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Activity Related Energy Expenditure, Appetite and Energy Intake: Potential Implications for Weight Management

D.M. Harrington, **C.K. Martin**, **E. Ravussin**, and **P.T. Katzmarzyk**
Pennington Biomedical Research Center, 6400 Perkins Road, Baton Rouge, Louisiana 70808, USA.

Abstract

The aim was to investigate relationships between activity related energy expenditure (AREE), appetite ratings and energy intake (EI) in a sample of 40 male (26.4 years; BMI 23.5 kg/m^2) and 42 female (26.9 years; BMI 22.4 kg/m^2) participants. AREE was expressed as the residual value of the regression between total daily EE (by doubly labeled water) and resting EE (by indirect calorimetry). EI was measured using an *ad libitum* buffet meal and visual analogue scales measured subjective appetite ratings before and after the meal. AREE was divided into low, middle and high sex-specific tertiles. General linear models were used to investigate differences in appetite ratings and EI across AREE tertiles. Before the meal, males in the high AREE tertile had significantly lower desire to eat and lower prospective food consumption and higher feelings of fullness compared to those in the low tertile. Males in the middle tertile had significantly higher satiety quotients after the meal and lower EI compared to the other tertiles. No significant differences across tertiles were found in females. Sex differences in relationships between AREE, appetite ratings and EI may lead to differing patterns of EI and subsequent weight maintenance.

Keywords

hunger; fullness; visual analogue scale; doubly labeled water; habitual physical activity

Introduction

The importance of physical activity for the maintenance of weight loss is well established (Wing & Phelan, 2005). While there is no doubt that physical activity alone has independent and significant effects on health (Duncan et al., 2003; King, Hopkins, Caudwell, Stubbs, & Blundell, 2009; Solomon et al., 2009; Weintraub, Rosen, Otto, Eisenberg, & Breslow, 1989), its effect on inducing weight loss may be modest (Fogelholm & Kukkonen-Harjula, 2000) and variable (King, Hopkins, Cauldwell, Stubbs, & Blundell, 2008; Manthou, Gill,

Corresponding author: peter.katzmarzyk@pbrc.edu (Peter Katzmarzyk) Not for publication: Telephone 225-763-2536 Fax 225-763-2927.

InSight Research Group
Peter T. Katzmarzyk, PhD; Eric Ravussin, PhD; Steven R. Smith, MD; Sudip Bajpeyi, PhD; Claude Bouchard, PhD; Stephanie Broyles, PhD; Catherine Champagne, PhD; Conrad Earnest, PhD; Alok Gupta, MD; William Johnson, PhD; Corby Martin, PhD; Robert Newton, PhD; Tuomo Rankinen, Leanne Redman, PhD; Jennifer Rood, PhD; Yourka Tchoukalova, MD, PhD; Catrine Tudor-Locke, PhD.

Wright, & Malkova, 2010). This lack of efficacious effect on weight loss can be linked to metabolic and behavioral changes that occur as a result of altering physical activity volume, intensity and patterns (Hagobian & Braun, 2010; King et al., 2007), all changes that affect daily energy expenditure (EE). It is important to determine whether the EE component of the energy balance equation may undermine weight loss efforts so that appropriate weight management strategies can be employed (King et al., 2008). Recent, well controlled studies have demonstrated how different doses of EE result in participants not losing as much weight as was predicted (Church et al., 2009; Rosenkilde et al., 2012). These people have been termed ‘compensators’ (King et al., 2008) and the identification of the mechanisms that lead to this compensation could lead to better interventions for weight management.

A possible mechanism for the variable effect of EE on weight management may be informed by the relationships with both appetite and energy intake (EI). For example, the appetite and EI response to varying levels of EE from discrete physical activity/exercise sessions or interventions has been investigated where the total EE has varied across groups with varying results (Broom, Batterham, King, & Stensel, 2009; Rosenkilde et al., 2012; Stubbs et al., 2002). Furthermore, a short bout of exercise has the potential to suppress hunger in the short term (King, Burley, & Blundell, 1994) while the long term (days) effects of acute exercise or EE through physical activity are variable and inconsistent (see Martins, Morgan, and Truby (2008) for a review).

