# Planned Aerobic Exercise Increases Energy Intake at the Preceding Meal

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**ABSTRACT**

BARUTCU, A., S. TAYLOR, C. J. MCLEOD, G. L. WITCOMB, and L. J. JAMES. Planned Aerobic Exercise Increases Energy Intake at the Preceding Meal. *Med. Sci. Sports Exerc.*, Vol. 52, No. 4, pp. 968–975, 2020. **Purpose:** Effects of exercise on subsequent energy intake are well documented, but whether preexercise energy intake is affected by future planned exercise is unknown. This study investigated the effect of planned late-afternoon exercise on appetite and energy intake before (breakfast and lunch) and after (evening meal/snacks) exercise. **Methods:** Twenty healthy, active participants (10 male; age, 23 ± 5 yr; body mass index 23.7 ± 3.2 kg·m$^{-2}$; $\dot{V}O_{2peak}$, 44.1 ± 5.4 mL·kg$^{-1}$·min$^{-1}$) completed randomized, counterbalanced exercise (EX) and resting (REST) trials. After trial notification, participants were provided *ad libitum* breakfast (0800 h) and lunch (1200 h) in the laboratory, before completing 1-h exercise (30-min cycling, 30-min running) at 75%–80% maximal HR (EX, 2661 ± 783 kJ) or 1-h supine rest (REST, 310 ± 58 kJ) 3 h after lunch. Participants were provided a food pack (pasta meal/snacks) for consumption after exercise (outside laboratory). Appetite was measured regularly, and meal and 24-h energy intake were quantified. **Results:** *Ad libitum* energy intake was greater during EX at lunch (EX, 3450 ± 1049 kJ; REST, 3103 ± 927 kJ; $P$ = 0.004), but similar between trials at breakfast (EX, 2656 ± 1291 kJ; REST, 2484 ± 1156 kJ; $P$ = 0.648) and dinner (EX, 6249 ± 2216 kJ; REST, 6240 ± 2585 kJ; $P$ = 0.784). Total 24-h energy intake was similar between trials ($P$ = 0.388), meaning that relative energy intake (24-h energy intake minus EX/REST energy expenditure) was reduced during EX (EX, 9694 ± 3313 kJ; REST, 11,517 ± 4023 kJ; $P$ = 0.004). **Conclusion:** Energy intake seems to be increased in anticipation of, rather than in response to, aerobic exercise, but the increase was insufficient to compensate for energy expended during exercise, meaning that aerobic exercise reduced energy balance relative to rest. **Key Words:** APPETITE, ENERGY INTAKE, EATING BEHAVIOR, WEIGHT LOSS, EXERCISE

Obesity remains a major public health concern responsible for many deaths each year, with the prevalence of overweight and obesity continuing to rise both in the United Kingdom (1) and globally (2). Overweight and obesity develop because of an accumulation of body fat caused by a long-term positive energy balance (i.e., energy intake greater than energy expenditure; (3)). Although conceptually simple, the mechanisms responsible for regulating energy balance are complex, making treatment of overweight/obesity extremely difficult (4). Although there is a clear need to identify strategies that help to facilitate weight loss, increases in overweight/obesity prevalence must, at least partially, be caused by previously lean individuals gaining weight (5). Therefore, although most research tends to focus on weight loss (i.e., treatment), far more research is warranted on how to maintain weight in lean individuals (i.e., prevention). Therefore, it is of interest to better understand the mechanisms by which energy balance is regulated and affected by exercise in lean individuals.

To effectively attenuate energy balance, strategies that decrease energy intake and/or increase energy expenditure without compensatory alterations in the other components of energy balance are warranted. Regular exercise, which increases energy expenditure, has been identified as one such strategy that may assist in the battle against obesity (4). Aerobic exercise causes effects on gut-derived endocrine mediators of appetite/energy intake, producing reductions in the orexigenic hormone ghrelin and increases in the anorexigenic hormone peptide tyrosine tyrosine (PYY) (6,7). Presumably due to alterations in these homeostatic regulators of appetite, previous studies documenting the acute effects of exercise on appetite and energy intake have typically examined energy intake in response to, rather than in anticipation of, exercise. A meta-analysis of this now substantial body of evidence concluded that acute exercise training does not alter energy intake in the hours after exercise compared with a resting control condition (8). Consequently, relative energy intake (energy consumed minus energy expended through exercise/rest) is reduced, and an acute energy deficit is created (9). Although chronic aerobic exercise training facilitates weight loss, studies do not report the expected reduction in body mass/fat predicted from the acute responses (10–13). What accounts for this less-than-anticipated weight loss has not been elucidated, but compensatory increases in hunger and energy intake (13,14), and/or decreases in nonexercise

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physical activity (15) have been postulated. However, resting metabolic rate (13,16,17) and nonexercise physical activity energy expenditure seem to be unaffected by aerobic exercise training (13,18). Therefore, it seems likely that compensatory increases in energy intake are more likely to explain the less-than-expected weight loss observed with long-term aerobic exercise training (11,13,18). Indeed, a recent study (13) reported that 12-wk aerobic exercise training (5 × 500 kcal exercise per week) produced a less-than-anticipated decrease in body mass/fat, which was accompanied by an increase in *ad libitum* energy intake, but no change in resting metabolic rate or nonexercise physical activity.

