Original Article

Acute interval exercise intensity does not affect appetite and nutrient preferences in overweight and obese males

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This study investigated the influence of two different intensities of acute interval exercise on food preferences and appetite sensations in overweight and obese men. Twelve overweight/obese males (age=29.0±4.1 years; BMI =29.1±2.4 kg/m^2) completed three exercise sessions: an initial graded exercise test, and two interval cycling sessions: moderate-(MIIT) and high-intensity (HIIT) interval exercise sessions on separate days in a counterbalanced order. The MIIT session involved cycling for 5-minute repetitions of alternate workloads 20% below and 20% above maximal fat oxidation. The HIIT session consisted of cycling for alternate bouts of 15 seconds at 85% VO_{2max} and 15 seconds unloaded recovery. Appetite sensations and food preferences were measured immediately before and after the exercise sessions using the Visual Analogue Scale and the Liking & Wanting experimental procedure. Results indicated that liking significantly increased and wanting significantly decreased in all food categories after both MIIT and HIIT. There were no differences between MIIT and HIIT on the effect on appetite sensations and Liking & Wanting. In conclusion, manipulating the intensity of acute interval exercise did not affect appetite and nutrient preferences.

Key Words: interval exercise, exercise intensity, appetite sensations, nutrient preferences, Liking & Wanting

INTRODUCTION

High-intensity interval training is proposed as a more effective training method for weight management,[1] due to its capacity to increase fat oxidation and decrease waist circumference.[2] For example, aerobic high-intensity interval training (8 seconds cycling at 60% VO_{2max} followed by 12 seconds slow recovery for 20 minutes) significantly decreased abdominal fat to a greater extent than moderate-intensity continuous training among healthy males.[3] Obesity has been implicated in the impairment of skeletal muscle metabolism,[4-6] and the increase in exercise intensity leads to an increase in perceived exertion,[7] particularly among the obese.[8] This in turn could lead to a reward-induced increase in food intake after high-intensity interval training. The compensatory effect of exercise on food intake results in less weight loss than expected. Therefore, high-intensity interval exercise could be viewed as a counterproductive prescription for weight loss.

There is some evidence to suggest that exercise leads to an increase in snack intake,[9] and that exercise promotes a preference for high-fat, sweet foods among some individuals.[10] This sparse evidence is based on studies employing medium term moderate-intensity continuous exercise sessions or acute single bouts of continuous exercise. Metabolic studies showed that the effects of interval and continuous training at the same intensity of training on physiological outcomes are different.[11] The effect of moderate intensity continuous and interval training at the same intensity on eating behaviour could also be different. As high-intensity interval training may have many health benefits,[3,12,13] a key issue is whether high-intensity interval exercise will exert the same effects on food intake and appetite as moderate-intensity interval sessions.

Two studies reported a greater reduction in fat mass after high-intensity interval training compared with moderate-intensity continuous training.[3,14] The difference was attributed to the moderating effects of high-intensity interval exercise on appetite suppression. Recently, Deighton et al[15] reported that an acute bout of energy-matched continuous and high-intensity interval exercise (HIIE) (ten 4-min cycling at 85.8%VO_{2max}, with a 2-min rest) were equally as effective at inducing an energy deficit without an increase in appetite, and that an acute bout of

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Manuscript received 7 August 2013. Initial review completed 3 September 2013. Revision accepted 16 November 2013.
doi: 10.6133/apjcn.2014.23.2.07

endurance exercise resulted in lower appetite perceptions in the hours after exercise than supramaximal sprint interval exercise (six 30-s repeated Wingate tests).[16] While the effect of exercise on appetite sensations is important, it can be argued that its effect on actual food intake is more important. Deighton et al[16] reported a lower relative energy intake after continuous exercise compared with sprint interval exercise, but Sim et al[17] found that sprint interval exercise suppresses subsequent ad-libitum energy intake to a greater extent than moderate-intensity continuous exercise in overweight inactive men. A relatively under-studied area is the effect of exercise on macronutrient intake and food preference. There is evidence to suggest that high-intensity exercise increases fat intake on the day following exercise training compared with moderate-intensity exercise in normal weight adults,[18] whereas prolonged moderate-intensity exercise did not affect macronutrient intake in lean males.[19]