The evidence linking EE, EI and appetite ratings has mainly been in response to some form of physical activity stimulus, either an acute bout or a short-term intervention that aims to increase EE. It appears as though no cross-sectional analyses have been conducted to relate energy expended through habitual physical activity, called activity related energy expenditure (AREE) herein, and appetite ratings, where AREE has been measured using doubly labeled water (DLW). This will allow for better understanding of the effects of AREE on appetite ratings and the implications for EI and appetite control. Sex differences in this possible relationship have also not been explored.

The primary aim of this study was to explore the relationship between AREE, EI and subjective appetite ratings. Based on Mayer’s theory (Mayer, Roy, & Mitra, 1956), we hypothesize that those with a moderate level of AREE will have lower EI than those with both low and high AREE. We also hypothesize that appetite ratings will differ between AREE groups. A secondary aim was to investigate whether baseline appetite ratings could predict weight changes over one year.

Methods

Participants

The sample includes adults who participated in the baseline evaluation for the InSight study, a prospective study of weight gain and the development of obesity among initially healthy young adults. All procedures were approved by the Pennington Biomedical Research Center Institutional Review Board. Participants were recruited from the greater Baton Rouge area, Louisiana. To be included in the study, participants had to be aged between 20 and 35 years, have a BMI < 27.5 kg/m^2 and fasting blood glucose < 126 mg/dL. All participants underwent a clinical and physical examination to ascertain their health status prior to inclusion. Exclusion criteria included a history of diabetes or obesity (BMI ≥ 30 kg/m^2), a known inherited medical condition or current or planned medication usage that might influence future health status, a history of chronic or infectious disease or injury, abuse of alcohol or illegal drugs, pregnant, breastfeeding or postpartum, or a history of disordered or abnormal eating.

Originally, 90 individuals provided written informed consent and participated in the larger study, but 3 participants did not have either doubly labeled water (DLW) or food intake test data. As menstrual cycle phase can affect hunger and EI (Brennan et al., 2009), and menstrual data were correlated with some measures in the current sample, we statistically controlled for phase of the menstrual cycle. As such, 5 of the 46 females were excluded due to missing data on their menstrual cycle. Thus, this study relied on 82 participants with complete data for analysis.

Experimental Design

This analysis examined baseline associations as well as changes in weight 1 year after baseline. For all visits, participants reported to the clinic in the fasted state (at least 10 hours) and were asked to avoid alcohol, caffeine and strenuous exercise for at least 24 hours prior to each visit. If these criteria were not met, the visit was rescheduled.

Demographics and Anthropometry

Participants self-reported their date of birth and ethnicity, and females also reported their menstrual cycle details. Height and weight were measured using standardized procedures by staff trained in anthropometry. Height was measured to the nearest 0.5 cm using a wall-mounted stadiometer and weight was measured using a digital scale to the nearest 0.1 kg. Each measurement was taken twice and a third reading was taken if the first two readings were greater than 0.5 cm or 0.5 kg apart, respectively. The average was used in calculations.

Resting Energy Expenditure

Resting energy expenditure (REE) was measured using a Deltatrac II metabolic cart (Datex-Ohmeda, Helsinki, Finland) with a connecting transparent plastic hood. The analyzer was calibrated before each measurement with standardized gases. Calculations of O_2 consumption and CO_2 production were made from continuous measurements of CO_2 and O_2 concentrations in inspired and expired air diluted at a constant air flow (~ 40 L/min) as the participant lay awake and motionless for 30 minutes. The last 20 minutes only were used in calculations. From the above, energy expenditure standardized for temperature, pressure, and moisture was calculated at one-minute intervals.

