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The Effect of an Acute Bout of Exercise on Food Motivation, Energy Intake, and Total Physical Activity in Normal-Weight and Obese Woman: An Event-Related Potential Study

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The Effect of an Acute Bout of Exercise on Food Motivation, Energy Intake, and Total Physical
Activity in Normal-Weight and Obese Woman: An ERP Study

Bliss Hanlon

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of
Master of Science

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ABSTRACT

The Effect of an Acute Bout of Exercise on Food Motivation, Energy Intake, and Total Physical Activity in Normal-Weight and Obese Woman: An Event-Related Potential Study

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Master of Exercise Science

This study examined the effect of acute exercise on food motivation, energy intake, and total physical activity in normal-weight and obese women. Participants of both groups were matched (except for Body Mass Index) and conditions (exercise vs. non-exercise) were randomized and counter-balanced. Eighteen normal-weight and 17 obese women completed an exercise and non-exercise day, each performed on the same day of the week. Exercise was performed on a motor-driven treadmill at 3.8 mph and 0% grade for 45 continuous minutes. To test for food motivation, participants were shown a continuous stream of pictures of food and flowers (control) while neural activity was monitored. Data were analyzed using a 2-group x 2-exercise condition x 2-picture type repeated measures analysis of covariance on event-related potential (ERP) amplitude and latency. Dietary records were analyzed using the Food Processor SQL nutrition software. Physical activity was monitored using a GT1M accelerometer. For both groups under both conditions, ERP amplitude was higher and latency was lower for food pictures compared to flower pictures. When normal-weight and obese women were combined, there was a significant condition*picture type interaction for late positive potential ($P=0.04$) with participants showing less neurological response to food pictures following a 45-minute exercise bout. Exercise did not alter energy intake. However, the exercise condition resulted in significantly more total physical activity, moderate intensity, vigorous intensity, moderate-to-vigorous (MVPA) intensity activity, and less sedentary time than the non-exercise condition. There was a significant group*condition interaction for MVPA ($P=0.043$) with obese women showing less MVPA than the normal-weight group. The sample of women studied did not show neurological differences in response to pictures of food based upon BMI. However, exercise decreased neurological responses to food, which may indicate lower food motivation. A supervised and planned exercise bout dramatically increased total physical activity in normal-weight and obese women compared to a day without planned exercise. There may be some negative compensation for MVPA in obese women following a 45-minute exercise bout compared to normal-weight women.

Keywords: energy intake, food motivation, event-related potentials

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Introduction

The high prevalence of obesity has become a significant public health concern in the United States [11]. Poor diet may contribute to weight gain and obesity. There are several known environmental and physiological factors that can influence eating behavior, such as environmental or visual stimuli, and hormones [6, 7, 26, 34, 35]. However, investigation of neural outcomes relative to food behavior is only beginning to be explored [3, 4]. Recent data suggests that neurological responses to pictures of food may be different between normal-weight and obese adults and may be a predictor of food motivation and energy intake [17].

In addition to diet, exercise may be a viable strategy to address the obesity epidemic [30]. It is widely accepted that exercise modestly counteracts the negative impacts of positive energy balance by increasing energy expenditure [8, 13, 15]. Interestingly, exercise not only increases energy expenditure but may also influence subsequent energy intake and correlates of energy intake, such as appetite [12, 18, 26].

While researchers have previously attempted to investigate the impact of exercise on energy intake and related correlates [18], there are several notable weaknesses in the current literature. Above all, most previous studies assessing appetite use subjective measures, such as surveys or visual analog scales. Subjective measures are prone to increased bias compared to more objective measures. In addition, there is no data examining objective differences in food motivation in response to exercise. Further, the extent to which obese and lean adults differ in their food motivation in response to exercise is not fully understood.

This study was designed to specifically address the above weaknesses. Therefore, the primary purpose of this study was to compare normal-weight and obese women under two separate conditions (non-exercise; exercise) for food motivation, as determined by objective

neurological responses to food pictures, and energy intake. A secondary outcome of this study was to compare normal-weight and obese women for objectively determined 24-hour physical activity following exercise or a no exercise (control) condition. This study was designed to provide insight into the role of exercise and BMI on food motivation, energy intake, and total physical activity; and ultimately, to gain increased insight into their potential influence on weight management.

Methods

This quasi-experimental study utilized a matched subject design with treatment conditions (non-exercise or exercise) randomized and counter-balanced. Primary outcomes for this study were food motivation, energy intake, and physical activity. Participants were followed for 24-hours under each condition and outcomes were assessed identically during both treatment conditions.

Participants

After approval by the university's Institutional Review Board, written consent from 35 healthy women was obtained. Select participant characteristics are listed in Table 1. Participants were classified as normal-weight ($BMI < 25 \text{ kg/m}^2$) or obese ($BMI \geq 30 \text{ kg/m}^2$). Additionally, all women were untrained but able to walk comfortably for 45 continuous minutes at a moderate-intensity, pre-menopausal, only right-handed, and matched for age and education. Participants were excluded if they had a chronic or metabolic disease (cardiovascular disease, cancer, diabetes, etc.), an orthopedic impairment, were participating in a vegetarian diet or other extreme dietary practice, had food allergies, were previously diagnosed with anorexia, bulimia, or instances of binge-eating, reported alcohol or substance abuse within the past year, used tobacco products, were pregnant or lactating, were using antiepileptic medications, reported a history of

learning disability, or had a neurological disorder (e.g., traumatic brain injury, seizure disorder, stroke), and/or Attention Deficit Hyperactivity Disorder (ADHD).

Experimental Conditions

Except for the exercise bout, the testing protocol for each condition was identical; including: the same time of morning, same day of the week, after at least seven hours of sleep the previous night, subsequent to the same dietary preload (energy shake) that morning two hours prior to testing, after voiding, and not having smoked, consumed caffeine, or performed vigorous intensity exercise during the previous day. The dietary preload was ~10% of the participant's estimated daily energy needs. Estimated energy needs were determined using the Harris-Benedict equation to predict basal metabolic rate and multiplied by an activity factor of 1.3 [5].

Non-Exercise Condition

The non-exercise condition acted as a control condition in which there was no supervised exercise bout. Upon arrival at the laboratory at approximately 8am, each participant was asked to begin wearing an accelerometer. Instead of a supervised exercise bout, participant heights were measured using a standard wall-mounted stadiometer and body weights were assessed using a digital scale, accurate to the nearest hundredth pound. Subsequently, participants were given a standard one-piece bathing suit and swim cap to wear and were tested for body composition using the BOD POD, a computerized, egg-shape chamber.

Following the conclusion of the above assessments (~10am), all participants were tested for food motivation and were subsequently instructed to resume their normal daily routine. However, participants were instructed to record all energy intake and continue to wear the accelerometer until the following morning (see methods below). There were no additional recommendations or limitations on energy intake or type of physical activity/exercise.