Energy intake is regulated by a host of homeostatic and nonhomeostatic mechanisms that ultimately drive behavior (19). Although exercise induces acute changes in the endocrine regulators of appetite, these changes do not seem to manifest in differences in subsequent energy intake. Given that exercise sessions are rarely spontaneous, there will usually be ample time for an exerciser to alter their energy/nutrient intake in anticipation of exercise. Energy/nutrient intake before exercise is commonly reported to increase exercise capabilities, and thus, exercisers may, over time, upregulate energy intake in the preexercise period to effectively prepare for the exercise session. Indeed, one recent study (20) reported that inactive overweight males who were restrained eaters chose more snack foods when they were served before exercise compared with a no-exercise control trial. However, the extent to which these effects are apparent over longer periods of time, or at complete meals in proximity to exercise, is currently unknown.

Therefore, this study aimed to investigate the effect of a planned late-afternoon exercise session on appetite and energy intake both before (at breakfast and lunch) and after (evening meal/snacks) exercise and to compare these responses to an identical resting control trial. It was hypothesized that energy intake at breakfast and lunch, but not in the evening after exercise, would be greater for exercise compared with rest.

## METHODS

**Participants.** Participants were 20 healthy, nonsmoking, weight-stable (self-reported), habitually active (<10 h· wk $^{-1}$) men ($n$ = 10; age, 23 ± 6 yr; body mass index, 23.9 ± 3.3 kg·m$^{-2}$; body fat, 16.3% ± 4.2%; $\dot{V}O_{2max}$, 47.7 ± 4.0 mL·kg$^{-1}$·min$^{-1}$) and women ($n$ = 10; age 24 ± 4 yr; body mass index, 23.5 ± 3.2 kg·m$^{-2}$; body fat, 28.6% ± 6.3%; $\dot{V}O_{2max}$, 40.6 ± 4.3 mL·kg$^{-1}$·min$^{-1}$). Participants provided written consent before taking part in the study. Ethical approval was obtained from the Loughborough University Ethics Approvals (Human Participants) Sub-Committee (reference number: R17-P024). Participants were not taking any medications known to affect appetite, and they were also not restricted, disinhibited, or hungry eaters, as determined by the Three-Factor Eating Questionnaire (21). Each participant completed two preliminary trials and two experimental trials in a randomized counterbalanced order and separated by 4–14 d. All female participants were using the combined oral contraceptive pill, with all trials taking place after at least 3 d of continuous contraceptive pill use. In the absence of any data to inform the size of the anticipated effect, the sample size used was in line with previous studies in this area using a similar crossover design.

**Pretrial standardization.** In the 24-h preceding the first experimental trial, participants recorded their dietary intake and habitual physical activity. These diet and activity patterns were then replicated before the second experimental trial. Strenuous exercise and alcohol intake were not permitted during this 24-h pretrial period, and adherence to all pretrial requirements was verbally checked before trials.

**Preliminary trials.** During the first preliminary trial, height (to the nearest 0.1 cm; SECA stadiometer, Hamburg, Germany) and body mass (to the nearest 0.01 kg; CFM-150 scales, Adam Equipment, Kingston, United Kingdom) were measured, whereas body composition was estimated using skinfold thickness (Harpenden, United Kingdom) at four sites (biceps, triceps, subscapula, suprailiac; (22)). Participants then completed questionnaires to assess health status and eating patterns before performing two submaximal exercise tests, one on a cycle ergometer (Lode Corival, Groningen, Holland) and one on a treadmill (h/p/cosmos sports & medical gmbh, Nußdorf, Germany). These submaximal tests involved four incremental 4-min stages on both a cycle ergometer (at workloads between 80 and 280 W) and treadmill (at speeds between 6 and 13 km·h$^{-1}$), with the specific intensities used dependent on each participant's fitness. Heart rate (Polar M400, Kempele, Finland) and RPE (23) were recorded at the end of each 4-min stage.

After a short break, participants completed a maximal incremental exercise test on the treadmill to determine their peak oxygen uptake ($\dot{V}O_{2peak}$). Exercise started at a gradient of 1% and at a speed estimated to elicit a heart rate of ~160 bpm, with the gradient increasing by 1% every minute until volitional exhaustion. Expired gas was collected during the final minute of the maximal incremental exercise test, with heart rate and RPE recorded at the end of each 1-min increment. During the second preliminary trial, participants arrived at the laboratory at 0800 h in a fasted state and completed visual analog scales to assess subjective appetite, consisting of ratings of hunger, fullness, desire to eat (DTE), and prospective food consumption (PFC). After a 25-min supine rest, a 5-min expired gas sample was collected into a Douglas bag to determine resting energy expenditure. Participants were then familiarized with experimental procedures by replicating procedures described hereinafter for the exercise trial, including appetite questionnaires, *ad libitum* breakfast and lunch meals, the exercise session, and the *ad libitum* evening food intake.

