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Research report

Appetite and gut hormone responses to moderate-intensity continuous exercise versus high-intensity interval exercise, in normoxic and hypoxic conditions ☆

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ABSTRACT

This study investigated the effects of continuous moderate-intensity exercise (MIE) and high-intensity interval exercise (HIIE) in combination with short exposure to hypoxia on appetite and plasma concentrations of acylated ghrelin, peptide YY (PYY), and glucagon-like peptide-1 (GLP-1). Twelve healthy males completed four, 2.6 h trials in a random order: (1) MIE-normoxia, (2) MIE-hypoxia, (3) HIIE-normoxia, and (4) HIIE-hypoxia. Exercise took place in an environmental chamber. During MIE, participants ran for 50 min at 70% of altitude-specific maximal oxygen uptake ($\dot{V}O_{2max}$) and during HIIE performed 6 × 3 min running at 90% $\dot{V}O_{2max}$ interspersed with 6 × 3 min active recovery at 50% $\dot{V}O_{2max}$ with a 7 min warm-up and cool-down at 70% $\dot{V}O_{2max}$ (50 min total). In hypoxic trials, exercise was performed at a simulated altitude of 2980 m (14.5% O_2). Exercise was completed after a standardised breakfast. A second meal standardised to 30% of participants' daily energy requirements was provided 45 min after exercise. Appetite was suppressed more in hypoxia than normoxia during exercise, post-exercise, and for the full 2.6 h trial period (linear mixed modelling, $p < 0.05$). Plasma acylated ghrelin concentrations were lower in hypoxia than normoxia post-exercise and for the full 2.6 h trial period ($p < 0.05$). PYY concentrations were higher in HIIE than MIE under hypoxic conditions during exercise ($p = 0.042$). No differences in GLP-1 were observed between conditions ($p > 0.05$). These findings demonstrate that short exposure to hypoxia causes suppressions in appetite and plasma acylated ghrelin concentrations. Furthermore, appetite responses to exercise do not appear to be influenced by exercise modality.

Introduction

The current obesity epidemic is a major concern since excess weight is associated with morbidity and premature mortality (Bigaard et al., 2004; Canoy et al., 2007). Exercise can play an important role in weight management as it may improve the comorbidities of obesity (Ross et al., 2000) and contribute to a negative energy balance by increasing energy expenditure (Catenacci & Wyatt, 2007). Individuals do not tend to compensate for the energy expended during exercise in the immediate hours after by altering food intake and such energy deficits could be important for weight management if repeated over long periods of time (Schubert, Sabapathy, Leveritt, & Desbrow, 2014). Increasing exercise intensity may increase energy expenditure and evidence suggests high-intensity exercise produces greater short term reductions in appetite compared to moderate-intensity exercise (Deighton, Barry, Connon, & Stensel, 2013; King, Burley, & Blundell, 1994).

One form of exercise training that is receiving more attention in health-enhancing research is high-intensity interval exercise (HIIE),

Abbreviations: PYY, peptide YY; HIIE, high-intensity interval exercise; MIE, moderate-intensity exercise; GLP-1, glucagon-like peptide-1; $\dot{V}O_{2max}$, maximum oxygen uptake; PFC, prospective food consumption; AUC, area under the curve.

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which may reduce cardiometabolic disease risk (Kessler, Sisson, & Short, 2012) and promote similar or even superior physiological adaptations compared to traditional endurance-based training (Gibala, Little, Macdonald, & Hawley, 2012). All-out sprint interval exercise may acutely suppress appetite more than continuous moderate-intensity exercise (MIE) (Deighton et al., 2013), but this form of supramaximal exercise may not be safe, tolerable, or practical for many individuals (Deighton et al., 2013; Gibala et al., 2012). Submaximal HIIE may thus be preferred and recent evidence suggests this form of interval exercise may also acutely suppress appetite and increase the satiating gut hormone, peptide YY (PYY), more than an energy-matched continuous bout of MIE (Deighton, Karra, Batterham, & Stensel, 2013). Bartlett et al. (2011). observed higher levels of enjoyment during a high-volume HIIE protocol that involved 3 min intervals at 90% of maximum oxygen uptake ($\dot{V}O_{2max}$) compared to a continuous MIE session matched for average intensity (70% $\dot{V}O_{2max}$). It would be of interest to explore whether this interval exercise protocol suppresses appetite and affects gut hormone concentrations more than continuous MIE.

A loss of appetite, termed "high altitude anorexia", is often apparent when individuals are exposed to high altitude (>2500 m) (Kayser & Verges, 2013). Reduced energy intake and weight loss are observed in both normobaric and hypobaric hypoxia and studies using hypobaric chambers suggest it is hypoxia, per se, that causes this altitude-related loss of appetite (Westerterp-Plantenga et al., 1999). The role of appetite-regulating hormones in high-altitude anorexia is unclear. The acute and chronic effect of hypoxia on leptin, a hormone released from white adipose tissue that reduces food intake and modulates adiposity, is controversial (Debevec, Simpson, Macdonald, Eiken, & Mekjavic, 2014; Kelly et al., 2010; Snyder, Carr, Deacon, & Johnson, 2008). Acute suppression of appetite and acylated ghrelin (the post-translationally modified form of this gut peptide essential for its appetite-stimulatory effects) was observed during 7 h exposure to normobaric hypoxia, whilst PYY tended to be higher than in normoxic conditions (Wasse, Sunderland, King, Batterham, & Stensel, 2012). The response of the satiating gut hormone, glucagon-like peptide-1 (GLP-1), to hypoxia has only been investigated in one previous study that showed a trend towards increased concentrations following overnight hypoxic exposure (Snyder et al., 2008). The effect of short exposure to hypoxia (i.e. ≤1 h) on appetite and appetite-related hormones has not been studied, nor has the effect of different exercise modalities performed in hypoxia.

