Title: Interactions of sprint interval exercise and psychological need-support on subsequent food intake among physically inactive men and women

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Abstract

The aim of this study was to investigate the effect of sprint interval exercise (SIT) and psychological need-support in exercise on post-exercise appetite and energy intake. Forty physically inactive men and women (BMI 24.6 ± 4.8 kg·m\(^{-2}\), VO\(_{2}\)peak 26.6 ± 4.9 mL·kg\(^{-1}·\)min\(^{-1}\)) were randomised to either a need-support or no-support condition, with each participant completing two experimental trials involving 30 min of moderate-intensity continuous cycling (MICT; 60% VO\(_{2}\)peak) and SIT (alternating 15 s at 170% VO\(_{2}\)peak and 60 s at 32% VO\(_{2}\)peak) matched for total work. Perceptions of appetite and appetite-related blood variables were assessed, together with ad libitum energy intake for three hours following exercise using a laboratory test meal and available snacks. Greater enjoyment, perceived exertion, heart rate, and blood lactate were observed in SIT compared with MICT (all \(p \leq 0.006\)). Ratings of perceived appetite were similar across conditions and trials (\(p > 0.05\)); however, active ghrelin was lower following SIT compared with MICT (\(p < 0.001\)), and there was a significant condition-by-type interaction for energy intake (\(p = 0.033\)), with participants in the support group consuming less energy from foods following SIT (1895 ± 1040 kJ) than MICT (2475 ± 1192 kJ). Findings from this work highlight the need to reconsider traditional exercise guidelines where dietary intake is a concern.

Novel points:
- Enjoyment was greater during SIT compared with MICT
- Enjoyment and choice were higher among participants provided with psychological need-support
- In a need-supportive environment, SIT reduced subsequent energy intake compared with MICT
Keywords: high-intensity intermittent exercise, appetite, energy intake, compensation, exercise motivation, appetite-regulating hormones

Introduction

It is well-recognised that exercise has numerous benefits for both physical and psychological health (Warburton et al. 2006). However, certain behaviours around exercise—such as ‘unhealthy’ and/or excessive food/drink intake—may counteract some of these benefits. The effect of exercise on eating behaviour appears to be highly variable across individuals and exercise conditions (Beaulieu et al. 2018; Schubert et al. 2013). In particular, energy intake around exercise may be influenced by both the physiological demands and psychological experiences of exercise (Dimmock, et al. 2015; Dorling et al. 2018), but research on the influence of these factors on post-exercise food consumption is still required.

With regards to the physiological demands of exercise, researchers have shown that the type of exercise (i.e., continuous or intermittent) may influence post-exercise food consumption (Alkahtani et al. 2014; Crisp et al. 2012; Sim et al. 2014). Sim et al. (2014), found that very high-intensity intermittent exercise (referred to herein as sprint interval training (SIT), in line with recently proposed definitions (Weston et al. 2014)) resulted in lower energy intake at a post-exercise single-item test meal compared to MICT, of matched overall duration (30 minutes) and total work, in overweight men. This was associated with lower blood concentrations of active ghrelin (high levels of which stimulate hunger). Others have also reported reduced energy intake
following high-intensity intermittent exercise and SIT compared with moderate-intensity continuous exercise (MICT) protocols in overweight/obese men (Alkahtani et al. 2014) and overweight boys (Crisp et al. 2012), although not all research is consistent in this area in healthy, young men (Deighton et al. 2013b). Regardless, little is known about how SIT influences objectively-measured laboratory food consumption beyond the immediate post-exercise meal, given that self-report measures are usually employed following this point. Additionally, whether SIT may also influence an individual’s food choices, remains to be determined given that overall energy intake has predominantly been assessed from a single-item test meal in the aforementioned studies.

In addition to the potential influence of the type of exercise on energy intake, psychological factors associated with different forms of exercise motivation may influence post-exercise food consumption (Beer et al. 2017; West et al. 2017). Briefly, according to Self-Determination Theory (SDT; Deci and Ryan, 1985), autonomous motivation reflects the pursuit of exercise with a sense of personal volition, enjoyment, and/or endorsement, whereas controlled motivation reflects the pursuit of exercise due to the imposition of internal or external pressures. Conceptual and empirical work indicates that controlled (as opposed to autonomous) motivation for exercise may be associated with cognitive and physiological factors that increase the desire for hedonically pleasurable and ‘unhealthy’ foods/drinks (see e.g., Dimmock et al. 2015; West et al. 2017). Within the broad framework of SDT, Ryan and Deci (2000) suggest that individuals have basic psychological needs for autonomy, competence, and relatedness, and that these needs foster psychological well-being and autonomous (higher-quality) motivation. Of note,
researchers have shown that providing a key component of autonomy-support—that of choice—during an acute bout of exercise attenuates post-exercise total and ‘unhealthy’ energy intake (Beer et al. 2017). However, the provision of choice is only one of the many recommended strategies for creating need-supportive exercise conditions, and it is possible that the support of individuals’ basic needs of autonomy, competence, and relatedness (i.e., need-support) may further attenuate the consumption of ‘unhealthy’ foods through the formation of high-quality autonomous motivation. Research is yet to be conducted to determine the effect of a full suite of need-supportive strategies to promote autonomy, competence, and relatedness (for a review see Vansteenkiste and Ryan 2013) in exercise on post-exercise food consumption, appetite, and appetite-related blood metabolites.

While both physiological characteristics and psychological experiences during exercise may influence subsequent appetite and food intake, questions also remain about the possible interaction between these factors in influencing post-exercise food consumption. Accordingly, the aim of this study was to explore the independent and interactive effects of the type of exercise (i.e., SIT relative to MICT) and psychological need-support (through the provision of support for autonomy, competence, and relatedness) on energy intake and food choices during the hours following an exercise session. It was hypothesised that i) there would be a main effect for exercise type, whereby SIT, relative to MICT, would result in reduced total and ‘unhealthy’ energy intake post-session, ii) there would be a main effect for need-support, whereby need-supportive conditions would result in less total and ‘unhealthy’ energy consumed by participants post-exercise compared with those in a no-support condition, and iii) there would be an
interaction between the type of exercise and provision of need-support, whereby SIT combined with need-support would result in the least amount of food consumed, particularly from ‘unhealthy’ sources, post-exercise.

