The acute effects of maximal sprint interval exercise on energy intake and appetite in adolescents

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Conflict of Interest.

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ABSTRACT

Background/Objectives: Imposed bouts of physical activity may alter subsequent energy intake (EI) and appetite in adolescents. The purpose of this study was to investigate the acute effects of maximal sprint interval exercise (MSIE) on EI and ratings of subjective appetite (hunger, fullness and prospective consumption) compared to a sedentary condition (SED) in thirteen boys and thirteen girls (12-13 y). Eating behaviours (emotional, restrained and external eating) were also investigated as potential attributors for the large variability commonly found for compensatory EI.

Subjects/Methods: MSIE comprised of fifteen 10 s maximal sprint cycling exercise each followed by 110 s of active recovery. A homogenised macronutrient composition lunch was offered *ad libitum* and weighed EI was recorded. Subjective appetite was rated throughout the test period.

Results: EI at the lunchtime meal was significantly greater (mean difference 0.56 MJ) following MSIE compared to SED ($P<0.05$) for the boys. There were no significant changes to EI between conditions for the girls. MSIE acutely reduced appetite in boys ($P<0.05$) but not girls ($P>0.05$), however by lunch (1 h post exercise) appetite had recovered for the boys to match that of the SED condition. Measures of eating behaviour did not significantly correlate with EI in either condition.

Conclusions: This is the first study to indicate acute changes to EI and appetite following MSIE in boys, but not girls in a controlled laboratory environment. These findings may suggest the utilisation of sex specific exercise modality prescriptions as a method of appetite and EI control for this age group.

INTRODUCTION

The effect of exercise on subsequent energy intake (EI) and subjective ratings of appetite has been investigated and reviewed in adults[1–4], with limited research conducted within the lean paediatric population[5–7]. Changes to EI and/or appetite following exercise are often attributed to the type of exercise (e.g. running, cycling, swimming or resistance exercise) intervention implemented or to sex differences. Another variable suggested to effect EI is eating behaviours, however this area has received limited focus to date[8] in adults and remains unstudied in children.

Exercise interventions utilised within the lean paediatric population, when assessing the effects of exercise on EI and/or appetite, have been either continuous moderate intensity[5–7,9] or continuous high intensity exercise[5,9,10,11]. Sprint intensity exercise interspersed with periods of low- to moderate-intensity exercise has been suggested as more representative of children's activity patterns under natural conditions[12]. A bout of high intensity interval exercise (HIIE), a mode similar to maximal sprint intensity exercise (MSIE), have only been investigated once within an obese adult male population[13] and once with an obese paediatric male population (8-12 y)[14]. Both indicated EI reductions following HIIE compared to control and no changes for ratings of appetite. Whether lean girls as well as boys also reduce their EI following a bout of MSIE compared to a control condition remain unstudied.

Large individual variability to changes in EI following exercise have previously been reported in adult literature[15,16] and large standard deviations around the mean for EI have been observed within paediatrics[5,10]. Eating behaviours (emotional, restrained and external eating) have been suggested as a measure that may correlate to the variability in EI[8].

The aims of the present study were firstly to examine the acute effects of MSIE on EI and appetite in both boys and girls. Secondly, to understand how eating behaviour impacts EI responses. Therefore we tested the hypothesis that EI will reduce acutely following a bout of MSIE although it will not alter appetite and secondly eating behaviours will correlate to EI variability.

SUBJECTS AND METHODS

Thirteen healthy boys (12.8±0.3 y) and 13 healthy girls (13.1±0.3 y) volunteered to participate in this study. The Institutional Ethics Committee approved the study (ref# 2011/70) and written informed consent was obtained from the parents/guardians and informed assent from adolescents. A brief medical history and food intolerance questionnaire was used to exclude adolescents with a history of metabolic disorders known to affect intermediary metabolism.

Design

The study utilised a within-subjects, randomly assigned design (**Figure 1**). Acute changes in appetite and EI from a lunch-meal were assessed following a period of sedentary activity (SED) or after completing MSIE. Participants

attended the Research Centre in pairs on three occasions (familiarisation and preliminary measurements, SED and MSIE conditions). Wherever possible, testing occurred on the same day of the week and was separated by 7-21 d. Based on the primary outcome variable of EI, a sample size of n=10 was calculated (mu1=4.57, mu2=5.92, σ=1.06, α=0.05 and desired power=0.80)[10]. To account for drop-out we recruited 13 participants.

