Anticipation of aerobic exercise increases planned energy intake for a post-exercise meal

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Abstract

In many situations, meals are planned (i.e. what and how much) before they are eaten, but how exercise influences this planning is unknown. Therefore, this study investigated whether anticipation of an exercise session alters food intake planned for post-exercise. Forty (16 male) regular exercisers (mean ± SD; age 23.3 ± 5.6 y, BMI 22.7 ± 3.3 kg/m^2, body fat 25.6 ± 7.6%) completed the study. Subjects arrived ≥3 h post-prandial and were given two hypothetical scenarios for the following day: 1) morning rest (REST), or 2) morning rest with the addition of 1 h of hard aerobic exercise at 10:00-11:00 (EXERCISE). For each scenario subjects had to plan their lunch, to consume at 12:00, by serving themselves cheesy tomato pasta and chocolate buttons. Scenarios were counterbalanced and separated by 5 minutes and foods were not consumed. EXERCISE increased total energy served by 24% (EXERCISE 3308 ± 1217 kJ; REST 2663 ± 924 kJ; P<0.001), with increases in energy served from both pasta (+25%; P<0.001) and chocolate buttons (+20%; P=0.024). These results suggest aerobic exercise increases planned post-exercise energy intake, if a meal is planned in advance of exercise. Future research should examine the impact of exercise on meal planning at other meals, as well as how this behaviour impacts weight loss with exercise training.

Introduction

The most recent public health statistics suggest that the prevalence of overweight and obesity continue to rise, with 61% of UK adults currently classified as overweight or obese (Health Survey for England, 2016). Weight gain occurs due to chronic positive energy balance (i.e. energy intake greater than energy expenditure), leading to accumulation of fat in adipose tissue (Schrauwen, 2007). Increasing physical activity, particularly aerobic activity, is one method of increasing energy expenditure that has been suggested to assist with weight management (Caudwell *et al.,* 2011). The premise of this strategy is that the accumulation of energy expended through physical activity manifests in a negative energy balance and subsequent reduction in body fat levels (Caudwell *et al*., 2011).

Clearly, the success of a weight loss strategy involving increased exercise will depend on the degree of compensation through the other components of energy balance (i.e. energy intake, resting energy expenditure and of physical activity; Caudwell *et al.,* 2011). Acute exercise studies have typically reported a transient reduction in subjective appetite (Broom *et al*., 2007; Pomerleau *et al*., 2004) and ideal portion size (Farah *et al.* 2012) during/ after exercise, with minimal effect on subsequent energy intake compared to a resting control trial (Schubert *et al*., 2013). Whilst some studies report a small increase in absolute energy intake (i.e. total energy consumed) after exercise (Martins *et al*., 2007a; Martins *et al*., 2007b; Pomerleau *et al*., 2004; Shorten *et al*., 2009), relative energy intake (energy consumed minus energy expended through exercise/ rest) is consistently reduced by exercise. Therefore, acute exercise studies suggest exercise produces an environment conducive to weight loss by increasing energy expenditure without a compensatory increase in energy intake.

However, chronic exercise interventions (i.e. ≥8 weeks) have typically not observed the anticipated weight loss that would be expected given the acute effects of exercise on relative energy intake (King *et al.,* 2008; Turner *et al.* 2010; Wu *et al.,* 2009). Typically, there is an initial weight loss, however, after this, the rate of weight loss attenuates or weight becomes stable over time (Curioni & Lourenco, 2005; Wu *et al*., 2009). Whilst there is likely a reduced energy requirement due to the reduction in body mass over time, these studies also suggest there is some alteration in the other components of energy balance to compensate in some way for the energy expended through exercise training. Given that non-prescribed physical activity energy expenditure (Turner *et al.,* 2010) and resting metabolic rate (Lee *et al..* 2009; Speakman & Selman, 2003) do not appear to change with exercise training, alterations in dietary intake/ eating behaviour have been suggested as the likely cause of this effect (Turner *et al.* 2010).

Aside from what we eat, a critical factor is how much we eat. Factors influencing portion size selection strongly affect energy intake, and therefore represent a crucial aspect of energy balance (Brunstrom, 2011). Previous studies that have investigated the relationship between exercise and energy intake have employed an *ad-libitum* approach to assess energy intake. In this approach, subjects are presented with a variety of food items in excess amounts and are asked to eat or drink until satiated. In day-to-day living this type of eating occasion is relatively rare for most humans, with meals generally involving some planning of the type of foods selected and/ or the amount of food selected, in advance of the eating occasion (Brunstrom, 2011). Additionally, food choice is generally reduced in a laboratory environment.