Total Daily Energy Expenditure and Activity-Related Energy Expenditure

Total daily energy expenditure (TDEE) was measured using DLW over 14 days. Two baseline urine samples were collected prior to administering an oral dose of 1.5 g/kg of body weight mixture of $^{2}H_2O$ and $H_2\,^{18}O$ labeled water. The mix was 1 part 99.9% deuterium and 19 parts 10% ^{18}O. Participants consumed two 100 ml tap water rinses following dose administration to assure complete delivery of the labeled water. After dosing and a first void, two timed urine samples were collected on site and participants provided 2 other urine samples 7 days and 14 days later. Samples were analyzed for $^{2}H_2O$ and $H_2^{18}O$ abundances by isotope ratio mass spectrometry and baseline values were subtracted from the post-dose values and elimination rates were calculated using linear regression. Total body water was determined by averaging deuterium dilution space/1.041 and oxygen dilution space/1.007 and the rate of CO_2 production was calculated (Racette et al., 1994; Schoeller, 1988). TDEE was calculated as rCO_2*(1.1+3.9/FQ)*22.4) which is rCO_2 multiplied by the energy equivalent of CO_2 based on the estimated food quotient of 0.86 (based on the average American diet) and estimated changes in body energy stores. Similar to Redman et al. (2009), AREE was expressed as the residual value of the regression between TDEE and 24-hour REE. This value is positive for participants with higher EE through physical activity and negative for participants with lower EE through physical activity and is self-adjusted for metabolic body size (i.e. REE).

Food Intake Test

Midway through the 14 day DLW procedure, the food intake test was administered once between 11am and 12pm. Twenty of the female participants were in the luteal phase of their menstrual cycle, while 22 were not. Each participant was offered an *ad libitum* buffet-style test meal consisting of 16 food items. These were classed as low fat (<20% fat) and high fat (>45% fat) foods and included snacks (chips, pretzels, nuts, popcorn), cheeses, grilled and breaded chicken bites, dips and dressings (salsa, ranch dressing), sauces (BBQ and sweet and sour), candy (mini-cakes and M&Ms) and beverages (punch and water). Approximately 5700 kcal were available in the buffet meal. The percent energy of the available food from protein: fat: carbohydrate ratio was approximately 19:23:58. Participants ate alone in an isolated location without the option of using cell phones, books or computers and they could consume as much or as little as they desired. General descriptions of the foods were given to participants if they asked but no specific details of the fat or calorie content of the foods were given. Food intake was assessed by covertly weighing food provision and plate waste. Total EI in kcals and the macronutrient content of food consumed was calculated from manufacturers' data and the USDA Food and Nutrient Database (Agricultural Research Service Food Surveys Research Group, 2008).

Visual Analogue Scales

Computerized visual analogue scales (VAS) were used before and after the *ad libitum* buffet test meal. They were used to measure subjective feelings of hunger, fullness, desire to eat and prospective food consumption ("how much food do you think you could eat?"). Participants rated each variable (example "how hungry are you right now?") on a 100 mm line, anchored at both extremes of the variable, i.e. from "not at all" to "extremely." The reliability of these VAS have been established and have been related to subsequent EI in males, including cases where diet on the days before the test were not standardized (Flint, Raben, Blundell, & Astrup, 2000). As appetite ratings after the test meal may simply be a function of the amount of food the participant has consumed, the satiety quotient (SQ) was also calculated, which takes into account the amount consumed during the test meal (Green, Delargy, Joanes, & Blundell, 1997). For each appetite rating, the appetite rating post meal was subtracted from the pre meal appetite rating and divided by the total EI of the meal. Additionally, perceived hunger, disinhibition, and dietary restraint were measured using an eating inventory (Stunkard & Messick, 1985).

Weight Change

Participants reported to the clinic approximately one year after baseline data collection. During this visit, height and weight were measured using the same protocol as at baseline. Analysis of whether participants' weight changed over the year was undertaken with all participants pooled and also with the group divided into those who lost weight, gained weight and maintained weight. Weight maintenance was defined as a change of < ±3% body weight (Stevens, Truesdale, McClain, & Cai, 2005) over the year.

Statistical Analysis

AREE was divided into sex-specific tertiles and represented low, middle and high AREE. For males, the low AREE tertile was demarcated as < -184 kcal/day and the high was >243 kcal/day. For females, the low AREE tertile corresponded to < -144 kcal/day while the high tertile corresponded to > 130 kcal/day. General linear models with Tukey post hoc comparisons, controlling for baseline body weight and menstrual cycle phase (females only), were used to investigate differences in EI and appetite ratings across AREE tertiles. Multiple regression (backward) was used to investigate whether any variables at baseline predicted weight change over one year. All analyses were completed using IBM SPSS v.20 (IBM Corp, Armonk, NY).

