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Effect of exercise duration on subsequent appetite and energy intake in obese adolescent girls

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Abstract

There is a growing interest regarding the effect of exercise on appetite and energy intake in youth. While the role of exercise intensity has been a primary focus of study, the effect of exercise duration on subsequent food intake has not been fully examined in obese adolescents. On three separate mornings in a randomly assigned order, obese adolescent girls (n=20) aged 12-15 years old were asked to perform a rest session (CON) or two cycling sessions for 20 (EX20) or 40 (EX40) minutes set at their ventilatory threshold. Absolute and relative energy intake were measured from an *ad libitum* lunch meal 30 minutes after rest or exercise and appetite feelings assessed using visual analogue scales throughout the day. Hunger, satiety and prospective food

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consumption were not significantly different between conditions. Absolute energy intake (kcal) did not differ between conditions while relative energy intake on EX40 (571±381 kcal) was significantly lower than during CON (702±320 kcal; $p<0.05$) and EX20 (736±457 kcal; $p<0.05$). Fat ingestion (in grams) was significantly lower on CON (7.8±3.2g) compared with EX20 (10.3±4.6g; $p<0.01$). Protein intake (in grams) was higher on EX20 (37.0±16.6g) compared with both CON (29.5±11.7g; $p<0.01$) and EX40 (33.1±10.9g; $p<0.05$). However, the percentage of total energy derived from each macronutrient was not different between conditions. Obese adolescent girls do not compensate for an acute bout of exercise set at their ventilatory threshold by increasing energy intake, regardless of the exercise duration.

Keywords

Exercise; appetite; food intake; pediatric obesity

INTRODUCTION

Pediatric overweight, obesity, and their multiple associated metabolic complications, are a public health concern, and their alarming progression supports the urgent need for new and effective preventive strategies and weight loss programs. As obese children and adolescents are now five times more likely to become obese adults compared to lean children, early interventions are required (Simmonds, Llewellyn, Owen, & Woolacott, 2016). Indeed, 55% of obese children will become obese adolescents, and 80% of these obese adolescents will remain obese once adults (Simmonds, et al., 2016). This is particularly worrying since, as suggested in the model proposed by Blair et al. (Blair, Clark, Cureton, & Powell, 1989), childhood physical activity and health predict later life activity and health. Moreover, physical activity level has a significantly low to moderate stability over time (Telama, 2009), with the time devoted to moderate-to-vigorous physical activity declining with age, coupled with a concomitant increase in sedentary time (Husu et al., 2016). Not only will this decline in physical activity result in lower energy expenditure, recent evidence suggests that it will also favor increased energy intake, contributing to the progression of obesity (Beaulieu, Hopkins, Blundell, & Finlayson, 2016). In this context, the relationships between energy expenditure (EE) and energy intake (EI) are of major interest. Long considered independently, EI and EE have been shown to closely interact suggesting new approaches to control and manipulate energy balance (Blundell, Gibbons, Caudwell, Finlayson, & Hopkins, 2015; Martins, Morgan, Bloom, & Robertson, 2007).

More recently, the relationship between exercise energy expenditure and energy intake has been examined in lean and obese children and adolescents (Schwartz, King, Perreira, Blundell, & Thivel, 2016; Thivel et al., 2016). The available evidence demonstrates the crucial role of exercise intensity, with moderate-to-high-intensity exercises favoring a transient anorexigenic effect in obese children and adolescents (Prado et al., 2015; Thivel et al., 2012). This effect has been attributed to higher post-exercise anorexigenic gastro-peptides concentrations (Prado, et al., 2015) and lower neurocognitive responses to food cues (Fearnbach, Silvert, et al., 2016). However, the potential role of exercise duration on the control of food intake and appetite sensations in children and adolescents has not been studied.

In a study by Moore and collaborators, 9- to 10-year-old healthy weight girls were asked to perform a 40-minute (set at 75% of their maximal aerobic capacities – VO_2peak) or a 60-minute (50% VO_2peak) cycling exercise in the morning (Moore, Dodd, Welsman, & Armstrong, 2004). According to their results, energy intake at the following lunch meal was lower after the longer exercise compared to the 40-minute one, which must be interpreted with caution since the intensities were different (Moore, et al., 2004). Bozinovsky et al. conducted a study specifically designed to test the effect of exercise duration on appetite in 9- to 14-year-old healthy weight boys and girls who ran for 15 or 45 minutes on a treadmill at their individually determined ventilatory threshold (Bozinovski et al., 2009). Their results showed that neither a short nor a longer exercise bout performed at the same intensity modified subsequent food intake in healthy weight children and adolescents, while only the shorter duration attenuated appetite feelings (Bozinovski, et al., 2009). More recently, the same team showed that a 15-minute exercise bout (run at ventilatory threshold) had no effect on subsequent energy consumption in overweight/obese adolescents (Tamam, Bellissimo, Patel, Thomas, & Anderson, 2012). It must be noted that these last two studies used an *ad libitum* pizza –buffet, which might have affected their results due to the high palatability of such food items (Thivel, Duché, & Morio, 2012). Using the same exercise intensity, Prado and collaborators recently suggested that a 30-minute run does not affect energy intake in obese adolescent girls, however they used self-reported food diaries, which could limit their interpretations (Prado, et al., 2015).