Exercise Condition

This condition was identical to the non-exercise condition except that each participant completed a single moderate-to-vigorous intensity exercise bout instead of body composition assessments. Like the non-exercise condition, the accelerometer was worn beginning at ~8am (prior to the exercise bout). Each participant completed the exercise bout on a motor driven treadmill at 3.8 mph, 0% grade, for 45 consecutive minutes. The volume of exercise for this study was chosen based upon recommendations from the American College of Sports Medicine and based on pilot research, was well tolerated by the target population [28]. As noted above, all participants were subsequently tested for food motivation and were released to follow their normal routine, while recording all energy intake and wearing the accelerometer, until the following morning.

Food Motivation

Immediately following the body composition testing and exercise bout, participants completed a computerized task while brain activity was monitored using electroencephalogram (EEG). This task required participants to be shown a continuous stream of visual pictures of either food or flowers (control). The magnitude of neural response to the pictures of food vs. flowers was used as an indicator of food motivation. Pictures were presented for 1000 ms each without a noticeable inter-stimulus gap. Forty pictures from a food and flower category were displayed twice and in random order. Electroencephalogram data was collected from 128 scalp sites using a geodesic sensor net and Electrical Geodesics, Inc., (EGI; Eugene, Oregon) amplifier system (20K gain, nominal band pass= .10-100 Hz).

We examined two ERP components commonly assessed in association with attentional allocation to picture stimuli. The P300 component is a positive deflection in the ERP that occurs

between 300 and 500 ms following the presentation of a stimulus. It reflects the allocation of capacity-limited resources toward stimuli with high-levels of motivational salience [14]. In the context of the present study, the P300 may reflect an automatic orientation to food-related information that would be seen in differential P300 amplitude or latency to food-related pictures relative to flower pictures. P300 amplitude was quantified as the peak positive amplitude over midline parietal electrode sites between 200 and 300 ms. The latency was quantified as the time of the peak amplitude within this window.

The second ERP component of interest is the late positive potential (LPP). The LPP is a late-occurring midline component with an onset after 300ms that is larger for items with higher levels of arousal, such as pleasant or unpleasant pictures, relative to neutral stimuli. The LPP was quantified as the mean amplitude between 400 and 550ms following stimulus presentation. No latency calculations were made for the LPP, as it is a more tonic (longer-lasting) and not peaked ERP component.

Energy Intake

Following food motivation testing, energy and macronutrient intake was tracked until the following morning for each experimental condition. To do this, each participant was given a food record spreadsheet to record all food and beverages consumed, amount consumed, time of day the food item was consumed, and any other pertinent details about the food or beverage such as the brand name and nutrition labels. To improve accuracy of food records, participants used food scales (Ohaus Inc., Parsippany, NJ) to weigh each food item. Each dietary record was analyzed for energy and macronutrient intake using the Food Processor SQL nutrition software (ESHA Research, Inc., Salem, OR).

Physical Activity

Physical activity was monitored beginning at initial testing until the following morning (24 hours), using a GT1M accelerometer (ActiGraph, Pensacola, FL). Based upon the number of accelerations per unit of time (epochs), sedentary time, intensity of activity, as well as total physical activity was determined. Accelerometers have previously been shown to have high reliability and validity and were therefore appropriate as an objective measure of physical activity [36].

Statistical Analysis

Analyses were completed using the statistical software PC-SAS (version 9.2, SAS Institute, Inc., Cary, NC). Descriptive data for body weight, BMI, body fat percentage, energy intake, and physical activity were reported in standard deviations and means. Food motivation was examined using a 2-group x 2-condition x 2-picture (food vs. flower) mixed model ANOVA on event-related potential amplitudes and latencies. Tests of simple effects were used to decompose significant main effects and interactions. The relationship between indices of food motivation, indices of health (e.g., BMI) and ERP amplitudes were assessed using zero-order correlations.

To characterize physical activity data via accelerometry, the following categories, based upon a report by Troiano et al., were utilized to describe sedentary time, light-intensity activity time, moderate-intensity activity time, and vigorous-intensity activity time: 249 counts or less per minute; 250-2019 counts per minute; 2020-5998 counts per minute, and 5999 or greater counts per minute, respectively [36]. Mixed effects models were utilized to test within group and within condition differences, and to test for a group*condition interaction in energy intake and physical activity.

Among the 35 participants who met the study criteria, one participant did not have a full exercise session recorded for their accelerometer data; therefore, is not included in the analysis for Table 3. In addition, there were five participants with faulty EEG data and were thus removed from the analysis in Tables 4 and 5.

Results

Characteristics of the 35 subjects completing the study are summarized in Table 1. The normal-weight women had a statistically lower BMI compared to their obese counterparts ($P < 0.001$). The average BMI (kg/m^2) was 22.9 ± 1.4 and 34.0 ± 4.9 for the normal-weight and obese group, respectively. There was no difference in age between groups ($P = 0.649$).

Table 2 reports the dietary intake by group and exercise condition. The source of energy consumed (carbohydrate, fat, protein, fiber), did not vary by group or by exercise condition ($P > 0.05$). Additionally, there was not a significant group*exercise condition interaction found for overall energy intake ($P = 0.361$) or any other macronutrient.

Table 3 summarizes the 24-hour physical activity levels by group and exercise condition. The exercise condition resulted in significantly more total physical activity (counts/day) for both the normal-weight and obese women. Physical activity counts were 73% and 57% higher during the exercise condition than the non-exercise condition for the normal-weight and obese group, respectively. Furthermore, moderate-intensity activity, vigorous-intensity activity, and MVPA was significantly greater and sedentary time (min) was significantly less for both groups under the exercise condition compared to the non-exercise condition ($P < 0.05$). Finally, there was a significant group*exercise condition interaction reported for MVPA ($P = 0.043$). The obese women performed significantly less MVPA (69 ± 18 min) on the exercise day than the normal weight group (89 ± 24 min).

Table 4 displays ERP amplitude, latency, and late positive potential by group, exercise condition, and picture condition. There was not a significant group*exercise condition*picture type interaction ($P>0.05$) for each ERP. However, picture type had a main effect as both groups under both exercise conditions had a higher ERP amplitude and lower latency for food pictures compared to flower pictures.

Table 5 shows event related potentials when groups were combined and analyzed for exercise condition*picture type. When normal-weight and obese women were combined, exercise condition by picture produced a significant interaction for late positive potential ($P=0.04$). The mean LPP (μV) for women in response to food images under the non-exercise condition was 2.64 ± 2.03 compared to 2.24 ± 2.08 under the exercise condition.

Discussion

The purpose of this investigation was to compare normal-weight and obese women under two separate conditions (non-exercise; exercise) for the following outcomes: food motivation, energy intake, and total physical activity. The primary finding of this study is that an acute bout of exercise, but not BMI category, influenced the immediate magnitude (within 1 hour) of the neural response to food pictures (late positive potential). The strength of this finding is in the objective neural determination of food motivation.