The effects of exercise on food and macronutrient preferences tends to be assessed by retrospectively examining food and nutrient intake from test meal or self-report diary data. A relatively new experimental platform designed to examine taste and nutrient preferences is the Liking & Wanting procedure.[20] The Liking & Wanting test records the responses of individuals to photographic food stimuli which are selected based on the contents of taste (sweet and non-sweet) and fat (high and low). The Liking & Wanting test differentiated between individuals susceptible to acute exercise-induced increased preference for high-fat sweet foods.[10] The impact of exercise intensity on Liking & Wanting has not been tested. Most studies examining the effects of exercise on appetite and food intake use lean participants. This study is novel because it includes the comparison of interval exercise in obese participants. High-intensity interval training is beneficial for the obese in improving several metabolic markers including insulin sensitivity, fat oxidation and abdominal fat loss.[3,12,13] The aim of this study was to compare the effects of matched total work load moderate- and high-intensity interval training (MIIT and HIIT) on appetite sensations and nutrient preferences among overweight/obese men.

METHODS

Participant characteristics

Participants included 12 sedentary overweight/obese men. The characteristics of participants were: age (29±4.1 years), BMI (29.1±2.4 kg/m^2), fat mass (31.7±4.4% body weight) and VO_{2peak} (31.8±5.5 mL/kg/min). Participants were recruited from the staff and student population at the Queensland University of Technology (QUT) and the Brisbane metropolitan region via e-mail and flyers posted on community notice boards. A consent form was signed and the participant was asked to gain medical clearance from a general practitioner prior to undertaking the study. The study protocol was approved by the Human Research Ethics Committee at QUT (HREC No. 0900000338).

All participants were asked to maintain their normal habitual dietary intake between tests, and to replicate their food intake as closely as possible on the day before the exercise tests. Participants were also asked to abstain from strenuous exercise and the consumption of caffeine and alcohol in the previous 24 hours. All tests were undertaken after an overnight fast in an air-conditioned laboratory with the temperature held constant at 21°C.

Experimental design

The experiment was conducted with a counterbalanced measures design, on different days with 5 days apart. Each of the 12 participants completed three exercise sessions on a braked cycle ergometer (Monark Bike E234, Monark Exercise AB, Sweden): a graded exercise test to determine maximal aerobic power (VO_{2max}) and the intensity that elicits maximal fat oxidation (FAT_{max}), and acute bouts of MIIT and HIIT.

The graded cycle ergometry protocol was adapted from a protocol described by Achten et al.[21] The test commenced at 35 W for 4 minutes followed by 4-minutes rest, and workload increased by 17.5 W. The Parvo Medics Analyser Module (TrueOne®2400, Metabolic Measurement System, Parvo Medics, Inc. USA) was used in the measurement of respiratory gas exchange. Calibration of the system was undertaken prior to each test. Five threshold criteria were used to determine if maximal aerobic power was achieved. The main criterion was the plateau in VO_2 in the last stage. The secondary criteria were heart rate (HR) ±10 beats/min relative to age-predicted maximal heart rate (HR_{max}) (220 – age), respiratory exchange ratio (RER) ≥1.10 and the concentration of blood lactate (BLa) ≥8 mmol/L, and volitional fatigue as determined by rating of perceived exertion (RPE) >18.

The mechanical work during the MIIT session consisted of 5-min stages at 20% above the mechanical work of FAT_{max} alternated with 20% below the mechanical work of FAT_{max} (±20% FAT_{max}) for 30-min. The HIIT session consisted of 15-sec high-intensity work at 85% VO_{2peak} and 15-sec low-intensity work at 0 W – unloaded cycling (i.e., unloaded cycling during a 5-min warm-up was 25±4% VO_{2peak}). The researcher adjusted the workloads and informed participants about the change in workload, and when the required durations (i.e., 15 and 45 seconds, and 30 and 60 seconds) were completed. Participants were verbally encouraged and instructed to use the cadence monitor on the handlebar to maintain a cadence of 70 rpm.