Interestingly, Werle *et al.* (2011) reported that participants who answered a series of questions related to exercise served themselves more snacks, and therefore more calories, than those in a control group whose questions were unrelated to exercise. In most cases, exercise sessions are scheduled in advance of being undertaken (i.e. individuals know that they will exercise and likely think about the exercise), meaning the size/ nature of any meals prepared/ cooked in advance of exercise might be influenced by the knowledge of the upcoming exercise session. However, the design of most previous exercise studies does not allow any planning behaviour in the context of exercise to be directly evaluated in advance of the session. More recently, Sim et al. (2018) reported that inactive overweight males scoring high for dietary restraint increased energy intake at a snack before exercise. These results suggest that exercise might increase energy intake (or planned energy intake) when decisions are made in advance of exercise, although the training or weight status of the volunteers may have influenced the results.

Therefore, the aim of this study was to examine how exercise influences meals planned for the post-exercise period of regularly exercisers by providing subjects with hypothetical exercise and rest scenarios and asking them to plan their post-exercise meal. It was hypothesised that subjects would plan to consume more energy after exercise than after rest.

Methods

Subjects

Twenty-four females (age 21 ± 3 years; BMI 22.0 ± 2.8 kg/m^2; body fat % 30.1 ± 4.5) and sixteen males (age 26 ± 8 years; BMI 24.0 ± 3.7 kg/m^2; body fat % 18.3 ± 5.5) completed this study, which was approved by the Loughborough University Ethics Approvals (Human Participants) Sub Committee (reference number: SSEHS-1917). Before participation, subjects provided written consent, and completed a health screen questionnaire and the Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985) which measures the three dimensions (restraint, disinhibition, hunger) of human eating behaviour (See Table 1 for mean ± SD) scores). All subjects were healthy, non-smokers, regular exercisers (3-4 aerobic exercise sessions per week) for at least the previous 6 months, weight stable (body mass within 3 kg for the past 6 months), not currently dieting and not taking medications known to affect appetite. All subjects were Loughborough University students/staff from a variety of departments. Four of the males and ten of the females scored within the 'clinical range' of the TFEQ (Males: 1 for restraint, 3 for hunger; Females: 4 for disinhibition, 2 for restraint, 1 for hunger; 2 for both restraint and disinhibition, 1 for restraint and hunger), with the 'clinical range' defined as per Stunkard and Messick (1985). Removal of these subjects from the analysis did not alter the results observed and as subjects completed both trials, acting as their own control, these subjects were not removed from the final analysis. Before each visit, subjects refrained from any strenuous exercise or alcohol intake in the preceding 24 hours. Visits were separated by >3 days.

Session 1: Familiarisation session

During the first session, the familiarisation trial, subjects visited the laboratory at lunch time (1100-1400 h) at least 3 h post-prandial to complete pre-trial questionnaires and for the collection of basic anthropometric measurements. Subjects were then familiarised with the meal-planning task to be used in the experimental trial. They were provided with a large bowl of cheese and tomato pasta and a large bowl of chocolate confectionary. They were then asked to serve themselves portions of both foods after being given the following instructions "*You are preparing your lunch to eat now. Please serve yourself the amount of food that you would choose to consume to fill you up if you were not going to eat again until you have dinner this evening*." Subjects then ate the food they had served to help familiarise themselves with the study foods.

Session 2: Experimental trial

Subjects visited the laboratory at least 3 h postprandial and performed two hypothetical meal-planning scenarios; a resting scenario (REST) and an exercising scenario (EXERCISE). The order of the scenarios was randomised across subjects in an attempt to control for any order effects and, within subjects, was separated by a 5-minute break. Before each scenario, subjects were asked to rate their subjective appetite using a set of visual analogue scales.

For each scenario, subjects were read the scenario and then asked to "*please serve yourself the amount of food that you would choose to consume to fill you up if you were not going to eat again until dinner".* For the REST scenario, subjects were told, "*For tomorrow, imagine you plan to have your usual breakfast in the morning. You then plan to spend the morning around the house doing some light household activities (e.g. light housework, reading, working on the computer etc.). You plan to have lunch at ~12 pm".* For the EXERCISE scenario, subjects were told, "*For tomorrow, imagine you plan to have your usual breakfast in the morning. You then plan to spend most of the morning around the house doing some light household activities (e.g. light housework, reading, working on the computer etc.), except for some time that you will spend exercising. The exercise you plan to do will be 1 hour of hard aerobic exercise from 10 to 11 am. You plan to have lunch 1 hour after finishing exercise (i.e. ~12 pm)".* In each scenario, subjects were instructed to plan their lunch for the following day in isolation and were provided with the same foods as in the familiarisation trial. Subjects did not consume the foods served in the experimental trial and they were made aware of this beforehand. Food bowls were weighed before and after serving, with manufacturer values used to determine the energy content of meals.