The LPP is a midline ERP that refer to a broad superior-posterior positivity during the presentation of emotional pictures. It indicates the level of arousal stimulated by emotional stimuli. Moreover, current theories of the LPP suggest that it reflects increased processing of motivational or emotionally intense stimuli that continues following stimulus offset [14]. Increased LPP amplitude to food versus flowers would, therefore, suggest food images are a more arousing than flowers and may be an indicator of food motivation.

Though this study cannot be directly compared to similar studies that used subjectively measured correlates of energy intake, such as appetite or hunger; a brief comparison of previous findings is nonetheless warranted. Many studies assert that exercise had no effect on appetite control, nor did it change subjects' feelings of appetite [20, 25]. However, evidence for exercise induced appetite suppression does exist [22, 26, 27, 37]. Some studies have shown suppression of appetite resulted in a decrease in energy intake after exercise [21, 37]. However, other studies utilizing mood and appetite questionnaires concluded exercise induced an increase in feeling of appetite although the increase in appetite did not result in an increase in energy intake [24]. Inconsistency in findings may be due to subjective analysis methods, which did not control for bias reporting and inaccuracies. Thus, the present study employed an objective analysis of food motivation in order to determine whether exercise triggers physiological responses, which may alter food perception and subsequent energy intake [16].

Despite the difference in food motivation, there was no difference in energy or macronutrient intake by exercise condition or BMI group. This observation is consistent with previous findings that have shown exercise does not alter food preferences or food selection [19]. This finding may be due to one of the following explanations. 1) The effect of exercise on food motivation was transitory and was not strong enough to suppress appetite over the course of the entire day. Future studies should investigate food motivation following exercise at several intervals of the day. 2) This study may have been unable to identify a difference in energy or macronutrient intake given that dietary intake was assessed using a single 24-hour food record. A significant weakness of food records is that they have been shown to be reactive; in other words, the activity of recording diet may have altered the diet in some way [29].

Moreover, this inconclusive finding elucidates the multi-factorial nature of eating. Previous studies have acknowledged alternative motives such as environment and emotional position as stronger determinants of dietary behavior than physiological drive [1, 18, 33]. The finding of no difference in energy intake between the control and exercise condition is consistent with studies that found there is only weak coupling between increased energy expenditure during exercise and energy intake [12, 18]. Furthermore, the exercise session was relatively brief (45 mins) and at a relatively moderate intensity. It is possible that this volume likely produced only transient decreases in food motivation that disappeared over time.

In regard to physical activity, this study indicates that a planned, supervised bout of exercise dramatically changes total physical activity and most other intensity of physical activity levels. Some studies have suggested that lifestyle interventions (parking further away, taking the stairs instead of elevators, walking during breaks, etc.) can result in similar levels of activity to interventions with planned exercise [2, 9]. Results from this study suggest that planned activity is associated with much more positive activity outcomes than not having a planned exercise activity. This warrants further discussion as to the appropriateness of lifestyle versus planned exercise recommendations.

Interestingly, this study showed spontaneous differences in MVPA by BMI category. In the present study, the obese women obtained less MVPA on the exercise day than the normal-weight group. Similar findings have been shown in other studies [10, 12, 21, 23, 31]. In accordance, there may be some degree of compensation for MVPA in obese women following a 45-minute exercise bout. A follow up study should further investigate the possibility of compensatory responses to exercise.

This study has two notable limitations. First, participants were gathered from a fairly homogenous population of healthy females; therefore, the findings may not apply to the general population. The homogeneity of the sample may also have inhibited the exposure of influential variables such as cultural customs and environmental cues on the outcomes of the study. Second, food motivation was measured immediately following (within 1 hour) the exercise bout. This indicates an acute response but does not show how long the response remains. Third, energy intake and total physical activity were only observed within a 24-hour period surrounding each exercise condition. Prolonged and repeated assessment of these variables would likely clarify the effects of exercise and disclose any relevant compensatory responses.

Conclusion

In conclusion, this study demonstrates that an acute bout of exercise may decrease food motivation but does not subsequently change energy intake for the remainder of the day; however, it does greatly increase total physical activity compared to not completing a planned exercise bout. Furthermore, there may be a spontaneous reduction in MVPA in obese women following a planned exercise session compared to normal-weight women. Additional research is necessary to examine these responses in various populations, over a longer period of time. Supplemental findings will lead to a more comprehensive understanding of the effects of exercise on eating and physical activity behavior.

References

1. Akio I, Meguid M, Laviano A. Satiety and Appetite as Regulators of Food Intake. *Encyclopedia of Gastroenterology* 2004; 329-334.
2. Andersen R., Wadden T., Bartlett S., Verde T., Franckowiak S. Effects of Lifestyle Activity vs Structured Aerobic Exercise in Obese Women: A Randomized Trail. *JAMA* 1999; 281(4):335-340.
3. Angelopoulos, Nicholas, Goula, Anastasia, Tolis, George. Current Knowledge in the Neurophysiologic Modulation of Obesity. *Metabolism* 2005; 54(9):1201-1217.
4. Babiloni, C., et al., Frontal Attentional Responses to Food Size are Abnormal in Obese Subjects: A Electroencephalograph Study. *Clin Neuro* 2009; 120:1441-1448.
5. Basal Energy Expenditure: Harris-Benedict Equation. Cornell Medical University, 2000. 29 January 2010. <http://www-users.med.cornell.edu/~spon/picu/calc/beecalculator.htm>.
6. Berthoud H.R. Homeostatic and Non-homeostatic Pathways Involved in the Control of Food Intake and Energy Balance. *Obesity* 2006; 14:197-200.
7. Blundell, J.E., et al., Cross Talk Between Physical Activity and Appetite Control: Does Physical Activity Stimulate Appetite? *Nutr Soc* 2003; 62(03):651-661.
8. Colley R., Hills A., King N.A., Byrne N.M. Exercise-Induced Energy Expenditure: Implications for Exercise Prescription and Obesity. *Patient Education and Counseling* 2010; 79(3):327-332.
9. Dunn A., Marcus B., Mapert J., Garcia M., Kohl H., Blair S. Comparison of Lifestyle and Structured Interventions to Increase Physical Activity and Cardiorespiratory Fitness: A Randomized Trail. *JAMA* 1999; 281(4):327- 334.