Methods

Participants
An estimated required sample of 36 participants was calculated to provide 80% power to detect a significant difference ($p < 0.05$) in total *ad libitum* energy intake at a post-exercise meal using G*Power* software (Faul et al. 2007) based on the effect size ($d = 0.60$) reported in previous related work (Beer et al. 2017). As such, 40 inactive men and women (men = 10; women = 30), who met inclusion criteria (described below), were recruited for the present study. Individuals were eligible for participation if they were aged between 18 and 40 years, had a body mass index (BMI) of 18.5 - 40, and physically inactive, defined as performing $\leq 75$ minutes of moderate to vigorous physical activity per week. Exclusion criteria were a history of medical conditions such as diabetes, cardiovascular disease, and/or eating disorders known to affect appetite and food intake, a score of $\geq 3.5$ on the restraint scale of the Dutch Eating Behaviour Questionnaire (DEBQ; Van Strien et al. 1986), injury or illness limiting the ability to exercise, current medication which would interfere with appetite, and dietary restriction (e.g., vegan, currently dieting to lose weight, etc.). This study was approved by the Institutional Human Ethics Committee and written consent was obtained from all participants; however, to minimise the potential for biased responses, participants were not informed that their food intake was being assessed in the study. Instead, they were informed that the aim of the study was to investigate the effect of exercise
on psychological and physiological markers of stress in the body, and that food would be provided following exercise given that they were required to arrive in a fasted state and remain in the laboratory for the entire morning. Participants were probed for suspicion by answering the single item “In your own words, please describe the purpose of this study”, which confirmed that no participants suspected the assessment of energy intake. All participants were debriefed as to the true purpose of the study upon completion of data collection.

**Experimental design**

Using a mixed-subjects yoked 2 (need-support vs no need-support) x 2 (SIT vs MICT) factorial design, each participant was required to attend three separate laboratory sessions. The first was an introductory session, which included baseline assessments of motivational orientations towards exercise, current exercise behaviours and preferences, eating habits and food preferences, fitness, and anthropometry (see “Introductory Session” section for further details). Following this session, participants were pair matched based on sex, age (± 5 years), peak oxygen consumption (VO\(_{2}\)\(_{\text{peak}}\); ± 5 mL·kg·min\(^{-1}\)), body mass (± 5 kg), and height (± 10 cm). Participants within each pair were then randomly allocated into either a support or no-support group (between-subjects factor), using a random number generator, and then required to complete two experimental trials at least one week apart (within-subjects factor; SIT vs MICT). The specific order of the trials was chosen by participants in the support condition, in line with the need-support manipulation by providing opportunities of choice which is fundamental to the experience of autonomy (60% of participants in the support condition completed MICT first). The effects of the type of exercise and need-support manipulations on subsequent perceived
appetite, food choices, and overall food intake, together with appetite-regulatory hormones, subjective vitality, and perceived need-support, were assessed. Women were tested in the follicular phase of the menstrual cycle (day 7 ± 3 as determined from onset of menstruation) given the well-established effect of menstrual cycle on appetite and energy intake (Dye and Blundell 1997).

**Introductory session**

Participants completed a series of questionnaires including the Godin Leisure Time Exercise Questionnaire (GLTEQ; Godin and Shephard 1985) to assess current exercise participation, and the Behavioural Regulation in Exercise Questionnaire-3 (BREQ-3; Markland and Tobin 2004) to assess motivational orientation toward exercise. Self-reported motivation for compensatory eating was measured using the 15-item Compensatory Eating Motives Questionnaire (CEMQ; Moshier et al. 2016), and food cravings (specifically the general desire for food) were assessed via the General Food Craving Questionnaire-Trait (GFCI-T; Nijs et al. 2007). Finally, a customised food preference questionnaire was administered to ensure the acceptability of food items provided in the laboratory test meal during the experimental trials. Participants were asked to indicate whether they were allergic to any of the foods and then rate their preference for each item on a seven-point Likert scale anchored at 1 (dislike extremely) and 7 (like extremely). Participants were also asked about their ‘typical breakfast’ and ‘favourite food treats’ to guide what foods would be provided in the experimental trial to ensure that the foods presented were liked by, and familiar to, the participants.
After completion of the baseline questionnaires, VO$_{2\text{peak}}$ was measured using a continuous graded exercise test on a calibrated front-access air-braked cycle ergometer (Model EX-10, Repco Cycle, Huntingdale, Victoria, Australia) interfaced with a customised software program (Cyclemax, School of Human Sciences, University of Western Australia, Perth, Australia). Starting at a workload of 50 W and increasing by 30 W every three minutes for men and 20 W every three minutes for women, participants were required to continue cycling until voluntary exhaustion was reached while heart rate (HR; Polar, Kempele, Finland) and oxygen consumption were monitored (TrueOne 2400, Parvo Medics Inc, Sandy, UT, USA). Individual VO$_{2\text{peak}}$ was determined from the highest minute average during the test. In addition, the power output and volume of oxygen consumption (VO$_2$) data for each test stage were plotted to determine the cycling power output required to elicit the appropriate exercise intensity for the experimental trials. Finally, participants completed 2 min of each exercise protocol for familiarisation purposes.

**Experimental sessions**

Participants arrived at the laboratory at 0800 after a 10-hour overnight fast having been instructed to consume 300 mL of water upon waking. Upon arrival, baseline measures were obtained (for more information, see “Experimental Measures” section). Next, participants completed 30 minutes of either i) MICT, performed on a stationary cycle ergometer at 60% VO$_{2\text{peak}}$ or ii) SIT, alternating high- and low-intensity efforts performed at a ratio of 1:4 (15 seconds at a power output equivalent to 170% VO$_{2\text{peak}}$) with an active recovery period (60 seconds at a power output of 32% VO$_{2\text{peak}}$) between efforts. Total work and mean power output were matched between protocols, and were set at levels that were expected to result in
significant differences in subsequent energy intake (Sim et al. 2014). Need-support was provided to participants randomised to the support group through a number of techniques that have been described previously (see e.g., Edmunds et al. 2011) from arrival until cessation of the exercise. For example, autonomy was supported by providing clear rationales and benefits of the exercise, offering choices where possible (e.g., of the music accompaniment, order of completion of the SIT and MICT trials), inviting questions, and using non-controlling language. Competence was supported by providing clear instructions and demonstrations of the exercise to participants and offering positive, relevant feedback. Relatedness was supported by offering empathy where appropriate, standing with close proximity to participants, and displaying appreciation and concern for participants’ well-being. Autonomy, competence, and relatedness were not intentionally supported in the no-support condition; however, to increase the ecological validity of the study, no attempts were made to purposely undermine participants’ experiences (i.e., participants in the no-support condition received ‘neutral’ exercise conditions).

