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Energy and macronutrient intake in the Midwest Exercise Trial-2 (MET-2)

Richard A. Washburn[1], **Jeff J. Honas**[1], **Lauren T. Ptomey**[1], **Matthew S. Mayo**[2], **Jaehoon Lee**[3], **Debra K. Sullivan**[4], **Kathleen Lambourne**[1], **Erik A. Willis**[1], and **Joseph E. Donnelly**[1]

[1]Cardiovascular Research Institute, Division of Internal Medicine, The University of Kansas Medical Center, Kansas City, KS

[2]Department of Biostatistics, The University of Kansas Medical Center, 3901 Rainbow Boulevard, Kansas City, KS

[3]Institute for Measurement, Methodology, Analysis, and Policy, Texas Tech University, Lubbock, TX

[4]Department of Dietetics and Nutrition, The University of Kansas Medical Center, Kansas City, KS

Abstract

PURPOSE—To examined the effect of exercise training over 10 months at 2 levels of energy expenditure on energy and macronutrient intake in a sample of previously sedentary, overweight/ obese young adults.

METHODS—We conducted a 10 month trial in 141 young adults who were randomized to supervised exercise, 5 days•wk^{-1} at 400 and 600 kcal•session^{-1}, or non-exercise control. Participants were instructed to maintain their usual ad-libitum diets. Energy/macronutrient intake was assessed at baseline, 3.5, 7 and 10 months over 7-day periods of ad libitum eating in a university cafeteria using digital photography. Foods consumed outside the cafeteria were assessed using multiple-pass recalls.

RESULTS—There were no significant between group differences in absolute energy intake at baseline or any other time point in the total sample or in men. In women, absolute energy intake was significantly greater in the 600 kcal•session^{-1} group vs. controls at both 3.5 and 7 months. There were no significant between group differences in relative energy intake (kcal•kg•d^{-1}) at any time point in the total sample, men or women. There were no significant within or between group differences of change in absolute or relative energy intake in any of the 3 study groups in the total sample, or in men or women. No clinically relevant changes in macronutrient intake were observed.

CONCLUSION—Aerobic exercise training does not significantly alter energy or macronutrient intake in overweight and obese young adults. The possibility of a threshold level beyond which

Corresponding author: Richard Washburn, Robinson Center, Rm. 100, The University of Kansas-Lawrence, 1301 Sunnyside Avenue, Lawrence, KS 66045, Phone: 785-864-1688, Fax: 785-864-2009, rwashburn@ku.edu.

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increased exercise energy expenditure fails to produce a more negative energy balance, and potential sex differences in the energy intake response to increased levels of exercise are potentially important.

Keywords

Energy Intake; Macronutrient intake; Obesity; Health Eating Index; Exercise

INTRODUCTION

Compensatory increases in energy intake may be at least partially responsible for the limited magnitude of mean weight loss induced by aerobic exercise training without energy restriction (33). For example, King et al (20) demonstrated significant increases in energy intake among participants who did not reduce weight or fat mass in response to aerobic exercise training (12 wks., 5 d•wk^{-1}, 500 kcal•session^{-1}, 70% max heart rate). However, empirical evidence for an effect of exercise on energy intake or dietary macronutrient composition is not compelling. Our recent systematic review, which included cross-sectional, acute/short term, non-randomized and randomized trials (9), and a recent meta-analysis of acute trials by Schubert et al. (30), both indicated that observed increases in post-exercise energy intake only partially compensate for the energy expended during acute or short-term (2–14 days) exercise and dietary macronutrient composition was generally unchanged. Results from our systematic review on the response of energy and macronutrient intake to exercise training were in general agreement with those from acute and short-term trials (9). Only 2 of 36 (~6%) non-randomized and randomized trials identified, ranging in duration from 3 to 72 weeks, reported an increase in energy intake and 18 of 31 (58%) of trials reported alterations in dietary macronutrient composition in response to exercise training. However, the literature on this topic should be interpreted cautiously as several design issues limit our full understanding of how exercise training influences energy intake. For example, available randomized trials have been conducted in small samples (i.e. ≤ 20/group) (12, 27) over time frames of ≤ 12 weeks (21, 24, 33). In addition, with the exception of the study by Donnelly et al (10), energy intake in most studies has been assessed using 2 to 7-day food records (4, 21, 24, 27). Food records have been shown to underestimate energy intake when compared with energy expenditure assessed by doubly labeled water (28). The adequacy of self-report measures of energy intake to form the basis of scientific conclusions have been recently questioned (29).

Data from the Midwest Exercise Trial-2 (MET-2) afforded a unique opportunity to examine the effect of exercise training at 2 levels of exercise energy expenditure (EEEx) on energy and macronutrient intake in a sample of previously sedentary, overweight/obese young adults. The primary aim of MET-2 was to evaluate the role of aerobic exercise training without energy restriction on weight and body composition; however, several secondary outcomes, including changes in energy and macronutrient intake, were included a-priori in the original study design. A detailed description of the design and methods for MET-2 (14), results for the primary outcome (weight change) (11) as well as changes in non-exercise energy expenditure and physical activity (38) have been published. A description of differences in changes in both energy intake and energy expenditure between participants who achieved or failed to achieve clinically significant weight loss (≥ 5%) in response to exercise will be presented in a forthcoming manuscript. Briefly, MET-2 randomized young adults age 18–30 years, BMI 25–40 kg•m^{-2} to a 10 month, 5 day•week^{-1} supervised exercise intervention at 2 levels of EEEx (400 or 600 kcal•session^{-1}) or non-exercise control.

METHODS

Participant eligibility

Potential participants were excluded for the following reasons: Age outside the range 18–30 years, BMI outside the range 25–40 kg•m^{-2}, a history of chronic disease (i.e. diabetes, heart disease, etc.), elevated blood pressure (>140/90), lipids (cholesterol > 6.72 mmol•L^{-1}; triglycerides >5.65 mmol•L^{-1}), or fasting glucose (> 7.8 mmol•L^{-1}), use of tobacco products, taking medications that would affect physical performance (i.e., beta blockers), or metabolism (i.e. thyroid, steroids), inability to perform laboratory tests or participate in moderate-to-vigorous intensity exercise, and currently engaged in planned physical activity greater than 500 kcal•week^{-1} as assessed by recall (32).