Results

Descriptive characteristics of the 82 participants are shown in Table 1. There was no significant difference in age ($p = 0.33$) between the males and females, while females had a lower BMI than males ($p < 0.05$).

Differences in adjusted mean appetite ratings across the AREE tertiles are shown in Tables 2 and 3. In relation to fasting appetite ratings before the test meals (Table 2), males in the low tertile had significantly higher desire to eat, higher PFC and lower fullness than those in the high tertile. There was no significant difference between the middle and high tertiles in any of these variables for males. Males in the low AREE tertile had significantly higher desire to eat values compared to both the middle and high AREE groups ($p < 0.01$). Males in the low tertile reported being significantly hungrier than males in the middle tertile ($p < 0.05$). No significant differences were seen between tertiles in females in any of the fasting appetite variables.

In relation to appetite ratings after the test meal (Table 3), no significant differences were found between any of the AREE tertiles in either sex. Although not significant, there was a trend for males in the high tertile to have higher desire to eat, higher hunger, lower fullness and higher PFC compared to those in the low tertile. These trends are reflected in significant correlations between AREE and hunger, desire to eat and PFC of 0.20, 0.34 and 0.27 ($p = 0.05$) respectively in males.

Significant differences in *ad lib* EI during the buffet test meal across AREE tertiles were seen in males only (Table 4). Males in the middle AREE tertile had significantly lower EI than those in the high tertile ($p = 0.001$) and a trend towards a lower EI compared to those in the low tertile ($p = 0.08$). The mean SQ per kcal results are also provided in Table 4. For both males and females, as AREE increased the SQ decreased indicating a less satiating effect per kcal consumed in the test meal. Males in the high AREE tertile experienced a significantly lower SQ for each appetite rating compared to those in the middle tertile. A significant difference between the males in the low and high groups was seen for the desire to eat SQ only.

Weight Change After 1 Year

Follow-up data were available on 75 of the 82 participants. Of these 75, two participants' data were outliers and were excluded- one gained a substantial amount of weight after being immobilized due to an injury (10.3 kg) and the second radically changed their diet after becoming a student athlete (−14.7 kg). Mean one year follow-up duration was 386 (±24) days, ranging from 344 to 526 days. Mean weight change of the group after 1 year was −0.73 kg (−1.0 kg for men and 2.0 kg for women). These averages mask the large variability in the weight change of both sexes. The range of weight change of the males was −7.9 kg to 8.9 kg while the range was −5.8 kg to 4.3 kg for the females (Figure 1). Thirty nine participants were considered to have maintained their weight over the year (< 3% change of body weight) while 11 participants gained more than 3% of their baseline weight over the year. No significant differences in anthropometric measurements, EI during the test meal or fasting appetite ratings at baseline were found between participants who lost weight, who maintained their weight and who gained weight (data not shown). Furthermore, neither fasting appetite ratings, EI nor AREE at baseline were correlated with the weight change after one year (data not shown). Exploratory analysis on the group as a whole (regardless of loss, maintenance or gain) and stratified by loss, maintenance and gain revealed no

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significant models/predictors (variables that were included in the regression analysis were gender, age at enrollment, baseline weight, AREE, full before, desire to eat before and PFC before the test meal). No significant models were found for any of the groups.

Discussion

This study suggests that the link between energy expended through habitual physical activity and both EI and appetite ratings are variable among individuals and may differ between males and females. Specifically, we have shown that EI of males was lower in the middle AREE group compared to the high AREE group. Also, males with lower levels of AREE had a significantly higher drive to eat in the fasted state compared to those with high AREE and SQs were higher in the middle AREE compared to the high AREE group. Non-significant trends were found for appetite ratings after the test meal that may promote overconsumption in males. In females, no differences were found in EI, appetite ratings or SQs across AREE groups.