Immediately following the exercise, a number of assessments were conducted (detailed later), before participants were provided (approximately 20 minutes post-exercise) with a laboratory test meal for 30 minutes. After the test meal, participants remained in the laboratory for an additional 2.5 hours before final assessments were conducted (Figure 1). During this time, participants were allowed to read a book, use their mobile phones, or watch a film. Upon leaving the laboratory, free-living energy intake and physical activity levels were monitored for the remainder of the day.
Experimental measures

Exercise characteristics

The prescribed exercise intensities were confirmed by monitoring cycling power output and total work. Ratings of perceived exertion (RPE; Borg 1982) were collected immediately post-exercise, whereas HR was measured every 5 minutes during exercise.

Perceptions of the exercise task

Participants’ perceptions of the exercise instructor’s need-support were assessed via a 15-item questionnaire developed by Markland and Tobin (2010), containing items assessing autonomy-(e.g., “The exercise instructor provided me with choices and options”) structure/competence-(e.g., “The exercise instructor helped me feel confident about exercise”) and involvement/relatedness-support (e.g., “The exercise instructor cared about me”). Responses were scored on a five-point scale ranging from 0 (not true for me) to 4 (very true for me). A modified version of this questionnaire was also completed by two independent observers, who were blind to the experimental conditions, to confirm that the desired psychological conditions had been achieved. The two observers rated each of the four possible conditions (i.e., SIT with need-support, MICT without need-support, etc.), except in the case of one session where only one observer could be present (7 observations in total). The Intrinsic Motivation Inventory (IMI; Plant and Ryan 1985) was administered immediately post-exercise to assess participants’ perceived enjoyment, choice, and competence of the exercise session using a seven-point response scale anchored at 1 (not true at all) to 7 (very true).
**Appetite and energy intake**

Perceived appetite was assessed using a modified visual analogue scale pre- and post-exercise. This validated scale (Flint et al. 2000) takes the form of two straight lines (100 mm in length each) accompanied by a question anchored with words representing extreme states of hunger and fullness at either end. In order to disguise the purpose of these questions (and possibly alert participants to the measurement of food intake), three ‘filler’ questions were included (e.g., “how stressed do you feel?”).

Energy intake was assessed using a laboratory test meal provided 20 minutes after completing the exercise bout, and over 2.5-hour period following the cessation of this test meal using a range of available snacks (3 hours of monitoring in total). The initial laboratory test meal consisted of products of known and differing macronutrient composition, including an assortment of typical breakfast foods and treats such as bread, spreads, cereal, milk, fruit, muffins, and biscuits. All food provided was weighed before participants’ arrival and re-weighed after consumption. Following the laboratory test meal, and for the remaining 2.5 hours of monitoring, participants had free-access to a number of typical snack items (e.g., fruit, chocolate, salted chips/crisps). These meals were provided and analysed separately in order to explore whether excess and/or unhealthy post-exercise food consumption is likely to occur at the immediate post-exercise meal and/or in the hours that follow. Water was not offered to participants during the exercise; however, a standardised bottle of plain drinking water (~ 1500 mL) was made available during the monitoring period. To determine energy intake, the post-consumption weight was subtracted from the pre-meal weight of each food item. The amount of food consumed (grams) was
multiplied by the number of kilojoules within the product, as specified by the manufacturer’s nutrition facts label, or by FoodWorks software package (FoodWorks v 4.2.0, Xyris Software, Qld, Australia) where nutrition labels were not available. In order to classify foods as ‘healthy’ and ‘unhealthy’, participants rated all of the food provided on a scale anchored at 1 (very unhealthy) to 7 (very healthy). Foods that scored on average below the midpoint of the scale (i.e., 3.5) were classified as ‘unhealthy’ and vice versa for ‘healthy’ foods. Foods that were classified as ‘healthy’ included fruits, low-fat milk, Sanitarium Weetbix breakfast cereal, wholemeal bread, and low-fat breakfast condiments (5.0 ± 1.4), and those considered ‘unhealthy’ included confectionary, muffins, chocolate breakfast biscuits, and Coco Pops breakfast cereal (2.0 ± 0.5).

**Appetite-related blood variables**

Capillary blood was sampled at baseline (pre-exercise) and immediately post-exercise. Blood (500 µl) was collected from a warmed fingertip using a sterile lancet (Unistick 2 Extra; Owen Mumford, Oxford, UK) after warming the entire hand in a box heated with warm air (approximately 55 °C) for five minutes. Whole blood was analysed for glucose (Hemocue glucose 201 RT; Hemocue AB, Ängelholm, Sweden) and lactate (Lactate Pro; Arkray, LT-1710, Kyoto, Japan). The remaining blood was treated with ethylenediaminetetraacetic acid (EDTA; Microtainer tubes with K2E (K2EDTA), BD Microtainer, Franklin Lakes, NJ, USA) and serine protease inhibitor (20 µl per 500 µl of blood; Pefabloc Sc, Roche Diagnostics, NSW, Australia) before being centrifuged at 1020 g for 10 minutes. Plasma obtained was stored at -80 °C and later analysed for pancreatic PP and active ghrelin using a commercially available assay kit (Milliplex Human Gut Hormone Panel; Millipore Corporation, Billerica, MA, USA). The intra-assay coefficient of variation was 5.2% for
ghrelin and 12.0% for PP. These metabolites and peptides were measured based on their potential role in influencing appetite in an exercise setting (Schubert et al. 2014).

**Free-living food Intake and physical activity**

Free-living food consumption was determined via self-report food diaries completed on the day before the experimental trial (to ensure prior dietary consistency) and the remainder of the experimental day upon leaving the laboratory (to examine any differences between conditions). Instructions on the use (including a one-day example) and the necessity for accurate and detailed recordings of food and/or drink intake immediately after consumption were emphasised. The total kilojoules ingested were calculated using a commercially available software program (FoodWorks).

Participants wore an accelerometer (GT3X+ Activity Monitor, ActiGraph, Florida, USA) on the right hip with a log provided to note when the device was positioned and removed. Data were recorded in 60-second epochs. Energy expenditure were determined using the ActiLife software (version 6.9.3, 2014, Florida, USA).