In an attempt to distract subjects from the true focus of the study (i.e. comparison of exercise and rest) they were told that there were multiple hypothetical scenarios involving different types of activities and that they would be randomly assigned to two of these scenarios.

Study Foods

The meal provided was a cheese and tomato pasta as a main course (fusilli pasta, cheddar cheese, Bolognese sauce and olive oil; all Tesco, Cheshunt, UK) and chocolate confectionary as dessert (Cadbury's Dairy Milk Buttons; Cadbury, UK). The cheese and tomato pasta meal was prepared the day prior to the trials using identical cooking and cooling procedures for all meals and was presented to subjects cold. During the familiarisation trial, where subjects ate their selected portion, the pasta was warmed before being eaten. The cheese and tomato pasta was homogenous in nature and provided 6.7 (± 0.03 SD) $kJ\cdot g^{-1}$ (with 14%, 61%, 24% and 2% of the energy provided by protein, carbohydrate, fat and fibre, respectively). The chocolate confectionary provided 22.2 $kJ\cdot g^{-1}$ (with 6%, 43%, 51% and 0% of the energy provided by protein, carbohydrate, fat and fibre, respectively). Foods were presented in large serving bowls in excess of expected consumption and subjects self-served portions into eating bowls in line with the above instructions.

Subjective appetite

Subjective feelings of hunger, fullness, desire to eat (DTE), and prospective food consumption (PFC) were rated on 100 mm visual analogue scales. The scales were anchored "not at all/ none at all/ no desire at all" at the 0 mm point and "extremely/ a lot/ very" at the 100 mm point. Subjects were instructed to draw a line at the point on the 100 mm line that corresponded to their appetite.

Statistical Analysis

Data was analysed using SPSS 22.0 for Windows (SPSS Inc., Somers, NY, USA). All data were checked for normality and were analysed using paired t-tests or Wilcoxon signed-rank tests, as appropriate. Statistical significance was accepted at the 5% level. Results in text and tables are presented as mean ± SD, unless otherwise stated. Spearman's correlation coefficients were determined for the difference in energy selected between trials (total energy selected in EXERCISE minus total energy selected in REST) and TFEQ scores to establish any relationship.

Results

Subjective appetite

Pre-trial values for hunger (*Z=-1.013; P*=0.311), fullness (*Z=-0.014; P*=0.989), DTE (Z=-*0.587; P*=0.557) and PFC (Z=*-1.356; P*=0.175) were not different between REST and EXERCISE trials (Table 2).

Portion size selection

There was no trial order effect for the total energy content served, with similar amounts served for trial 1 and trial 2 (Trial 1 2990 ± 1096 kJ; Trial 2 2982 ± 1160 kJ; *Z*=-0.168; *P*=0.867). Similarly, there was no difference between trial 1 and trial 2 for energy served from pasta (*Z*=-0.511; *P*=0.610) or chocolate buttons (*Z*=-1.136; *P*=0.256). Additionally, there was no interaction effect (*F*(1)= 0.177; *P* = 0.676) between condition (EXERCISE and REST) and the order in which trials were completed (i.e. EXERCISE-REST or REST-EXERCISE), suggesting the absence of a contrast/ demand effects.

During the EXERCISE condition subjects served themselves a significantly larger portion of pasta (*t*(39)=-7.343; *P*<0.001; Figure 1) and chocolate (*Z*=-2.251; *P*=0.024; Figure 1) compared to the REST condition, representing a 24% increase (*Z*=-4.624; *P*<0.001; Figure 1) in the total energy content of the served food.

When energy served was explored with sex as a between-subject factor (Table 3), responses for energy served for pasta (*F*(1)=2.487; *P*=0.100) and in total (*F*(1)=0.013; *P*=0.908) were similar between sexes. Whilst there was a trend for a sex*trial interaction for energy served from chocolate (*F*(1)=3.730; *P*=0.061), this did not reach statistical significance.