Previous studies have investigated EI and appetite ratings across levels of EE based on differing EE doses from discrete sessions. For example, Stubbs et al. (2002) increased daily EE by 0, 1.6 and 3.2 MJ/day and found no differences in daily EI over a 9 day protocol (Stubbs et al., 2002). Whybrow et al. (2008) demonstrated that male participants increased their EI when their exercise EE increased incrementally over 16 days as they moved from no exercise, to moderate and to high exercise. This increase was not evident in females and there was no difference in appetite ratings as EE increased in either sex (Whybrow et al., 2008). Broom, Batterham, King, and Stensel (2009) found that appetite was suppressed in the hours immediately after two different levels of EE exercise (high EE from running and low EE from resistance training) and slightly more in the higher EE bout in males (Broom et al., 2009). Most recently, Rosenkilde et al., (2012) found that EI and non-exercise activity of overweight, sedentary males was similar between a 300 kcal dose group and a 600 kcal dose group following a 13 week running and cycling intervention. This study also demonstrated compensation as although both groups lost similar levels of body weight and fat mass, compensation of 20% was evident in the high EE dose group while the lower dose was 83% more negative than expected (Rosenkilde et al., 2012).

An interesting pattern was revealed whereby males in the middle tertile consumed less than males who engaged in both less and more AREE. A similar but non-significant trend was shown for females. In 1956, using an observational design, Mayer and colleagues found that males with a sedentary occupation had a higher EI than those engaging in light physical work yet were similar to those engaged in heavy physical labor (Mayer et al., 1956). It seemed that EI and EE are coupled to match expenditure except in the case of sedentary individuals who have a higher EI despite low levels of EE (Mayer et al., 1956). It has been both hypothesized and demonstrated that intervention groups not losing the amount of body weight that was predicted can be due to behavioral responses leading to an increase in EI or a decrease in non-intervention physical activity (Church et al., 2009; Friedenreich et al., 2011; Manthou et al., 2010; Rosenkilde et al., 2012). The present results may go towards explaining this, in males at least. There is the possibility of an EI compensatory response by those who are highly active.

In the present study, males in the high AREE group had a lower drive to eat in the fasted state yet were less satiated following the *ad lib* meal. This was also reflected in the significantly lower SQs which males in the high AREE tertile experienced compared to the males in the middle tertile. Possible explanations for these discordant results were explored using the present data: (i) The specific macronutrient content of what the participants consumed in the test meal could have exerted a satiating (or less satiating) effect (Halton &

Hu, 2004). However, there were no differences in percentage fat, carbohydrate or protein of the buffet test meal between groups when controlling for either body weight or lean body mass from dual energy x-ray absorptiometry (results not shown); (ii) Dietary restraint (the cognitive intent to restrict calorie intake) and disinhibition (the tendency to overeat in response to certain stimuli) have been shown to influence the relationships between hunger, EI and body weight (Bryant, Caudwell, Hopkins, King, & Blundell, 2012; Lawson et al., 1995; Martins, Robertson, & Morgan, 2008). Again, when restraint and disinhibition were statistically controlled for, the direction and the strength of the relationships shown in Table 2 did not change (results not shown); (iii) The choosing of higher energy dense foods by higher active individuals may be hedonic rather than homeostatic whereby the higher active males were consuming more energy as a reward for the physical activity they regularly complete rather than in response to an energy deficit (Blundell et al., 2009). While no data were collected on hedonics or palatability of the foods presented, to be enrolled in the study, participants must at least not have disliked any of the foods to be presented in the buffet.

King et al., (2009) discussed how the expression of hunger manifests in at least two processes: a hormonal drive to eat and a food-related response immediately after a meal. While this study is cross-sectional and the use of one post meal rating for measurement of satiety may be inadequate to base conclusions, we too have seen a dual process response in males with a higher AREE. This dual process may be explained by a lower hormonal drive to eat due to low orexigenic (ghrelin for example) or high anorexigenic hormone (leptin for example) levels in the fasted state and the mechanical response during gastric emptying to the food stimulus following the buffet test meal (King et al., 2011). It is difficult to explore this hypothesis without the accompanying gut peptides or a measure of gastric emptying before and after the test meal which were not measured.