Importantly, exploring the effects of acute exercise on subsequent energy intake requires a fine choice and control of the exercise characteristics in terms of intensity, induced-expenditure and duration. For example, while in their work Moore et al. used different durations (40 *versus* 60 minutes), they also used different intensities (75% *versus* 50% VO_2peak) to induce the same expenditure (179 kcal) (Moore, et al., 2004). In our previous work, Thivel et al., asked obese adolescents to cycle at different intensities (40 versus 75% VO_2peak) using different exercise durations (30 *versus* 60 minutes) to induce a similar energy expenditure (334 kcal) (Thivel, Isacco, et al., 2012). Since it has been shown that subsequent absolute food intake was not related to the exercise-induced energy expenditure (Thivel, Aucouturier, Doucet, Saunders, & Chaput, 2013), intensity and duration appear as the main parameters to control. Although the effects of exercise's intensity have been widely studied, less is known concerning duration. Moreover, by calculating Relative Energy Intake (REI = energy intake minus exercise-induced expenditure), the energy expended during exercise can be considered, which provides a better view of the effects of exercise not only on energy intake but on the participants' overall energy balance, which has important implications for weight loss. For instance, Fearnbach and collaborators did not show any effect of an acute 30-minute cycling exercise on absolute energy intake in children at risk for obesity, but they did demonstrate a significantly lower REI following exercise compared with a rest condition (Fearnbach, Masterson, Schlechter, Ross, et al., 2016). Similarly, REI has been found significantly reduced after 45 minutes of cycling (moderate-to-high intensity) in obese adolescents despite unchanged absolute intake (Chaput, Tremblay, et al., 2015).

To help manage weight, it is important to identify exercise characteristics that increase energy expenditure while also helping to reduce energy intake. Therefore, the purpose of this study was to compare two different exercise duration times (20 vs. 40 minutes) on post-exercise energy intake in obese adolescent girls, while holding exercise intensity constant.

MATERIALS AND METHODS

Participants

Twenty obese (according to Cole et al., 2000 (Cole, Bellizzi, Flegal, & Dietz, 2000)) adolescent girls aged 12-15 years old (Tanner stage 3-4) participated in this study. The adolescents were recruited through pediatric consultations (Pediatric Obesity Department, Children Medical Centers, Romagnat, France and UGECAM SSR Nutrition and Obesity Ambulatory Hospital, Clermont-Ferrand, France). To be included in the study, participants had to be free of any medication that could interact with the protocol, could not present any contraindications to physical activity, and had to participate in less than 2 hours of physical activity per week (according to the International Physical Activity Questionnaire –IPAQ). This study has been conducted in accordance with the Helsinki declaration and all the adolescents and their legal representative received information sheets and signed consent forms as requested by the local ethical authorities (CPP Sud Est VI, 2015).

Overview of the study protocol

After a medical inclusion visit conducted by a pediatrician to determine participant eligibility for the study, the adolescent girls were asked to perform a maximal aerobic test and their body composition was assessed by dual-energy X-ray absorptiometry (DXA). The participants then visited the laboratory on 3 occasions (randomly assigned and separated by at least 7 and not more than 10 days): 1) a control session consisting of quiet sitting for 30 minutes (CON); 2) a 20-minute cycling session (EX20); 3) a 40-minute cycling session (EX40). For the 48h preceding each experimental session, the adolescents were asked to refrain from any intensive exercise and to follow the same diet the day before. For each of the 3 visits, participants arrived at the laboratory at 08:00 am after an overnight fast, received a standardized breakfast (08:30) and started one of the three experimental conditions at 11:15am. Heart rates were recorded during the three sessions and perceived exertion assessed after the 20- and 40-minute exercise. Thirty minutes after the end of the experimental conditions, participants were offered an *ad libitum* buffet meal. Appetite feelings were assessed at regular intervals through the day. *Ad libitum* lunch time energy intake (EI) and food preferences were assessed.