Recruitment

Potential participants were obtained from a variety of sources including advertisements in the local and campus newspapers and radio stations, flyers in campus buildings, and postings on our laboratory website. All forms of advertisement included our dedicated study phone number as well as our laboratory web site and study e-mail address. Potential participants were to complete a web-based initial eligibility screener regarding height and weight to determine BMI, use of medications, smoking and drinking habits, and current levels of physical activity. Those without web access completed the initial screen by hard copies or telephone phone interview. Participant who appeared eligible based on the initial eligibility questionnaire met with the project coordinator who described the study, answered questions, obtained written informed consent, and assessed height and weight to determine final eligibility. Approval for this study was obtained from the Human Subjects Committee at the University of Kansas-Lawrence. A total of 2,338 individuals completed an on-line initial eligibility questionnaire. One-hundred forty one individuals were determined to be eligible and were randomized to one of the 3 study groups. Approval for this study was obtained from the Human Subjects Committee at the University of Kansas-Lawrence. Participants were compensated for participation.

Randomization and blinding

Participants were stratified by sex and randomized within each sex by the study statistician (~80% exercise; ~20% control). All participants were instructed to continue their typical patterns of dietary intake and non-exercise physical activity over the duration of the 10 month intervention. The blinding of participants to group assignment was not possible due to the nature of the intervention. However, both investigators and research staff were blinded at the level of outcome assessments, data entry and data analysis.

Exercise training

Exercise, consisting primarily of walking/jogging on motor-driven treadmills, was supervised by trained research staff, and conducted in a dedicated exercise facility in the Energy Balance Laboratory at the University of Kansas-Lawrence. To provide variety and decrease the potential for overuse injuries, alternate activities including stationary biking, walking/jogging outside, and the use of elliptical trainers was permitted for 20% of the total exercise sessions (i.e., 1 session•wk^{-1}). The exercise protocol was designed to progress in intensity and amount from baseline to the end of month 4, both to provide time to adapt to exercise and prevent injuries.

The duration of exercise required to elicit either 400 or 600 kcal•session^{-1} for each participant in the exercise groups was determined as follows: At the baseline assessment, treadmill speed/grade was set at 3mph/0% grade and was adjusted by increments of 0.5 mph/1% grade until the participant reached 70% of maximal heart rate (HR) ± 4 beats• min^{-1}. Maximal HR was the highest HR achieved during the assessment of maximal aerobic capacity using a modified Balke protocol (1). EEEx was then assessed over a 15-minute interval (1-minute epochs) using a ParvoMedics TrueOne2400 indirect calorimetry system (ParvoMedics Inc., Sandy, UT). The average EEEx (kcal•min^{-1}) over the 15-minute interval was calculated from measured oxygen consumption and carbon dioxide production using the Weir equation (36). This value was used to provide the goal for the duration of exercise sessions for the first month of the intervention. For example: prescribed EEEx during month 1 = 150 kcal•session^{-1}, EEEx = 9.2 kcal•min^{-1}, exercise duration = 150 kcal•session^{-1} divided by 9.2 kcal•min^{-1} = 16 min•session^{-1}. Similar procedures to determine exercise duration were conducted at the end of each month over the course of the 10 month intervention to adjust for potential effects of changes in both body weight and cardiovascular fitness on EEEx, thus over time the treadmill speed and/or grade were increased. The duration and intensity of all exercise sessions were verified by a downloadable HR monitor (RS 400; Polar Electro Inc., Woodbury, NY) set to collect HR in 1-minute epochs. All exercise sessions and assessments of EEEx were preceded by a brief warm up on the treadmill (~ 2 minutes, 3–4 mph, 0% grade). Treadmill speed and grade were subsequently increased to achieve the prescribed target HR. Additionally, the level of perceived exertion (2), treadmill speed/grade and HR were recorded by the research assistant at 10 minute intervals during each exercise session. This procedure provided interaction between study staff and participants and helped to maintain compliance, as well as a detailed description of each exercise session. Compliance to the exercise protocol, an essential element of an efficacy study, was defined as successfully completing > 90% of scheduled exercise sessions. Successful completion was defined as maintaining the target exercise HR ± 4 beats• min^{-1} for the prescribed duration of the exercise session. Participants who were non-compliant during any 3 month interval (months 0–3, 3–6, 6–9) or during the final month (month 10) were dismissed from the study.

Control group

Participants assigned to the non-exercise control group were instructed to continue their typical patterns for physical activity and dietary intake over the duration of the 10 month study. With the exception of assessment of EEEx, the same outcome assessments were completed with both the exercise and control groups.

Energy/macronutrient intake

Energy and macronutrient intake was assessed at baseline, 3.5, 7, and 10 months over 7-day periods of ad libitum eating in a University of Kansas cafeteria using digital photography. Two digital photographs were obtained before and after consumption of each meal with the cafeteria trays placed in docking station to standardize the camera angle (Figure 1). One photograph was taken at a 90° angle above the tray and one photograph was taken at a 45° angle to maximize depth perception and identification of food and beverage items. Notes were placed on the tray to identify types of beverages (e.g. diet vs. regular soft-drink, skim vs. whole milk, etc.) and any other food items that would be difficult to identify from the photo. Foods consumed outside the cafeteria (i.e., snacks, non-cafeteria meals) over the 7-day periods were assessed using multiple-pass recall procedures using food models and standardized, neutral probing questions. The type and amounts of food and beverages consumed at the cafeteria and results from recalls were entered into the Nutrition Data System for Research (NDS-R Versions 2005, 2006, University of Minnesota, Minneapolis, MN) for the quantification of energy and macronutrient intake. Prior to data collection, all nutrition research staff completed standardized training, conducted by a registered dietitian, covering the digital photograph methodology, multiple-pass dietary recalls, and NDS-R computer coding, with refresher sessions every 2 months. Prior to collecting data on study participants, nutrition research staff were required to satisfactorily evaluate digital photographs from 10 sample meals (before and after) and complete ten 24-hr. recalls from non-study participants. Dietary intake data were then entered into NDS-R. Energy and macronutrient intake estimated from digital photographs was compared with weigh and measure values. An error ≤ 5% was required prior to data collection on study participants. Recalls were evaluated according to a published dietary recall documentation checklist (34). An error rate ≤ 5% on both the recall documentation checklist and computer coding was required prior to data collection. Inter-rater reliability coefficients for both digital photograph and 24-hr. recall assessments were ≥ 0.95. We have also demonstrated that 7 days of dietary data adequately characterize usual energy and macronutrient intake (16). Baseline data from the current study indicated that digital photography provided a significantly more accurate assessment of energy intake over 7 days (error = 6.8%) compared with energy intake assessed by 3-day food records during the same assessment period (error = 15.7 %) using total daily energy expenditure assessed by doubly labeled water as the standard. Thus, digital photography may provide better estimates of energy and macronutrient intake for studies on the effect of exercise training on dietary behavior where 24-hr. recalls or 3- to 7-day food records have been typically employed (24, 27). Participants were required to eat a minimum of 2 meals•d^{-1} on weekdays, and 1 meal•d^{-1} on weekends over the 7-day period in the cafeteria. Participants who were non-compliant with the energy intake assessment protocol were dismissed from the study.

