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Does exercising before or after a meal affect energy balance in adolescents with obesity?

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Abstract

Background and aim. Exercise timing has been suggested to affect appetite and energy intake (EI). The aim of this study was to examine the impact of exercising immediately before or after a meal on EI, appetite sensations and food reward (FR) in adolescents with obesity.

Methods and results. Seventeen adolescents with obesity completed 3 experimental sessions (randomized controlled trial): rest+lunch (CON); exercise+lunch (EX-MEAL); lunch+exercise (MEAL-EX). The exercise consisted of cycling 30 minutes at $65\%\dot{V}O_{2peak}$. Outcomes included *ad libitum* EI (weighed lunch and dinner), FR (Leeds Food Preference Questionnaire at pre- and post-combination of exercise/rest and lunch, and pre-dinner) and appetite sensations (visual analogue scales). EI was not different between conditions. Compared with CON, relative EI at lunch was lower in EX-MEAL and MEAL-EX ($p \leq 0.05$) and daily only in MEAL-EX ($p<0.01$). Postprandial fullness was higher in EX-MEAL compared to CON. Compared with CON, both EX-MEAL and MEAL-EX attenuated the increase in wanting for sweet food and reduced explicit liking for fat.

Conclusions. These preliminary results suggest that exercising immediately before or after a meal produce few differences in appetite and have small beneficial effects on overall energy balance in adolescents with obesity, as well as on FR.

Clinical trials. NCT03967782

Key Words. Exercise-Meal Timing, Appetite, Energy Intake, Food reward, Obesity, Adolescent

Introduction

It is now recognized that physical exercise not only increases energy expenditure but it can also affect appetite and energy intake (EI) in adolescents with obesity, depending on its duration (Masurier et al., 2018; Tamam et al., 2012), intensity (Thivel et al., 2012; Thivel, Isacco, Rousset, et al., 2011), induced-energy expenditure (Thivel et al., 2013) or as more recently suggested, its timing during the day (Fillon et al., 2020; Reid et al., 2019).

Albert and collaborators showed in lean adolescents that EI could be reduced by 11% (with a 23% decrease in fat intake) in response to acute exercise (30min at 65-70%$\dot{V}O_{2peak}$) performed immediately before lunch compared with the same exercise set 3h before lunch (Albert et al., 2015). Similar results have been recently observed in adolescents with obesity who decreased their EI by 115kcal (10%) 60min but not 180min after similar acute exercise (Fillon et al., 2020).

While these studies assessed the effect of the delay between exercise and the following meal on EI and appetite, Mathieu et al. recently investigated whether different meal-exercise patterns (exercise then meal or meal then exercise) could differently affect overall energy balance in normal-weight children (Mathieu et al., 2018). Although the authors did not find any differences between conditions, this remains unexplored among children and adolescents with obesity, who have shown different appetitive responses to exercise (Thivel et al., 2019).

The aim of the present study was to compare the effect of exercising immediately before or after a meal on EI, appetite sensations and food reward (FR) in adolescents with obesity.