**Experimental trials.** Participants completed two experimental trials: exercise (EX) and rest (REST) in a randomized counterbalanced order and separated by at least 4 d. Participants arrived at the laboratory at 0800 h in a fasted state, and baseline measures of subjective appetite and postvoid body mass in light clothing were made (0800 h). Participants were then informed if they were on the EX or REST trial that day, before subjective appetite was again measured 15 min later

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(0815 h). Participants were then given 30 min to consume breakfast, which consisted of a multi-item cold-food buffet, with subjective appetite measured again after breakfast (0845 h). Before eating breakfast, participants were provided the following standard instructions: "You have 30 min to eat your breakfast. Remember that you are on the exercise/rest trial today, so please choose your food items accordingly. You are welcome to eat whatever and how much you want from the selection. If you want more of anything, please let us know and we will put out more food." Participants left the laboratory after breakfast and continued with their daily activities (restricted to low-intensity activities), returning for lunch at 1200 h, which again consisted of a multi-item cold-food buffet for a period of 30 min. Before lunch, participants were given the same trial-specific instructions as before breakfast. Subjective appetite was measured before (1200 h) and after (1230 h) lunch. Participants then rested quietly in the laboratory for the next 3 h, with subjective appetite measured every hour (1330, 1430, and 1530 h), before they completed the exercise/rest session. In the EX trial, exercise consisted of 30 min of steady-state cycling at 75% heart rate max, followed by 30 min of steady-state running at 80% heart rate max. Heart rate and RPE were recorded every 5 min throughout exercise. Expired gas samples were collected between 14–15 and 29–30 min during cycling and running. In the REST trial, participants completed the equivalent duration of supine rest, with expired gas samples collected between 25–30 min and 55–60 min. Subjective appetite was measured at 30 min (1600 h) and upon completion (1630 h) of the exercise/rest period. Participants were then provided a food pack (main meal and snack options) to eat from over the evening and were free to leave the laboratory. Participants were also given appetite questionnaires to complete at certain times outside the laboratory (preevening meal, postevening meal, before bed, morning).

**Study foods.** Participants were only permitted to eat foods provided to them during experimental trials but were free to drink water *ad libitum* throughout trials (including during the exercise/rest periods). For all meals, food was provided in excess of expected consumption. For breakfast and lunch meals only, additional food was available on request. Foods provided at breakfast, lunch, and evening are presented in Table 1. For breakfast and lunch meals, foods were presented in a research kitchen, where participants were able to serve and/or make food items, before moving to a separate dining room to eat. For these meals, participants ate in isolation, and there was no interaction between researcher and participants, with participants free to select foods they wanted. For the evening food pack, participants were provided with a main meal (cheese and tomato pasta), along with a standard bowl and a variety of snacks. Participants were instructed to bring back any leftover items (including wrapping and fruit skins) for accurate measurements of energy intake and told that they were free to keep any food items after the food pack was remeasured. The pasta meal was prepared on the day of the experimental trial using standard cooking and cooling procedures and was given to participants cold. The cheese and tomato pasta provided 6.63 (±0.03 SD) $kJ \cdot g^{-1}$ (with 14%, 60%, 25%, and 1% of the energy provided by protein, carbohydrate, fat, and fiber, respectively).

TABLE 1. Food items provided at meals.

| | | |
|---|---|---|
| **Breakfast Buffet Items** | | |
| White bread | Cornflakes—cereal | Peanut butter spread |
| Brown bread | Weetabix—cereal | Nutella spread |
| Rice crispies—cereal | Strawberry yoghurt | Strawberry jam spread |
| Crunchy nut—cereal | Raspberry yoghurt | Banana |
| Shreddies—cereal | Cherry yoghurt | Apples |
| Coco pops—cereal | Apple juice | Clementine |
| Cheerios—cereal | Orange juice | Milk |
| **Lunch Buffet Items** | | |
| White bread | Cherry yoghurt | Salt and vinegar crisps |
| Brown bread | Strawberry yoghurt | Cheese and onion crisps |
| Mature cheddar cheese | Raspberry yoghurt | Orange squash |
| Honey smoked ham | Cadbury mini rolls | Summer fruits squash |
| Grilled chicken pieces | Mayonnaise | Apples |
| Can of tuna | Butter | Clementine |
| Lettuce | Chocolate chip cookies | |
| Tomato | Salted crisps | |
| **Evening Meal** | | |
| Nutrigrain apple cereal bar | Cheese and onion crisps | Clementine |
| Nutrigrain blueberry cereal bar | Prawn cocktail crisps | Banana |
| Nutrigrain strawberry cereal bar | Salt and vinegar crisps | Strawberry yoghurt |
| Mars chocolate—fun size | Salted crisps | Cherry yoghurt |
| Twix chocolate—fun size | Mini cookies | Raspberry yoghurt |
| Maltesers chocolate—fun size | Apple | Tomato pasta meal |