Diet Quality

Diet quality was estimated using the Healthy Eating Index-2010 (HEI-2010) developed by the United States Department of Agriculture (17) to assess conformance to the 2010 Dietary

Guidelines for Americans (5). The HEI-2010 was calculated using NDSR output obtained from digital photograph data following the method developed by Miller et al. (23) modified for the 2010 guidelines. HEI-2010 scores range from 0 to 100. Scores > 80 are considered "good", scores between 51 and 80 are classified as "needs improvement" and scores < 51 are classified as "poor" diet quality.

Analysis

Baseline measures and demographic characteristics were summarized using means and standard deviations for continuous variables, and frequencies and percentages for categorical variables. Analysis of variance (ANOVA) was performed to examine group differences in baseline characteristics. ANOVA and paired-sample t-tests were conducted to compare energy and macronutrient intake between and within treatment groups. General linear mixed modeling was also used to examine overall group differences (group effect), change over time (time effect), and group differences in this change (group-by-time interaction). Model parameters were estimated for each outcome, along with unconstrained correlations among repeated assessments which provide better model fit than other error covariance structures according to Akaike Information Criterion and Bayesian Information Criterion (3). Models were adjusted for age and sex thereby providing unbiased estimates of the treatment effects. When the group effect or group-by-time interaction was significant at 0.05 alpha level, adjusted means were pairwise compared using Bonferroni-correction for Type 1 error inflations. All analyses were conducted using SAS 9.3 (SAS Institute, 2002–2010).

RESULTS

Participants

Ninety-one of the 141 participants randomized at baseline (65%) complied with the study protocol and completed all outcome assessments. The completion rate was 75%, 70% and 60% for the control, 400 and 600 kcal•session^{-1} groups, respectively. Approximately 44% of those who did not complete the study were dismissed by the investigators for failure to comply with the study protocol. Additional reasons for drop out included lack of interest/ time, schedule conflicts, and unwillingness to comply with the dietary assessment protocol. The baseline characteristics of the 91 participants who completed the study are presented in Table 1. The sample mean age was ~ 23 years, BMI ~ 31 kg•m^{-2} and the sample was comprised of ~ 50% women and 16% minorities. There were no differences in baseline characteristics (age, BMI, body composition, percent female, energy intake) between participants who completed or did not complete the study protocol, with the exception of a small but significantly higher level of aerobic fitness ($p < 0.05$) in participants who completed (33.4 ± 5.9 ml•kg•min^{-1}) versus those who did not complete the study protocol (31.4 ± 5.5 ml•kg•min^{-1}). No major adverse events were reported among participants in either the exercise or control groups.

Exercise compliance/EEEx

Attendance at exercise sessions (≥ 91%) and did not differ by sex or exercise group. The mean EEEx from month 4 to 10 for the 400 and 600 kcal•session^{-1} groups was 402 ± 6 and 604 ± 7 kcal•session^{-1}, respectively. There were no differences in exercise intensity, or between men and women assigned to exercise at 400 or 600 kcal•session^{-1}. Due to higher body weight, men required less time to complete the 400 (men = 31 ± 6 min, women 48 ± 7 min) or 600 kcal•session^{-1} (men = 42 ± 8 min, women = 63 ± 9 min) protocols compared with women.

Weight/body composition

Results for change in weight and body composition, assessed by dual energy x-ray absorptiometry, are presented in detail elsewhere (11). Briefly, weight change over the 10-month intervention in both the 400 (−3.9 ± 4.9 kg; 4.3%) and 600 kcal•session^{-1} (−5.2 ± 5.6 kg; 5.7%) groups was significantly different from controls (+ 0.5 ± 3.5 kg; 0.5%); however, weight change did not differ significantly between the exercise groups. There were no significant differences in weight change between men and women in either the 400 (men: − 3.8 ± 5.8 kg; −3.7%; women: − 4.1 ± 4.2 kg; 4.9%) or 600 (men: − 5.9 ± 6.7 kg; 5.9%; women: − 4.4 ± 2.1 kg; 5.4%) kcal•session^{-1} groups. Fat mass decreased significantly from baseline to 10 months in both the 400 (−3.5 ± 4.8 kg) and 600 kcal•session^{-1} (−5.2 ± 5.2 kg) but not in controls (+0.2 ± 3.2 kg). There were no significant differences for change in fat mass between men and women in either the 400 (men: − 3.6 ± 5.3 kg, women: − 3.4 ± kg) or 600 kcal•session^{-1} groups (men: − 5.9 ± 6.0 kg, women: − 4.4 ± 4.3 kg). There were no significant changes in fat-free mass any study group; thus, the reductions in body weight observed in the exercise groups were a result of decreased fat mass.

Energy intake

Absolute energy intake (kcal•d^{-1}) over the 10-month intervention in the total sample, and in men and women is presented in Figure 2A and Table 2. There were no significant group differences in absolute energy intake at baseline, 3.5, 7, or 10 months in the total sample or in men. However, in women, absolute energy intake was significantly greater in the 600 kcal•session^{-1} group compared with controls at both 3.5 and 7 months. Mixed modeling revealed that after controlling for age and sex there were no significant between-or-within-group differences (group or time effect) or group-by-time interaction in absolute energy intake in the total sample, or in men or women. There was a consistent pattern for change in absolute energy intake from baseline to 10 months in the total sample and in men and women. That is, absolute energy intake increased in the 600 kcal•session^{-1} group and decreased in both the 400 kcal•session^{-1} and control groups. Increased energy intake was observed in the 600 kcal•session^{-1} group in spite of a mean weight loss of 5.7%.

Although we observed no significant change in mean energy intake in response to a 10-month aerobic exercise program; inter-individual variability was considerable (Figure 3). In the total sample, energy intake at 10 months was increased compared to baseline in ~ 33% of controls (mean increase = 438 ± 358 kcal•d^{-1}), ~ 42% of the 400 kcal•session^{-1} group (293 ± 159 kcal•day^{-1}) and ~ 62% of the 600 kcal•session^{-1} group (444 ± 243 kcal•d^{-1}). Interestingly, despite the high percentage of participants in the exercise groups that increased energy intake over the 10 month intervention, 71% of participants in the 400 kcal•session^{-1} group and 81% of the participants in the 600 kcal•session^{-1} group lost weight.