Anthropometric and body composition measurements

A digital scale (Seca, Les Mureaux, France) was used to measure body weight to the nearest 0.1 kg, and barefoot standing height was assessed to the nearest 0.1 cm using a wall-mounted stadiometer (Seca, Les Mureaux, France). Body mass index (BMI) was calculated as body weight (kg) divided by height squared (m^2). Fat mass (FM) and fat-free mass (FFM) were assessed using DXA following standardized procedures (QDR4500A scanner, Hologic, Waltham, MA, USA). These measurements were obtained during the preliminary visit by a trained technician.

Aerobic capacity—VO_2peak was measured during a graded exhaustive cycling test that was performed during a preliminary session at least one week prior to the experimental sessions, by a specialized medical investigator from the Department of Sports Medicine, Functional and Respiratory Rehabilitation (Clermont-Ferrand University Hospital). The initial power was set at 30 W for three minutes and followed by 15 W increments every 1.5 minutes. Adolescents were strongly encouraged by experimenters throughout the test to perform a maximum effort. Criteria for reaching VO_2peak were subjective exhaustion, with heart rate above 195 beats.min^{-1} and/or respiratory exchange ratio (RER= VCO_2/VO_2) above 1.02 and/or a plateau of VO_2 (Rowland, 1996). An electromagnetically-braked cycle ergometer (Ergoline, Bitz, Germany) was used to perform the test. VO_2 and VCO_2 were measured breath-by-breath through a mask connected to O_2 and CO_2 analyzers (Oxycon Pro-Delta, Jaeger, Hoechberg, Germany). Calibration of gas analysers was performed with commercial gases of known concentration. Ventilatory parameters were averaged every 30 seconds. ECG was monitored for the duration of the test. The first ventilatory threshold (VT) was determined graphically as an increase in VE/VO_2 without concomitant increase in VE/VCO_2 according to Wasserman's method by two experienced operators in charge of the test (Wasserman, Stringer, Casaburi, Koike, & Cooper, 1994).

Description of the experimental sessions

Control session (CON): from 11:15 am to 11:45 am, the participants remained seated on a comfortable chair (30 minutes). They were not allowed to talk, read, watch TV or to complete any intellectual tasks.

Exercises conditions

i. *20-minute cycling exercise session (EX20):* from 11:15 am to 11:35 am, the participants were asked to cycle at their individually determined first ventilatory threshold. The intensity (ventilatory threshold) is commonly used among obese adolescents who present a relatively low physical fitness (especially those with a high degree of obesity). This choice is also consistent with the recent literature using a similar intensity (Bozinovski, et al., 2009; Prado, et al., 2015; Tamam, et al., 2012). The intensity was controlled using heart rate records and the workload imposed to the ergocycle (using the results from the maximal aerobic capacity testing). The participants were asked to rate their perceived exertion (Williams, Eston, & Furlog, 1994) by the end of the exercise.

ii. *40-minute cycling exercise session (EX40):* this session is similar to EX20 except that the adolescents were asked to cycle at their individually determined first ventilatory threshold from 11:15 am to 11:55 am.

The energy expended (EE) during the 3 conditions (30 minutes rest and the two exercises) was estimated using the heart rate records (Polar technology monitors) based on the linear relationship between heart rate and energy expenditure obtained during the maximal aerobic capacity testing (Astrand, 1960).

Perceived exertion

After both exercise sessions (EX20 and EX40), the adolescents were asked to rate their perceived exertion using the Children's Effort Rating Table (CERT) from Williams et al. (Williams, et al., 1994). This scale uses a range of items from 1 to 10, the number 1 corresponding to an extremely easy exercise, while 10 indicates an effort leading the subject to stop the test due to difficulty.

Energy intake assessment

At 8:30 am, a standardized breakfast similar to the adolescents' usual breakfast habits (composed of one dairy product, bread, and one fruit or fruit juice, same composition and caloric content as previously detailed (Thivel et al., 2011)) and meeting the nutritional recommendations was offered. Thirty minutes after the end of the experimental session, an individually tailored *ad libitum* lunch was offered to the participants based on the taste preferences, determined by a food questionnaire completed prior to the experimental sessions (i.e., during the preliminary visit). Top rated items were avoided to limit overconsumption, as generally seen in *ad libitum* feeding experiments with adolescents (Thivel, Genin, Mathieu, Pereira, & Metz, 2016). The buffet offered to each participant was identical for the 3 experimental sessions, and they were told to eat until satisfied. Additional food was provided if desired. Briefly, the buffet contained at least two choices of each dish (e.g., green salads, and tomato salads, mashed potatoes, pasta, beef, chicken, different cheeses, yogurts, compote, and a variety of fruits were the most commonly served food items). Food consumption was weighed and recorded by investigators (Bilnut 4.0 SCDA Nutrisoft software, France) to calculate total energy intake during lunch. The proportion of the total energy intake derived from fat, carbohydrate and protein was calculated using the same nutritional software. *Ad libitum* lunch meal methodology and spontaneous energy intake assessment have previously been detailed (Thivel, Genin, et al., 2016). Relative energy intake (REI) was then calculated as energy intake (EI) minus energy expenditure (EE) (REI = EI-EE) for each condition.