In this cross-sectional analysis, the lack of association between AREE and appetite ratings in females is not surprising. Past research has found that while EE impacts EI in females, this is not reflective of a change in appetite ratings but rather a change in EI regulating hormones (Hagobian et al., 2009). Pomerleau, Imbeault, Parker, and Doucet (2004) reported no effect of a high or low intensity exercise sessions (designed to expended the same EE) on appetite ratings in females, although EI was highest following the high intensity session. The variability in results requires further, well designed and controlled studies.

These results, coupled with the possible link between physical activity and an increased drive to eat, have resulted in the perception that physical activity is not effective in terms of weight loss. If this drive to eat does exist in certain highly active individuals then it may be offset by an improvement in appetite regulation (King et al., 2009), a lower EI relative to the energy expended in any exercise bouts (Imbeault, Saint-Pierre, Alméras, & Tremblay, 1997; King et al., 1994; Maraki et al., 2005; Martins, Morgan, Bloom, & Robertson, 2007; Unick et al., 2010), and an improvement in the quality of subsequent EI (Long, Hart, & Morgan, 2002). It cannot be discounted that certain individuals will experience this drive to eat due to the complex interactions between metabolic, behavioral, contextual and environmental influences. However, past studies that demonstrated appetite changes were overt exercise training studies and not habitual physical activity studies so the effect of activities of daily living (i.e. AREE) on appetite variables have not been studied using either short-term stimulus or longer term interventions.

While the appetite ratings did not predict weight change after 1 year follow-up, the relationship between AREE, EI and appetite variables may lead to differing patterns of food intake and may help explain the modest effects of physical activity on weight loss. In particular, fullness measures (Drapeau et al., 2005) and the lower satiating effect of the food consumed could lead to further intake in future eating episodes and are worrying in terms of weight management. Although this was not an interventional study, and all participants were not responding to any form of a stimulus over one year, there was a large amount of variability in weight change that was masked by using a group mean. To have a simple appetite measure that could be administered at baseline and aid in predicting those who may be a non-responder cannot be underestimated. While it is possible that some of the more global measures of eating behavior are not good predictors of weight change compared to specific dieting profiles (Lowe et al., 2006), baseline and changes in appetite sensations have been related to weight change in past follow-up studies (Drapeau et al., 2007; King et al., 2009).

To our knowledge this is the first study to examine the link between DLW-measured AREE and EI and a range of appetite ratings. Past studies have used an intervention design to induce differences in activity or total daily EE. The present study did not intervene to alter typical physical activity levels but rather compared EI and appetite ratings based on levels of EE through physical activity. Long, Hart, and Morgan (2002) had participants self-report their own physical activity participation level and, similar to the present study, found that non-exercising males were hungrier in the fasted state than their exercising counterparts (Long et al., 2002). Furthermore, DLW has not been used to categorize participants into physical activity groups; tertiles for example, in appetite-related studies. Limitations to the current analysis must also be considered. Similar to other studies in the area of exercise and appetite regulation, the sample was young and healthy. A complex interaction between EE and its various domains and features cannot be elucidated by a cross-sectional analysis. There was no measure of key circulating hormones, leptin and ghrelin for example, which would have allowed for a more robust analysis. A perceived limitation of the test meal method includes the assumption that food intake in the laboratory is representative of habitual food intake. In the present sample, kcal intake from the test meal and kcal estimated from a self-reported food frequency questionnaire was correlated significantly at 0.38 ($p=0.02$) in males only. Percentage of protein from both tests (0.52, $p=0.001$) and percentage of carbohydrate from both tests (0.47, $p=0.004$) also correlated significantly in males only. This was not seen for females. Despite this limitation, researchers have concluded that food intake in the laboratory is indeed representative of habitual food intake (Kissileff, Thornton, & Becker, 1982), has reliability in terms of macronutrient preference (Geisleman et al., 1998) and food intake measured during individual food intake tests is similar to food intake measured in cafeteria settings (Kim & Kissileff, 1996). Finally, the assessment of EI and appetite occurred at one time point (before and after one test meal) during the full 14 day DLW procedure and thus the measurement of EI could be considered limited compared to the robustness of EE.