Energy intake relative to body weight (kcal•kg•day^{-1}) over the 10- month intervention is presented in Figure 2B and Table 2. There were no significant group differences in relative energy intake at baseline, 3.5, 7, or 10 months in the total sample, or in men or women. However, mixed modeling showed that after controlling for age and sex, the group-by-time interaction was significant in the total sample ($p < 0.01$), and in both men ($p=0.03$) and women ($p =0.01$). Relative energy intake increased from baseline to 10 months in the 600 kcal•session^{-1} group and was essentially unchanged or slightly decreased in the 400 kcal•session^{-1} and control groups.

Macronutrient intake

Macronutrient intake at baseline, 3.5, 7, and 10 months in the total sample and by sex is presented in Table 3. There were no significant group differences in intake of carbohydrate, fat or protein expressed as either g•day^{-1} or as a percentage of energy intake at baseline, 3.5, 7, or 10 months in the total sample. In men, fat intake as a percentage of energy intake was significantly higher in the 400 compared with the 600 kcal•session^{-1} group at baseline and 7 months. There were no significant group differences in fat intake as a percentage of energy intake at any time point in women. However, in women, fat intake (g•d^{-1}) was significantly higher in the 600 kcal•session^{-1} group compared with controls at 3.5 and 7 months, reflecting the decreased absolute energy intake in control women. Also, protein intake (g•d^{-1}) in women was significantly higher in the 400 compared with the 600 kcal•session^{-1} group at 3.5 months and significantly greater in the 600 kcal•session^{-1} group compared with controls at 7 months; however, no significant group differences in protein intake as a percentage of energy intake were observed at any time point. Mixed modeling revealed no significant treatment effects on the intake of carbohydrate, fat or protein expressed as either g•d^{-1} or as a percentage of energy intake in the total sample or in men or women.

HEI-2010

There were no significant between-or within-group differences in HEI in the total sample, or in men or women. The HEI-2010 score averaged across all time periods was 37.6 ± 8.9, 35.6 ± 8.4 and 36.7 ± 8.5 for the 400 kcal•session^{-1}, 600 kcal•session^{-1}, and control groups, respectively. HEI-2010 scores were significantly higher in women (38.8 ± 9.0) compared with men (34.6 ± 7.7, $p < 0.01$).

DISCUSSION

We found no significant change in energy intake assessed by digital photography in response to a 10-month, supervised aerobic exercise program, at 2 measured levels of EEEx, in a sample of previously sedentary, overweight and obese young adults. This finding is consistent with results from previous randomized and non-randomized trials conducted by our group (12, 13, 31) and others (6, 7, 19, 20, 24, 27). However, randomized and non-randomized trials have also reported both significantly increased (22) and decreased energy intake in response to exercise training (8, 21). The observation that exercise training does not induce compensatory increases in mean energy intake is relatively consistent; however, these trials were not specifically designed to address this issue. Additionally, these trials have generally assessed energy intake by self-report food records (4, 21, 24, 27), which may not provide data of sufficient quality to adequately address this question (29). However, trials which employed more precise estimates of energy intake, such as weigh and measure test meals (6, 7, 20, 27), or observed weigh and measure ad-libitum eating (13), have also reported no change in mean energy intake in response to exercise training. In addition, most previous trials have not prescribed exercise by level of energy expenditure or assessed the actual level of EEEx achieved (9). Without precise measures of both energy intake and EEEx it is not possible to quantify the association between these two variables.

The change in energy intake in response to exercise training displayed considerable individual variability, which is at least partially responsible for the high levels of individual variability in weight change observed in this trial (11), and other exercise and weight loss trials (8, 10, 20). Interestingly, ~ 52% of participants in the exercise groups increased energy intake over the 10-month intervention (mean increase = ~369 kcal•d^{-1}) with 38% of exercise participants increasing energy intake ≥ 200 kcal•d^{-1}. However, 77% of exercise group participants lost weight. As described in detail in a companion paper (38),total daily energy expenditure assessed by doubly labelled water increased ~250 kcal•d^{-1} in the exercise groups from baseline to 10 months. Therefore, in a majority of participants the increased energy intake did not fully compensate for the imposed EEEx and resulting increased total daily energy expenditure, allowing most participants to achieve a negative energy balance. The observation that both absolute and relative energy intake tended to increase in the 600, but not in the 400 kcal•session^{-1} group suggests there may be a level of EEEx that induce compensatory increases in energy intake. However, the increased energy intake even in the 600 kcal•session^{-1} group was insufficient to fully compensate for that level of EEEx and an associated mean increase in total daily energy expenditure of ~289 kcal•d^{-1} (38); as 81% of participants in the 600 group lost weight (mean = − 5.7%). Thus, exercise without energy, restriction represents a positive behavioral approach which may be an attractive first line weight loss recommendation for overweight or obese young adults who are unwilling or unable to comply with energy restriction or intensive behavioral counseling. Identification of characteristics of participants who increase energy intake in response to aerobic exercise, and the levels of EEEx at which compensatory increases occur, will be important for tailoring exercise interventions for both the prevention and treatment of obesity. However, in this trial, as well as previous trials (13) we have been unable to identify any baseline characteristics which differentiate participant who do or do not increase energy intake in response to aerobic exercise.

Our finding of no significant sex difference for change in energy intake in response to exercise training is in agreement with previous results from our group (13) and others (7, 37). The current trial, and the trial by Caudwell et al (7) both showed non-significant differences for weight loss between men and women in response to exercise of equal energy expenditure, which argues against the notion that women are unable to achieve clinically significant weight loss with exercise without energy restriction. In the current trial, mean weight loss in men in the 600 kcal•session^{-1} group (−5.9%) was greater than in the 400 kcal•session^{-1} group (−3.7%); however, in women mean weight loss in the 400 kcal•session^{-1} (−4.9%) and 600 kcal•session^{-1} groups (−5.4%) were nearly identical. Sex differences in energy intake between the 400 and 600 kcal•session^{-1} groups offer a potential explanation for the observation of greater weight loss with increased exercise energy expenditure in men, but not in women. In men, energy intake during the exercise intervention (i.e., mean of months 3.5, 7 and 10) was similar in both the 400 kcal•session^{-1} (3205 kcal•day^{-1}, 33.8 kcal•kg•day^{-1}) and 600 kcal•session^{-1} groups (3208 kcal•day^{-1}, 32.8 kcal•kg•day^{-1}). However, in women energy intake during the intervention was greater in the 600 kcal•session^{-1} (2619 kcal•day^{-1}, 34.2 kcal•kg•day^{-1}) compared with the 400 kcal•session^{-1} (2459 kcal•day^{-1}, 31.3 kcal•kg•day^{-1}). Although based on a relatively small sample, potential sex differences in the energy intake response to different levels of EEEx may warrant additional investigation.