Three Factor Eating Questionnaire (TFEQ)

Correlation analyses between the absolute difference in energy selected between trials and three factor eating questionnaire responses revealed weak correlations for disinhibition (*r*=-0.269; *P*=0.094) and hunger (*r*=0.000; *P*=0.998). Although there was a trend for a significant relationship with dietary restraint, the correlation was still weak/moderate (*r*=-0.307; *P*=0.054).

Discussion

The aim of the present study was to investigate the effect of exercise on post-exercise meal planning. The main finding was that individuals chose a larger portion size (~24% increase in energy content of food served) to consume after a hypothetical future aerobic exercise scenario compared to a hypothetical rest scenario.

To our knowledge, this is the first study to examine the effect of aerobic exercise on meal planning behaviour in anticipation of exercise. Previous investigations have generally taken the approach of performing exercise or rest, with assessment of subsequent appetite and energy intake (Deighton & Stensel, 2014; Schubert *et al*., 2013;) after exercise/ rest. Generally, these studies have reported that exercise does not effect subsequent absolute energy intake. Consequently, relative energy intake (energy intake minus energy expended through exercise/rest) is reduced and an acute energy deficit is induced by the exercise bout. In contrast, some studies have observed a reduction (Ueda *et al*., 2009; Jokisch *et al*., 2012; Sim *et al*., 2014) or an increase (Erdmann *et al.,* 2007; Martins *et al.,* 2007a; Shorten *et al.,* 2009) in absolute energy intake after exercise compared to rest. However, these differences in absolute energy intake are generally small and an acute decrease in relative energy intake is consistently observed with exercise.

The results of the present study suggest that knowledge of a future exercise session results in an increase in planned energy intake at a meal after exercise, at least in habitual exercisers. The magnitude of this increase was ~650 kJ (i.e. ~150 kcal) at this meal, which is unlikely to fully compensate for energy expended during 1 hour of aerobic exercise. Therefore, these results partially support those of previous studies, as relative energy intake would be expected to be lower in the exercise scenario than the rest scenario. However, it is important to consider that in the present study, only planned energy intake at lunch (i.e. the meal immediately post-exercise) was measured. If exercise increases planned energy intake, it is possible this effect might not be constrained to a single meal and that other meals before and/ or after exercise might be subject to the same changes in planning behaviour, providing greater opportunity to compensate for energy expended during exercise. This increase in planned energy intake might attenuate the negative energy balance induced by exercise and consequently might reduce any weight loss with chronic exercise training (Curioni & Lourenco, 2005). It must also be acknowledged that an hour of 'hard aerobic exercise' would represent different levels of energy expenditure for different subjects, depending on their fitness, mass and exercise of choice.

Whilst previous studies have not assessed meal planning in the context of exercise, Farah *et al.* (2012) used a computer based method to evaluate the effect of exercise on ideal portion sizes of a variety of different foods. Subjects selected a smaller ideal portion size of a number of different foods (pasta, crackers, KitKat chocolate bar, garlic bread and cheese baguette) after a 60 minute walk compared to a 60 minute resting period. This effect was only apparent immediately after exercise, and coincided with a decrease in subjective hunger at this time. Clearly previous studies that have assessed the effects of exercise on subsequent energy intake will have incorporated some element of meal planning, as subjects will have made decisions about what, and how much food to eat. However, these decisions are likely to have been made after exercise and it is possible the alterations in subjective and physiological mediators of appetite augmented by exercise (Broom *et al.* 2007) might interact with meal planning behaviour to attenuate energy intake. Therefore, whilst the results of the present study contrast previous findings, they suggest that food intake after exercise might differ based on when decisions about the meal are made (i.e. before or after conducting exercise).

Traditionally, meal size is believed to be regulated by physiological and psychological mechanisms that occur during a meal and lead to the termination of eating. While the disossociation between the two (homeostatic and cognitive) has been argued to be limited (Liu & Kanoski, 2018), other evidence suggests that meal size might be controlled by decisions made in advance of eating (Guillocheau et al., 2018; Hetherington et al., 2018; Fay et al., 2011; Brunstrom, 2011). In this context, the expected satiety/ satiation of a specific food have been shown to vary widely (Forde et al., 2013; Brunstrom et al., 2008), and are strong predictors of the amount of food served (Brunstrom & Shakeshaft, 2009; Brunstrom & Rogers, 2009), with self-served meals tending to be consumed in their entirity (Wansink & Cheney, 2005). This suggests that there are elements of eating behaviour that are learned based on previous experience of foods/ meals. Indeed, there is evidence to suggest that previous experience of a food modulates expectations about the food's satiation (Brogden & Almiron-Roig, 2010; Wilkinson & Brunstrom, 2009) and ultimately these beliefs might play an important role in determining a self-served portion size. Given these learned eating behaviours pertaining to expected satiety/ satiation, it might be plausable to suggest that similar learned responses might govern eating behaviours in response to (or anticipation of) exercise. It is possible that a habitual exerciser might make decisions about meal size and type in response to exercise based on their previous experience of the effect of that exercise session on parameters of appetite/ energy balance regulation. Therefore, this mechanism might act to allow the exerciser to better compensate for the energy expended during exercise and allow them to maintain energy balance. This hypothesis, whilst speculative, is supported by the findings from chronic exercise training studies, that generally report weight loss slows down over time