In summary, different relationships between AREE and appetite ratings were shown in males but not in females. The finding that males in the middle AREE tertile had lower *ad libitum* EI and higher SQs than those in the high tertile is important in terms of weight maintenance. While the appetite ratings did not predict weight change after 1 year, the cross-sectional relationship between high AREE, EI and appetite ratings in males may lead to sex differences in overall patterns of EI and weight change. This study provides evidence for sex differences that may play a role in energy balance and prepares the groundwork for future investigations.

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Highlights

- Activity related energy expenditure (AREE) was estimated from doubly labeled water
- Men with high AREE had a lower drive to eat in the fasted state than men with low AREE
- Men with moderate AREE had lower energy intake and higher satiety quotients than men with high AREE
- No differences were seen across levels of AREE in women

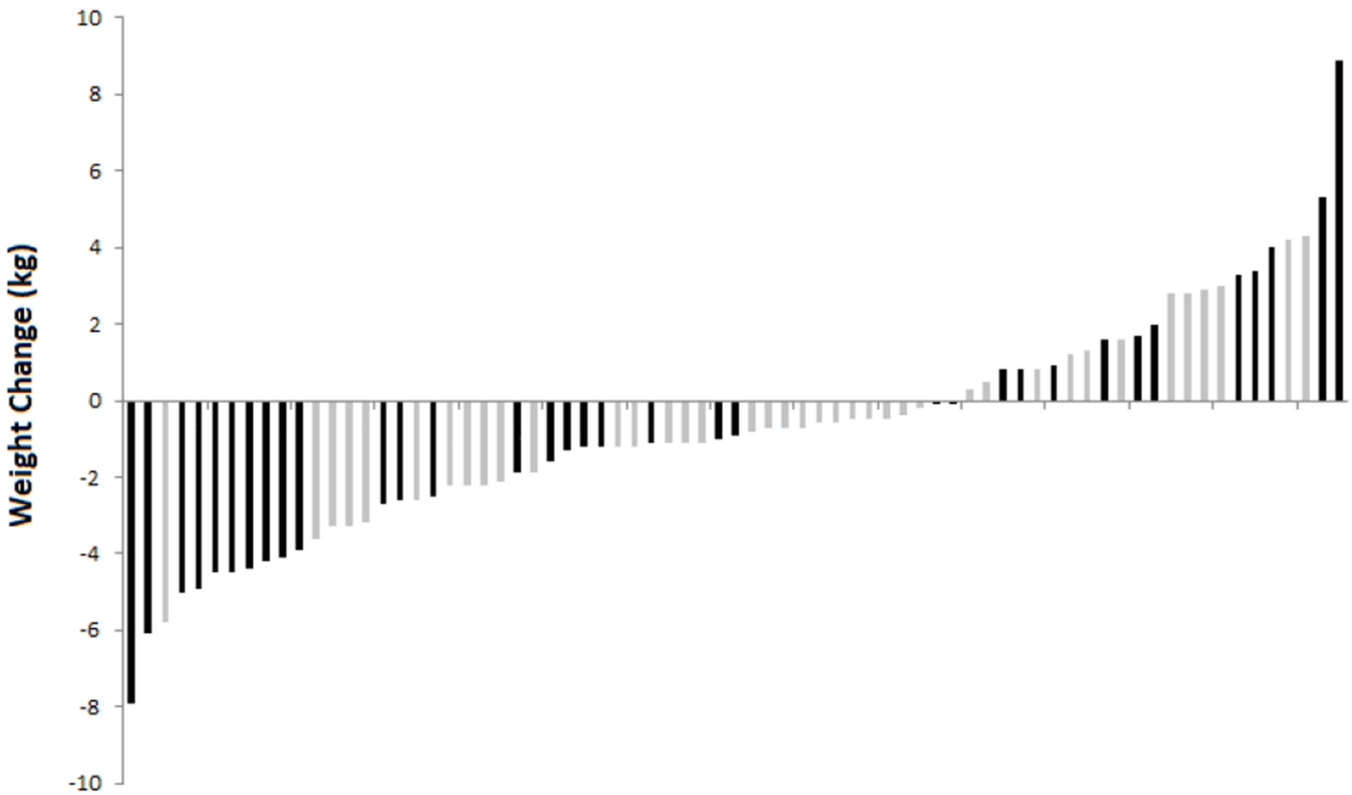

Figure 1.
Weight change for each individual participant at 1 year follow-up
Legend. Black denotes male (n=34) and grey denotes female (n=39)