We found no clinically relevant changes in macronutrient intake in response to aerobic training, a result in agreement with previous reports from our group (12, 13, 31) and others (8, 19, 20, 22, 24, 27). However, changes in macronutrient intake in response to exercise training have been reported. For example, Brandon et al (4) reported a significant increase in absolute carbohydrate intake in white, but not African American women, while Kirkwood et al (21) reported a significant increase in fat intake as a percentage of total energy intake, with no change in the percentage of energy intake from carbohydrate or protein. Studies have also reported both significant increases (39, 40) and decreases in carbohydrate intake (4) and significant increases (12) and decreases in fat intake (39) in response to exercise training.

Diet quality, as assessed by the HEI-2010, was poor and did not change in response to exercise training. Thus, simply engaging in aerobic exercise training does not result in changes in diet quality that may be associated with improved health. The average HEI-2010 score observed in our sample of young adults (36.6) was lower than that reported for the average American (53.5) (35). Diets were very low in fruits, vegetables, seafood and plant proteins, and very high in sodium. Our observation of poor diet quality among college age individuals, and higher diet quality in women compared to men, has been reported previously (15, 18). We are unaware of other trials that have evaluated the effect of exercise on HEI-2010.

Strengths of the current investigation include: 1) the use of a randomized efficacy design, 2) a relatively long intervention (10 months), 2) inclusion of both men and women, 3) the use of supervised exercise at 2 verified levels of energy expenditure, and 3) multiple assessments of energy and macronutrient intake using digital photography. Potential limitations may include: 1) The study was not specifically designed to detect differences in change in energy and macronutrient intake either within or between intervention groups. 2) Although energy intake was assessed using digital photography, our protocol provided direct observation of a minimum of 57% of meals consumed at baseline, 3.5, 7 and 10 months. Thus, our inability to detect significant changes in energy and macronutrient intake may be a function of under-reporting of foods not consumed under direct observation, 3) Participant attrition (35%). We emphasize that MET-2 was an efficacy trail designed to answer questions relative to the effect of exercise training on body weight, energy intake etc. when the exercise was competed as intended., thus higher rates of attrition, when compared with effectiveness trials, are expected. However, our observed attrition rate was similar to the attrition rate we used in our power calculations for our primary aim (33%) and nearly identical to attrition rates reported in other longer term randomized trials (> 6 months) which have evaluated the impact of exercise training on energy intake (~36%) (25, 26). Additionally, MET-2 was an efficacy trial conducted in overweight and obese young adults, thus generalization of results to other groups, such as middle age or older adults, or comparisons with trials using and intent-to-treat analysis are unwarranted.

In summary, we found no significant change in energy or macronutrient intake in response to a 10 month, supervised exercise program in overweight and obese young adults. The possibility of a threshold beyond which further increases in EEEx do not produce a more negative energy balance, and potential sex differences in the energy intake response to increased levels of EEEx observed in this study, are potentially important and worthy of investigation in an adequately powered trial. Randomized trials designed and powered to evaluate the effect of additional exercise parameters, e.g. mode, frequency, intermittent vs. continuous, time of day, and participant characteristics including age, body weight/composition, race/ethnicity, and aerobic capacity on energy and macronutrient intake are warranted. This information will be important for both the design and targeting of weight management intervention using exercise alone, or exercise in combination with energy restriction.

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The results of the present study do not constitute endorsement by ACSM

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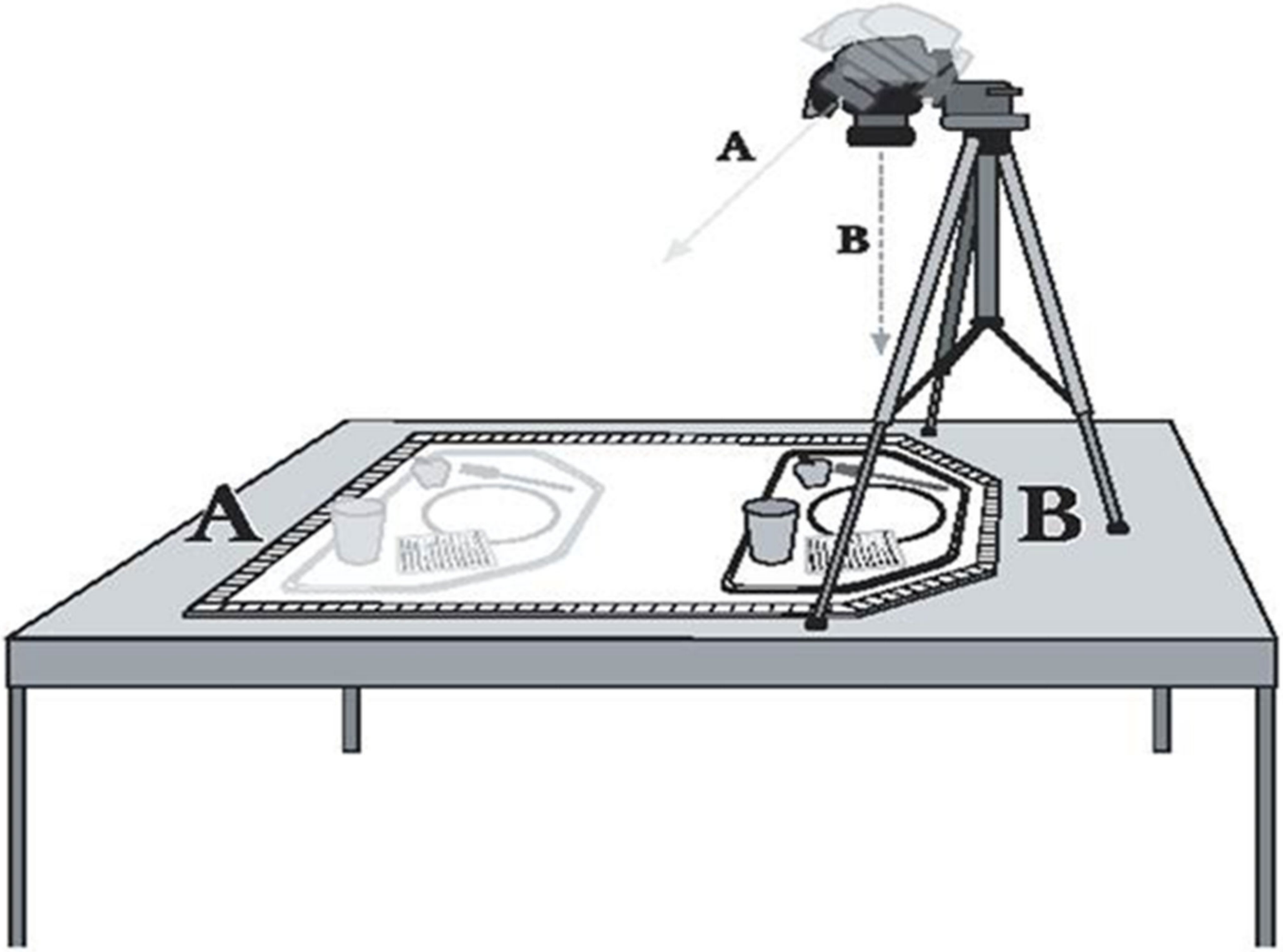