Participants completed questionnaires related to liking of study foods to ensure that the available foods were adequately palatable. For each meal, food consumed was quantified by weighing foods before and after consumption and taking into account any leftovers. Energy and macronutrient content of foods was ascertained from manufacturer values. Upon arrival for lunch, participants verbally confirmed that they had not eaten/drunk anything except water since breakfast and, upon returning uneaten evening food, that they had only eaten food items from the food pack.

**Subjective appetite sensations.** Using paper and pen scales, participants rated their feelings of hunger ("How hungry do you feel?"), fullness ("How full do you feel?"), DTE ("How strong is your desire to eat?"), and PFC ("How much food do you think you could eat?") on 100-mm visual analog scales throughout the day. Verbal anchors of "not at all/none at all/no desire at all" and "extremely/a lot" were placed at 0 and 100 mm, respectively.

**Statistical analysis.** Data were analyzed using SPSS 23.0 (SPSS Inc., Somers, NY). All data were checked for normality of distribution using a Shapiro–Wilk test. Sex differences were initially explored through two-way (sex–trial) or three-way (sex– trial–time) repeated-measures ANOVA. Where interaction effects were observed (energy expenditure during the 1-h exercise/rest and fullness), data were analyzed with sexes separated and combined. All other data were analyzed for both sexes combined. Significant interaction effects were followed by Bonferroni-adjusted paired *t*-tests or Bonferroni-adjusted Wilcoxon signed rank tests, as appropriate. Data containing one factor were analyzed using a *t*-test or Wilcoxon signed rank test, as appropriate. Data sets were determined to be significantly different when $P < 0.05$. Data are presented as mean ± SD throughout, unless otherwise stated.

## RESULTS

**Pretrial measures.** There were no differences between trials for pretrial body mass ($t = -1.243$; $P = 0.229$), or subjective appetite sensations of hunger ($Z = -0.318$; $P = 0.763$), fullness ($Z = -0.201$; $P = 0.852$), DTE ($Z = -0.486$; $P = 0.641$), and PFC ($Z = -1.007$; $P = 0.327$).

**Energy and macronutrient intake.** Energy intake at the different eating occasions and over the 24 h is presented in Table 2. Energy intake at breakfast ($Z = -0.485$; $P = 0.648$) and during the evening ($Z = -0.299$; $P = 0.784$) was similar between trials, but lunch energy intake was increased by ~11% in EX compared with REST ($t = 3.324$; $P = 0.004$). Furthermore, total preexercise/rest energy intake (breakfast + lunch) was ~9% greater in EX compared with REST ($t = 2.212$; $P = 0.039$). However, total 24-h energy intake was similar between trials ($Z = -0.896$; $P = 0.388$). Relative energy intake (total 24-h energy intake minus energy expended through exercise/rest) was reduced by ~16% in EX compared with REST (EX, 9694 ± 3313 kJ; REST, 11,517 ± 4023 kJ; $Z = -2.800$; $P = 0.004$; Fig. 1).

There were no differences between trials for carbohydrate, fat, protein, and fiber intakes ($P \geq 0.245$) at breakfast or over the evening (Table 2). However, protein ($t = 2.657$; $P = 0.016$) and fat ($t = 3.369$; $P = 0.003$) intakes at lunch were greater in EX compared with REST, with carbohydrate and fiber intake at lunch being similar between trials ($P \geq 0.059$).

There were no sex–trial interaction effects for energy intake at breakfast ($F_1 = 0.061$; $P = 0.808$), at lunch ($F_1 = 0.018$; $P = 0.893$), at breakfast + lunch ($F_1 = 0.019$; $P = 0.893$), in the evening ($F_1 = 1.218$; $P = 0.284$), or over the 24 h ($F_1 = 0.702$; $P = 0.413$). There was a sex–trial interaction effect for energy expenditure during the 1-h exercise/rest ($F_1 = 22.835$; $P < 0.001$), with the energy expended during exercise representing a greater proportion of energy expenditure during the 1-h rest in male participants (male, 939% ± 164%; female, 776% ± 142%; $P = 0.028$). Consequently, there was a trend for a sex–trial interaction for relative energy intake ($F_1 = 3.660$; $P = 0.072$).