Body composition

Stature and sitting stature (Seca stadiometer, Seca, Germany) and body weight was measured (Hampel digital scales, Hampel Electronics Co. Taiwan) in light sports clothing and no shoes. Body density was measured by air displacement plethysmography, (BODPOD, Life measurement instruments, Concord, USA) and estimated maturity status was calculated[17]. **Table 1** represents the participants' anthropometric characteristics.

Preliminary visit

Heart rate (HR) monitors were fitted to adolescents before exercise commenced. Participants completed an incremental ramp test to volitional exhaustion for determination of $\dot{V}O_{2peak}$ on a cycle ergometer (Lode Excalibur Sport V2, Lode BV, The Netherlands) using methods described in previous investigations from our laboratory[18]. Before leaving the adolescents were asked to select their breakfast (choice of cereal or toast) and lunch preferences (choice of sandwich fillings) so that acceptable meals could be provided to them on subsequent experimental days. To measure eating behaviour, the adolescents were asked to complete the Dutch Eating Behaviour Questionnaire-Children[19].

122

123 **Testing days**

124 Participants arrived at the laboratory at 0830 h following a 12 h overnight fast.
125 Between 0840 h and 0900 h participants consumed an *ad libitum* breakfast.
126 Intake weight was recorded to standardise breakfast for the subsequent testing
127 day. Breakfast intake was not included in EI calculations as it remained a
128 constant between conditions. Additional standardisation included participants'
129 recall of the dinner meal from the previous night that was recorded and
130 requested to be repeated before the next test visit. This was verbally verified on
131 the subsequent visit.
132 When participants were required to remain sedentary, they chose to read,
133 complete homework, watch DVDs or play computer games.

134 **Exercise day**

135 The exercise started 2 h after breakfast (1050 h) for all participants. The
136 protocol commenced with 5 minutes warm-up, pedalling at 25 W at a self-
137 determined cadence, but actively encouraged to be below 50 rpm, after which
138 the MSIE bout began. The work rate resistance was applied, calculated from 70
139 g·kg body weight (BW)$^{-1}$ for boys and 67 g·kg BW^{-1} for girls for 10 s. Different
140 work rates were selected for each sex, as previous literature has indicated that
141 the force needed to yield the highest mean power differs between the sexes[20]
142 and when the resistance is the same, girls end up working on average 19 %
143 harder than boys[21]. As work rates were different between the sexes, sex
144 comparison analysis was not appropriate. Settings on the electronically braked
145 cycle ergometer allowed the work rate to be added at a rate of 1000 W·s

ensuring a negligible delay in achieving the desired work rate. In the lead up to the sprint, the participants were given a 5 s countdown to gradually increase pedal cadence before the load was added. The adolescents were asked to sprint for the duration of the 10 s and were given verbal encouragement to ensure completion. After each sprint the adolescents reduced pedal cadence (between 30-40 rpm), whilst the power output returned to 25 W for 110 s of active recovery. In total the exercise lasted 40 min and incorporated 5 minutes warm up, 15 sprints and 5 minutes cool down. Between 3 and 5 of these sprints were practiced on the preliminary day so the adolescents understood the procedures of the exercise. Expiration data was collected throughout the MSIE using a respiratory gas system (oxygen consumption ($\dot{V}O_2$) and expired carbon dioxide ($\dot{V}CO_2$); Cortex Metalyzer 3B, Germany and Metasoft v2.1 software). Following the exercise bout participants were offered 250 mL of water. Any water remaining was measured and recorded, to control for any EI or appetite altering effects previously demonstrated[22,23].

Sedentary day

As with the exercise day, the participants performed sedentary activities following breakfast. To mimic water provisions offered on the exercising day, participants were offered 250 mL of water at 1130 h, any water remaining was weighed and recorded. At 1140 h, resting expired air samples were collected through the respiratory gas system for 15 min in a seated position and used to calculate EE at rest[24].