10. Forbes GB, Kreipe RE, Lipinski B. Body Composition and the Energy-Cost of Weight Gain. *Human Nutrition-Clinical Nutrition* 1982; 36:485-7.
11. Flegal, K.M., Carroll, M.D., Ogden, C.L; et al., Prevalence and Trends in Obesity among US Adults, 1999-2008. *JAMA* 2010; 303(3):235-241
12. George VA, Morganstein A. Effect of Moderate Intensity Exercise on Acute Energy Intake in Normal and Overweight Females. *Appetite* 2003; 40:43-6.
13. Gleeson M., Brown J.F., Waring J.J., Stock M.J. The Effects of Physical Exercise on Metabolic Rate and Dietary-Induced Thermogenesis. *Brit J Nutr* 1982; 47: 173-181.
14. Hajcak G., MacNamara A., Olvet D.M. Event-Related Potentials, Emotion, and Emotion Regulation: An Integrative Review. *Developmental Neuropsychology* 2010; 35(2):129-155.
15. Hollowell R.P., Willis L, Slentz C., Topping J., Bhakpar M., Kraus W. Effects of Exercise Training Amount on Physical Activity Energy Expenditure. *Med Sci Sport & Exsc* 2009; 41(8):1640-1645.
16. Hubert P, King NA, Blundell JE. Uncoupling the Effects of Energy Expenditure and Energy intake: Appetite Response to Short-Term Energy Deficit Induced by Meal Omission and Physical Activity. *Appetite* 1998; 31:9-19.
17. Ilse, M.T., et al., Differences in Attention to Food and Food Intake Between Overweight/Obese and Normal-Weight Females Under Conditions of Hunger and Satiety. *Appetite* 2010; 54:243-254.
18. King NA. What Processes are Involved in the Appetite Response to Moderate Increases in Exercise-Induced Energy Expenditure? *Proc. Nutr. Soc.* 1999; 58(1):107-13.

19. King NA, Burley VJ, Blundell JE. Exercise-Induced Suppression of Appetite: Effects on Food Intake and Implications for Energy Balance. *European J Clinical Nutrition* 1994; 48(10):715-24.
20. King NA, Snell L, Smith RD, Blundell JE. Effects of Short-Term Exercise on Appetite Responses in Unrestrained Females. *European J Clinical Nutrition* 1996; 50:663-7.
21. Kissileff HR, Pisunyer FX, Segal K, Meltzer S, Foelsch PA. Acute Effects of Exercise on Food-Intake in Obese and Non-Obese Women. *American J Clinical Nutrition* 1990; 52:240-5.
22. Lluch A, King NA, Blundell JE. Exercise in Dietary Restrained Women: No Effect on Energy Intake but Change in Hedonic Ratings. *European J Clinical Nutrition* 1998; 52:300-7.
23. Manson JE, Willett WC, Speizer FE. Body Weight and Mortality Among Women. *New England J Medicine* 1996; 334:733.
24. Maraki M, Tsofliou F, Pitsiladis YP, Malkova D, Mutrie N, Higgins S. Acute Effects of a Single Exercise Class on Appetite, Energy Intake and Mood. Is There a Time of Day Effect? *Appetite* 2005; 45:272.
25. Martins C, Kulseng B, King NA, Holst JJ, Blundell JE. The Effects of Exercise-Induced Weight Loss on Appetite-Related Peptides and Motivation to Eat. *Journal of Clinical Endocrinology & Metabolism* 2010; 95:1609-16.
26. Martins C, Morgan L.A., Truby H. Short-term Appetite Control in Response to a 6-Week Exercise Program in Sedentary Volunteers. *British Journal of Nutrition* 2007; 98:834-42.
27. Martins C, Morgan LM, Bloom SR, Robertson MD. Effects of Exercise on Gut Peptides, Energy Intake and Appetite. *The Journal of endocrinology* 2007; 193(2):251-8.

28. Physical Activity and Public Health Guidelines. American College of Sports Medicine, 2007. 11 Dec 2010. <http://www.acsm.org/AM/Template.cfm>.
29. Poslusna K., Ruprich J., Vries J., Jakubikova M., Van't Veer P. Misreporting of Energy and Micronutrient Intake Estimated by Food Records and 24 Hour Recalls, Control and Adjustment Methods in Practice. *Brit J Nutr* 2009; 101:73-85.
30. Powell L.H., James C.E. Effective Obesity Treatments. *American Psychologist* 2007; 62(3):234-246.
31. Speakman JR, Stubbs RJ, Mercer JG. Does Body Mass Play a Role in the Regulation of Food Intake? *Proceedings of the Nutrition Society* 2002; 61:473-87.
32. Stubbs RJ, Sepp A, Hughes DA, et al. The Effect of Graded Levels of Exercise on Energy Intake and Balance in Free-Living Men, Consuming their Normal Diet. *European Journal of Clinical Nutrition* 2002; 56:129-40.
33. Stubbs, R.J., Whybrow, S., Blundell, J.E. Psychobiological and Behavioral Aspects of Appetite. *Enc Human Nutr* 2005; 27(6):154-163.
34. Thompson, D.A., L.A. Wolfe, and R. Eikelboom, Acute Effects of Exercise Intensity on Appetite in Young Men. *Med Sci Sports Exerc* 1988; 20:222-7.
35. Thompson, J.K. and P. Blanton, Energy Conservation and Exercise Dependence: A Sympathetic Arousal Hypothesis. *Med Sci Sports Exerc* 1987; 19(2):91-9.
36. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical Activity in the United States Measured by Accelerometer. *Med Sci Sports Exerc* 2008; 40:181-8.
37. Westerterp Plantenga MS, Verwegen CRT, Ijedema MJW, Wijckmans NEG, Saris WHM. Acute Effects of Exercise or Sauna on Appetite in Obese and Non-Obese Men. *Physiology & Behavior* 1997; 62:1345-54.

Table 1. Participant characteristics at baseline.

	Normal-Weight Group	Obese Group	F	P
	n = 18	n = 17		
Age	31.9 ± 9.3	32.9 ± 9.1	0.46	0.649
Height (cm)	167.7 ± 5.9	167 ± 7.4	0.28	0.781
Weight (kg)	64.5 ± 5.7	95.7 ± 18.8	9.31	<0.001
BMI (kg/m ²)	22.9 ± 1.4	34.0 ± 4.9	12.87	<0.001
Body Fat (%)	24.6 ± 6.3	42.1 ± 7.7	10.50	<0.001

Values represented are mean ± SD.

F and P values represent differences between the normal-weight and obese groups at baseline.

BMI = Body Mass Index.

Table 2. Dietary intake by group and exercise condition.

	Normal-Weight Group		Obese Group		F	P
	(n=18)		(n=17)			
	<u>Non-exercise</u>	<u>Exercise</u>	<u>Non-exercise</u>	<u>Exercise</u>		
Energy Intake (kcal)	1741 ± 638	1940 ± 893	1766 ± 718	1829 ± 491	0.86	0.361
CHO (g)	241 ± 109	275 ± 178	239 ± 95	255 ± 644	0.37	0.545
Fat (g)	59 ± 26	63 ± 33	63 ± 39	65 ± 28	0.08	0.786
Protein (g)	69 ± 32	77 ± 27	71 ± 34	66 ± 23	1.64	0.209
Fiber (g)	34 ± 48	21 ± 15	20 ± 11	20 ± 9	1.85	0.184

F and P = group*condition interaction.

No within group or within condition differences.