**Subjective appetite sensations.** There were time and trial–time interaction effects for all subjective appetite ratings (Fig. 2; $P < 0.05$). In addition, there were trial effects for hunger ($F_1 = 4.611$; $P = 0.045$), DTE ($F_1 = 4.741$; $P = 0.042$) and PFC ($F_1 = 10.251$; $P = 0.005$), but not fullness ($F_1 = 0.352$; $P = 0.560$). Participants reported lower hunger, PFC, and DTE at 1600 and 1630 h (i.e., midexercise and postexercise, respectively) in EX ($P < 0.05$), with DTE also reduced at 1530 h (i.e., preexercise). PFC was lower and fullness was higher at 1230 h (i.e., immediately after lunch) in EX versus REST ($P < 0.01$), with fullness being lower after the evening meal in EX versus REST ($P < 0.05$).

There was a trial–time–sex interaction effect for fullness ($F_{6.095} = 2.315$; $P = 0.038$), with the only significant *post hoc* difference within or between sex, being that male participants reported greater fullness at 1230 h (i.e., after lunch) in EX versus REST (EX, 87 ± 7 mm; REST, 79 ± 9 mm; $t = 5.622$; $P = 0.005$).

**Steady-state exercise and energy expenditure.** Mean RPE and heart rate during the 60-min exercise in EX were 12 ± 1 and 147 ± 19 bpm, respectively. Mean RER, $\dot{V}O_2$, carbohydrate, and fat oxidation over the 60-min exercise/rest were all greater during EX compared with REST ($P < 0.001$; Table 3).

## DISCUSSION

This study investigated the effect of a planned 60-min late-afternoon aerobic exercise session on appetite and energy intake both before (i.e., at breakfast and lunch) and after (i.e., over the evening) exercise compared with an identical resting control trial. It was hypothesized that energy intake before exercise (i.e., at breakfast and lunch) would be greater than before rest, but that energy intake in the evening would be similar between trials. In line with this hypothesis, energy intake in the preexercise/prerest period was significantly greater (~9%) in the EX trial, whereas energy intake over the evening was similar between trials. Interestingly, the increased energy intake before exercise was mainly caused by an ~11% increase in energy intake at lunch, whereas energy intake at breakfast was not different between trials.

To our knowledge, this is the first study to investigate energy intake and appetite responses at meals consumed both before and after a planned exercise session compared with a resting control trial. Previous studies examining the acute

TABLE 2. Total energy (kJ), carbohydrate (CHO), protein (PRO), fat, and fiber intake over the course of each trial.

| | Energy, kJ | CHO, g | PRO, g | FAT, g | Fiber, g |
|---|---|---|---|---|---|
| Breakfast | | | | | |
| EX | 2656 ± 1291 | 108.5 ± 49.9 | 18.9 ± 11.3 | 12.5 ± 9.6 | 6.3 ± 4.9 |
| REST | 2484 ± 1156 | 103.8 ± 45.9 | 18.3 ± 9.5 | 10.5 ± 6.9 | 5.6 ± 4.1 |
| Lunch | | | | | |
| EX | 3450 ± 1049[a] | 74.3 ± 22.9 | 38.7 ± 13.7[a] | 39.5 ± 17.4[a] | 8.3 ± 2.5 |
| REST | 3103 ± 927 | 70.3 ± 20.7 | 34.4 ± 12.9 | 34.2 ± 15.2 | 7.7 ± 2.3 |
| Breakfast + lunch | | | | | |
| EX | 6105 ± 1980[a] | 182.8 ± 68.3 | 57.7 ± 21.1[a] | 52.0 ± 19.7[a] | 14.6 ± 7.0 |
| REST | 5588 ± 1933 | 174.0 ± 64.4 | 52.7 ± 19.3 | 44.6 ± 19.0 | 13.4 ± 6.0 |
| Evening meal | | | | | |
| EX | 6249 ± 2216 | 223.2 ± 81.0 | 40.1 ± 14.1 | 43.8 ± 15.7 | 10.2 ± 4.3 |
| REST | 6240 ± 2585 | 229.4 ± 100.8 | 41.6 ± 15.7 | 45.7 ± 19.2 | 10.5 ± 4.9 |
| Total 24 h | | | | | |
| EX | 12,354 ± 3920 | 405.9 ± 141.7 | 97.7 ± 32.4 | 95.8 ± 27.7 | 24.8 ± 10.7 |
| REST | 11,827 ± 4069 | 403.4 ± 151.5 | 94.3 ± 31.9 | 90.3 ± 31.7 | 23.9 ± 9.9 |

Data are mean ± SD.
[a]Significantly different from REST.