Methods

Eighteen adolescents with obesity (Cole et al., 2000) from the local Pediatric Obesity Center (La Bourboule, France) were recruited for this randomized controlled trial. To be included the adolescents had to: be aged 12-16 years; have a BMI ≥ 97th percentile (Rolland-Cachera et al., 1991); be inactive (IPAQ (Craig et al., 2003) ; be free of any contraindication to physical activity; be free of medication that could influence their nutritional response and metabolism; sign the information notice and consent form as well as their legal representatives; have no medical or surgical history and/or pathology/treatment judged incompatible with the study; not be undergoing an energy restriction or weight-loss program through physical activity at the time of inclusion or within the last 6 months; not be a smoker or regular alcohol consumer. Anthropometric measurements, body composition (Dual-energy X-ray absorptiometry, QDR4500A Hologic, Waltham, MA, USA) and maximal aerobic capacity ($\dot{V}O_{2peak}$) (Rowland, 1993) were assessed as previously described (Miguet et al., 2019). Adolescents randomly completed three experimental sessions (one week apart): i) CON: no exercise and 30-min rest before lunch (CON); ii) EX-MEAL: 30-min cycling exercise (65%$\dot{V}O_{2peak}$) between 12:00-12:30pm followed by lunch between 12:30-1:30pm; iii) MEAL-EX: lunch between 12:30-1:30pm followed by 30-min cycling exercise (65%$\dot{V}O_{2peak}$) between 1:30-2:00pm. Exercise intensity was controlled by the mechanical load imposed to the cycle ergometer and verified using heart rate recording (Polar V800). Energy expenditure was estimated based on the maximal oxygen uptake evaluation. The experimenters weighed the food items before and after each meal. The lunch buffet was composed of beef steak, pasta, mustard, cheese, yogurt, compote, fruits and bread and the dinner of ham/turkey, beans, mashed potato, cheese, yogurt, compote, fruits and bread. The adolescents were allowed to drink water only. *Ad libitum* EI in kcal and macronutrient composition (proportion of fat, carbohydrate and protein) were calculated using the software Bilnut4.0. Adolescents did not have access to food outside the test meals. Relative energy intake (REI) was obtained by subtracting exercise-induced energy expenditure from lunch and total (=lunch+dinner) EI. Hunger, fullness, desire to eat (DTE) and prospective food consumption (PFC) were assessed throughout the day (pre-breakfast, post-breakfast, post-breakfast+30min, post-breakfast+60min, pre-ex/rest, post-ex/rest, pre-lunch, post-lunch, post-lunch+30min, post-lunch+60min, pre-dinner, post-dinner) using visual analogue scales (Flint et al., 2000). Pre- and post-combination of exercise/rest and lunch, as well as pre-dinner FR (liking and wanting for high-fat relative to low-fat food (fat bias) and sweet relative to savoury food (taste bias)) was assessed using the Leeds Food Preference Questionnaire (Finlayson et al., 2008) as previously described (Miguet et al., 2019). This study was approved by the appropriate ethical institutions (2019-A00507-50) and registered as a clinical trial (NCT03967782). Of the 18 participants, one did not complete all the sessions for personal reasons (not related to the study) leaving the final sample at 17 adolescents.

Sample size was determined according to previous works reported in literature (Fillon et al., 2020) and to an estimation based on effect-size difference greater than 0.6, for a two-sided type I error at 1.8%, a statistical power at 80% and an intra-class correlation coefficient at 0.5 (three conditions for a same subject). Area under the curve (AUC) was calculated using the trapezoidal method. Random-effects models for repeated data were performed. A particular focus was also given to the magnitude of differences, in addition to inferential statistical tests expressed using p-values (two-sided Type I error set at 0.05 and Sidak's type I error correction applied to multiple comparisons).

Results

Seventeen adolescents (9 boys) with obesity participated in this study. Their mean age was 12.8±1.4 years, body weight was 88.0±15.4kg, with a body mass index of 33.4±5.7kg/m^2 (z-BMI 2.2±0.4), body fat mass of 38.0±4.2%, fat-free mass of 52.5±9.2kg and $\dot{V}O_{2peak}$ of 21.8±5.9ml/min/kg.

Lunch, dinner and daily EI were not different between conditions (Table 1). Lunch REI was lower in EX-MEAL ($p<0.05$) and MEAL-EX ($p<0.01$) compared to CON. Daily REI was lower in MEAL-EX compared with CON ($p<0.01$). Macronutrient intake at lunch, dinner and daily was not different between conditions.

Table 1. Absolute and Relative Energy Intake in response the three conditions.