Total accumulated workloads at MIIT were determined as follows: workload at high-intensity (+20% FAT_{max}) × 15 min + workload at low-intensity (-20% FAT_{max}) × 15 min. Every minute during HIIT consisted of 30-sec cycling at the workload corresponding to 85% VO_{2peak} and 30-sec unloaded cycling. The workload at 85% VO_{2peak} was halved to calculate the mean workload per minute. The accumulated workload at MIIT was divided by the calculated workload per minute at HIIT to calculate the total time required for the HIIT session.

Measurement of physiological variables and ratings of perceived exertion (RPE) during MIIT and HIIT

Expired breaths were collected and HR was averaged for every 30 seconds automatically via the Parvo Medics Analyser. Data were then exported to an Excel file. Fingertip blood lactate samples were collected at the end of exercise sessions, and RPE using the Borg scale 6-20 was undertaken every five minutes.

Appetite sensations and Liking & Wanting

Subjective appetite sensations were measured using a computerised and validated version of Visual Analogue Scale(VAS).[22] All participants used this procedure immediately before and after each exercise session to record subjective appetite sensations for hunger, desire to eat and fullness.

Liking & Wanting were assessed at the same time as the appetite measure assessment using a computer-based paradigm (E-prime v 1.1.4).[23] This paradigm uses 20 photographic food stimuli varying along two dimensions, fat (high or low) and taste (sweet or non-sweet). The categories of foods were organised either equally into separate generic categories of high-fat (HF), low-fat (LF), non-sweet (NS), and sweet (SW), or combined categories of high-fat non-sweet (HFNS), low-fat non-sweet (LFNS), high-fat sweet (HFSW) and low-fat sweet (LFSW).

Explicit liking - the hedonic impact of each food - was assessed using a 100 unit VAS anchored at each end with "not at all" and "extremely" combined with the statement "How pleasant would it be to experience a mouthful of this food now?" The rating scale was presented on the monitor beneath each food stimulus. Participants used the mouse to move a centred cursor along the line to indicate their response. When a rating had been made, a continue button cycled the program to the next stimulus.

Implicit wanting - the reinforcement of each food category - was assessed by a forced choice methodology. In this task, a food stimulus from each of the four food categories was paired with a stimulus from another category to form one trial in which the subjects were given the standardised instruction to select the food they "would most like to eat now." Each choice, made via key-press on the keyboard, triggers the next pair of stimuli and so on until all possible pairs of combinations (N=150) have been presented. The time taken to select a food (reaction time) is automatically measured in milliseconds (msec). Reaction time of implicit wanting (RT implicit wanting) was used to describe the response of implicit wanting to exercise.

Treatment of data

Data of appetite sensations and Liking & Wanting were calculated and presented as follows:

Delta values: calculated by subtracting the post from the pre-exercise measures during the measurement of appetite sensations and Liking & Wanting.

Pooled means: reflects the average means of four food categories (HFNS, HFSW, LFNS and LFSW) during the measurement of Liking & Wanting.

Statistical analysis

Data were presented as mean values and standard error of mean (SEM), unless otherwise indicated. Mixed model was used to assess the main fixed effects of intensity and duration of exercise with participant identity code as random-effects on the variables of appetite sensations and Liking & Wanting during MIIT and HIIT. Significance was accepted at $p \leq 0.05$. Statistical analyses were carried out with SPSS for Windows (version 18.0.1, 2010, PASW Statistics SPSS, Chicago, IL, USA).

RESULTS

Exercise duration, physiological variables and RPE during MIIT and HIIT

The duration of MIIT (30-min) was constant between participants, whereas the duration of HIIT varied between participants. Table 1 shows exercise duration and workload for the MIIT and HIIT sessions. Table 2 shows the physiological responses and RPE during MIIT and HIIT. RPE was significantly affected by time, $p \leq 0.001$, but there was no significant interaction between intensity and time on RPE, $p=0.80$.