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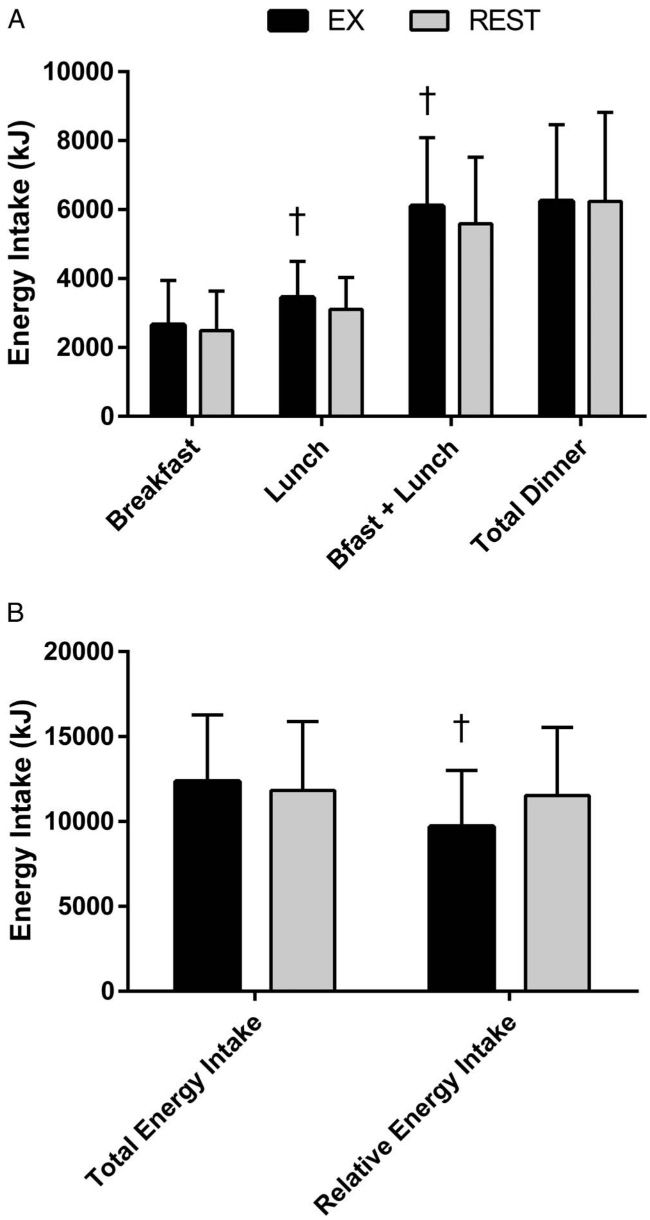


**FIGURE 1—A, Energy intake (kJ) at each meal. B, Total and relative energy intake (kJ) for EX (■) and REST (□) trials. †Significantly different from the REST trial. Data are mean ± SD.**

effects of exercise on energy intake have generally used the approach of assessing appetite and energy intake after exercise/rest (6,24,25). Aerobic exercise has been shown to modulate circulating concentrations of acylated ghrelin and PYY, hormones secreted from the gastrointestinal tract that are thought to play a role in the regulation of appetite and energy intake (26,27). Interestingly, and perhaps counterintuitively, aerobic exercise decreases acylated ghrelin concentrations and increases PYY concentrations, producing a hormonal milieu conducive to the suppression of appetite/energy intake (7). Despite these consistent effects on hormonal mediators of appetite, acute exercise studies mainly suggest that energy intake after exercise is no different from that after a similar duration of rest (8). Therefore, relative energy intake (energy intake minus energy expended through exercise/rest) is reduced with aerobic exercise, suggesting that exercise helps to facilitate an acute negative energy balance. The present study supports the findings of these previous studies, as energy intake after exercise was similar between EX and REST trials, but demonstrates that regular exercisers might increase their energy intake in anticipation of an exercise session. However, this increase in preexercise energy intake was not sufficient to offset the extra energy expended during exercise, meaning that exercise reduced relative energy intake compared with the rest trial.

In a similar recent study, Sim et al. (20) investigated the effects of a future exercise bout on preexercise energy intake in inactive overweight male individuals. After standardized breakfast and lunch meals, participants were provided an *ad libitum* snack (potato chips) an hour before a known exercise (self-selected exercise duration/intensity) or a rest session. Although overall there was no effect of exercise on energy intake, the authors observed that restrained eaters ate significantly more (~162 kcal or ~677 kJ) before exercise, an effect that was not present in the unrestrained eaters. In contrast to the results of Sim et al. (20), the present study observed that unrestrained eaters increased their energy intake at a preexercise meal in anticipation of a 1-h aerobic exercise session. There are a number of differences in study design that likely account for these discordant findings. First, in the present study, participants were provided with two multi-item buffet meals (breakfast and lunch) 7.5 and 3.5 h before exercise, respectively, whereas in the study of Sim et al. (20), participants were provided only a preexercise *ad libitum* snack of potato chips 1 h before exercise. The additional opportunities to eat, choice of foods, or the more distal (but more realistic) positioning of meals relative to exercise in the present study might have provided greater opportunity to increase energy intake in the exercise trial. Furthermore, participants in the present study were regular exercisers, whereas those in the study of Sim et al. (20) were inactive individuals. The lack of experience with exercise of the participants in this previous study (20), compared with participants in the present study, may have reduced their propensity to increase energy intake in anticipation of exercise. Alternatively, the fact that participants in the present study were not attempting to lose weight might mean that they were more likely to increase their energy intake in anticipation of exercise (although exercise still created an energy deficit). Future studies should look to examine these effects in those attempting to lose weight, who might be less likely to increase energy intake.