Table 3. Physical activity by group and exercise condition.

	Normal-Weight Group		Obese Group		F	P
	(n=17)		(n=17)			
	<u>Non-Exercise</u>	<u>Exercise</u>	<u>Non-Exercise</u>	<u>Exercise</u>		
Counts/Day*	316,004 ± 131,155	546,080 ± 143,007	314,336 ± 151,908	494,114 ± 113,549	2.04	0.164
Sedentary *	1198 ± 70	1157 ± 81	1202 ± 81	1156 ± 64	0.26	0.615
Light Activity	199 ± 59	194 ± 62	201 ± 71	215 ± 54	0.03	0.855
Moderate Activity*	38 ± 23	81 ± 25	33 ± 20	59 ± 24	3.16	0.086
Vigorous Activity*	2 ± 4	8 ± 14	4 ± 10	10 ± 16	0.09	0.763
MVPA*	40 ± 25	89 ± 24	37 ± 25	69 ± 18	4.48	0.043

Counts/Day represents the average total counts over 24 hours.

MVPA = Moderate to vigorous physical activity.

Data for sedentary, light-, moderate-, vigorous-intensity time, and MVPA represent minutes for a 24-hour period in mean and SD.

Control variables included sequence and not-worn time.

F and P = Group*exercise condition interaction.

*Significant by exercise condition only.

Table 4. Event-related potentials by group, exercise, and picture condition.

	Normal-Weight Group (n=15)		Obese Group (n=15)	
	<u>Non-Exercise</u>	<u>Exercise</u>	<u>Non-Exercise</u>	<u>Exercise</u>
P300				
Amplitude –Flower (μV)	3.96 \pm 2.671	3.86 \pm 2.225	4.11 \pm 2.977	4.01 \pm 3.508
Amplitude –Food (μV)	4.50 \pm 2.891	4.49 \pm 2.647	4.96 \pm 2.616	4.34 \pm 3.148
P300 Latency				
Latency – Flower (ms)	251.24 \pm 19.633	252.36 \pm 13.034	243.20 \pm 24.891	241.24 \pm 25.004
Latency– Food (ms)	246.49 \pm 23.712	248.04 \pm 20.630	240.22 \pm 25.913	238.80 \pm 29.19
LPP				
LPP – Flower (μV)	1.58 \pm 1.929	1.77 \pm 1.837	1.28 \pm 1.427	1.44 \pm 1.867
LPP– Food (μV)	2.69 \pm 1.744	2.55 \pm 2.418	2.59 \pm 2.032	1.93 \pm 1.702

μV = microvolts; ms=milliseconds; LPP=late positive potential.

Data are in means and SD.

Group*condition*picture interaction was not significantly different ($P>0.05$).

Table 5. Event-related potentials by exercise and picture condition.

	Non-Exercise Condition (n=30)		Exercise Condition (n=30)		F	P	Partial η^2
	<u>Flower</u>	<u>Food</u>	<u>Flower</u>	<u>Food</u>			
Amplitude (μV)	4.03 \pm 2.78	4.73 \pm 2.72	3.94 \pm 2.89	4.41 \pm 2.86	0.623	0.44	0.022
Latency (ms)	247.22 \pm 22.40	243.36 \pm 24.61	246.80 \pm 20.39	243.42 \pm 25.28	.008	0.93	<0.001
LPP (μV)	1.43 \pm 1.67	2.64 \pm 2.03	1.61 \pm 1.83	2.24 \pm 2.08	4.618	0.04	0.142

μV = microvolts; ms=milliseconds; LPP = Late Positive Potential.

Data are in means and SD.

F and P represents an exercise condition*picture interaction.

Prospectus

Introduction

Obesity is a major problem among Americans, and the statistics behind this growing epidemic are shocking. Nearly 34% of Americans are obese, as defined by body mass index (BMI) [11]. This statistic is greater among women (35.5%) than men [11]. Overall, 68% of American adults are classified as overweight or obese [9]. Obesity is directly related to higher incidences of cardiovascular disease [7], diabetes, [11] and certain cancers [24]. This ultimately results in an increased risk of morbidity, mortality, and higher economic costs primarily through medical expenses [11].

A potentially viable strategy to address the obesity epidemic is exercise. It is widely accepted that exercise may modestly counteract the negative impacts of obesity by increasing energy expenditure. Interestingly, exercise not only increases energy expenditure but may also influence subsequent energy intake and correlates of energy intake, such as appetite and food motivation. Appetite typically refers to the psychological drive to eat. Similarly, food motivation may be described as the desire and drive to obtain food. It has been postulated that both acute and chronic exercise can influence energy intake and appetite; however, the direction and magnitude of its effect remains uncertain and may be important to understand the true effect of exercise on weight management and obesity. Further, the effect of exercise on subsequent food motivation has received little attention in the scientific literature. A brief review of the literature of the effect of exercise on energy intake, appetite, and food motivation follows.

First, researchers have been unable to observe a consistent effect of exercise on energy intake. For instance, Blundell et al. found that the short to medium term effect of exercise is weight loss [5] as exercise can induce a negative energy balance. However, the study noted that in cases when the acute energy deficit was coupled with compensatory responses, such as

decreased physical activity throughout the day, weight loss was perturbed [19]. On the other hand, King et al. examined the processes involved in the energy intake response to exercise, and determined there was only a weak coupling between increased energy expenditure during exercise and energy intake [21]. Another study found that exercise did not have an effect on energy intake; however, it did change perceived pleasantness and desire of food [23].

Unfortunately, most previous studies have assessed the exercise-energy intake relationship primarily in lean individuals. These studies have also produced contradictory findings [16, 20, 18, 30, 41]. However, one study by George and Morganstein did examine the differences in exercise response among lean and obese individuals. In this study researchers assessed the food intake of 12 lean and 12 obese subjects after both an exercise treatment and a non-exercise period [13]. Following the testing, participants were fed an ad libitum meal. These participants were unaware that their intake was being monitored. These researchers concluded that energy intake was greater in obese participants under both conditions [13]. However, they were unable to establish a significant difference in energy intake based on exercise treatment. Overall, it seems clear that further investigation is needed to understand the response in energy intake to exercise and how obese and lean individuals differ in that response.

Second, there are mixed results as to the effect of exercise on subsequent appetite. A study on short-term appetite control by Martins, Truby, and Morgan [28] suggests that physically trained individuals are more sensitive to energy needs than those who are sedentary. This awareness may be attributed to hormonal changes [7], or alterations in substrate utilization following exercise [41]. These chemical adaptations may vary food perception, and consequently could be responsible for modifying energy intake. In addition, data from other studies support the idea of exercise-induced suppression of appetite [13, 36]. In contrast, other studies have found

that exercise had no effect on appetite [13, 18, 15, 20]. Given these inconsistent conclusions from previous studies, it is difficult to deduce a clear effect of exercise on appetite.