**Statistical analyses**

Statistical analyses were conducted using SPSS version 25 software package for Windows, with statistical significance being accepted at an alpha level of $p < 0.05$. To assess whether the background characteristics of participants randomised to the two groups (between-subjects factor) differed prior to the experimental manipulation, a multivariate analysis of variance
(MANOVA) was conducted to compare age, body mass, height, BMI, \( \text{VO}_2 \text{peak} \), and baseline activity levels (i.e., GLTEQ scores). In a separate MANOVA, self-reported motivation toward exercise (using a relative autonomy index), restrained eating, compensatory eating motives, and food cravings were compared between groups. Physiological responses to exercise (i.e., HR, RPE, mean power, and mechanical work done) were assessed using two-way (need-support x type) MANOVA. Perceptions of the exercise session (i.e., IMI scores and perceived need-support) were assessed using two-way analysis of variance (ANOVA). Perceived appetite and appetite-regulating blood variables were assessed using three-way (need-support x type x time) ANOVA. The effect of exercise type (i.e., SIT or MICT) and need-support on energy intake at the laboratory meal, energy intake from snacks, as well as the intake from ‘healthy’ and ‘unhealthy’ sources, were assessed using two-way (need-support x type) ANOVA. Cohen’s \( d \) effect sizes (\( d \)) were calculated for pairwise comparisons of energy intake.

**Results**

**Participant characteristics**

Participants were well matched between groups (see Table 1), with no significant differences in age, fitness, current physical activity levels, body mass, and height observed, \( F(5, 34) = 0.218, p = 0.952, \eta^2_p = 0.031 \). Likewise, there were no significant between-group differences on self-reported motivation toward exercise, restrained eating, compensatory eating motives, or food cravings, \( F(7, 32) = 0.554, p = 0.787, \eta^2_p = 0.108 \).
**Exercise characteristics**

The descriptive characteristics of the exercise are shown in Table 2. The environmental temperature and humidity in the laboratory were well controlled (21.2 ± 0.3 °C, range: 20.1 – 22.6 and 54.5 ± 5.9 %, respectively), with no significant differences between conditions (p > 0.05).

Likewise, the physical demands of the exercise were matched within each pair (mechanical work done, mean power, HR, RPE), with no effect of need-support, $F(4, 32) = 0.436, p = 0.781, \eta^2_p = 0.052$, or interaction between need-support and exercise type, $F(4, 32) = 2.212, p = 0.090, \eta^2_p = 0.217$. However, there was a significant effect for type, $F(4, 32) = 8.094, p < 0.001, \eta^2_p = 0.503$, with greater HR, $F(1, 35) = 15.566, p = 0.001, \eta^2_p = 0.308$, and RPE, $F(1, 35) = 29.845, p < 0.001, \eta^2_p = 0.460$, recorded during SIT compared with MICT (Table 2).

**Perceptions of the exercise task**

Perceived autonomy-support, structure (competence-support), and involvement (relatedness-support; as rated by participants and the independent observers) is shown in Table 3. Participants’ perceived autonomy-support was higher in the support group compared with the no-support group, $F(1, 38) = 19.369, p < 0.001, \eta^2_p = 0.338$. No significant effects emerged for exercise type, $F(1, 38) = 0.191, p = 0.665, \eta^2_p = 0.005$, or need-support-by-exercise type interaction, $F(1, 38) = 0.000, p = 1.000, \eta^2_p = 0.000$. Structure was not statistically different across sessions with no significant effects observed for exercise type $F(1, 38) = 3.081, p = 0.087, \eta^2_p = 0.075$, need-support, $F(1, 38) = 3.506, p = 0.069, \eta^2_p = 0.084$, or need-support-by-exercise type interaction, $F(1, 38) = 0.000, p = 1.000, \eta^2_p = 0.000$. Perceived involvement did not differ according
to exercise type $F(1, 38) = 0.064, p = 0.802, \eta^2_p = 0.002$, need-support, $F(1, 38) = 0.240, p = 0.603, \eta^2_p = 0.007$, or need-support-by-exercise type interaction, $F(1, 38) = 0.064, p = 0.802, \eta^2_p = 0.002$.

In contrast, the independent observers' ratings of autonomy, $F(1, 3) = 29.950, p = 0.032$, structure, $F(1, 3) = 225.000, p = 0.004$, and involvement, $F(1, 3) = 18.753, p = 0.049$ were all higher for the support group compared with the no-support group (for specific mean comparisons, see Table 3).

Enjoyment scores were higher in SIT compared with MICT, $F(1, 37) = 8.674, p = 0.006, \eta^2_p = 0.190$; and in support compared with no-support, $F(1, 37) = 4.629, p = 0.038, \eta^2_p = 0.111$; however, the interaction was non-significant, $F(1, 37) = 2.336, p = 0.135, \eta^2_p = 2.336$. Perceived choice was higher in the support compared to no-support condition, $F(1, 37) = 4.878, p = 0.033 \eta^2_p = 0.116$, but was similar across SIT and MICT trials, with no effect of exercise type, $F(1, 37) = 0.309, p = 0.582, \eta^2_p = 0.008$, or need-support-by-exercise type interaction, $F(1, 37) = 0.813, p = 0.373, \eta^2_p = 0.021$. Perceived competence was higher in MICT than SIT, $F(1, 37) = 10.693, p = 0.002, \eta^2_p = 0.224$; however, the need-support, $F(1, 37) = 1.651, p = 0.207, \eta^2_p = 0.043$, and need-support-by-exercise type interaction, $F(1, 37) = 1.245, p = 0.272, \eta^2_p = 0.033$, effects were non-significant.

*Appetite and energy intake*

For self-reported hunger, there was a three-way interaction between need-support, exercise type, and time, $F(1, 37) = 6.634, p = 0.014, \eta^2_p = 0.152$. Post-hoc analysis revealed that hunger was significantly higher prior to the SIT trial in the no-support condition, compared with the support condition. There was no main effect of exercise type, $F(1, 37) = 0.117, p = 0.734, \eta^2_p = 0.033$, effects were non-significant.
0.003, and need-support, $F(1, 37) = 3.037, p = 0.076, \eta^2_p = 0.076$; however, there was a main effect of time, $F(1, 37) = 24.784, p < 0.001, \eta^2_p = 0.401$, whereby hunger significantly increased from pre- to post-exercise (Figure 2a). With respect to perceived fullness, there was no three-way interaction between need-support, type, and time, $F(1, 37) = 2.261, p = 0.141, \eta^2_p = 0.058$. Fullness did not differ according to SIT or MICT, $F(1, 37) = 0.019, p = 0.892, \eta^2_p = 0.001$, support or no-support, $F(1, 37) = 2.701, p = 0.109, \eta^2_p = 0.068$, or time, $F(1, 37) = 1.858, p = 0.181, \eta^2_p = 0.048$ (Figure 2b).