(Curioni & Lourenco, 2005). This suggests the possibility of learned compensatory behaviours, as experience with the specific exercise stimulus increases. The subjects recruited for this study were all recreationaly active and regularly undertook aerobic exercise, meaning their previous experiences with the impact of aerobic exercise on appetite/ energy balance etc. might have played a role in their choice to serve more food.

Whilst there was no significant difference in food intake between males and females, there was a trend for selection of the chocolate confectionary to be increase in the exercise trial in females, but not males. This trend is interesting and should be explored in future studies that are better powered to investigate sex-specific differences A recent study found that palatable foods may be more rewarding to females than males (Sinclair *et al.,* 2017). The underlying cause for this behaviour is thought to be the increased responsiveness of neural substrates that settle the hedonic and motivational responses to palatable foods in females (Stoeckel *et al.*, 2008). It has also been found that in western countries like the Unites States, Canada, Spain and United Kingdom chocolate is the single most desired food among women, and recurring changes in cravings have been reported to differ between different phases of the menstrual cycle (Asarian & Geary, 2013). Although female subjects of this study were tested at an uncontrolled point in their menstrual cycle, both exercise and rest scenarios were completed on the same day, thus controlling for any hormonal-based effects.

Typically, studies that have investigated the effects of exercise on appetite, exclude subjects who score within the clinical range of the Three Factor Eating Questionnaire. In an attempt to examine whether elevated scores were driving the observed effects, correlation analyses were carried out. However, these revealed only weak/ moderate associations and removal of these subjects did not change the reported results. There was a trend for a weak/ moderate negative relationship between dietary restraint sore and additional energy consumed in the EXERCISE trial, suggesting that those with greater restraint are less likely to compensate for energy expended through exercise by increased mealplanning behavior. Although this relationship was pretty weak, it is interesting that Sim et al (2018) reported the reverse effect, in that overweight/ obese individuals with high dietary restraint were more likely to increase energy intake at a pre-exercise snack meal. These differential findings might be explained by differences in the activity or weight status of the voluneteers (i.e. lean regular exercisers in the present study vs overweight/obese sedentary individuals in the study of Sim et al. [2018]). Estimation of energy expended during exercise is achieved with varying success for lean individuals (Holliday & Blannin, 2014; Willbond et al., 2010), but this ability appears to be worse in overweight/ obese individuals (Brown et al., 2016), perhaps explaining the difference in findings between the present study and that of Sim et al. (2018). Future studies should better consider the interaction between restraint and possibly disinhibition and meal planning responses in the context of exercise. Additionally, weight status should also be investigated in this regard.

In conclusion, this study demonstrates that knowledge of a planned aerobic exercise session increases portion size selection by ~24%. This finding suggests that aerobic exercise might impact meal planning, at least in regular exercisers, which might account for some of the reasons behind stabilisation of weight loss in chronic exercise intervention studies. Future studies should examine meal planning in response to both acute and chronic aerobic exercise, as well as other exercise modalities.

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Table 1. Three Factor Eating Questionnaire scores for males (n = 16) and females (n = 24). Values are mean ± SD.

	Male	*Female*	*Total*
Restraint	9 ± 4	11 ± 4	10 ± 4
Disinhibition	5 ± 2	8 ± 4	7 ± 4
Hunger	6 ± 3	6 ± 3	6 ± 3

Table 2. Pre-trial subjective appetite ratings (0-10 cm). Values are mean ± SD.