Third, food motivation allows for a more objective predictor of energy intake than previously used subjective measures of appetite; however, food motivation in response to exercise has not been investigated. Despite the lack of exercise and food motivation data, researchers recently showed that food motivation was increased in obese compared to lean adults [19]. These data indicated that obese individuals automatically focus their attention to food related stimuli to a greater extent than their lean counterparts [19]. This suggests that reward-related cues are perceived as more attention grabbing in heavier individuals [19]. However, the extent to which obese and lean adults perceive food differently in response to exercise is not fully understood.

Food motivation may be objectively determined by assessing changes in brain activity in response to visual food stimuli. More specifically, the use of event-related potential (ERP) studies utilize electroencephalograph (EEG) signals to track attention responses to visual food stimuli. The assessment of food motivation using ERP and EEG eliminates reliance on subjective methods of determining correlates of food motivation (such as, appetite). Moreover, ERPs objectively assess attention levels (given to stimuli depicting food) based on cortical responses in order to determine food motivation [2]. This method of analysis can more clearly measure the neurological responses to food following exercise.

While researchers previously attempted to investigate the impact of exercise on energy intake and its correlates [21], there are several weaknesses in the literature; specifically, the relationship between exercise and food motivation is unclear. First, many studies are limited by poor measurement of energy intake in response to exercise. Second, many studies assess appetite

using subjective measures. Third, most studies do not control for variables such as total physical activity and other compensatory responses that may influence overall energy intake. Fourth, there is little to no data studying neurological differences in food motivation in response to exercise. Fifth, the extent to which obese and lean adults differ in response to exercise for these variables is not fully understood. Therefore, it is the intention of this study to overcome these weaknesses through adoption of more rigorous scientific protocols and methodologies including having subjects utilize: food scales to measure energy intake, accelerometers to assess total physical activity levels, and EEG testing to evaluate food motivation via brain activity. These modifications will ensure a more clear understanding of the role exercise plays in subsequent energy intake and food motivation, in both lean and obese adults, and ultimately, how exercise influences weight gain and weight control.

Statement of Purpose

Therefore, the purpose of this study is to compare obese and lean women under two separate conditions (exercise; non-exercise) for the following outcomes: energy intake, food motivation, and total physical activity.

Hypothesis

We hypothesize the following: 1) food motivation immediately following an exercise bout will be lower compared to the non-exercise condition; 2) there will be a compensatory effect such that energy intake over the first 24 hours will be greater following the exercise bout compared to the non-exercise condition; 3) there will be a compensatory effect such that total physical activity will not be different between the exercise and no exercise conditions; and 4) the obese subjects will show greater energy intake, food motivation, and less total physical activity compared to the lean participants.

Null Hypothesis

Exercise will not alter food motivation. There will be no differences in energy intake, food motivation, and total physical activity between obese and lean participants.

Assumptions

The following assumptions apply to this study:

- Participants receive treatment in randomized order.
- Participants *only* consume the provided dietary preload (energy shake) two hours prior to each testing session.
- Level of hydration is regulated among participants.
- Participants accurately weigh and record food consumption for 24 hours after testing.
- Participants wear the accelerometers, as instructed, for each 24 hours testing period.

Delimitations

Participants in this study will be limited to women ages 18-55 yrs. Lean participants will have a BMI ≤ 25 . Obese participants will have a BMI ≥ 30 . Participants in both groups will be matched for age and education. Participants are required to meet specific inclusion criteria. Participants must be able to walk on a treadmill for 45 minutes at 3.8 MPH without pain. Participants must be able to speak English and be right handed. Additionally participants must be pre-menopausal. Participants who have a chronic or metabolic disease, or who have been diagnosed with psychiatric/neurological disorders, will be excluded from the study. Participants with special dietary restrictions will similarly be excluded, as will participants who are pregnant or lactating.

Definition of Terms

Event Related Potentials (ERP): Brain response of a thought or perception measured by electroencephalography (EEG)

Definition of Operational Terms

Body Mass Index: Normal $< 25 \text{ kg/m}^2$ Obese $\geq 30 \text{ kg/m}^2$

Acute Bout of Exercise: 45 minutes on treadmill at 3.8 MPH, 0% incline

Food Perception/Motivation: Degree of stimulation elicited by visual food cues, measured by EEG

Untrained: Vigorous activity no more than three times per week for 20 minutes per session

Physical Activity:

Sedentary time- 249 counts or less per minute

Light-intensity activity time- 250-2019 counts per minute

Moderate-intensity activity time- 2020-5998 counts per minute

Vigorous-intensity activity time- 5999 or greater counts per minutes

Review of the Literature

Obesity levels have increased continuously over the past several years [10]. Consequently, the prevalence of related diseases such as diabetes, cardiovascular disease, stroke, and certain cancers, has also increased [9]. Therefore, it is imperative that health professionals further investigate the potential causes and correlates associated with obesity. The purpose of this review of the literature is to assess the findings and limitations of existing studies dealing with the exercise and energy intake relationship. Furthermore, this review will establish precedence to utilize an objective measure of energy intake, food motivation, and total physical activity that will be examined in this study.

Exercise and Energy Intake

Previously conducted research of the effects of exercise on energy intake has relied primarily on subjective methods of analysis. These measurements include but are not limited to: food journals, surveys, and self-report. The findings of these reports are contradictory, which may be partially due to the lack of consistent and objective assessments.

In a study performed by George et al., the energy intake of 12 normal weight females and 12 obese females was assessed over two days [13]. Subjects exercised for one hour on the treadmill at 60% of their maximal heart rate. Post-exercise energy intake was compared to non-exercise energy intake. Participants were allowed to eat ad libitum from a university cafeteria. Total energy intake was determined by a nutritionist who recorded subjects' food selections and adjusted for uneaten food at the end of the meal. Findings showed that obese participants consumed more food under both conditions but did not report a significant variation in energy intake between treatments [13]. Weaknesses in this study that may have limited the researchers' ability to observe an effect of exercise include: inaccuracies in caloric calculations, food

availability, and cafeteria environment. Food was not consumed under normal conditions therefore it is reasonable to assume some level of bias.

Another study further examined the short-term coupling between energy expenditure and energy intake [18]. Hunger was suppressed after an intense bout of physical activity however, hunger was only suppressed temporarily. Specifically, King et al. concluded that suppression of hunger did not continue throughout the day and consequently did not significantly alter food consumption. The effects of exercise were presumed limited or short term; there was no within-day effect of exercise on energy intake [18]. Furthermore, exercise did not alter food preferences or food selection [18]. A study by Hubert et al. similarly concluded that the metabolic effects of exercise did not trigger excitatory signals of hunger and food intake [14]. Both studies affirm that there is no scientific data to support the theory that increased physical activity results in increased energy intake [14, 18]. Additional studies by Imbeault et al. and King et al. also confirm there is no strong evidence to suggest exercise effects energy intake [16,20]. After testing 11 healthy men under two exercise intensities and one control treatment, Imbeault et al. found no significant change in post-exercise energy intake as well as level of hunger and fullness compared to the control session [16]. These findings support King et al.'s previous conclusion that short-term exercise does not significantly alter food responses [20]. However, one study conducted by Lluch et al. [23] suggested an alternative effect of exercise. Lluch et al. explored the effect of exercise in dietary restrained females and found that while energy intake did not vary, the perceived pleasantness of food changed with exercise [23]. The study found that exercise influenced participants' ratings of the tastiness and pleasantness of low fat foods they were served at lunch. The group concluded that exercise increased the perception of pleasantness

of food; however, it does not increase motivation to eat within eight hours of exercise completion [23].

