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Timing of moderate-to-vigorous exercise and its impact on subsequent energy intake in young males

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HIGHLIGHTS

- The impact of exercise timing on energy intake has been previously unknown.
- An exercise session closer to a meal reduces subsequent energy and lipid intake.
- In this context, appetite was not linked to actual ingestion.
- Timing appears to potentially affect energy balance.

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ABSTRACT

Exercise can suppress appetite and energy intake but the impact of the timing of exercise remains unknown. Knowing that orexigenic hormone levels decrease during exercise but rapidly increase afterward, the aim of the current study was to investigate whether energy intake is increasingly reduced when exercise immediately precedes a meal compared to when a delay occurs between the exercise and the meal. Non-obese boys (15–20 years old; $N = 12$) were individually evaluated while performing two randomly assigned experimental visits: 1) a 30-min exercise session of moderate-to-vigorous intensity followed immediately by an *ad libitum* buffet at 12 PM and 2), an identical session followed by a 135-min waiting period and an *ad libitum* buffet-type meal at 12 PM. In both conditions, a snack in the afternoon and a second *ad libitum* buffet-type meal at 5 PM were served. Findings showed that hunger ratings were similar under both conditions. The exercise session immediately prior to the meal compared with the condition with a >2 h delay led to reduction of 11% and 23% in overall and lipid energy intakes at lunch, respectively (P-values > 0.05). No significant differences were found in the energy intakes from the afternoon snack and dinner. Apart from lipids at lunch, the proportions of energy from the various macronutrients at each meal were similar. This study reveals that being physically active before a meal plays a role in acute energy intake reduction when a shorter delay is present between exercise and a meal. In addition, the absence of compensation over several hours is noteworthy.

1. Introduction

Energy balance is central to body weight control, with energy expenditure and energy intake (EI) independently contributing to energy balance [1]. Interestingly, energy expenditure can also influence energy balance by having an indirect impact *via* EI. It is currently known that a longer duration, higher intensity and a selection of cardiovascular rather than resistance exercises can help reduce subsequent hunger, appetite and EI, thereby creating an acute energy deficit [2–7].

Among the mechanisms investigated in this exercise-induced anorexia, changes in acylated ghrelin levels are revealing. A reduction in levels of this orexigenic hormone has been reported during and after exercise, coinciding with hunger and appetite reductions [8–10]. However, hunger and acylated ghrelin levels rapidly increase during the recovery period following exercise [3,8,9]. These observations are in line with the delay in the onset of a meal observed following exercise compared to no exercise [2,11]. These findings suggest that the anorexigenic effect of exercise is transitory and that a window of opportunity might exist that more substantially reduces EI following exercise.

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The timing of physical activity is a relatively novel concept; recent studies address its significance in enhancing cardiometabolic health outcomes. For example, exercising at night reduces blood pressure to a greater extent than morning exercise in hypertensive patients that are usually resistant to the hypotensive effects of exercise [12]. Greater reductions in blood glucose and lipid levels have also been found following night time exercise or when exercise strategically occurs around mealtime [13–19], while enhanced lipid oxidation can occur following morning exercise or fasting [16,20]. To date, the effect of the timing of exercise on energy balance through EI remains unknown.

In studies on the anorexigenic effect of exercise, a meal is served either shortly after the end of exercise (<15 min) [6], within 1 h following exercise [4,10,21,22] or more than 1 h after exercise [8,22]. However, no study has compared the timing as it relates to meals. As a result, the main purpose of the current study was to confirm the hypothesis that EI is reduced when exercise immediately precedes lunch compared to when a delay occurs between exercise and lunch.

2. Materials and methods

2.1. Participants

Twelve non-obese males aged between 15 and 20 years old were recruited to participate in this crossover study. The participants met the following exclusion criteria: they were not on any specific diet; did not have a diagnosis of anorexia, bulimia or any metabolic disease; were not taking any medication that could influence appetite; did not have any intestinal disorders and were able to communicate in French. The consent form was approved by the Sainte-Justine University Hospital Centre ethics committee and a physical activity readiness questionnaire [23] was completed by the participants and parents/tutors of minors.

After a first preliminary visit, two additional experimental visits were randomly conducted. The participants were presented with a false scenario (hypothesis): the study of cardiac response to exercise, rest and caloric intake to prevent influence on the main outcome of the study (EI); they were asked to wear a heart rate monitor to enhance credibility. Financial compensation ($12 CAN) was provided after each visit. A final consent form indicating the real purpose of the study was administered at the end of the last visit. All participants consented to further use of the data collected.