Subjective appetite sensations

At regular intervals throughout the day from 8:00 am, participants were asked to rate their hunger, fullness, and prospective food consumption using visual analogue scales (VAS of 100 mm) whose reliability has been previously reported (Flint, Raben, Blundell, & Astrup, 2000). Participants filled in VAS before and after breakfast, before and after rest/exercises, and before and after lunch. This method has previously been used among obese adolescents to evaluate appetite feelings (Bozinovski, et al., 2009; Prado, et al., 2015; Thivel, Isacco, et al., 2012).

Statistical analysis

Statistical analyses were performed using Statview 5.0 (SAS Institute, NC, USA). Results are expressed as mean (standard deviation). According to the EI variability reported in the available literature for obese adolescents (standard deviation = 6.5% (Thivel, Isacco, et al., 2012)) it appears that 17 subjects would allow to underline a minimal difference equal to 6.5% of EI (i.e. effect size at 1) for a two-tailed type one error at 1.7% (inflate due to multiple comparison), statistical power at 90% and intra-subject correlation coefficient at 0.5. Finally, 20 subjects were enrolled considering possible drop out. The distribution of the data was tested using the Smirnov-Kolmogorov test and data did not require any transformation prior to analysis. ANOVA with repeated measures were used to compare between the 3 experimental sessions (CON; EX20; EX40): absolute EI; REI; absolute fat, carbohydrate, and protein intake; percentage of energy ingested from fat, carbohydrate, and protein; energy expenditure; appetite feelings Area Under the Curve (hunger, satiety, prospective food consumption, and desire to eat). When appropriate (omnibus $p<0.05$) post-hoc tests for multiple comparisons (Bonferroni) were applied. Finally, correlations were performed between the participants' perceived exertion, FM percentage, FFM (kg), session-induced energy expenditure and the *ad libitum* EI difference between: i) the exercise sessions and the control session (EI EX20 – EI CON and EI EX40 – EI CON). The level of significance was set at $p<0.05$.

RESULTS

The 20 obese adolescent girls had a mean age of 13.3 ± 1.0 years and a BMI of 31.6 ± 3.9 kg/m^2. Mean body weight was 85.9 ± 13.2 kg, mean FM percentage was 38.6 ± 3.2%, and mean FFM was 49.4 ± 7.7 kg.

The sample presented a mean VO_2peak of 2.2 ± 0.3 $L.min^{-1}$ and a first ventilatory threshold of 1.2 ± 0.2 $L.min^{-1}$, corresponding to 54.1 ± 5.4% of VO_2peak. The mean heart rate during exercise was 107 ± 10 bpm. The EE during EX40 (235 ± 44 kcal) was significantly higher compared with CON (35 ± 2 kcal) and EX20 (117 ± 22 kcal); EE during EX20 was also significantly higher than CON ($p<0.001$), as detailed in Table 1. The adolescents rate of perceived exertion was not statistically different between EX40 (6 ± 2) and EX20 (5 ± 2).

As detailed in Table 1, absolute EI did not differ significantly between conditions ($p>0.05$) while the ANOVA analysis revealed significant differences for REI ($p<0.05$). REI-EX40 (571 ± 381 kcal) was significantly lower than REI-CON (702 ± 320 kcal; $p<0.05$) and REI-EX20 (736 ± 457 kcal; $p<0.05$). Although REI-EX20 trended higher than REI-CON, this did not reach the level of significance (Figure 1). As illustrated by the Figure 2, overall hunger, satiety, and prospective food consumption were not significantly different between conditions (using area under the curve).

There was no difference between conditions regarding the energy consumed derived from each macronutrient (% of the total EI). There was no significant difference between conditions regarding the ingestion of carbohydrate expressed in grams. However, the absolute ingestion of fat (grams) was significantly lower on CON (7.8 ± 3.2 g) compared with EX20 (10.3 ± 4.6 g) condition ($p<0.01$). The absolute consumption of protein (grams) was significantly higher on EX20 (37.0 ± 16.6 g) compared with both CON (29.5 ± 11.7 g; $p<0.01$) and EX40 (33.1 ± 10.9 g; $p<0.05$). Table 2 presents the results for both absolute and relative macronutrient intake during each condition.

No significant correlation was found between energy intake (absolute, REI, EI EX40 – EI CON, or EI EX20 – EI CON) and FM percentage, FFM kg or the perceived exertion induced by either exercise bout.