Energy intake at the laboratory test meal is presented in Figure 3a. With respect to total energy intake, there were no effects of exercise type, $F(1, 38) = 2.806, p = 0.102, \eta^2_p = 0.069, d = 0.27$, or need-support, $F(1, 38) = 0.040, p = 0.842, \eta^2_p = 0.001, d = 0.09$; however, there was a need-support-by-exercise type interaction, $F(1, 38) = 4.894, p = 0.033, \eta^2_p = 0.114$, such that total energy intake was lower following SIT with support than MICT with support ($d = 0.73$). When intake was considered separately from ‘healthy’ and ‘unhealthy’ sources, consumption from ‘healthy’ foods was similar across conditions and trials, with no significant main effects of exercise type, $F(1, 38) = 0.235, p = 0.630, \eta^2_p = 0.006, d = 0.09$, or need-support, $F(1, 38) = 0.695, p = 0.410, \eta^2_p = 0.018, d = 0.37$, and no need-support-by-type interaction, $F(1, 38) = 1.875, p = 0.179, \eta^2_p = 0.047$. In contrast, consumption of ‘unhealthy’ foods from the laboratory test meal was lower following SIT ($953 \pm 1075 \text{ kJ}$) compared with MICT ($1244 \pm 952 \text{ kJ}$), $F(1, 38) = 6.995, p = 0.012, \eta^2_p = 0.155, d = 0.41$, but did not differ based on need-support, $F(1, 38) = 0.824, p = 0.370, \eta^2_p = 0.021, d = 0.44$, or the type of exercise and need-support interaction, $F(1, 38) = 2.744, p = \ldots$
0.106, \eta^2_p = 0.067. Water consumption was similar between the SIT (207 ± 136 mL) and MICT trials at this time (201 ± 111 mL), \( t(39) = 0.207, p = 0.837. \)

Analysis of total energy intake from snacks (i.e., for the remaining 2.5 hr after the laboratory test meal) revealed no main effect of exercise type, \( F(1, 38) = 1.761, p = 0.192, \eta^2_p = 0.044, d = 0.28, \)
or need-support, \( F(1, 38) = 3.424, p = 0.072, \eta^2_p = 0.083, d = 0.83; \) however, there was a need-support-by-type interaction, such that participants consumed less total energy following SIT without support (500 ± 432 kJ) than MICT without support (783 ± 541 kJ), \( F(1, 38) = 6.531, p = 0.015, \eta^2_p = 0.147, d = 0.82 \) (Figure 3b). When intake was considered separately from ‘healthy’ and ‘unhealthy’ sources, ‘healthy’ energy intake was not different between conditions with no significant effects for exercise type, \( F(1, 38) = 0.400, p = 0.531, \eta^2_p = 0.010, d = 0.20, \)
need-support, \( F(1, 38) = 1.190, p = 0.282, \eta^2_p = 0.030, d = 0.49, \) and need-support-by-type interaction, \( F(1, 38) = 1.571, p = 0.218, \eta^2_p = 0.040. \) With respect to ‘unhealthy’ energy intake, there were no differences between the support and no-support group, \( F(1, 38) = 3.099, p = 0.086, \eta^2_p = 0.075, d = 0.91, \) or SIT and MICT, \( F(1, 38) = 1.580, p = 0.216, \eta^2_p = 0.040, d = 0.41; \) however, the need-support-by-type interaction approached significance, \( F(1, 38) = 3.641, p = 0.064, \eta^2_p = 0.087, \) such that ‘unhealthy’ energy intake in the no-support group tended to be lower following SIT than MICT, \( d = 0.64. \) Water consumption did not differ significantly between SIT (355 ± 273 mL) and MICT trials during the snack period (328 ± 221 mL), \( t(39) = 0.719, p = 0.476. \)
Appetite-related blood variables

Blood lactate and glucose responses to exercise are shown in Table 4. With respect to blood lactate, there was a no interaction between need-support, exercise type, and time, $F(1, 37) = 0.002, p = 0.966, \eta^2_p = 0.000$. However, there was an interaction between exercise type and time, $F(1, 37) = 52.785, p < 0.001, \eta^2_p = 0.588$, such that lactate was significantly higher following SIT compared with MICT, and a main effect for time with higher lactate post- compared with pre-exercise, $F(1, 37) = 122.690, p < 0.001, \eta^2_p = 0.768$. No significant main effect emerged for need-support, $F(1, 37) = 3.426, p = 0.072, \eta^2_p = 0.072$. With respect to glucose, there was no interaction between need-support, exercise type, and time, $F(1, 37) = 0.190, p = 0.666, \eta^2_p = 0.005$. There were also no main effects for exercise type, $F(1, 37) = 2.161, p = 0.150, \eta^2_p = 0.055$, or time, $F(1, 37) = 2.905, p = 0.097, \eta^2_p = 0.073$; however, there was a significant main effect for need-support, $F(1, 37) = 5.328, p = 0.027, \eta^2_p = 0.126$, such that glucose concentrations were higher in the support group compared with no-support group.

There was no interaction between need-support, exercise type, and time, $F(1, 29) = 1.665, p = 0.207, \eta^2_p = 0.054$, for active ghrelin. However, there was a two-way interaction between exercise type and time, $F(1, 29) = 12.039, p = 0.002, \eta^2_p = 0.293$, such that active ghrelin was significantly lower following SIT compared with MICT. Specifically, 31 of 34 participants experienced a decrease in ghrelin following SIT, compared with 23 of 34 participants following MICT. Likewise, there was a main effect of time, $F(1, 29) = 18.662, p < 0.001, \eta^2_p = 0.392$, such that active ghrelin decreased from pre- to post-exercise. No significant main effect emerged for need-support, $F(1, 29) = 1.294, p = 0.265, \eta^2_p = 0.043$. PP remained similar across conditions and trials, with non-
significant main effects observed for exercise type, \(F(1, 14) = 0.197, p = 0.664, \eta^2_p = 0.014\), need-support, \(F(1, 14) = 0.811, p = 0.383, \eta^2_p = 0.014\), and time, \(F(1, 14) = 2.205, p = 0.160, \eta^2_p = 0.136\), as well as a non-significant three-way interaction, \(F(1, 14) = 1.40, p = 0.284, \eta^2_p = 0.08\).