Appetite sensations and Liking & Wanting

There were no significant interactions between intensity and time on appetite sensation variables. The main effect of time on hunger approached significance, $p=0.054$. Figure 1 shows the exercise-induced changes (delta scores) in appetite sensations for both exercise sessions.

Explicit liking increased for all food categories after both exercise sessions. The pooled means of explicit liking during MIIT and HIIT were similar immediately before (43±19.2 millimetre (mm) and 40.6±17.9 mm, respectively) and after (51.7±21.2 mm and 49.2±21.3 mm, respectively) exercise. There was a significant effect of time on explicit liking for all food categories, highest $p<0.001$ except the HFNS foods. The interaction between intensity and time was not significant. Figure 2 shows delta values of pre- and post-measures of explicit liking during the MIIT and HIIT sessions.

There was a significant decrease in RT implicit wanting (i.e. faster reaction time) for all food categories after both intensities of exercise, $p \leq 0.001$ (see Figure 3). The analysis of the effect of time and intensity on nutrient and taste food categories revealed significant effects of time on all food categories, highest $p<0.01$. The pooled means of RT implicit wanting were not significantly different between MIIT and HIIT.

DISCUSSION

We hypothesised that appetite sensation (decreases in hunger and desire to eat, and an increase in fullness) would be significantly lower after HIIT than MIIT, and

Table 1. Exercise durations and mechanical work during MIIT and HIIT. Data represented as Mean±SEM, for 12 participants

	MIIT	HIIT
Total duration of session (min)	30^{***}	18.47±1.25
Actual duration of exercise (min)	30^{***}	9.24±0.54
Total distance (km)	$14.1±0.4^{***}$	8.8±0.8
Upper workload (W)	60±5	$161±6^{***}$
Lower workload (W)	40±5	0 "unloaded cycling"
Mean workload (W)	50±5	$80±6^{***}$
Calculated workload per session (W)	1488±79	1492±152

MIIT: moderate-intensity interval training; HIIT: high-intensity interval training.
*** Significant difference between MIIT and HIIT, $p \leq 0.001$

Liking & Wanting of high fat, sweet foods would be significantly higher after HIIT. The main outcome of this study was that two different intensities of interval exercise exerted similar effects on appetite sensations and Liking & Wanting.

Table 2. Physiological and perceived exertion (RPE) responses to MIIT and HIIT. Data represented as Mean ±SEM for 12 participants

	MIIT	HIIT Average of work/rest
BLa end of session (mmol/L)	1.9±0.1	3.1±0.3***
RPE	11.5±0.4	12.4±0.5
VO_2 (mL/kg/min)	11.1±0.6	15.2±0.6***
$\%VO_{2peak}$	34±3	48±3***
HR (beats/min)	106±2	124±3***

MIIT: moderate-intensity interval training; HIIT: high-intensity interval training; BLa: concentration of blood lactate; RPE: rating of perceived exertion; VO_2: the volume of oxygen consumption; HR: heart rate.
*** Significant difference between MIIT and HIIT, $p \leq 0.001$

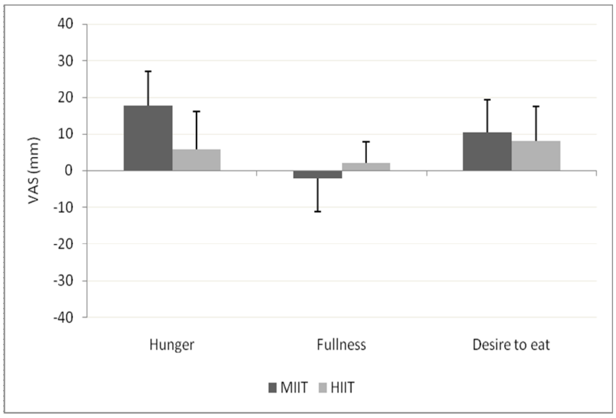

Figure 1. Exercise-induced (delta) changes in appetite sensations for the MIIT and HIIT sessions. Data represented as Mean±SEM for 12 participants. VAS: visual analogue scale; MIIT: moderate-intensity interval training; HIIT: high-intensity interval training.