DISCUSSION

The aim of the present study was to compare two imposed acute exercises of different duration (20 *versus* 40 minutes) on subsequent EI and appetite feelings in obese adolescent girls. Our results show for the first time that 12-15 years old obese girls do not compensate for an acute cycling exercise set at their ventilatory threshold by increasing their absolute *ad libitum* energy intake, regardless of the exercise duration. Interestingly, 40 but not 20 minutes of cycling (both performed at the same intensity) was able to reduce their relative EI.

Although Moore et al. previously showed that a 60-minute exercise was able to reduce subsequent absolute EI compare to a 40-minute bout in lean children (9-10 years old), the two proposed exercises were not performed at the same intensity (50% versus 75% VO_2peak, respectively) (Moore, et al., 2004). Our results are in accordance with those from Bozinovski and collaborators, who found unchanged absolute EI in response to either 15 or 45 minutes of running (both performed at the ventilatory threshold, as in the present work) in healthy weight adolescents boys and girls (Bozinovski, et al., 2009). As previously mentioned, these later results must be considered with caution since EI was assessed using an *ad libitum* pizza buffet, and the palatability and lack of item choices might have influenced the results (Thivel, Duché, et al., 2012). Following the design proposed by Bozinovski et al. (exercise intensity and buffet type), Tamam and colleagues also did not observe any food intake modification after a 15-minute run in a sample of obese adolescents (Tamam, et al., 2012). Also using the ventilatory threshold to set the exercise intensity, Prado et al. suggested that obese adolescent girls would decrease their 24-hr food consumption after a 30-minute run, but their study utilized self-reported food intake diaries (Prado, et al., 2015) limiting then the accuracy of the assessment (Schwartz & Thivel, 2015). According to the available literature, the present work seems then to be the first to be properly designed to test the effect of exercise duration on subsequent food intake in obese adolescents.

Although previous studies have shown in obese adolescent boys and girls (Fearnbach, Silvert, et al., 2016; Thivel, Isacco, et al., 2012; Thivel, et al., 2011) that an acute bout of exercise was able to induce a transient anorexigneic effect by decreasing subsequent food intake, this was only after moderate-to-high intensity exercises, which may explain the present divergent results. Indeed, the two exercise bouts proposed here were set at the individually determined ventilatory threshold, representing about 54.1 ± 5.4 % of VO_2peak, which is certainly not intensive enough to observe such effects.

Few studies have been so far methodologically designed to assess relative EI in youth. Recently, Fearnbach and collaborators showed that while a 30-minute cycling exercise (set at 70% VO_2peak) did not affect subsequent absolute EI in children at risk for obesity, relative EI was significantly lower compared with a rest condition (Fearnbach, Masterson, Schlechter, Ross, et al., 2016). REI was also significantly reduced after 45 minutes of cycling at moderate-to-high intensity in both lean and obese adolescents despite unchanged absolute food consumption in the obese sample (Chaput, Tremblay, et al., 2015). The present results interestingly point out that only the EX40 condition was able to induce a significantly lower REI compared with both CON and EX20. Although not significant, the 20-minute exercise induced a slight food intake increase at the following meal, which removed any effect on REI despite significantly higher energy expenditure. In their work, Bozinovski et al. showed that REI was significantly lower after both short- and long-exercise without any exercise duration effect (Bozinovski, et al., 2009). Although this discrepancy between our results might be related to the weight status of the participants (lean versus obese), the previously detailed methodological issues (palatability of the test meal and lack of food choice) must be considered.

Although few studies so far report post-exercise macronutrient intake differences in children and adolescents, the present results are in line with previously published studies in similar populations (Chaput, Schwartz, et al., 2015; Chaput, Tremblay, et al., 2015; Fearnbach, Silvert, et al., 2016). Studies conducted among obese adolescents have also not found any differences between their exercise and control sessions in terms of energy derived from fat, carbohydrates, and proteins (Chaput, Schwartz, et al., 2015; Chaput, Tremblay, et al., 2015; Fearnbach, Silvert, et al., 2016). Interestingly, when expressed in absolute (grams), protein intake is significantly increased after both the 40- and 20-minute exercise bouts in the present work, while fat ingestion is increased after EX20 only. A few previous studies found similar increased absolute fat and protein intake after moderate intensity exercises among both 9- to 12-year-old children at risk for obesity (Fearnbach, Masterson, Schlechter, Ross, et al., 2016) and obese adolescents (Thivel et al., 2013). These results remain difficult to discuss due to the lack of available evidence, and further studies are need to better understand any potential cognitive or physiological mechanisms that could explain these effects of exercise on subsequent macronutrient preferences.