Previous work has demonstrated that there are elements of eating behavior that are learned, with experience of a food influencing expectations about a food's satiation (28). Indeed, expected satiety and satiation are strong predictors of portion size selection (29,30). Although speculative, it might be hypothesized that exercise (or energy expenditure *per se*) might illicit a similar response, where previous experience with an exercise task might facilitate learned increases in portion size selection and energy intake. In line with this hypothesis, Werle et al. (31) observed that energy served from snacks was

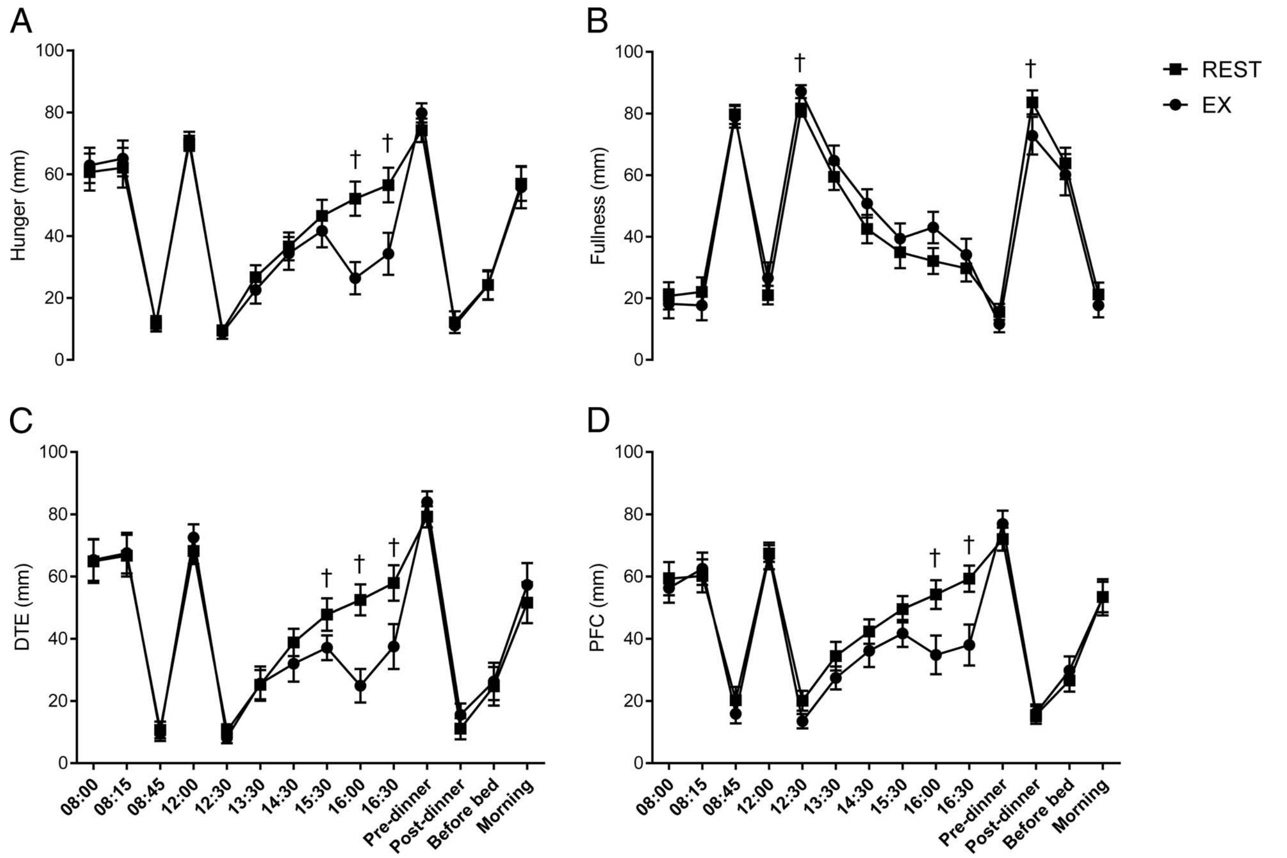


**FIGURE 2—Change in hunger (A), fullness (B), DTE (C), and PFC (D) over the trial day for both EX (– – –) and REST (—). †Significantly different from the REST trial. Data are mean ± SEM.**

increased in participants who answered a series of questions related to exercise compared with those who answered questions unrelated to exercise (31). Thus, in the present study, participants' previous experience with aerobic exercise might have meant they had "learned" to increase their energy intake in the preexercise period to prepare for the coming exercise/energy expenditure. Although speculative, this hypothesis might go some way to explain the results of chronic training studies, where weight loss slows down over time (11,32). Alternatively, it is possible that the preexecise period represents a time where exercisers are more likely to increase energy intake to compensate for impending energy expenditure. Indeed, in support of this theory, a recent study (33) observed that planned energy intake at a future lunch meal was increased when participants were told the meal would be consumed after 1 h of hard aerobic exercise compared with that after a period of rest.