169 **Lunch provisions**

170 The lunchtime meal was offered *ad libitum*, to all participants at 1230 h, (1 h
171 after exercise had concluded). All test meals were prepared by one researcher
172 and consisted of sandwiches (a choice from: cheese and margarine; sausage,
173 margarine and ketchup; chocolate spread; jam and margarine, or peanut butter
174 and margarine) and a plain sponge cake with vanilla frosting. The same
175 selected sandwich was provided for each test visit. Each food item had
176 homogenised macronutrient compositions of 53 % energy from carbohydrate,
177 35 % from fat and 12 % from protein to prevent any effects of macronutrient
178 satiety hierarchy[25] or changes in macronutrient preferences following
179 exercise[26]. The macronutrient composition is similar to the average
180 macronutrient requirement for adolescents of this age group[25]. As the meals
181 were offered *ad libitum,* volumes of food placed on the plate were offered in
182 excess of requirement and were similar to the daily estimated average
183 requirements of energy for adolescents of this age[25]. The boys were offered 6
184 MJ of sandwiches and 4 MJ of cake whilst the girls had 4 MJ of sandwiches and
185 4 MJ of cake. Each food item was cut into bite-sized pieces to disguise the
186 quantity being offered. Such large amounts of food were offered to encourage
187 the adolescents to eat until they felt comfortably full and not when the plate was
188 empty. The adolescents were informed that they were not expected to finish the
189 plates of food however, more could be provided if requested. Water (250 mL)
190 was offered with the lunch meal. Food and water intakes were calculated from
191 subtracting the final plate/glass weight from the initial weight to the nearest 1 g
192 (Air Super Slim Kitchen Scales, Salter, UK). Adolescents were separated from
193 one another for the lunch meal and constantly observed by the researcher who

194 sat between the two rooms. Participants had until 1300 h to finish their meal (30
195 min).

196 **Appetite ratings**

197 At set times throughout the SED and MSIE conditions (0930 h, 1045 h, 1130 h,
198 1200 h, 1230 h and 1300 h) adolescents were asked to rate their hunger,
199 fullness and prospective consumption (desire to eat) on a Visual Analogue
200 Scale (VAS) 100 mm line[5,10].

201 **Calculation of energy expenditure**

202 EE for SED and MSIE was calculated using the $\dot{V}O_2$ and $\dot{V}CO_2$ output from the
203 respiratory gas system expressed as 1 s readings. EE per 1 s was calculated
204 using the respiratory quotient equations by Weir (ref.24) and totalled to give
205 exercising EE from the 40 min bout and resting EE for a 40 min period.

206 **Statistical analysis**

207 Data are presented as mean ± SD unless otherwise stated. EI, EE and water
208 consumption were investigated for boys and girls using Students paired t-test.
209 Appetite from the VAS: (hunger, fullness and prospective consumption) were
210 investigated using mixed model ANOVA (2x6) for condition and time and any
211 interactions for condition*time. Significant findings were further investigated with
212 Bonferroni corrected post hoc tests.
213 Pearson's product moment correlations were performed between eating
214 behaviours and EI for both conditions. The data were analysed using SPSS
215 (version 20, SPSS Inc., Chicago, US). Statistical significance was accepted at
216 $P<0.05$, except for the results from Students paired t-tests where the alpha level
217 was adjusted to $P<0.025$.

RESULTS

Energy intake was significantly higher (P=0.011) following MSIE (4.14±1.04 MJ) compared to SED (3.58±0.87 MJ) for the boys; but there were no significant differences for girls EI (P>0.05) between MSIE (3.30±0.92 MJ) and SED (3.37±0.88 MJ). Energy expenditure was significantly higher (P<0.001) following MSIE (boys: 0.83±0.06 MJ; girls: 0.69±0.10 MJ) compared to SED (boys: 0.23±0.03 MJ; girls: 0.21±0.03 MJ). Water intake was significantly higher (P=0.004) following MSIE (339±122 mL) compared to SED (221±182 mL) for the boys. In contrast, there were no significant differences for girls water intake (P>0.05) between MSIE (260±163 mL) and SED (215±142 mL).