The unchanged appetite feelings (hunger, satiety, and prospective food consumption) observed in the present work are in line with most of the previous studies that observed unchanged feelings despite modifications of the participants' effective energy intake, reinforcing the potential uncoupling effect of acute exercise on subsequent food consumption and appetite sensations in children and adolescents (for review see Thivel & Chaput, 2014 (Thivel & Chaput, 2014)) as well as adults (Hubert, King, & Blundell, 1998).

While there is a growing interest regarding the role of body composition on post-exercise food intake responses, the literature remains quite limited. Recently, Fearnbach et al. showed a positive relationship between body mass, BMI, FFM (but not FM percentage) and the energy consumed by children at risk for obesity after a 30-minute cycling exercise set at 70% of their individual aerobic capacities (Fearnbach, Masterson, Schlechter, Loken, et al., 2016; Fearnbach, Masterson, Schlechter, Ross, et al., 2016). In the present work, neither FFM nor FM percentage assessed by DXA have been found related to post-exercise intake, regardless of the exercise duration. This lack of relationship might be explained by the low-to-moderate exercise intensity (based on the adolescents' individual ventilatory threshold as previously detailed) while both studies from Fearnbach and collaborators used more intensive exercises. The relatively lower exercise intensity used in the present work can also explain the lack of relationship between the adolescents' perceived exertion and subsequent food intake. RPE was not different between EX20 and EX40, and illustrated the low difficulty imposed by both exercises with ratings of 5±2 and 6 ± 2, respectively.

Although this work seems to be the first to be especially designed to compare the effect of short- and longer-duration exercises set at the same intensity on subsequent energy intake in adolescents with obesity, some limitations have to be considered. Caution must be used when interpreting and extrapolating laboratory-based studies into free-living environment, even if the exercise used in the present work is similar to what is usually prescribed to obese adolescents as part of their physical activity program. Similarly, the laboratory setting might have impacted the adolescents' energy intake as compared with free-living conditions. Finally, the dietary status of the adolescents (restrained/unrestrained for instance) was not assessed in the present study, which might influence such results.

To conclude, obese adolescent girls do not compensate for an acute bout of exercise set at their ventilatory threshold by significantly increasing their absolute energy intake, regardless of the exercise duration. Longer exercise duration was effective in reducing their relative energy intake, without altering their appetite feelings. Our Figure 3 however clearly highlights the need for more research examining the inter-individual variability when it comes to post-exercise energy intake, suggesting that some individuals might be more prone to modify (increase or decrease) their energy intake after acute exercise compared to others. Importantly, the present results effectively suggest that compared to longer exercises, a short 20-minute cycling exercise might have negative effects on energy balance by favoring a rise in subsequent energy intake that overcomes the energy expended during exercise, resulting in a slightly higher relative energy intake compared to rest. Based on these results, practitioners implementing medium intensity exercises (like ventilatrory threshold) should be encouraged to use longer exercise durations in order to avoid any counter-productive effects on energy balance. Importantly, when short duration exercises are used, our results, in addition to the existing literature, encourage practitioners to use higher intensities (>70% VO_2peak) that have been shown to favor low perceived exertion in such a population (Thivel, Isacco, O'Malley, & Duche, 2016), in order to optimize energy balance by affecting both energy expenditure and intake.

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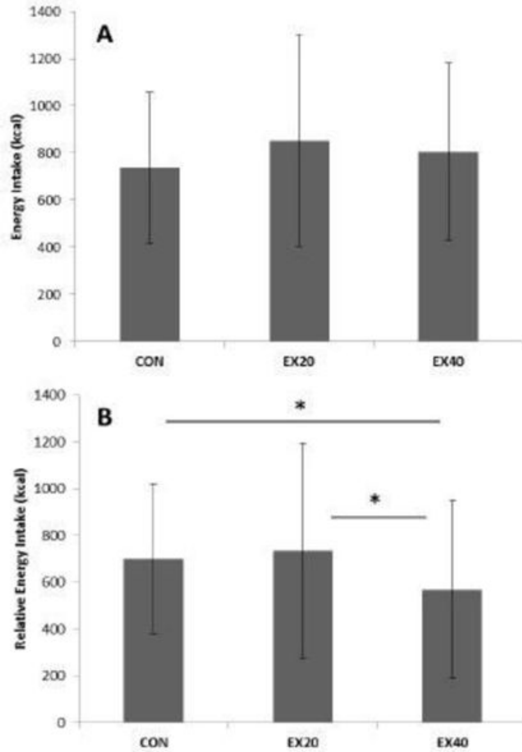