Alternatively, the results of the present study might be explained by other possible mechanisms. First, the Compensatory Health Beliefs Model (34) postulates that certain unhealthy behaviors can be compensated for by positive (healthy) behaviors, and this model might, at least partially, explain the findings. Knowledge of a planned future exercise session (perceived as a healthy behavior) might allow an exerciser to justify, to themselves, having extra energy/food (perceived as an unhealthy behavior) in the lead up to exercise (35,36). Second, and on a similar line to the health beliefs model, general scientific recommendations are for athletes to increase energy, and particularly carbohydrate, intake in the hours before exercise (37). As these recommendations, which are made for athletes, permeate into lay publications/online resources, they might promulgate the idea that exercisers (not only athletes) should increase their food and energy intake to appropriately prepare for a future exercise session. Interestingly, there was no difference in preexercise carbohydrate intake, although energy, protein, and fat intakes were all higher in the EX trial. However, an increase in energy (or indeed carbohydrate) intake after exercise would also be predicted by the compensatory health beliefs model and would also be consistent with current scientific recommendations for athletes (37), but this was not found. Therefore, the finding that energy and macronutrient intakes in the evening were similar between REST/EX trials suggests that these possible mechanisms are not likely to explain the findings. One consideration is the wording used to inform participants of which trial they are on. We aimed to ensure that participants had the impending exercise/rest in mind when

TABLE 3. Mean RER, $\dot{V}O_2$, carbohydrate, and fat oxidation values for EX and REST trials.

| | $\dot{V}O_2$, L·min$^{-1}$ | RER | Carbohydrate Oxidation, g·min$^{-1}$ | Fat Oxidation, g·min$^{-1}$ |
|---|---|---|---|---|
| EX | 2.02 ± 0.166[a] | 0.96 ± 0.03[a] | 2.369 ± 0.088[a] | 0.125 ± 0.098[a] |
| REST | 0.29 ± 0.003 | 0.86 ± 0.01 | 0.338 ± 0.001 | 0.019 ± 0.001 |

Data are mean ± SD.
[a]Significantly different from REST.

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making decisions about food to consume, although this meant that the wording was possibly leading. Although this possibly represents a limitation of the present work, the fact that an increased energy intake was observed at lunch, but not at breakfast, suggests that the wording did not bias participants to eat more food (energy) in the exercise trial. That said, given that this is one of the first studies to investigate these effects, future studies should carefully consider how information on the impending exercise sessions is given to participants.

Although the mechanism explaining the present results remains to be elucidated, the findings suggest that energy intake is increased in anticipation of, rather than in response to, exercise. These findings for postexercise energy intake are similar to those reported in the vast majority of the previous literature in this area (8). Although energy intake was significantly increased before exercise, the increase was only ~518 kJ (~124 kcal), and when this was combined with the energy intake after exercise, there was no significant difference between trials, although mean energy intake was arithmetically greater in the EX trial. Furthermore, when the energy expended during the 60-min exercise/rest was factored in, relative energy intake was ~1823 kJ (~436 kcal) less in the EX trial. In this regard, the present study is consistent with the vast majority of the previous literature examining the short-term effects of exercise on *ad libitum* energy intake (6,8,24–26). The present study, along with these previous studies, demonstrates that a single bout of aerobic exercise does not induce a substantial increase in energy intake around exercise, thus facilitating an energy deficit that should be conducive to weight loss if exercise training continues. The present study only explored the period immediately preceding an exercise session, and given that exercise sessions are generally planned well in advance (i.e., an exerciser might habitually do exercise classes on a particular day of the week every week), there may be further opportunity to increase energy intake before exercise. Future studies should examine eating behavior over longer periods before exercise, as well as how eating behavior before and after exercise is affected by long-term exercise training. Furthermore, whether diet goals (i.e., maintain vs lose weight) influence these responses should also be investigated.

In conclusion, this study demonstrates that energy intake is increased in anticipation of aerobic exercise (i.e., before exercise) rather than in response to the exercise session (i.e., after exercise). The increase in energy intake was not sufficient to offset the energy deficit created by the exercise session, meaning that aerobic exercise reduced energy balance relative to rest, which is consistent with previous literature examining postexercise energy intake. However, the finding that energy intake is increased in anticipation of an aerobic exercise session perhaps changes our understanding of how exercise might influence energy intake and, speculatively, suggests regular exercisers might "learn" to increase their energy intake in preparation for an exercise session, a behavior that might attenuate the negative energy balance induced by exercise. However, clearly further research is needed to better understand this phenomenon.

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