	CON	**EX-MEAL**	**MEAL-EX**	**p**	**ES [95% CI]**		
	Mean (SD)	**Mean (SD)**	**Mean (SD)**		***CON vs. EX-MEAL***	***CON vs. MEAL-EX***	***EX-MEAL vs. MEAL-EX***
Energy Intake (kcal)							
Lunch	1245 (372)	1163 (288.9)	1150 (314)	0.49	-0.14 [-0.62,0.33]	0.26 [-0.73,0.22]	0.12 [-0.36,0.59]
Dinner	752 (279)	776 (302)	732 (262)	0.69	0.15 [-0.33,0.62]	-0.07 [-0.54,0.41]	0.21 [-0.27,0.68]
Total	1997 (514)	1939 (501)	1882 (488)	0.36	-0.04 [-0.51,0.44]	-0.31 [-0.79,0.16]	0.27 [-0.21,0.74]
Relative Energy Intake (kcal)							
Lunch	1206 (383)	989 (286)*	989 (300)**	0.03	-0.76 [-1.24,-0.29]	-0.86 [-1.34,-0.39]	0.10 [-0.38,0.57]

Total	1929 (520)	1786 (511)	1721 (477)*	0.08	-0.42 [-0.90,0.05]	-0.69 [-1.17,-0.22]	0.27 [-0.21,0.74]

CON: control condition; EX-MEAL: Exercise before test meal; MEAL-EX: Exercise after test meal; SD: Standard Deviation; * : *vs.* CON (p<0.05) ; ** : *vs.* CON (p<0.01)

Hunger was lower at 12:00pm in EX-MEAL compared with CON (p=0.003) and MEAL-EX (p=0.0003). Fullness was higher post-lunch (p=0.01) and post-lunch+30mins (p=0.04) in EX-MEAL compared with CON (Figure 1). No differences in daily AUC were found between conditions.