Mean ratings of hunger (**Figure 2**), fullness (**Figure 3**) and prospective consumption (**Figure 4**) are present for both boys and girls.

For the boys a significant effects of time and time*condition were found for hunger ($F_{(2.664,31.967)}$=56.933, P<0.001; $F_{(5,60)}$=3.069, P=0.016) fullness ($F_{(2.485,29.784)}$=56.747, P<0.001; $F_{(5,60)}$=3.447, P=0.008) and prospective consumption ($F_{(3.185,38.219)}$=50.130, P<0.001; $F_{(5,60)}$=3.299, P=0.011). No significant effects between conditions for all 3 appetite scales were found (P>0.05). Post hoc pairwise comparisons indicated boys' felt significantly less hungry and more full following MSIE at time point 1130 h when compared to SED (hunger: P=0.037, mean change 23 mm; fullness: P=0.049, mean change 23 mm). Whereas, for the girls a significant effect of time was found for hunger

242 ($F_{(2.070,24.841)}$=32.186, P<0.001), fullness ($F_{(1.880,22.564)}$=40.524, P<0.001) and
243 prospective consumption ($F_{(1.735,20.824)}$=48.808, P<0.001). Whilst no significant
244 effects between conditions nor interaction effects of time*condition for all 3
245 appetite scales were found (P>0.05).
246
247 **Eating behaviour**
248 Emotional eating was significantly correlated to EI during SED but not MSIE for
249 the girls. There were no other significant correlations for the three eating
250 behaviours to EI following SED or MSIE for either the boys or girls. Results are
251 shown in **Table 2**.
252
253 **DISCUSSION**
254
255 Following MSIE when compared to SED, EI was significantly increased in the
256 boys but no changes were observed for the girls. Therefore, we rejected our
257 hypothesis that EI will reduce acutely following MSIE. There were no significant
258 differences for appetite between conditions for either boys or girls. However, a
259 significant interaction effect for condition and time was found for the boys.
260 Therefore, the hypothesis that there will be no significant changes to appetite
261 between conditions is accepted for girls but rejected for boys. Our second
262 hypothesis was to test whether eating behaviours would correlate to EI.
263 Emotional eating was found to significantly correlate to EI during SED but not
264 MSIE, with girls only. Therefore, we rejected the second hypothesis. The
265 findings from the present study extend the current paediatric literature

surrounding changes to EI and appetite following a previously untested mode of exercise: MSIE. Reporting similar exercise interventions for both sexes are sparsely investigated within the paediatric population and provide novel findings to extend the literature.

Energy intake

Significant increases in EI following MSIE for boys and but no change for girls is not in comparison to previous findings using a similar style of exercise (HIIE) in obese adults[13] and obese children[14], where both studies observed reduction in EI. Methodological differences may explain the variance between the results were either the test meal was initiated 5-10 min after the cessation of the exercise[14] or a post exercise preload (1.1 MJ) had been consumed, prior to measuring EI, 70 mins post exercise[13]. The present study had a 1 h time delay between cessation of exercise and provision of the lunch-meal, as it was deemed more indicative of habitual activity, both in school (where lessons occur following bouts of activity) and outside of the school environment (where travel time between the location of the physical activity and meal location may occur). The adolescent boys may have significantly increased their EI following MSIE based on an exercise-induced increase in hedonic reward following the heavy exertion of performing MSIE. Hedonic reward has been theorised as an increase in the enjoyment of food following exercise despite a suppression in hunger[2]. Application of this theory suggests that hedonic reward maybe higher in boys, as they increased their EI following exercise. Whereas, the girls who were working at a slightly lower intensity may not have experienced the same

hedonic reward therefore did not increase their EI. This theory needs further explorative testing, particularly within the paediatric populations.

Appetite

A significant acute reduction in appetite immediately following the MSIE in boys was not comparable to similar HIIE where no change to appetite were observed[13,14]. However, it is comparable to HIE where suppression of hunger has been observed in lean adults[27–30] and paediatrics[7]. This may suggest the differences observed between the present study and the HIIE studies[13,14], who recruited obese participants, could be attributed to body size.