Figure 1.
Set-up for the assessment of energy intake by digital photography
A = Photo at 45 degrees; B = Photo at 90 degrees

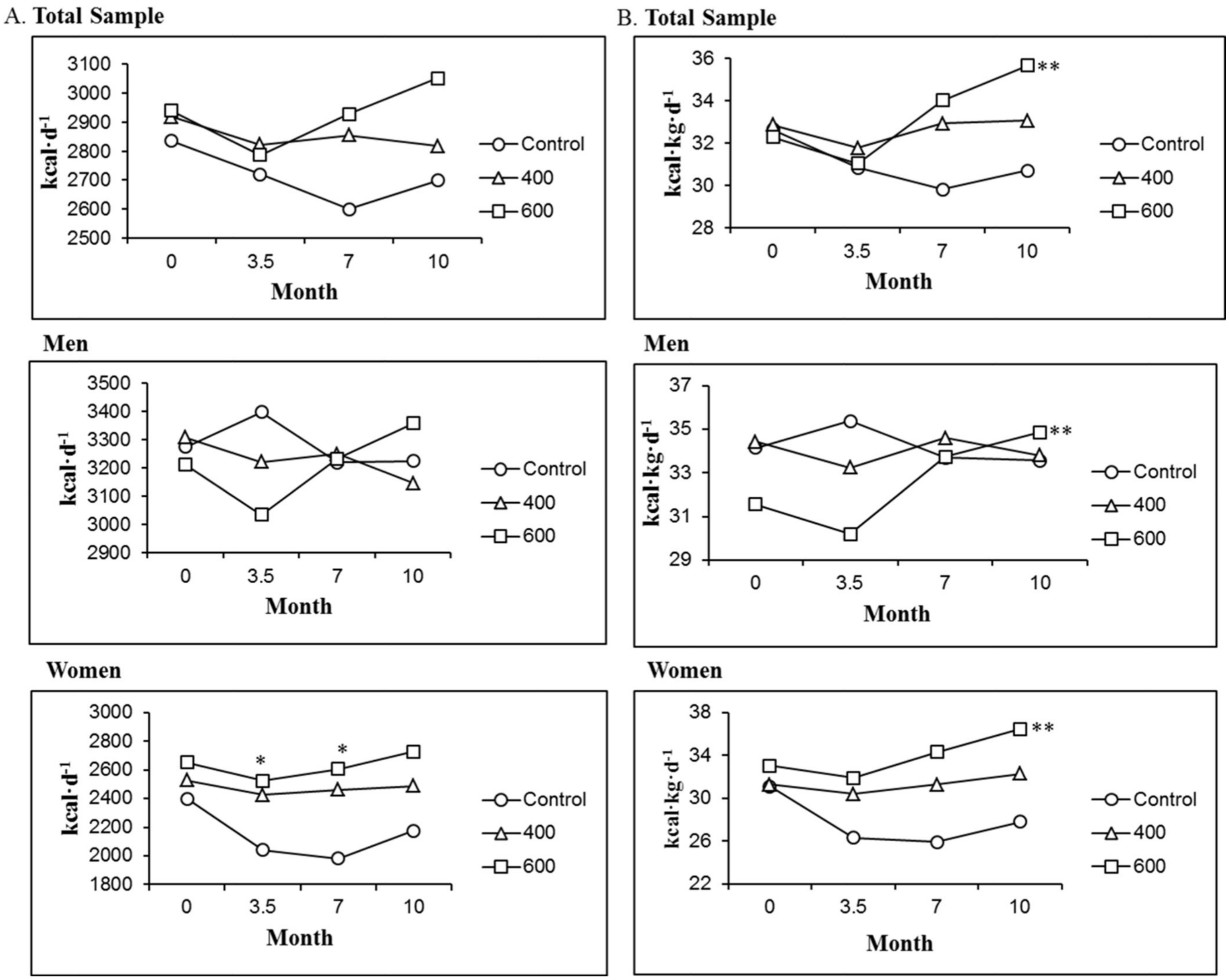

Figure 2.
A. Absolute energy intake (kcal•day^{-1}) over 10 months in the total sample, men and women. * 600 kcal•session^{-1} group significantly greater than control (p <0.05).
B. Relative energy intake (kcal•kg^{-1} body weight•day^{-1}) over 10 months in the total sample, men and women. ** Significant group-by-time interaction based on mixed modeling. Total sample (p < 0.01), men (p=0.03) and women (p =0.01).