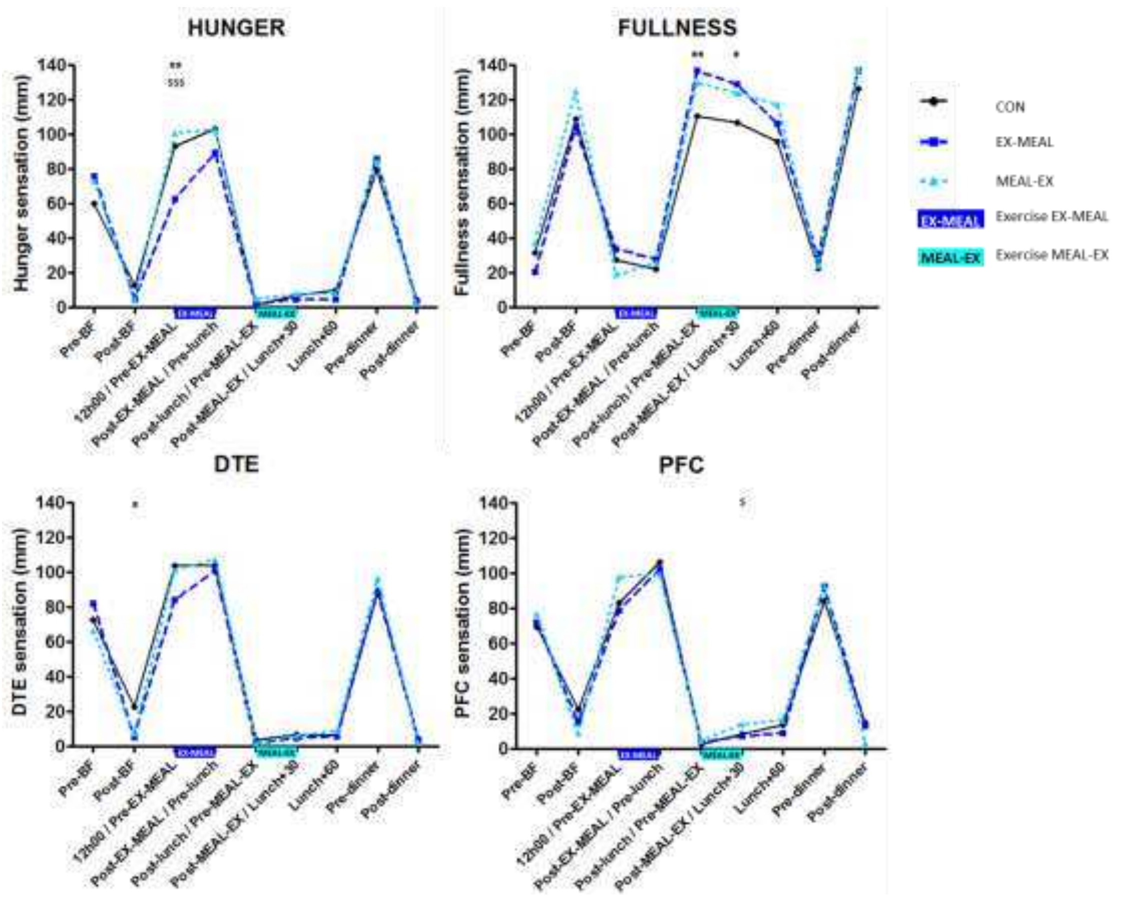

Figure 1. Daily Hunger(A); Fullness(B); Desire to Eat(DTE;C) and Prospective Food Consumption(PFC;D); BF: Breakfast; CON: rest condition; EX-MEAL: Exercise before test meal; MEAL-EX: Exercise after test meal; *: CON *vs.* EX-MEAL p<0.05; **: CON *vs.* EX-MEAL p<0.01; $: EX-MEAL *vs.* MEAL-EX p<0.05; $$$: EX-MEAL *vs.* MEAL-EX p<0.001.

Pre- and post-combination of exercise/rest and lunch, and pre-dinner implicit wanting and explicit liking for fat and savory foods did not differ between conditions (Table 2). In response to the combination of rest+lunch (CON), implicit wanting for sweet foods increased (p=0.04). Explicit liking for fat foods decreased only after the exercise conditions (EX-MEAL p<0.001, MEAL-EX p=0.03). Explicit liking for sweet foods increased only in EX-MEAL (p=0.05).

Table 2. Pre- and post-combination (exercise/rest and lunch) food reward

	CON	EX-MEAL	MEAL-EX		Interaction time x condition		
	Mean (SD)	Mean (SD)	Mean (SD)	**p**	***CON vs. EX-MEAL***	***CON vs. MEAL-EX***	***EX-MEAL vs. MEAL-EX***
<u>Implicit Wanting</u>							
Fat Bias							
Before comb.	20.7 (31.3)	24.6 (32.6)	26.3 (38.5)	0.24	0.97	0.89	0.95
After comb.	18.8 (34.9)	21.1 (42.8)	15.5 (34.0)	0.38			
p before vs. after	*0.32*	*0.72*	*0.33*				
Before dinner	14.0 (33.4)	2.3 (27.8)	25.5 (50.2)	0.40			
Taste Bias							
Before comb.	13.3 (21.6)	4.5 (33.9)	-0.1 (48.2)	0.38	0.54	0.79	0.54
After comb.	30.0 (30.5)	12.8 (41.0)	22.2 (55.9)	0.57			
p before vs. after	***0.04***	*0.48*	*0.25*				
Before dinner	12.1 (44.8)	11.9 (44.8)	20.2 (36.0)	0.78			
<u>Explicit Liking</u>							
Fat Bias							
Before comb.	3.3 (17.8)	2.6 (18.5)	5.5 (14.0)	0.33	0.50	0.93	0.53
After comb.	3.6 (15.4)	-0.4 (13.0)	3.4 (15.9)	0.61			
p before vs. after	*0.94*	***p<0.001***	***0.03***				
Before dinner	5.7 (14.0)	4.1 (16.5)	5.0 (20.5)	0.23			
Taste Bias							
Before comb.	9.2 (12.8)	7.6 (23.6)	9.3 (25.6)	0.85	0.80	0.96	0.81
After comb.	15.6 (23.1)	15.9 (16.5)	5.4 (17.3)	0.31			
p before vs. after	*0.23*	***0.05***	*0.50*				
Before dinner	7.6 (22.8)	13.7 (30.0)	7.1 (26.4)	0.32			

CON: rest condition; EX-MEAL: Exercise before lunch; MEAL-EX: Exercise after lunch; SD: Standard Deviation; comb.: combination of rest/exercise and lunch.