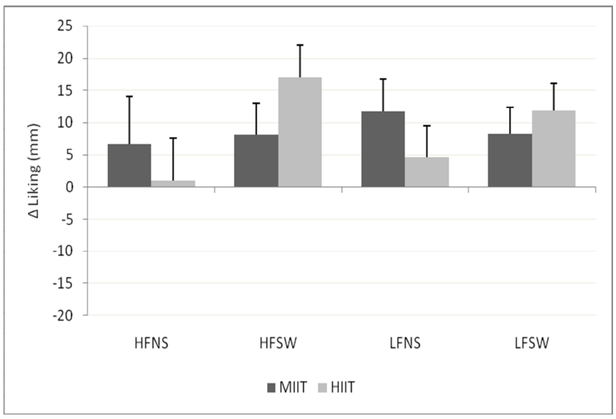

Figure 2. Exercise-induced (delta) changes in explicit liking for the MIIT and HIIT sessions. Data represented as Mean±SEM for 12 participants. MIIT: moderate-intensity interval training; HIIT: high-intensity interval training.

The tendency of suppression of hunger after HIIT was concordant with King et al[19,24] who reported a transitory suppression of hunger after high-intensity exercise. However, the difference between MIIT and HIIT was not significant. The current study of short high-intensity interval exercise (15:15 seconds) at $85\%VO_{2peak}$ is in agreement with Deighton et al[15] who reported that long high-intensity interval exercise(4:2 minutes) at $85.8\%VO_{2max}$ did not increase appetite, in comparison with moderate-intensity continuous exercise. Different protocols and intensities of high-intensity interval exercise resulted in different effects on appetite sensation. For example, a recent study found that an acute bout of endurance exercise resulted in lower appetite perceptions in the hours after exercise than supramaximal sprint interval exercise.[16] Another study compared 60-min of continuous exercise at $50\%VO_{2max}$ with 60-min of interval exercise (30-min at $50\%VO_{2max}$, and 30-min intervals consisted of 1-min at $70\%VO_{2max}$ alternating 3-min at $40\%VO_{2max}$), and found a greater suppression of hunger immediately after interval exercise.[25] It was not clear whether the effect on hunger was due to the interval protocol or the intensity. In conclusion, the manipulation of short-duration (30-min) interval training might not be sufficient to reveal a significant difference between exercise intensities.

Explicit liking increased for all four food categories after exercise, independent of intensity. Finlayson et al[20] reported that explicit liking increased for all food categories in the hungry state and decreased in the satiated state. In a separate study by Finlayson, explicit liking increased after a 50-min exercise and non-exercise period, and decreased after the test meal compared to after exercise and non-exercise.[10] In the present study, RT implicit wanting decreased for all food categories after MIIT and HIIT, similar to Finlayson et al[10] who found that RT implicit wanting decreased for all food categories after acute exercise. These results suggested that the responses of explicit liking and implicit wanting after exercise can be attributed to the effect of time, but this is intuitive because the current study did not include resting control session. Explicit liking and implicit wanting responded to interval exercise in a similar way as to constant-load exercise.

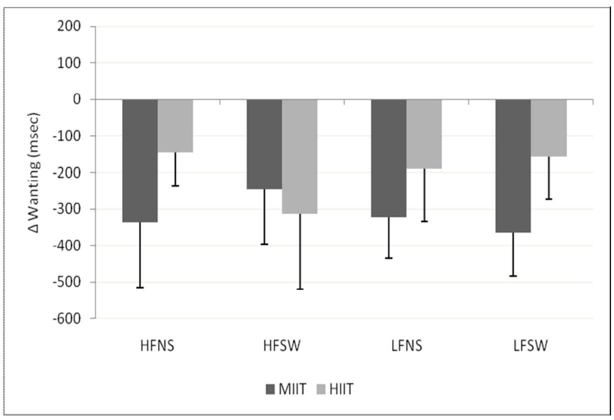

Figure 3. Exercise-induced (delta) changes in RT implicit wanting for the MIIT and HIIT sessions. Data represented as Mean±SEM for 12 participants. MIIT: moderate-intensity interval training; HIIT: high-intensity interval training.