Exercise and Appetite

The extent to which exercise alters appetite is unknown. Many studies assert that exercise has no effect on appetite control, nor does it change subjects' feelings of appetite [20,27] however, evidence for exercise induced appetite suppression does exist [28, 29, 45]. Some studies have shown suppression of appetite results in a decrease in energy intake after exercise [22, 45]. Blundell et al. performed a study assessing cross talk between physical activity and appetite control. This group determined the short to medium term effect of exercise is weight loss [7]. These researchers assert that there evidence to show that men and women can tolerate negative energy balances of ≤ 4 MJ energy cost/day induced by exercise for up to 16 days before compensatory behavior sets in [7]. These results contradict previous studies that suggested exercise results in increased appetite and food consumption [17, 23].

Weaknesses in Energy Intake/Appetite Literature

Inconsistency in findings may be due to variations of exercises performed (including duration, type, and intensity) as well as differences in study design. Studies that utilized subjective analysis methods did not control for bias reporting and inaccuracies. For example, Makari et al. [25] conducted a study that assessed the effects of a single exercise class on appetite, energy intake, and mood in 12 normal weight females. The group used mood and appetite questionnaires 15 minutes before and after trails to determine the changes induced by exercise. Energy intake was calculated from 24-hour diet records submitted by the subjects. After analyzing the questionnaires and food journals, researchers concluded that exercise induced an increase in the feeling of appetite [25]. However, the increase in appetite did not

result in an increase in energy intake [25]. These findings are counterintuitive. The discrepancy may be due to the fact that participants knew their food logs would be reviewed. This could lead individuals to omit foods they would typically consume or indulge in. An alternative explanation may be that energy intake is a result of various motivational factors that may overpower physiological drive. Data supports the theory that appetite responses to exercise are partially determined by eating behavior traits [21]. Consequently, the assessment of energy intake alone, especially when using poor measurement methods, does not explain mechanisms that may influence the desire for food and subsequent energy intake. In a review of psychobiological and behavioral aspects of appetite, R. J. Stubbs asserted, “feeding responses are not an inevitable response to an altered physiological signal or need” [37]. It is essential, therefore, to recognize there are various motives of food intake including environmental and cognitive factors [32].

Food Motivation

Scientific analysis of food motivation, using EEG and ERP technology, allows for more controlled, objective assessment of correlates of energy intake and may be a better measurement to elucidate the effect of exercise on energy intake. Currently, coupling between exercise induced changes in energy expenditure and energy intake has been determined as weak [21]. In reality, the emotional position of an individual may impact food intake in response to exercise [21]. R.J. Stubbs states, “eating behavior and appetite are not regulated completely by the body’s physiological demands” [37]. This would suggest that food intake is both flexible and responsive to environmental and cognitive impressions. Meguid et al. distinguishes hunger, a metabolic feeling, from appetite, the expression of hunger, based on cognitive inputs [1]. Meguid et al. attributes palatability of food, texture, and one’s previous experience with that food, as indicators of food choices [1].

Eating is a multi-factorial process. A strict assessment of energy intake underestimates the role one's emotional state and exercise training plays in food consumption. Indeed, food modulation depends on intricate neural pathways and networks that interpret both sensory and motor information [2]. Authors, such as Berthoud, acknowledge various cognitive, as well as environmental factors that overpower homeostatic regulation [3].

Therefore, understanding food motivation is critical in order to develop preventative care plans to better address the obesity epidemic. If obese adults show higher levels of food motivation, particularly following exercise, one may conclude that exercise has counterproductive results to efficient regulation of energy intake. Thus, it is important to further investigate the differences in food motivation, and the effect of exercise on food motivation, among lean and obese populations.

Total Physical Activity

Researchers have been unable to observe a consistent effect of exercise on energy intake because previous studies have failed to identify and control for influential variables, such as the compensatory response in subsequent 24-hour physical activity. Response to exercise varies among individuals and populations [13, 22, 24]. For instance, Stubbs et al. [35] determined baseline body fat as having the greatest impact on compensatory responses such as increased food consumption and decreased physical activity after exercise [18]. This would affect overall energy intake patterns in obese populations.

It is assumed that because exercise increases energy expenditure it must trigger an increase in energy intake in order to maintain homeostasis in the body. This compensatory behavior may cause net energy expenditure to remain the same had exercise not been performed. This would limit the positive effects of exercise and challenge its ability to produce weight loss.

However, numerous studies have found insignificant levels of energy intake compensation after exercise [22, 31, 45]. Other studies limit compensatory behavior to a brief time period following exercise completion [12, 34]. One study in particular tracked women and found that total energy intake compensation over seven days was small relative to the increases in energy expenditure produced by exercise [36]. However, none of these studies controlled for total physical activity after an exercise session.

Physical activity increases energy expenditure, which may create a negative energy balance. Over time this could result in weight loss. However, change in energy expenditure during non-exercise time can significantly alter the overall energy balance produced by exercise. In cases when acute energy deficit triggered compensation in physical activity levels, weight loss was agitated [19]. Therefore, it is important to consider how acute exercise affects subsequent physical activity levels. Furthermore, it is important for future studies to account for total physical activity when assessing the effects of acute exercise on subsequent energy intake as it may be an influential variable.

Summary

In review, while researchers previously attempted to investigate the impact of exercise on energy intake and its correlates [21], there are several weaknesses in the literature. First, present studies are limited by primarily subjective methods of determining correlates of energy intake. Second, studies generally are inefficient because they fail to recognize that there are multiple factors that affect eating such as: emotional state, learned eating behavior, and gastro-intestinal content. Therefore, assessing food consumption is not a clear indicator of physiological drive. Finally, studies do not control for variables such as total physical activity and other compensatory responses that may influence overall energy intake. In order to determine whether

exercise triggers physiological responses (which may alter food perception and subsequent energy intake [14]) it is necessary to objectively examine food motivation using event-related potential (ERP).