Figure 1.
Absolute energy intake (A) and relative energy intake (REI) (B) on the three experimental conditions Data presented as mean ± SD; EI: Energy intake; REI: Relative Energy Intake, CON: Control session; EX20: 20-minute cycling session; EX40: 40-minute cycling session; *p<0.05 for REI EX40<CON and REI EX40<EX20

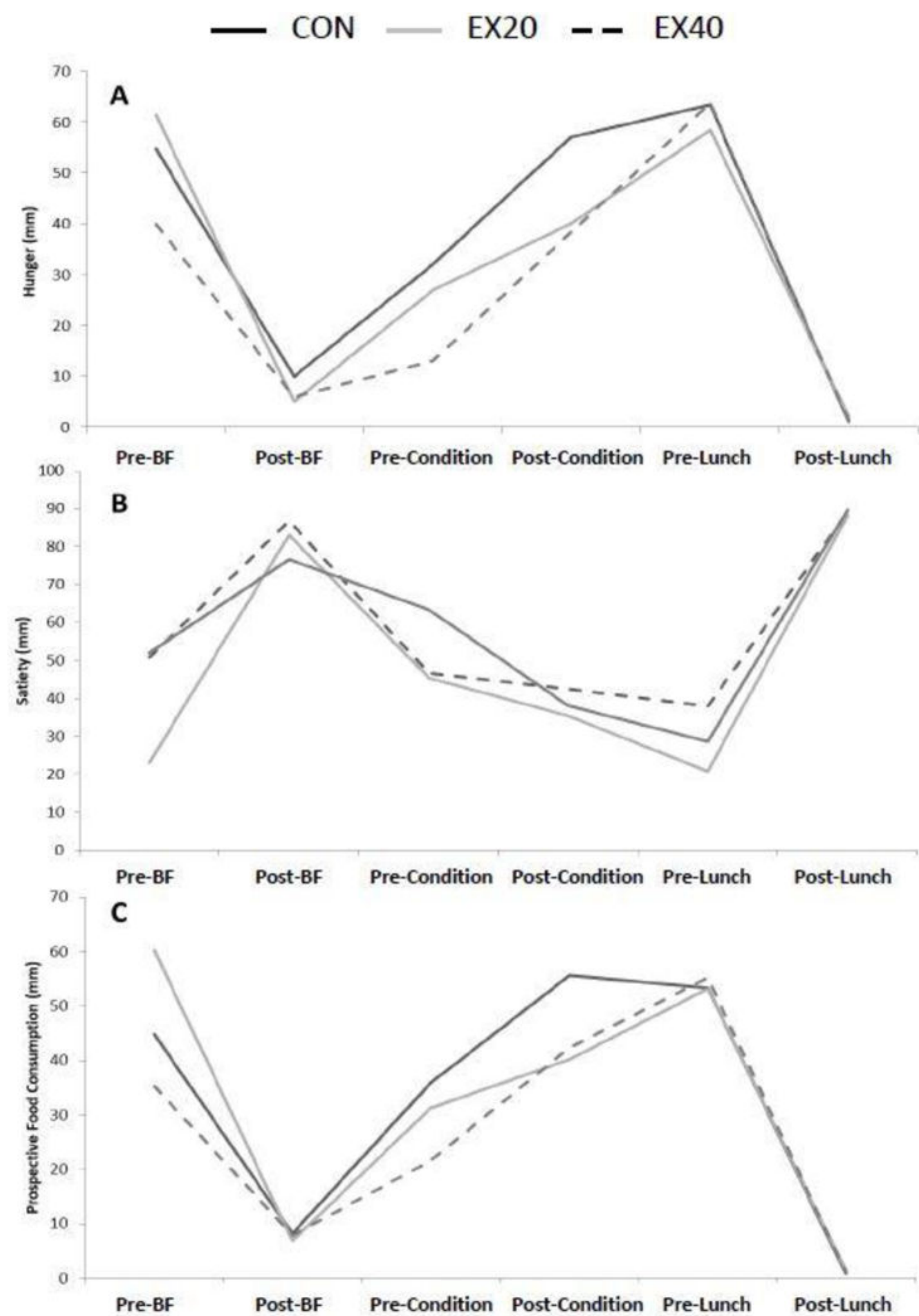

Figure 2.