Finlayson et al's study[10] reported that noncompensators, whose relative energy intake was the same or less than exercise-induced EE, showed stable values of RT implicit wanting after 50-min of exercise at 70% HR_{max} whereas compensators showed a greater decrease. The faster reaction time of implicit wanting among the compensators reflected a stronger trigger to increase desire to eat after exercise. In comparison with the present study, the percentage decreases in RT implicit wanting were 13% after HIIT and 20% after MIIT compared with 45% among compensators after 50-min moderate-intensity continuous exercise. Although the current participants showed lower levels of RT implicit wanting compared with the compensators in Finlayson's study, the duration of exercise was different in these three conditions.

Physiological responses were significantly greater during HIIT than MIIT, whereas the responses of RPE were similar. Although implicit wanting is a psychological trigger that is derived from neurotransmission rather than physiological processes,[20,26] it is difficult to uncouple the psychological and physiological effects of exercise on food and nutrient preference. There is evidence to suggest that exercise bouts as short as 15-min significantly attenuate taste craving,[27] whereas 30-min of moderate-intensity exercise increased the perceived palatability of sweet and sour solutions.[28]

The current study concluded that two different intensities of interval exercise exerted similar effects on appetite sensations and Liking & Wanting. HIIT can improve cardiorespiratory fitness and blood glucose greater than steady-state training,[29] and individuals' enjoyment of HIIT is greater than continuous endurance exercise.[30] Giving these potential benefits of HIIT without increasing subsequent hunger, this training dose provides an appropriate weight-loss training option that individuals may engage in and adhere to.

The limitations of this study are that FAT_{max} was very low, such that the level of FAT_{max} was not comparable with other studies in overweight/obese cohorts. In addition, the measurement of eating behaviour was taken immediately after the exercise bouts. It is recommended to conduct the measurements also during the day and before bed time. Although the current measures of eating behaviour are validated, they are subjective. Exercise alters energy regulating hormones and perceived appetite in sex-specific manner, and post-exercise ad libitum food intake is also sex-specific response.[31,32] Studies on the influence of interval training intensity on Liking & Wanting among women and its relation to these seemingly related variables (hormones, appetite and food intake) are warranted. Future studies may investigate the effect of medium-term training of moderate- and high-intensity interval training on appetite sensations and Liking & Wanting. The effect of exercise training on eating behaviour would help to evaluate the appropriateness of such training in weight management.

ACKNOWLEDGEMENTS
This study was funded by Institute of Health and Biomedical Innovation at Queensland University of Technology and University of Dammam. The cost of publication was kindly funded by De'aam Medical Equipment in Saudi Arabia.

AUTHOR DISCLOSURES
There is no conflict of interest.

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间歇性剧烈运动不影响超重和肥胖男性的食欲和营养喜好

本研究探讨了两种不同强度的间歇剧烈运动对超重和肥胖男性食物的喜好和食欲的影响。12 位超重/肥胖男性(年龄为 29.0±4.1 岁，体重指数为 29.1±2.4 kg/m^2)完成了 3 个运动：一个初始分级运动试验，以及两个间歇踩脚踏车运动：在不同日期进行中等强度和高强度间歇运动。中等强度运动期包括交替重复 5 分钟最大脂肪氧化 20%以上和 20%以下的踩脚踏车运动。高强度运动期包括交替 15 秒 85%最大耗氧量和 15 秒卸载恢复的踩脚踏车运动。采用视觉模拟量表和喜欢&需求实验程序，在运动之前和之后立即测量研究对象的食欲和食物偏好。结果表明：中等和高强度运动之后对所有食物类别的喜欢显著增加，而需求显著降低。中等和高强度运动对食欲和喜欢&需求的影响没有差别。总之，调整剧烈间歇运动的强度对食欲和营养喜好没有影响。

关键词：间歇锻炼、运动强度、食欲、营养喜好、喜欢&需求