This study therefore investigated the effects of continuous MIE versus HIIE in combination with short exposure to hypoxia on appetite and plasma concentrations of acylated ghrelin, PYY, and GLP-1.

Methods

Participants

Following approval from the University of Bedfordshire Ethics Review Board, 12 physically active (≥150 min/wk of moderate-to-vigorous physical activity) and apparently healthy normal-weight men (mean ± SD; age, 21.6 ± 2.0 years; body mass index, 23.5 ± 2.0 kg/m^{-2}) gave written informed consent to participate in the study following a verbal and written explanation of the nature and risks involved. Participants were non-smokers, normotensive, not taking any medications, and had no known history of cardiometabolic disease.

Preliminary tests

Participants attended the University of Bedfordshire Sport and Exercise Science laboratories for preliminary tests to attain anthropometric measures (height and body mass) and determine $\dot{V}O_{2max}$. Height was measured to the nearest 0.1 cm using a stadiometer (Horltain Ltd, Crymych, UK) and body mass to the nearest 0.1 kg using electronic weighing scales (Tanita BWB-800, Tanita Corp., Tokyo, Japan).

Maximum oxygen uptake

$\dot{V}O_{2max}$ was assessed under two blinded conditions: normoxia and hypoxia. Both conditions were generated by a custom built environmental chamber (T.I.S. Services, Hampshire, UK) regulated by a microprocessor control. In addition to the chamber control panel display readings, all environmental conditions were monitored and checked by independent calibrated instruments: temperature and humidity via a Testo 625 hygrometer and oxygen levels via a Kane 250 Gas Meter. Humidity and temperature were controlled at 40% relative humidity and 18 °C, respectively. Hypoxic conditions represented a simulated altitude of 2980 m (14.5% O_2). In both conditions an incremental exercise test was performed on a motorised treadmill (Woodway PPS55 Med-i, GmbH, Germany) with a 0% gradient. Oxygen uptake was measured continuously during exercise using an online gas analysis system (Cortex Metalyzer 3B, GmbH, Germany). The gas analyser used was daily volume- and gas-calibrated and corrected for barometric pressure, temperature, and humidity. Following familiarisation, participants were asked to warm up for 5 min at a velocity they felt they could comfortably maintain for 30 min. The participants then began the test with a 2 min stage at this speed. The speed was then increased by 1 km/h every 2 min until volitional exhaustion. $\dot{V}O_{2max}$ was taken as the highest $\dot{V}O_2$ value averaged over a 10 sec period. Criteria used to confirm a true maximum value included two or more of the following: (1) heart rate within 10 bpm of age predicted maximum, (2) respiratory exchange ratio >1.15, (3) plateau of $\dot{V}O_2$ despite increasing workload, and (4) rating of perceived exertion ≥18 on the Borg scale (Borg, 1982). $\dot{V}O_{2max}$ was significantly higher in normoxia compared to hypoxia (56.0 ± 7.8 vs. 44.0 ± 5.8 mL/kg^{-1}/min^{-1}, respectively, $p < 0.001$).

Main trials

This was a randomised four-way cross-over design study. Participants completed four trials separated by ≥7 days: (1) MIE-normoxia, (2) MIE-hypoxia, (3) HIIE-normoxia, and (4) HIIE-hypoxia. The environmental condition of each trial (normoxic vs. hypoxic) was single blinded. Figure 1 shows the trial protocol. Participants weighed and recorded food intake for 24 h before the first main trial and were asked to replicate the quantity and timings of eating prior to each subsequent testing day and to refrain from alcohol and moderate-to-vigorous physical activity during this time.

Participants arrived at the laboratory between 7am and 8am having fasted for a minimum of 9 h overnight and were weighed in light clothing and no footwear. A breakfast meal was then consumed followed by a 1.75 h rest period. Exercise bouts then commenced at 0 h and participants were informed of the exercise session (MIE or HIIE) that they would be performing upon entering the chamber. The environmental condition remained blinded to the participant during all trials. The chamber replicated those conditions outlined above for the normoxic and hypoxic conditions, respectively. Exercise was performed for 50 min in the environmental chamber with participants seated in a normal laboratory testing room for the remainder of each trial. During MIE, participants ran for 50 min at a speed predicted to elicit 70% $\dot{V}O_{2max}$. HIIE consisted of 6 × 3 min bouts at a running velocity corresponding to 90% $\dot{V}O_{2max}$ interspersed with 6 × 3 min bouts of active recovery at a velocity corresponding to 50% $\dot{V}O_{2max}$, and was preceded by a 7 min warm-up and followed by a 7 min cool-down at a velocity of 70% $\dot{V}O_{2max}$. This protocol thus consisted of 36 min interval exercise and total exercise duration of 50 min. These protocols were selected based on a comparative study in recreationally active males that reported greater levels of perceived enjoyment following HIIE, similar energy expenditure (811 ± 83 and 832 ± 136 kcal for the HIIE and MIE protocols, respectively), and were matched for an average