Subjective hunger (A), satiety (B) and prospective food consumption (C) throughout the experimental sessions. CON: Control session, EX20: 20-minute cycling session; EX40: 40-minute cycling session; Pre-BF: Before Breakfast; Post-BF: After Breakfast: Pre-condition: before exercise or rest period; Post-condition: after exercise or rest period

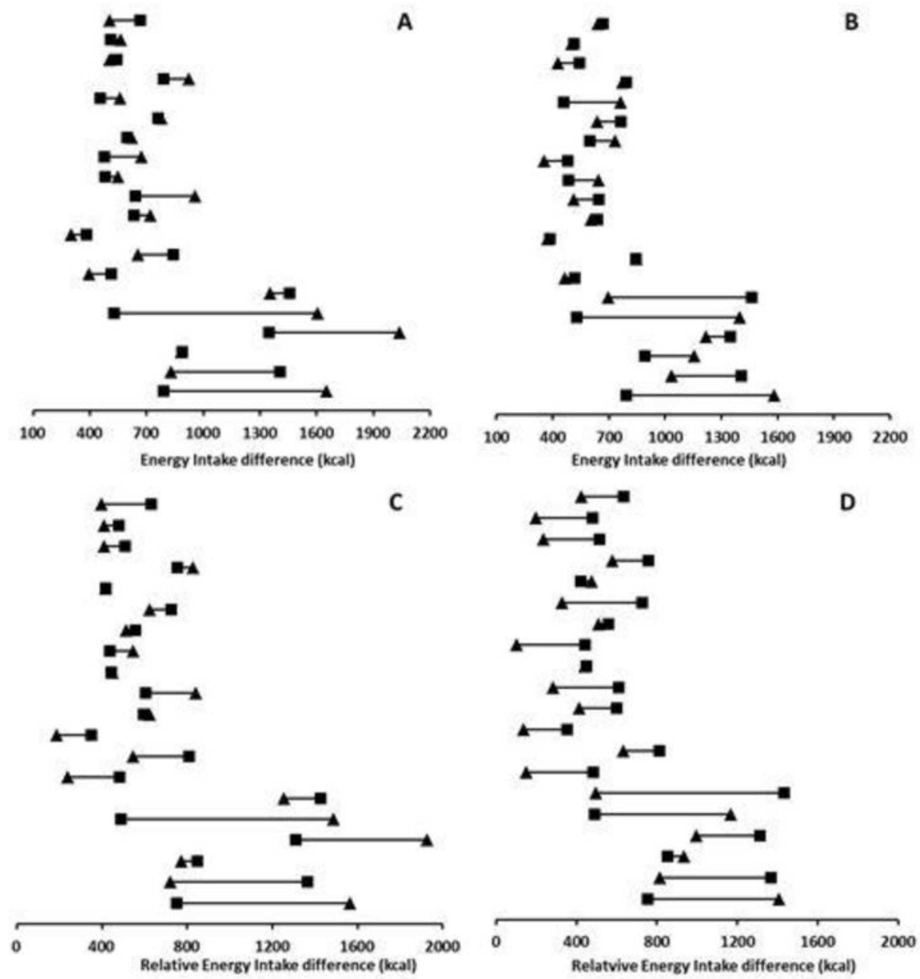

Figure 3.

Graphical representation of Individual variability of the absolute energy intake response after EX20 (A) and EX40 (B) compared with CON and of the relative energy intake in response to EX20 (C) and EX40 (D) compared with CON. CON: Control session, EX20: 20-minute cycling session; EX40: 40-minute cycling session; ■: EI (A and B) or REI (C and D) values during the CON condition; ▲ EI (A and B) or REI (C and D) values during the EX20 (A and C) and EX40 (B and D) sessions.

Table 1

Energy intake (absolute and relative) and energy expenditure for each conditions.

	CON		EX20		EX40		ANOVA	
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***		
EI (kcal)	738	320	854	450	806	375		
EE (kcal)	35	2	117	22	235	44	***	CON/EX20 *** CON/EX40 *** EX20/EX40 ***
REI (kcal)	702	320	736	457	571	381	*	CON/EX40 * EX40/EX20 *

EI: Energy intake; REI: Relative Energy Intake, CON: Control session; EX20: 20-minute cycling session; EX40: 40-minute cycling session; ANOVA: Analysis of variance.

* $p<0.05$;

** $p<0.01$;

*** $p<0.001$.

Table 2

Macronutrient intake during each experimental session

	CON		EX20		EX40		ANOVA	
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***		
Protein (g)	29.5	11.7	37.0	16.6	33.1	10.9	*	CON/EX20 ** EX40/EX20 *
Fat (g)	7.8	3.2	10.3	4.6	9.2	3.3	*	CON/EX20 **
CHO (g)	131.3	66.1	151.8	91.2	146.3	76.9		
Protein (%)	16.3	4.2	18.2	4.5	17.5	3.2		
Fat (%)	9.7	2.6	11.5	3.4	11.1	2.7		
CHO (%)	71.1	13.1	69.9	7.4	71.0	5.4		

CHO; Carbohydrates; CON: Control session; EX20: 20-minute cycling session; EX40: 40-minute cycling session; ANOVA: Analysis of variance.

* p<0.05;

** p<0.01;

*** p<0.001.