*Free-living food intake and physical activity*

Energy intake during the day before experimental trials was well-matched between exercise trials, with no within-group, \(F(1, 36) = 1.325, p = 0.257, \eta^2_p = 0.035\), or between-group, \(F(1, 36) = 0.418, p = 0.522, \eta^2_p = 0.011\), differences. Free-living energy intake for the remainder of the day upon leaving the laboratory remained similar with no significant main effect for need-support, \(F(1, 30) = 0.271, p = 0.606, \eta^2_p = 0.009\), exercise type, \(F(1, 30) = 0.380, p = 0.542, \eta^2_p = 0.012\), or need-support-by-type interaction \(F(1, 30) = 0.903, p = 0.350, \eta^2_p = 0.029\) (MICT no-support 1383 ± 585 kJ; SIT no-support 1404 ± 660 kJ; MICT support 1220 ± 870 kJ; SIT support 1302 ± 688 kJ).

Data from 30 participants, who provided ≥10 hours of accelerometer data for the remainder of both trial days, were analysed for objectively measured physical activity. Energy expenditure after leaving the laboratory did not differ between trials, with no effect of exercise type, \(F(1, 28) = 0.190, p = 0.667, \eta^2_p = 0.007\), need-support, \(F(1, 28) = 0.313, p = 0.580, \eta^2_p = 0.011\), or type-by-need-support interaction, \(F(1, 28) = 0.067, p = 0.797, \eta^2_p = 0.002\).

**Discussion**

The primary aim of this study was to investigate the main and interactive effects of exercise type and psychological need-support during exercise on subsequent food intake. Specifically, we
investigated the influence of MICT compared with SIT, and did so using conditions which were intended to be supportive or not-supportive of the three basic needs posited in SDT; autonomy, competence, and relatedness (Ryan and Deci 2000). Our hypotheses—that exercise type and need-support would independently influence subsequent energy intake—were partially supported, with consumption of ‘unhealthy’ foods at the laboratory test meal lower following SIT than MICT, independent of need-support. More importantly, however, our third hypothesis—that exercise type and need-support would interact to influence subsequent energy intake—was supported, such that participants consumed less total energy at the laboratory test meal following SIT with need-support, compared to MICT with need-support, and was notably less than all other sessions. Total energy intake from snacks was also lower following SIT compared with MICT with respect to the no-support condition. The attenuated food intake following SIT was associated with greater enjoyment, higher perceived effort, greater concentrations of blood lactate, and lower blood concentrations of active ghrelin post-exercise.

This investigation is the first to consider the issue of post-exercise food compensation from a multidisciplinary approach, with researchers having previously only investigated the effects of the physiological demands and psychological experiences of exercise in isolation (e.g., Beer et al. 2017; Sim et al. 2014). With respect to the effect of exercise type on subsequent energy intake, we observed similar total energy intake between SIT and MICT; however, our finding that SIT resulted in lower consumption of ‘unhealthy’ foods at the laboratory test meal compared with MICT both supports (Sim et al. 2014) and opposes (Deighton et al. 2013b; Martins et al. 2015) previous investigations in which researchers have compared the effects of SIT and MICT on
subsequent total energy intake. A number of methodological differences in both the exercise stimulus studied and the assessment of energy intake may assist with explaining these discrepancies. While the aforementioned studies did not incorporate multi-item test meals comprising of both ‘healthy’ and ‘unhealthy’ foods to assess food choices, Sim and colleagues utilised a sweet test meal, whereas Deighton et al. and Martins et al. utilised savoury test meals. Therefore, these differences may be attributed, at least in part, to the composition of the test meal used. There are studies, however, in which individuals have consumed similar energy from test meals which have incorporated both sweet and savoury items following SIT and MICT (Deighton et al. 2013a); therefore, other factors, such as the exercise characteristics or population studied, may be of relevance. Notably, we utilised the same SIT protocol employed in the study by Sim and colleagues (i.e., 15 s at 170% VO$_{2\text{peak}}$ separated by a 60-second recovery), as opposed to the protocol by Deighton and colleagues (four-minute efforts performed at ~ 85% VO$_{2\text{peak}}$ separated by a two-minute recovery) and Martins and colleagues (8 s all-out sprint followed by 12 s slow pedalling), which together with the aforementioned variables, may also affect subsequent eating behaviour.

Mechanistically, it is possible that the suppression of ‘unhealthy’ energy intake following SIT may have been contributed to by the differences in appetite-regulatory metabolites and peptides which affect overall energy intake. While blood concentrations of PP remained similar across all trials, blood lactate was higher following SIT, which may be of relevance given its potential satiating role in appetite regulation (Schultes et al. 2012). Additionally, lower concentrations of active ghrelin were observed following SIT compared with MICT, which is consistent with
previous work of this nature (Islam et al. 2017; Sim et al. 2014). Although there is no research linking these appetite-regulatory metabolites and peptides with the preferential intake of ‘healthy’ or ‘unhealthy’ foods, there may be a potential for individuals to consume high-energy (in this instance ‘unhealthy’) foods in response to increased active ghrelin concentrations; however, this hypothesis requires further investigation. Interestingly, despite these changes in appetite-regulating metabolites, we saw no differences in ratings of perceived appetite between conditions; however, it is has been shown that feelings of appetite do not always reflect actual food consumption (Mattes, 1990). Regardless, other appetite-related hormones not measured here such as PYY_{3-36} or metabolites such as interleukin-6, which increases in an intensity-dependent manner during exercise, may have contributed to the suppression of energy intake following SIT seen in the current study (Almada et al. 2013).

In addition to the potential influence of the physiological demands associated with SIT on subsequent energy intake, consideration of individuals’ psychological responses to this type of exercise is crucial. Some scholars have argued that this type of exercise (and specifically the high-intensity intervals) may result in reduced pleasure, adherence, and motivation for exercise (Hardcastle et al. 2014). Others have suggested that individuals may experience greater enjoyment of, and preference for SIT over MICT (Stork et al. 2017). The latter argument is supported by results from our study as participants rated SIT as more enjoyable than MICT, despite higher RPE scores and perceived effort, which is in line with other work of this nature (Thum et al. 2017). Given that enjoyment is associated with autonomous motivation (Deci and Ryan 1985), and the accumulating evidence that exercise motivation may influence subsequent
eating behaviour (Beer et al. 2017; West et al. 2017), it is possible that the varied psychological responses to SIT and MICT may have contributed to the lower energy intake from ‘unhealthy’ sources seen following the SIT trial.