	REST	*EXERCISE*
Hunger (0-10 cm)	6.9 ± 2.1	7.0 ± 1.8
Fullness (0-10 cm)	2.3 ± 2.1	2.2 ± 1.5
DTE (0-10 cm)	7.1 ± 2.2	7.2 ± 1.9
PFC (0-10 cm)	6.8 ± 1.9	6.8 ± 1.9

Table 3. Energy (kJ) selected for pasta, chocolate and total in males (n = 16) and females (n = 24) during EX and REST trials. Values are mean ± SD.

	Pasta		***Chocolate***		***Total***	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*
EXERCISE	*3169 ± 967*	*2189 ± 615*	*699 ± 750*	*746 ± 534*	*3868 ± 1427*	*2935 ± 905*
REST	*2501 ± 691*	*1762 ± 483*	*736 ± 426*	*519 ± 436*	*3237 ± 956*	*2280 ± 684*

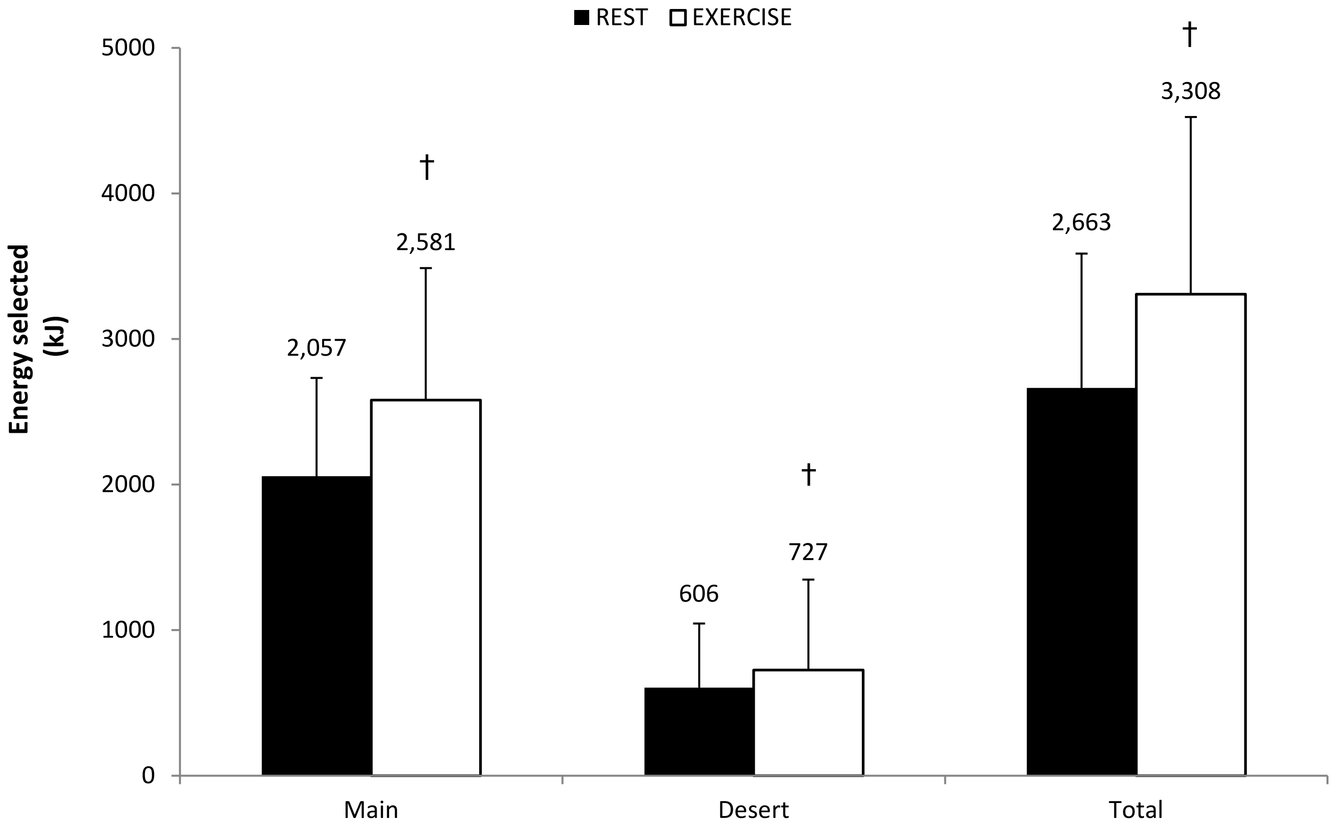

Figure 1. Energy (kJ) selected in REST (dark bar) and EXERCISE (white bar) conditions. Values are mean ± SD (n=40). †Significantly different between trials (*P*<0.05).