2.2. Preliminary visit

Body mass was measured to the nearest 0.1 kg and body fat percentage determined by bioimpedance analysis on a Tanita BC-418 Segmental Body Composition Analyzer (Tanita Corporation of America Inc., Arlington Heights, IL, USA). Height and waist circumference were measured to the nearest 0.5 cm. The absence of abdominal obesity was confirmed using a waist circumference criterion specific to young [24] and adult [25] subjects. Body mass index (BMI, in kg m^{-2}) was calculated: participants had a BMI percentile ≤ 85th age and sex-specific percentile according to the Centers for Disease Control and Prevention curve (<18 y) or a BMI value ≤ 25 kg m^{-2} (≥18 y) [26,27].

Maximum oxygen uptake was measured by indirect calorimetry using a Quark CPET system (COSMED Srl, Rome, Italy). A progressive maximal test on a treadmill adapted from the shuttle test was performed [28]. The test started at 6 km h^{-1} and increased by 1 km h^{-1} every 2 min. Maximum effort was confirmed by a respiratory exchange ratio (carbon dioxide production·oxygen $consumption^{-1}$) ≥ 1.1 and/or a maximum heart rate ≥ 200 beats min^{-1} [29]. These results were used to determine the running speed required for subsequent exercise sessions performed at 70% of individual maximum oxygen uptake. After the running test, each participant was invited to eat from a 38-item *ad libitum* buffet type meal (see description below) to provide an initial exposure to food prior to the experiment.

2.3. Experimental visits

Each participant took part in two experimental visits in a counterbalanced measures design with ≥5 and <21 days between trials using ExMeal and Ex_{delay}Meal (Fig. 1). During ExMeal, the exercise was followed within 15 min by a buffet-type meal. In the Ex_{delay}Meal, the exercise was followed by a waiting period of 135 min before the buffet-type meal. This was important for assessing the timing effect since it allowed a comparison of the two Ex sessions performed with the same two meals and with a maximum time difference between them.

At 7:00 AM and after an overnight fast, the participants ate at home the standard breakfast provided. It contained ~2993 kJ and was composed of white bread (100 g), smooth peanut butter (18 g), orange juice (200 ml), butter (6 g) and cheddar cheese (42 g). Arrival at the laboratory was scheduled for 8:45 AM and compliance with breakfast (start time, duration and consumption of the complete meal provided and nothing more) was confirmed by the participant to the research team. The testing sequence started at 9:00 AM. It included a 30-min moderate-to-vigorous exercise session on the treadmill at 70% maximal oxygen uptake according to the experimental visit either early (9:00 AM) or late (11:15 AM) morning (Fig. 1). Sedentary activities (puzzles, Sudoku, hidden word games, books and listening to personal music) were performed during the morning waiting periods. The order and duration of each activity of the first visit were repeated during the second visit. The first *ad libitum* buffet-type meal was served at 12:00 PM and the second at 5:00 PM. Between meals, participants remained in or around the laboratory while wearing an NL1000 Digi-Walker® pedometer (New-Lifestyles®, Lees Summit, MO, USA) while carrying a prepared snack.

2.4. Energy intake and appetite sensations

An *ad libitum* buffet-type meal composed of 38 liquid and solid items based on a buffet described by Arvaniti et al. (2000) [30] was served at lunch. In the afternoon, each participant was given an *ad libitum* snack of cheese (~50 g), crackers (~25 g) and carrots (~75 g). At 5:00 PM, the *ad libitum* buffet was comprised of 35 items (similar to the items included in the lunch buffet, but without the snack items), and one hot meal selected by the participant for both conditions (macaroni and

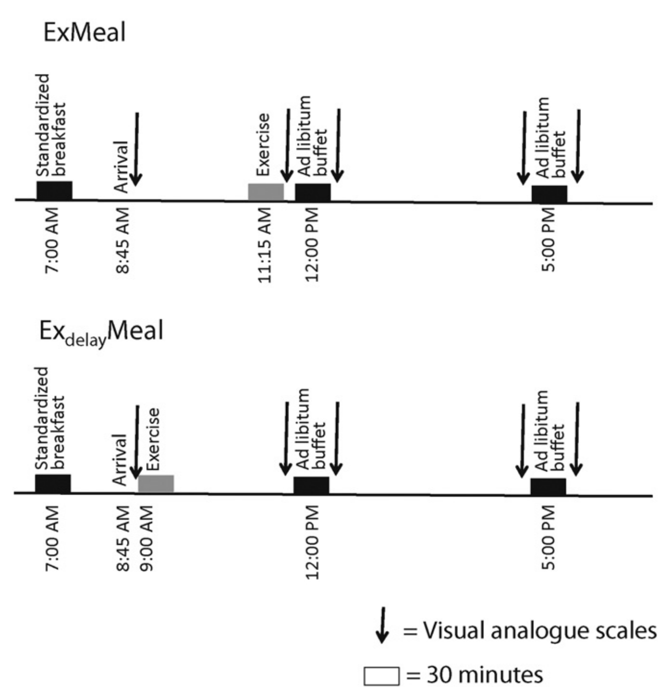

Fig. 1. Detailed protocol of experimental visits.