cycle performance and thermoregulation during prolonged exercise in the heat

Ross E. Beaumont*, Lewis J. James

School of Sport, Exercise and Health Sciences, Loughborough University, UK

ARTICLE INFO

Article history:
Received 9 November 2016
Received in revised form 28 February 2017
Accepted 23 March 2017
Available online 31 March 2017

Keywords:
Stimulants
Supplements
Core temperature
Exercise
Fatigue
Substrate oxidation

ABSTRACT

Objectives: This study investigated the influence of a moderate caffeine dose on endurance cycle performance and thermoregulation during prolonged exercise in high ambient temperature.
Design: Double-blind cross-over study.
Methods: Eight healthy, recreationally active males (mean ± SD; age: 22 ± 1 years; body mass: 71.1 ± 8.5 kg; VO_{2peak}: 55.9 ± 5.8 mL kg^{-1} min^{-1}; W_{max}: 318 ± 37 W) completed one VO_{2peak} test, one familiarisation trial and two experimental trials. After an overnight fast, participants ingested a placebo or a 6 mg kg^{-1} caffeine dose 60 min before exercise. The exercise protocol consisted of 60 min of cycle exercise at 55% W_{max}, followed by a 30 min performance task (total kJ produced) in 30 °C and 50% RH.
Results: Performance was enhanced (Cohen's *d* effect size = 0.22) in the caffeine trial (363.8 ± 47.6 kJ) compared with placebo (353.0 ± 49.0 kJ; p = 0.004). Caffeine did not influence core (p = 0.188) or skin temperature (p = 0.577) during exercise. Circulating prolactin (p = 0.572), cortisol (p = 0.842) and the estimated rates of fat (p = 0.722) and carbohydrate oxidation (p = 0.454) were also similar between trial conditions. Caffeine attenuated perceived exertion during the initial 60 min of exercise (p = 0.033), with no difference in thermal stress across trials (p = 0.911).
Conclusions: Supplementation with 6 mg kg^{-1} caffeine improved endurance cycle performance in a warm environment, without differentially influencing thermoregulation during prolonged exercise at a fixed work-rate versus placebo. Therefore, moderate caffeine doses which typically enhance performance in temperate environmental conditions also appear to benefit endurance performance in the heat.

1. Introduction

Caffeine (1,3,7-trimethylxanthine) is a well-established ergogenic aid commonly consumed by endurance athletes.[1] Intakes of low to moderate doses (3–6 mg kg^{-1}) consistently enhance performance in temperate environmental conditions (~20 °C), especially when exercise is performed for 30 min or longer.[2] Few studies have investigated the ergogenic effects of caffeine in the heat, with some,[3,4] but not all,[5–7] reporting improved performance following caffeine ingestion. Hence, from the limited data available, it is unclear whether caffeine benefits endurance performance in the heat, despite a high prevalence of intake among athletes competing in warm environments.[1]

The progressive impairment in endurance capacity with increasing ambient temperature is well-documented.[8] Several explanations for this deterioration in performance have been proposed, including an increased physiological burden to dissipate heat via the skin and an elevated core temperature.[9] The resulting hyperthermia and increased brain temperature reduce central drive to continue exercise, thus precipitating the onset of fatigue.[10] During prolonged exercise in the heat, caffeine has elicited higher core temperatures than placebo.[5,6,11] Therefore, these perturbations to thermoregulation might explain the lack of performance benefit in the heat after caffeine intake.[5] Interestingly, larger caffeine doses (≥ 9 mg kg^{-1}) consistently induce elevations in core and body temperature during exercise in the heat.[6,11] Hence, the provision of smaller doses (~6 mg kg^{-1}), which typically improve performance in temperate conditions,[2] might prove a more useful strategy to enhance performance in the heat.

Supplementation with 6 mg kg^{-1} caffeine enhanced maximal voluntary contraction of the quadriceps after prolonged cycle exercise in a hot (36 °C) environment.[4] However, during exercise under the same environmental conditions, the same caffeine dose co-administered with carbohydrates elicited a higher core temperature than isolated carbohydrate intake.[12] To date, only two

* Corresponding author.
E-mail addresses: r.e.beaumont@lboro.ac.uk, rossbeaumont86@hotmail.co.uk (R.E. Beaumont).

http://dx.doi.org/10.1016/j.jsams.2017.03.017
1440-2440/

laboratory-based studies have examined the influence of 6 mg kg^{-1} caffeine on endurance cycle performance in the heat without additional carbohydrates.[5,3] Roelands et al.[5] reported no ergogenic effect of caffeine but an increase in core temperature during prolonged exercise at a fixed work-rate, while Ganio et al.[3] observed an improvement in endurance cycle performance but no thermogenic effects. Hence, it is unclear whether moderate caffeine doses influence endurance cycle performance or thermoregulation during prolonged exercise in the heat. Given the widespread intake of caffeine by athletes,[1] it would be of interest to determine whether moderate doses which consistently enhance performance in temperate conditions,[2] also confer performance benefits in the heat.

Consequently, the aim of this study was to examine the performance and thermoregulatory responses to prolonged exercise in the heat following the ingestion of a 6 mg kg^{-1} caffeine dose versus a placebo condition.

2. Methods

Eight healthy, recreationally active, low-caffeine consuming, non-heat acclimated males (116 ± 46 mg day^{-1}; age: 22 ± 1 years; body mass: 71.1 ± 8.5 kg; height: 1.74 ± 0.08 m; VO_{2peak}: 55.9 ± 5.8 mL kg^{-1} min^{-1}; peak power output at VO_{2peak} [W_{max}]: 318 ± 37 W) took part in this investigation, which employed a double-blind, randomised, repeated-measures, cross-over design. Participants provided written informed consent and were free from chronic disease. The experimental protocol was approved by the Ethics Approvals (Human Participants) Sub-Committee of Loughborough University, UK (Ref.: R15-P104).