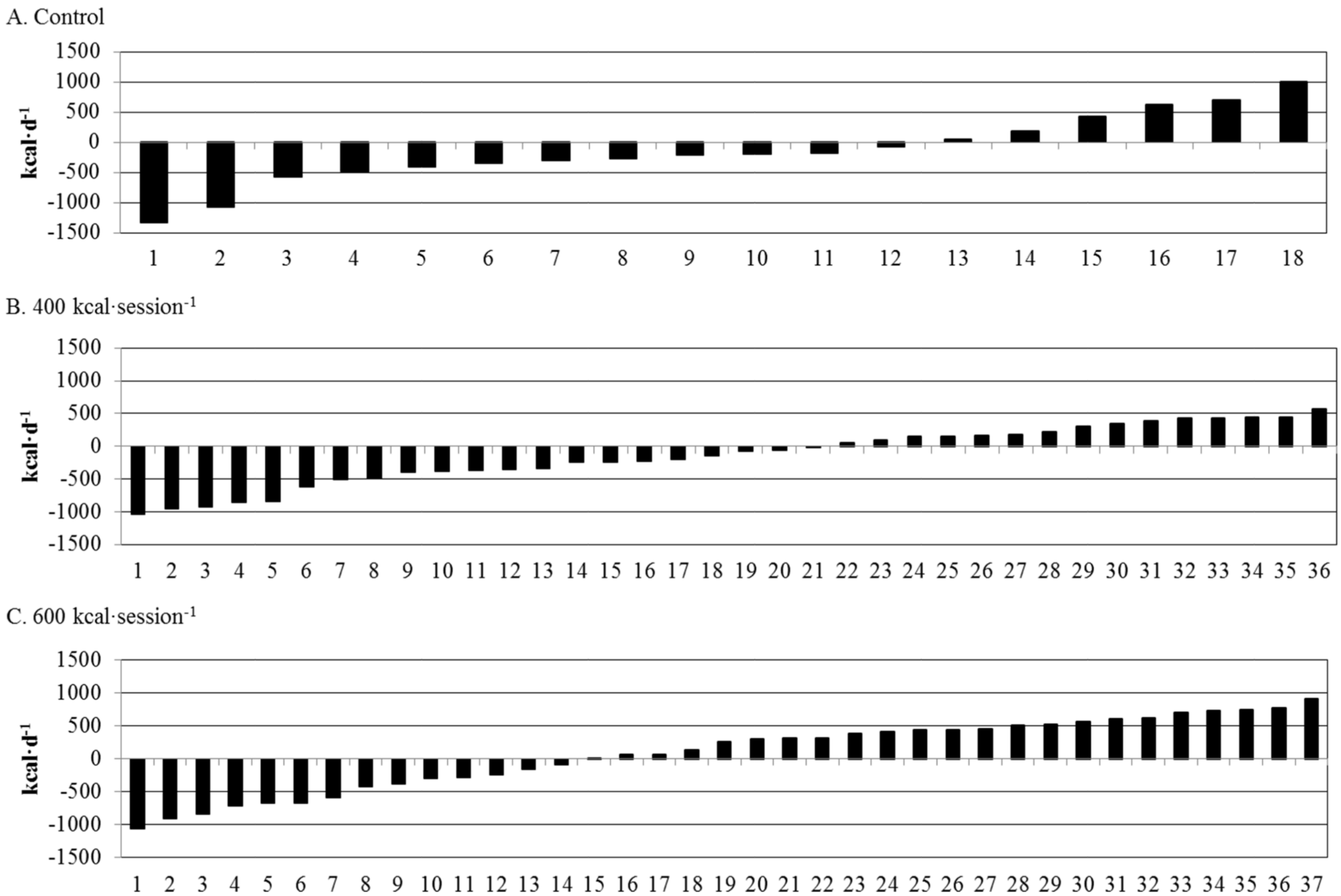

Figure 3.

Inter-individual variability in change in absolute energy intake (kcal•day^{-1}), 10 month minus baseline) by intervention group.

Table 1

Baseline Participant Characteristics

	400 (*n* = 36)	**600 (*n* = 37)**	**Control (*n* = 18)**
Age (yrs.)	23.1 ± 3.0	23.0 ± 3.5	22.6 ± 3.0
Anthropometrics			
Weight (kg)	91.4 ± 20.7	92.0 ± 16.1	87.4 ± 14.6
BMI (kg·m^2)	31.2 ± 5.6	30.6 ± 3.9	29.7 ± 3.8
Body fat (%)	39.6 ± 7.5	40.2 ± 6.2	41.0 ± 6.1
Cardiovascular Fitness			
Maximal VO_2 (L·min^{-1})	3.0 ± 0.7	3.1 ± 0.8	2.8 ± 0.6
Maximal VO_2 (ml·kg·min^{-1})	33.4 ± 6.5	34.1± 5.7	32.3 ± 5.0
Minorities (*n*/%)	6/17%	1/3%	5/28%
Women (*n*/%)	18/50%	18/49%	9/50%

Note: Unless otherwise stated values are mean ±SD.

Table 2

Absolute and relative energy intake (mean ± SD) across 10 months by intervention group (400 kcal•session^{-1}, 600 kcal•session^{-1}, control) in the total sample and by sex.

		Total Sample			Men			Women		
Variable	**Month**	**400 (*n* = 36)**	**600 (*n* = 37)**	**Control (*n* = 18)**	**400 (*n* = 18)**	**600 (*n* = 19)**	**Control (*n* = 9)**	**400 (*n* = 18)**	**600 (*n* = 18)**	**Control (n = 9)**
Absolute energy intake (kcal•d^{-1})										
	0	2918 ± 659	2940 ± 685	2836 ± 642	3309 ± 657	3210 ± 758	3274 ± 526	2528 ± 376	2654 ± 467	2398 ± 408
	3.5	2823 ± 693	2787 ± 797	2720 ± 883	3221 ± 756	3035 ± 938	3398 ± 566	2425 ± 284	2525 ± 523	2041 ± 550[a]
	7	2855 ± 783	2927 ± 722	2600 ± 753	3248 ± 815	3233 ± 731	3219 ± 476	2462 ± 520	2605 ± 569	1981 ± 340[b]
	10	2817 ± 748	3051 ± 724	2699 ± 836	3145 ± 717	3356 ± 738	3224 ± 728	2489 ± 641	2728 ± 565	2175 ± 580
Relative energy intake (kcal•kg•d^{-1})										
	0	32.9 ± 8.2	32.3 ± 6.3	32.6 ± 6.0	34.4 ± 9.5	31.6 ± 6.7	34.2 ± 5.0	31.3 ± 6.5	33.0 ± 6.1	31.1 ± 6.8
	3.5	31.8 ± 7.1	31.1 ± 7.5	30.8 ± 7.7	33.2 ± 8.1	30.2 ± 7.9	35.4 ± 4.5	30.4 ± 5.8	31.9 ± 7.3	26.3 ± 7.6
	7	32.9 ± 8.8	34.4 ± 8.7	29.8 ± 6.7	34.5 ± 9.5	33.7 ± 7.0	33.5 ± 4.9	31.3 ± 8.0	35.1 ± 10.4	25.9 ± 6.2
	10	33.1 ± 9.2	35.4 ± 8.2	30.7 ± 7.8	33.3 ± 9.4	34.9 ± 5.2	33.6 ± 7.7	32.3 ± 9.3	36.1 ± 10.4	27.8 ± 7.2

[a] 600 significantly > control, $p = 0.036$,

[b] 600 significantly > control, $p = 0.016$

Table 3

Macronutrient intake (mean ± SD) across 10 months by intervention group (400 kcal•session^{-1}, 600 kcal•session^{-1}, control) in the total sample and by sex.