Discussion

This study investigated the effect of exercising immediately before or after lunch on EI, appetite sensations, FR and overall energy balance in adolescents with obesity. While lunch and daily absolute EI did not differ between conditions, daily EI was reduced by 58kcal (3%) and 115kcal (6%) in EX-MEAL and MEAL-EX, respectively. Furthermore, both exercise conditions favorably affected overall energy balance. In fact, this reduction of the adolescents' EI in EX-MEAL and MEAL-EX, combined with the observed increased energy expenditure during the exercise (on average 135kcal in EX-MEAL and 122kcal in MEAL-EX), can favor a reduction of their daily energy balance of 193kcal in EX-MEAL and 237kcal in MEAL-EX, which could favor weight loss if repeated and sustained over time (the chronic effect remaining to be further studied), as previously suggested (Fillon et al., 2020).

This is in line with Mathieu et al. who also did not observe any differences in EI but a reduced REI in lean children who performed acute moderate-to-vigorous exercise in two different meal-exercise patterns (exercise then meal or meal then exercise) in a school setting (Mathieu et al., 2018). Their results suggest that further studies should be conducted to assess whether exercising at high-intensity immediately before or after a meal can differently affect EI in youth.

In terms of appetite sensations, moderate-intensity 30-minute cycling exercise before lunch seems to favor a higher postprandial fullness compared with rest, suggesting a potential effect of pre-meal exercise not only on EI but also on satiety signaling. Indeed, exercise before a meal appears to increase postprandial fat oxidation (Wallis & Gonzalez, 2019) and may improve glucose tolerance (Gonzalez & Stevenson, 2012) which offer potential mechanisms to explore in the impact of meal-exercise timing on appetite control. Although Mathieu and colleagues did not assess appetite sensations in their study, our finding is in line with another study in adolescents with obesity showing increased satiety quotient when acute exercise is performed before eating (Fillon et al., 2020). Furthermore, an anticipatory effect on subjective appetite may have occurred as differences in hunger and fullness were observed prior to the exercise in EX-MEAL and MEAL-EX, respectively. Importantly, our results suggest that exercising immediately after a meal does not lead to any perceived-discomfort that could discourage adolescents to exercise or decrease their compliance to physical activity.

Regarding FR, the results suggest that performing exercise, regardless of its timing around a meal, may attenuate the increase in wanting for sweet foods observed after rest then lunch (CON). Moreover, liking for fat decreased after both exercise conditions and only EX-MEAL led to an increase in liking for sweet. This increase in liking for sweet (in parallel with a decrease in fat) may reflect an increase in preference for low-fat sweet foods such as fruits, etc., but remains to be explored further. As recently highlighted by Beaulieu et al. (Beaulieu et al., 2020), it appears that exercise has beneficial effects on food reward and preferences.

While similar results are observed when the same exercise is performed after the meal (MEAL-EX), it must be noted that both the pre- and post-combination LFPQ have were performed with a 30-minute delay compared with the two other conditions, in order to keep the lunch meal at the same time of the day, which might have impacted the results. Implementing a fourth condition with Meal-Rest that would have followed the same timings and architecture as MEAL-EX may have provided a better comparison. Similarly, although it could have been great to have a larger sample size and gender repartition to question a potential sex effect, it has been previously shown that adolescent boys and girls with obesity experience the same nutritional responses to acute exercises (Thivel, Isacco, Taillardat, et al., 2011).

To conclude, these preliminary results suggest that exercising at moderate-intensity both immediately before or after a meal have small beneficial effects on overall energy balance in adolescents with obesity, as well as on food reward. Pre-meal exercise resulted in increased postprandial sensations of fullness. These findings have implications for practitioners who are constrained by adolescents' daily schedules either in the school or clinical setting.

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Tables Legends

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Table 2. Pre- and post-combination (exercise/rest and lunch) food reward

Figure Legends

Figure 1. Daily Hunger(A); Fullness(B); Desire to Eat(DTE;C) and Prospective Food Consumption(PFC;D); BF: Breakfast; CON: rest condition; EX-MEAL: Exercise before test meal; MEAL-EX: Exercise after test meal; *: CON vs. EX-MEAL p<0.05; **: CON vs. EX-MEAL p<0.01; $: EX-MEAL vs. MEAL-EX p<0.05; $$$: EX-MEAL vs. MEAL-EX p<0.001.