All participants completed one maximal exercise test, one familiarisation trial and two experimental trials. The initial visit consisted of an incremental exercise test to volitional exhaustion conducted on an electronically braked cycle ergometer (Lode Corival, Groningen, Holland) to determine W_{max} and the power required to elicit 55% and 75% of W_{max}. This test was performed in temperate conditions (~20 °C). After a brief recovery period (15 min), participants completed the performance task used in the familiarisation and experimental trials to practice pacing and control of the ergometer. After 5–7 days, the familiarisation trial was undertaken to ensure that participants became fully accustomed to the procedures employed during the investigation and to minimise any learning or anxiety effects. This trial was performed in environmental conditions maintained at 30 °C and 50% RH and was identical to the experimental trials in all respects, although no treatment was administered.

The familiarisation and experimental trials were separated by 7–10 days to minimise the development of heat acclimation. Additionally, all trials were performed at the same time of day to minimise circadian-type variance. Participants were instructed to record their dietary habits and physical activity patterns during the 24 h before the familiarisation trial and to replicate this in the 24 h preceding each experimental trial. Furthermore, no strenuous exercise or caffeine intake was permitted during this period and participants were provided with a list of commonly consumed caffeinated foods and drinks to help achieve this. On the evening before each trial, participants ingested a radio-telemetry pill (CoreTemp, HQ Inc., Palmetto, Florida, USA) to enable the measurement of core temperature.

Participants arrived at the laboratory in the morning (8–9 a.m.) after an overnight fast (10–12 h) with the exception of ingesting 500 mL of plain water approximately 90 min before arrival. Post-void nude body mass was recorded upon arrival (Adam AFW-120, Milton Keynes, UK) and a heart rate telemetry band (Polar Beat, Kempele, Finland) was positioned. Skin surface thermistors (Grant Squirrel SQ800, Cambridgeshire, UK) were attached to four sites (chest, upper arm, thigh and calf) for the determination of weighted mean skin temperature.[13] Next, an indwelling 21 g cannula was inserted into an antecubital vein to enable repeated blood sampling; this was flushed with a small volume of saline after each sample to ensure patency. After 15 min of seated rest at room temperature (20 °C), a baseline 7 mL venous sample was collected, following which participants ingested a capsule containing either 6 mg kg^{-1} of caffeine (Sigma–Aldrich, UK) or 250 mg of starch (placebo; BDH Ltd, Poole, UK) with 50 mL of plain water. All capsules were indistinguishable with regards to dimension, weight and colour. Participants then remained seated for a further 60 min at room temperature. After 45 min, core and skin temperature and heart rate were recorded at 5 min intervals, with a second 7 mL venous sample collected at 60 min.

Participants then entered the climatic chamber (Weiss-Gallenkamp, UK) maintained at 30 °C and 50% RH and began 60 min of cycle exercise at a workload corresponding to 55% W_{max}. During this period, core and skin temperature and heart rate were recorded every 5 min. Rating of perceived exertion (RPE)[14] and perceived thermal stress (using a 21 point scale ranging from −10, unbearable cold, to +10, unbearable heat) were recorded every 10 min. Expired gas samples (1 min) were collected every 30 min using the Douglas bag method; these values were used to determine the rates of substrate oxidation during exercise.[15] Participants were provided with 150 mL of plain water (temperature: 20 °C) every 15 min and a third 7 mL venous sample was collected at 60 min while participants remained seated on the ergometer.

Subsequently, there was a 2–3 min delay while the ergometer was programmed for the performance task. Participants were instructed to produce as much work (kJ) as possible within 30 min; this method is consistent with previous studies.[6,3] Before starting, all participants were encouraged to produce a maximal effort. The initial workload was set at 75% W_{max}, but participants were free to adjust their power output as desired from the outset. During this period, participants received information regarding time elapsed and cadence, but no other information or verbal encouragement was provided. Core and skin temperature and heart rate were recorded every 5 min. A final 7 mL venous sample was collected immediately after the performance task while participants remained seated on the ergometer. The cannula, telemetry band and skin thermistors were then removed and after a short rest period, nude body mass was recorded after participants towelled dry. The change in body mass, corrected for fluid intake, was used to estimate sweat rate.

All venous samples were collected into dry syringes. A small volume (2 mL) was dispensed into tubes containing K_2EDTA and duplicate 100 μL sub-samples were deproteinised in 0.3 M perchloric acid. These were centrifuged, and the resulting supernatant was used to determine plasma glucose concentrations using a commercially available assay (GOD-PAP, Randox Ltd., UK). Haemoglobin (cyanmethemoglobin method) and haematocrit (microcentrifugation) values were used to estimate percentage changes to blood and plasma volumes relative to the baseline sample.[16] The remaining 5 mL was dispensed into tubes containing clotting activator and left for approximately 1 h prior to centrifugation at 1750 × *g* for 10 min at 4 °C. The resulting serum was stored at −21 °C for the subsequent determination of cortisol and prolactin with ELISA (DRG diagnostic, Germany) and caffeine with reverse-phase HPLC.[17]

All data were analysed using IBM SPSS statistics version 22.0. Normality of distribution was determined using the Shapiro–Wilk test. Exercise performance, pre-exercise body mass, initial core temperature, fasting plasma glucose, and estimated sweat rates were examined using a paired *t*-test. Cohen's *d* effect size (ES) for differences in total work produced during the performance task was determined ([mean 1 − mean 2]/pooled SD) and interpreted as trivial (0–0.19), small (0.2–0.49), medium (0.5–0.79) or large