Although no previous work has been conducted to examine the effect of supporting individuals’ basic psychological needs of autonomy, competence, and relatedness in exercise on subsequent energy intake, there is evidence that a key component of autonomy support (i.e., choice) during an acute bout of exercise may reduce the consumption of ‘unhealthy’ foods during recovery (Beer et al. 2017). The discrepancy between these findings, and the lack of independent effect of need-support on subsequent food intake in the present study, may be explained by participants’ perceived need-support from the exercise instructor, and in turn, need-satisfaction during the exercise. With respect to participants’ ratings of the instructor’s need-support, autonomy support was rated higher among participants in the support condition; however, structure and involvement remained similar across groups. In contrast, the independent observers’ ratings of autonomy, structure, and involvement during exercise were significantly higher in the support, compared with the no-support, group, indicating that the desired social conditions had been achieved. The differences in ratings by participants and observers may be due to the fact that observers were well-trained in SDT communication techniques, whereas participants may not have been as aware of these behaviours and/or participants may not have accurately separated prior experiences (i.e., recruitment, baseline testing) with the instructor from the experimental trial which they rated. Importantly, our intention was not to undermine participants’ experiences in the no-support condition, but rather provide a ‘neutral’ condition; however, future researchers
could consider whether the results observed here may differ if the psychological conditions of exercise are shaped, such that some individuals’ basic needs are supported, and others are thwarted.

A unique feature of the present study is the consideration of two separate exercise-related factors (i.e., exercise type and psychological need-support) and their interactive effects on subsequent food intake. We observed an interaction of the type of exercise and need-support that supported our third hypothesis, such that SIT attenuated total energy intake at the laboratory test meal, compared with MICT, among participants provided with need-support. This 31% difference in energy intake (580 kJ) may be of clinical significance, given the evidence to suggest that an additional energy intake of 125 kJ·day⁻¹ can lead to a small, consistent degree of energy balance, resulting in continuous gradual weight gain (Hall et al. 2011); however, further research is needed to determine whether the difference seen here is sustained with repeated bouts of this nature. Closer inspection of the composition of this meal revealed that this composition was largely made up of ‘unhealthy’ foods, although this interaction did not reach significance. At this stage it is not clear which mechanism/s may be contributing to these results, given our aim was to identify whether an interaction may exist rather than the processes underpinning this interaction; however, examination of perceived need-support, appetite, and appetite-related blood variables revealed no significant interactions between exercise type and need-support. On the other hand, the significant interaction effect observed between exercise type and need-support may also assist with explaining the discrepancies in findings by previous researchers. Specifically, it is noteworthy that the attenuation of total energy intake following SIT
was only noted in participants provided with need-support, which raises the question of whether prior studies, in which differences in energy intake resulted following SIT and MICT, also provided psychologically need-supportive conditions for participants (albeit not consciously). This certainly highlights the necessity to control or measure psychological factors during exercise which may interact with type of exercise when assessing their influence on subsequent dietary behaviour.

Whilst the direct assessment of food consumption under laboratory conditions did not extend beyond the three-hour period, we are confident that the suppression of energy intake seen following SIT with need-support was not compensated for after leaving the laboratory, given that self-reported food/drink intake for the remainder of the day was similar between conditions. Likewise, the suppression of energy intake was not compensated for by reduced physical activity levels, with similar energy expenditure estimated by accelerometry between conditions upon leaving the laboratory. Other strengths of the study include the variety of foods provided at the laboratory test meal and snacks from both ‘healthy’ and ‘unhealthy’ sources, the pair-matching of participants, and the matched exercise characteristics (duration, mechanical work, and mean power) which allowed us to isolate the effects of exercise type and need-support on subsequent food intake. While the use of a pair-matched, between-subjects design was necessary to investigate the effect of need-support (given that it would not have been possible to isolate the psychological experiences from one session to another using a within-subjects design), this likely also contributed to the difference in baseline hunger and glucose between groups. Additionally, the order of the experimental trials was chosen by participants in the support condition in order to strengthen the need-support manipulation; however, it is possible that participants selected
the exercise condition which they perceived to be more or less effortful, which may in turn have influenced their perceptions of the second session. Future researchers may wish to overcome this potential limitation by randomising the order of the exercise trials.

In summary, we have shown that SIT is associated with reduced subsequent energy intake, particularly from ‘unhealthy’ food sources, when individuals’ autonomy, competence, and relatedness are supported during exercise, compared with traditionally recommended moderate-intensity exercise. This may have implications for a number of preventable lifestyle diseases associated with ‘unhealthy’ and/or excessive eating, such as cardiovascular disease and type-2 diabetes (Parillo and Riccardi 2004). The findings from this work also have implications for exercise prescription and instruction, and highlight the importance of adopting a multidisciplinary approach, particularly when energy balance is of concern.

Acknowledgements

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Conflict of interest

The authors have no conflicts of interest to report.
References


### Tables

Table 1. Descriptive characteristics of participants randomised to the support and no-support exercise conditions (mean ± SD).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Support (n = 20)</th>
<th>No-support (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>24.5 ± 7.2</td>
<td>24.4 ± 6.3</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>72.65 ± 20.55</td>
<td>67.88 ± 15.42</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.9 ± 10.1</td>
<td>167.4 ± 8.2</td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>25.2 ± 5.3</td>
<td>24.1 ± 4.3</td>
</tr>
<tr>
<td>( \dot{V}O_{2\text{peak}} ) (mL·kg·min⁻¹)</td>
<td>26.88 ± 5.29</td>
<td>26.32 ± 4.65</td>
</tr>
<tr>
<td>GLTEQ</td>
<td>19.65 ± 14.39</td>
<td>19.70 ± 15.45</td>
</tr>
<tr>
<td>Dietary restraint</td>
<td>2.39 ± 0.68</td>
<td>2.49 ± 0.81</td>
</tr>
<tr>
<td>CEMQ</td>
<td>2.35 ± 0.39</td>
<td>2.40 ± 0.43</td>
</tr>
<tr>
<td>GFCI-T</td>
<td>5.28 ± 8.02</td>
<td>4.90 ± 5.22</td>
</tr>
</tbody>
</table>

**Motivation for exercise**

<table>
<thead>
<tr>
<th></th>
<th>Support (n = 20)</th>
<th>No-support (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amotivation</td>
<td>0.36 ± 0.46</td>
<td>0.34 ± 0.56</td>
</tr>
<tr>
<td>External regulation</td>
<td>0.93 ± 0.87</td>
<td>0.95 ± 0.89</td>
</tr>
<tr>
<td>Introjected regulation</td>
<td>2.10 ± 1.03</td>
<td>2.03 ± 1.10</td>
</tr>
<tr>
<td>Identified regulation</td>
<td>2.73 ± 0.73</td>
<td>2.58 ± 0.65</td>
</tr>
<tr>
<td>Integrated regulation</td>
<td>1.14 ± 0.78</td>
<td>1.28 ± 0.88</td>
</tr>
<tr>
<td>Intrinsic motivation</td>
<td>1.85 ± 0.94</td>
<td>1.91 ± 0.99</td>
</tr>
</tbody>
</table>