		Total Sample			Men			Women		
Variable	**Month**	**400 (*n* = 36)**	**600 (*n* = 37)**	**Control (*n* = 18)**	**400 (*n* = 18)**	**600 (*n* = 19)**	**Control (*n* = 9)**	**400 (*n* = 18)**	**600 (*n* = 18)**	**Control (*n* = 9)**
Cho (g•d^{-1})										
	0	343 ± 77	344 ± 102	316 ± 85	375 ± 81	386 ± 118	377 ± 63	312 ± 58	300 ± 58	255 ± 54
	3.5	338 ± 92	328 ± 124	312 ± 107	365 ± 114	363 ± 147	388 ± 72	310 ± 52	291 ± 84	235 ± 77 [c]
	7	336 ± 90	338 ± 98	299 ± 96	368 ± 102	379 ± 104	374 ± 69	304 ± 64	293 ± 69	224 ± 46 [d]
	10	332 ± 87	355 ± 97	313 ± 101	361 ± 92	389 ± 104	371 ± 93	303 ± 73	319 ± 76	256 ± 74
Cho (% EI)										
	0	48 ± 6.7	47 ± 5.9	45 ± 4.7	45 ± 4.5	48 ± 7.1	46 ± 4.4	50 ± 7.8	46 ± 4.3	43 ± 4.6 [e]
	3.5	48 ± 7.1	47 ± 6.8	46 ± 5.1	45 ± 6.0	48 ± 6.8	46 ± 4.1	51 ± 6.8	46 ± 6.9	46 ± 6.3
	7	48 ± 63	47 ± 6.1	46 ± 4.0	45 ± 5.5	48 ± 5.9	47 ± 3.0	50 ± 6.1	46 ± 6.1	46 ± 5.0
	10	46 ± 5.3	47 ± 6.1	47 ± 3.7	46 ± 4.0	46 ± 5.7	46 ± 2.8	50 ± 5.9	47 ± 6.5	47 ± 4.6
Fat (g•d^{-1})										
	0	124 ± 36.9	122 ± 29.7	123 ± 28.3	146 ± 34.2	128 ± 31.6	138 ± 25.3	101 ± 23.2	115 ± 26.5	108 ± 23.5
	3.5	117 ± 32.6	116 ± 31.1	111 ± 38.5	140 ± 28.3	122 ± 35.1	140 ± 24.7	94 ± 16.4	108 ± 27.7	82 ± 24.7 [f]
	7	121 ± 39.1	124 ± 32.5	108 ± 33.3	143 ± 37.7	132 ± 31.2	132 ± 23.5	100 ± 26.6	115 ± 32.5	84 ± 22.8 [g]
	10	118 ± 35.6	125 ± 32.5	112 ± 40.8	134 ± 30.0	137 ± 33.9	136 ± 34.3	102 ± 34.7	111 ± 25.7	87 ± 31.7
Fat (% EI)										
	0	38 ± 5.6	37 ± 4.6	39 ± 4.6	40 ± 4.5	36 ± 4.5	38 ± 2.8 [a]	36 ± 6.0	39 ± 4.5	40 ± 5.7
	3.5	37 ± 5.7	37 ± 5.0	37 ± 4.2	40 ± 5.4	36 ± 5.0	37 ± 3.1	35 ± 5.3	38 ± 4.9	36 ± 5.2
	7	38 ± 5.5	38 ± 4.8	37 ± 4.5	40 ± 5.1	36 ± 4.0	37 ± 3.1 [b]	36 ± 5.2	39 ± 5.0	37 ± 5.7
	10	37 ± 4.3	37± 4.8	37 ± 4.0	38 ± 3.8	37 ± 5.2	37 ± 2.5	36 ± 4.8	37 ± 4.5	36 ± 5.0
Pro (g•d^{-1})										
	0	104 ± 28.7	108 ± 23.0	105 ± 24.3	123 ± 26.7	119 ± 23.5	121 ± 22.1	85 ± 14.7	95 ± 15.6	89 ± 13.8
	3.5	100 ± 28.9	102 ± 27.1	103 ± 33.2	121 ± 26.0	110 ± 32.3	127 ± 26.8	80 ± 12.6	93 ± 17.0	78 ± 16.5 [h]
	7	101 ± 32.8	108 ± 24.8	95 ± 29.2	120 ± 32.2	120 ± 23.6	119 ± 17.3	82 ± 20.0	95 ± 18.9	71 ± 13.2 [i]

		Total Sample			Men			Women		
Variable	**Month**	**400 (*n* = 36)**	**600 (*n* = 37)**	**Control (*n* = 18)**	**400 (*n* = 18)**	**600 (*n* = 19)**	**Control (*n* = 9)**	**400 (*n* = 18)**	**600 (*n* = 18)**	**Control (*n* = 9)**
	10	103 ± 29.9	115 ± 29.0	101 ±35.3	120 ± 27.8	129 ± 27.2	125 ± 24.6	85 ± 19.9	99 ± 22.9	78 ± 28.0
Pro (%EI)										
	0	14 ± 2.0	15 ± 1.9	15 ± 1.7	15 ± 1.8	15 ± 2.2	15 ± 1.4	14 ± 2.0	15 ± 1.5	15 ± 2.1
	3.5	14 ± 2.0	15 ± 2.7	15 ± 2.4	15 ± 1.7	15 ± 1.8	15 ± 1.7	13 ± 1.9	15 ± 3.5	16 ± 3.0
	7	14 ± 2.5	15 ± 2.0	15 ± 2.1	15 ± 2.5	15 ± 1.9	15 ± 1.8	13 ± 2.2	15 ± 2.2	15 ± 2.4
	10	15 ± 2.3	15 ± 2.3	15 ± 2.2	16 ± 2.0	16 ± 2.0	16 ± 1.7	14 ± 2.4	15 ± 2.5	15 ± 2.6

[a] 400 > 600, $p = 0.044$,

[b] 400 > 600, $p = 0.028$,

[c] 400 > control, $p = 0.047$,

[d] Both 400 and 600 > control, $p = 0.010$,

[e] 400 > control, $p = 0.011$,

[f] 600 > control, $p = 0.027$,

[g] 600 > control, $p = 0.032$,

[h] 400 > 600, $p = 0.02$,

[i] 600 > control, $p = 0.007$,

Abbreviations: Cho = carbohydrate, EI = energy intake, Pro= protein