Table 1

Participant characteristics

	All (n = 82)	Male (n = 40)	Female (n = 42)
Age, yrs	26.7 (4.4)	26.4 (4.0)	26.9 (4.7)
Height, cm	172.1 (10.1)	179.8 (6.9)	164.7 (6.5)
Weight, kg	68.1 (10.9)	75.9 (8.1)	60.7 (7.5)
BMI, kg/m^2	22.9 (2.3)	23.5 (2.5)	22.4 (2.0)

Note: Values are presented as means (SD)

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Table 2

Adjusted mean appetite ratings before the test meal for males (n = 40) and females (n = 42) stratified by AREE tertile

	Hungry		Full		PFC		Desire to Eat	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**
P for trend	0.08	0.43	0.09	0.71	0.11	0.88	0.01	0.46
Low	83 ± 5^{c}	76 ± 6	9 ± 5^{c}	18 ± 5	78 ± 4 ^{c}	69 ± 4	90 ± 5^{ab}	73 ± 6
Middle	68 ± 4^{c}	76 ± 7	21 ± 4	19 ± 5	71 ± 3	66 ± 4	71 ± 4^{a}	81 ± 6
High	71 ± 4	66 ± 6	24 ± 4^{c}	23 ± 5	67 ± 3^{c}	67 ± 4	71 ± 4^{b}	70 ± 6

Note: Values are presented as adjusted means (std error); Values with the same letter are significantly different within each gender group.

$^{a, b}$ *< 0.01*

^{c} *< 0.05*;

PFC = Prospective Food Consumption ("How much food do you think you could eat?"); Means are adjusted for body weight (kg), females also controlling for phase of menstrual cycle.

Table 3

Adjusted mean appetite ratings after the test meal stratified by AREE tertile

	Hungry		Full		PFC		Desire to Eat	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**
P for trend	0.28	0.59	0.53	0.72	0.33	0.97	0.32	0.82
Low	5 ± 3	4 ± 2	83 ± 4	79 ± 4	16 ± 4	13 ± 3	11 ± 4	7 ± 3
Middle	5 ± 3	3 ± 2	77 ± 3	74 ± 5	12 ± 4	12 ± 4	12 ± 4	8 ± 3
High	10 ± 3	6 ± 2	79 ± 3	78 ± 4	20 ± 4	12 ± 3	19 ± 4	10 ± 3

Note: Values are presented as adjusted means (std error); PFC = Prospective Food Consumption ("How much food do you think you could eat?"); Means are adjusted for body weight (kg), females also controlling for phase of menstrual cycle.

Table 4

Adjusted mean energy intake and appetite rating satiety quotients stratified by AREE tertile

	EI (kcal)		SQ Desire to Eat		SQ Hungry		SQ Full		SQ PFC	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
P for trend	0.006	0.34	0.04	0.16	0.03	0.26	0.13	0.63	0.006	0.53
Low	1090	740	0.076^{a}	0.101	0.074	0.103	−0.071	−0.088	0.059	0.086
	± 111	± 69	± 0.011	±0.010	±0.009	±0.008	± 0.012	±0.012	±0.008	±0.009
Middle	866^{c}	653	0.078^{b}	0.111	0.080^{a}	0.105	-0.077^{a}	−0.090	0.075^{c}	0.089
	± 104	± 80	± 0.010	±0.011	±0.007	±0.010	± 0.010	±0.013	± 0.007	±0.010
High	1365^{c}	819	0.044^{ab}	0.080	0.052^{a}	0.085	-0.048^{a}	−0.074	0.041^{c}	0.074
	± 101	± 74	± 0.010	±0.011	± 0.008	±0.010	± 0.011	±0.013	± 0.007	±0.010

Note: Values are presented as adjusted means (std error); Values with same superscripts are significantly different within each sex

^{a,b}< 0.05;

^{c}= 0.001.

EI = Energy Intake; SQ = Satiety Quotient; PFC = Prospective Food Consumption (“How much food do you think you could eat?”); Means are adjusted for body weight (kg), females also controlling for phase of menstrual cycle.