**Note.** BMI, body mass index; CEMQ, Compensatory Eating Motives Questionnaire; GLTEQ, Godin Leisure Time Exercise Questionnaire, where higher scores denote greater leisure time physical activity; GFCI-T, General Food Craving Inventory – Trait. No significant differences were observed between groups on any variable.
Table 2. Characteristics of 30 min of SIT and MICT exercise performed with and without need-support (mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>Support (n = 20)</th>
<th>No-support (n = 20)</th>
<th>Total (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SIT</td>
<td>MICT</td>
<td>SIT</td>
</tr>
<tr>
<td>Mechanical work (j)</td>
<td>158 935 ± 53 239</td>
<td>157 716 ± 61 233</td>
<td>142 155 ± 43 595</td>
</tr>
<tr>
<td>Mean power (W)</td>
<td>89.6 ± 28.8</td>
<td>88.1 ± 33.5</td>
<td>79.0 ± 24.2</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>148 ± 12</td>
<td>136 ± 16</td>
<td>146 ± 13</td>
</tr>
<tr>
<td>RPE</td>
<td>14 ± 1</td>
<td>13 ± 1</td>
<td>14 ± 1</td>
</tr>
</tbody>
</table>

Note. RPE, rating of perceived exertion. * Significantly different to MICT based on a main effect for exercise type (p < 0.01).
Table 3. Subjective exercise experience and perceived need-support during 30 min of SIT and MICT exercise performed with and without need-support (mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>Support (n = 20)</th>
<th>No-support (n = 20)</th>
<th>Independent observer ratings (n = 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SIT</td>
<td>MICT</td>
<td>SIT</td>
</tr>
<tr>
<td><strong>Need-support</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autonomy †</td>
<td>3.75 ± 0.44</td>
<td>3.70 ± 0.57</td>
<td>2.90 ± 0.79</td>
</tr>
<tr>
<td>Structure (competence)</td>
<td>3.90 ± 0.31</td>
<td>3.75 ± 0.44</td>
<td>3.65 ± 0.59</td>
</tr>
<tr>
<td>Involvement (relatedness)</td>
<td>3.75 ± 0.44</td>
<td>3.70 ± 0.57</td>
<td>3.65 ± 0.59</td>
</tr>
<tr>
<td><strong>Need-satisfaction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enjoyment * †</td>
<td>5.05 ± 0.94</td>
<td>4.80 ± 1.20</td>
<td>4.58 ± 1.26</td>
</tr>
<tr>
<td>Choice †</td>
<td>6.50 ± 0.61</td>
<td>6.45 ± 0.69</td>
<td>5.95 ± 0.85</td>
</tr>
<tr>
<td>Competence *</td>
<td>4.00 ± 0.92</td>
<td>4.75 ± 0.91</td>
<td>3.79 ± 1.23</td>
</tr>
</tbody>
</table>

* Significant difference between SIT and MICT based on a main effect for exercise type (p < 0.01); † significant main effect of need-support as rated by participants (p < 0.05); ‡ significant main effect of need-support as rated by independent observers (p < 0.05).
Table 4. Concentrations of appetite-related blood variables in response to 30 minutes of SIT and MICT exercise performed with and without need-support (mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>Support (n = 20)</th>
<th>No-support (n = 20)</th>
<th>Total (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SIT</td>
<td>MICT</td>
<td>SIT</td>
</tr>
<tr>
<td>Blood lactate pre-exercise (mM)</td>
<td>1.0 ± 0.3</td>
<td>1.0 ± 0.3</td>
<td>1.2 ± 0.4</td>
</tr>
<tr>
<td>Blood lactate post-exercise (mM) *</td>
<td>4.9 ± 2.8</td>
<td>1.9 ± 1.0</td>
<td>5.7 ± 2.1</td>
</tr>
<tr>
<td>Blood glucose pre-exercise (mM) †</td>
<td>4.2 ± 0.5</td>
<td>4.2 ± 0.4</td>
<td>4.0 ± 0.4</td>
</tr>
<tr>
<td>Blood glucose post-exercise (mM)</td>
<td>4.5 ± 0.8</td>
<td>4.2 ± 0.6</td>
<td>4.2 ± 0.8</td>
</tr>
<tr>
<td>Active ghrelin pre-exercise (pg/mL)</td>
<td>102.4 ± 70.2</td>
<td>127.3 ± 77.9</td>
<td>129.6 ± 65.5</td>
</tr>
<tr>
<td>Active ghrelin post-exercise (pg/mL) *</td>
<td>58.3 ± 41.0</td>
<td>102.1 ± 42.5</td>
<td>74.3 ± 50.2</td>
</tr>
<tr>
<td>Pancreatic polypeptide pre-exercise (pg/mL)</td>
<td>101.2 ± 36.6</td>
<td>90.2 ± 38.7</td>
<td>153.8 ± 150.3</td>
</tr>
<tr>
<td>Pancreatic polypeptide post-exercise (pg/mL)</td>
<td>119.9 ± 99.0</td>
<td>116.7 ± 99.0</td>
<td>139.8 ± 84.9</td>
</tr>
</tbody>
</table>

* Significantly different to pre-exercise based on a main effect of time (p < 0.001); † significant difference between support and no-support conditions (p < 0.05); ‡ significantly different to MICT post-exercise based on an exercise type-by-time interaction (p < 0.05).
Figure captions

Figure 1. Experimental trial timeline.

Figure 2. Mean (± SE) perceived hunger (a) and fullness (b) following 30 min of SIT and MICT in support and no-support conditions. * Significant difference between SIT and MICT in no-support condition ($p = 0.014$); † significant main effect of time ($p < 0.001$).

Figure 3. Mean (± SE) energy intake at the laboratory test meal (a) and from snacks over 2.5 hrs (b) following 30 min of SIT and MICT under support and no-support conditions. * Significantly different to MICT in the support condition ($p = 0.033$); † significantly different to MICT based on a main effect of exercise type ($p = 0.012$); ‡ significantly different to MICT in the no-support condition ($p = 0.015$).