Mechanisms behind appetite suppression following exercise have been theorised as a redirection of blood flow, away from splanchnic circulation following HIE[31]. As the boys were working at a slightly higher work rate, this may explain why appetite suppressions were observed only in boys following MSIE. Appetite scores for the boys returned to match those of the control condition 60 min post exercise, suggesting the time delay between completion of the exercise and provision of the test meal allowed the blood flow to return towards the splanchnic circulation, thus losing the anorexic effect on appetite. Comprehensive investigations altering the time between exercise cessation and lunch-meal provision have yet to be explored within paediatrics. Suggested future work would examine specific sex changes following work-matched exercise at different intensities within paediatrics.

Water intake

The boys consumed significantly more water following MSIE, whereas there were no significant differences between conditions for girls. There is currently insufficient evidence to clarify the role of water on EI and appetite within the paediatric literature. However, there are some implications within the adult literature that water consumption would increase energy consumption[32], a theory that is comparable to our findings in the boys.

Eating behaviour

Observations of changes in EI from previous work indicate large variability for EI[5,10,15,16]. Similarly, the present study also reported large variability with standard deviations of 25 % of the mean value for EI. Eating behaviours were therefore examined as potential determinant for large inter-subject variability. Only emotional eating was significantly negatively correlated to EI following SED in girls from this work, suggests that the more controlled eating behaviour is by emotion, the lower total EI is likely to be in a sedentary condition. However, this is likely to be a chance finding as no significant correlations were found for emotional eating and EI following MSIE. Investigations as to why such large EI inter-person differences exist between conditions needs further exploration in both the adult and paediatric population as eating behaviour appears not to be an indicator.

Limitations

The present study was an acute highly controlled study, which consequently reduced ecological validity. As studies with paediatric populations are sparse, the aim was to ensure validity of acute measurements, thereby limiting its application to a more ecological, longer duration study with larger participant numbers.

We also acknowledge the limitation of the chosen sedentary activities may themselves alter EI[33]. However, this method of SED activities is commonly used within the paediatric literature and is more representative of habitual activities.

Circulating hormones are suggested to influence appetite and eating behaviour in adults[34]. Therefore, a further limitation to this study was the lack of control for female menstruation. Measuring menstruation was not included within the protocol, as it may have negatively impacted upon recruitment.

Conclusion

MSIE acutely reduced appetite in boys but not girls, however, by the time the lunch meal was administered (1 h post exercise), appetite had recovered in the boys to match the SED condition. EI in the lunchtime meal was significantly greater following MSIE compared to SED in the boys but not girls. Measures of eating behaviour (emotional, external and restrained eating) had no significant impact on EI for either sex. This is the first study to indicate significant sex differences for both EI and appetite in normal weight adolescents following MSIE.

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Figure 1. Experimental design: Participants undertook 2 conditions; maximal sprint intensity exercise (MSIE) and a sedentary condition (SED). VAS * indicates the time points where the appetite Visual Analogue Scales were recorded.

Table 1 - Participant physical and physiological characteristics.

Figure 2 - Mean (±SEM) visual analogue scales (VAS) for subjective feelings of hunger in boys (n=13) and girls (n=13) on sedentary (SED) and maximal sprint interval exercise (MSIE) conditions. Very hungry = 100. , Intervention (i.e. 40 min of exercise or rest); , lunch meal. * Indicates a significant difference at the time point (P>0.05) between conditions.

Figure 3 - Mean (±SEM) visual analogue scales (VAS) for subjective feelings of fullness in boys (n=13) and girls (n=13) in sedentary (SED) and maximal sprint interval exercise (MSIE) conditions. Very full = 100. , Intervention (i.e. 40 min of exercise or rest); , lunch meal. * Indicates a significant difference at the time point (P>0.05) between conditions.

Figure 4 - Mean (±SEM) visual analogue scales (VAS) for expressions of prospective consumption in boys (n=13) and girls (n=13) on sedentary (SED) and maximal sprint interval exercise (MSIE) conditions. Lots and lots = 100. , Intervention (i.e. 40 min of exercise or rest); , lunch meal.

Table 2 - Pearson's correlation coefficients for eating behaviours against energy intake for the maximal sprint interval exercise (MSIE) and sedentary (SED) conditions.