Methods

Study Design

This quasi-experimental study will utilize a matched subject design with treatment conditions randomized and counter-balanced. Obese and normal-weight women will be compared under two separate conditions (exercise condition or non-exercise condition). The following outcomes will be assessed for each condition: energy intake, food motivation as determined by brain activity, and physical activity. Data collection for each condition will occur for a single 24-hour period of time and each condition will be separated by one week. In addition, food motivation and brain activity measurements for each condition will be assessed at the same time of morning, same day of the week, following at least seven hours of sleep the previous night, subsequent to the same dietary preload (energy shake) that morning two hours prior to testing, after voiding, and not having smoked, consumed caffeine, or performed vigorous intensity exercise (except in the exercise condition) during the previous day.

Non-Exercise Condition. The non-exercise condition will act as a control condition in which energy intake, food motivation, and total physical activity will be assessed for 24-hours in the absence of any planned exercise. During this condition, each participant will be asked to conduct their normal routine but no exercise treatment will be applied. Additionally, participants will refrain from independent exercise prior to testing.

Exercise Condition. This condition will be identical to the non-exercise condition except that each participant will complete a single moderate to vigorous intensity exercise bout on a motor-driven treadmill at 3.8 mph, 0% grade, for 45 consecutive minutes 45-60 minutes prior to measurement of food motivation via brain activity. The volume of exercise for this study was chosen based upon recommendations from the American College of Sports Medicine [33].

Participants

Thirty women will complete all aspects of this study. Fifteen participants will be classified as normal-weight ($\text{BMI} < 25 \text{ kg/m}^2$) and 15 participants will be classified as obese ($\text{BMI} \geq 30 \text{ kg/m}^2$). Participants will be untrained (vigorous activity no more than three times per week for 20 minutes per session) but able to walk comfortably for 45 continuous minutes at a moderate-intensity, pre-menopausal, between the ages of 18-54 years, only right-handed, matched for age and education, and native English speakers. Only pre-menopausal women will be utilized in this study, as menopause may be associated with hormonal changes that could alter food motivation and energy intake. People aged 55 years and older have a greater association with age-related declines in cognitive ability and therefore are similarly excluded from participation. Only right-handed women will be recruited, as there may be differences in brain hemispheric dominance in individuals who are left handed compared to right-handed.

Participants will be excluded if they have a chronic or metabolic disease (cardiovascular disease, cancer, diabetes, etc.); orthopedic impairment, current participation in a vegetarian diet or other extreme dietary practice; food allergies; previous psychiatric diagnosis—including anorexia, bulimia, or instances of binge-eating; reported alcohol or substance abuse within the past year; use of tobacco products; pregnant or lactating, current antiepileptic medication use; reported history of learning disability, and neurological disorder (e.g., traumatic brain injury, seizure disorder, stroke), and/or Attention Deficit Hyperactivity Disorder (ADHD). Participants must be able to perform physical activity without being limited by pain. The BYU Institutional Review board will approve this study and all participants will sign an informed consent prior to beginning the study.

Participants will be recruited primarily from the BYU and surrounding communities via BYU classroom visits, fliers, posters, Facebook, and word of mouth. Participants will be offered financial compensation for their time. Payment will be dispersed via petty cash periodically throughout the experiment.

Procedures

Testing will be comprised of five visits to the Human Performance Laboratory. Visit 1) The initial visit will be to administer the informed consent, other testing materials, and to take body measurements. Visit 2) Participants will be required to return for testing under the first condition. Visit 3) The day following the first experimental condition is completed, participants will come back and return food/physical activity logs, food scales, and accelerometers. Visit 4) Participant will be tested under the second condition. Visit 5) Participants will return food/physical activity logs, food scales, and accelerometers the day after the second condition is completed.

Interested participants will be screened over the telephone in order to ensure they meet the inclusion/exclusion criteria. Once participants have been approved and informed consent is provided, testing will begin. At the first visit, each participant will arrive at the Human Performance Laboratory (Richards Building) where the study details will be discussed, questions about the study will be answered, and informed consent will be provided. In addition, participants will arrive not having exercised or consumed food for the previous two hours, per recommendations to accurately assess body composition using the BOD POD. Participant height will be measured using a standard wall-mounted stadiometer. Body weight will be assessed using a digital scale, accurate to the nearest hundredth pound. Afterwards, participants will be given a

standard one-piece bathing suit and swim cap to wear; subsequently, each participant will have her body composition analyzed by the BOD POD.

Upon completion of these measurements, testing materials and instructions will be distributed to the participants, including a: food log, food scale, accelerometer, and powdered energy drink. Participants will then be scheduled for their first testing condition and will be instructed to sleep for seven to eight hours the evening before testing and to arrive at the following visit adequately hydrated. Additionally, they will be instructed to consume *only* the provided amount of breakfast drink two to three hours prior to when they arrive for testing; however, there will be no restrictions on water consumption. The breakfast energy powder/shake will be measured in advance to account for 10% of the participant's estimated daily energy needs. Estimated energy needs will be determined using the Harris-Benedict equation to predict basal metabolic rate and multiplied by an activity factor of 1.3 [4].

The two tests/conditions will be administered on the same weekday, at approximately the same time of day (8-9am), one week apart, for 24-hour continuous hours, and in random order. For each condition, participants will put on their accelerometers upon arrival at the laboratory and will be instructed not to remove it until a full 24 hours have passed the following day, except when bathing or swimming. If a participant is undergoing the exercise condition, participants will be weighed prior to beginning the workout in order to assess weight loss and the need for water replenishment upon completion of the exercise protocol. During the exercise condition, participants will be instructed to walk on the treadmill at 0% incline for 45 minutes at an intensity of 3.8 MPH. This pace is based on ACSM recommendations and was pilot tested to ensure participants could complete the exercise without excessive compensation [33]. Participants will be provided water as necessary throughout the workout. At the end of 45

minutes of exercise, participants will be weighed again and re-hydrated based upon the amount of water lost. Participants will then immediately walk up to the psychology lab (Kimball Tour) to be assessed for food motivation. Participants will not consume food or energy beverages between the exercise activity and food motivation assessments. Food motivation assessment will take place 45-60 minutes after the exercise period.

Under the non-exercise condition, participants will not complete an exercise protocol and will be asked to continue their normal routine throughout the remainder of the entire 24 hours test period. All other tests and conditions will be identical to those exercise condition including: measurement of energy intake, food motivation, and physical activity as well as sleep level, hydration levels, start time of accelerometer, and time of testing of food motivation. EEG testing under both conditions will be conducted between 9:15-9:30 am and will last approximately 90 minutes.

Following food motivation testing under both conditions, participants will be instructed to keep a food log of everything they eat throughout the remainder of the day. Participants will weigh their food with the food scales provided to help ensure an accurate assessment of macronutrient and energy intake. As well, participants will keep a written record of their planned physical activity and continue to wear their accelerometers for a 24-hour period. Participants will be instructed to return their completed food/physical activity logs, food scales, and accelerometers the next day. Participants will return exactly one week later to be tested under the second condition.

Measurements

Body Composition. Body weight will be assessed using a digital scale, accurate to the nearest hundredth pound. Height will be measured using a stadiometer to insure accuracy to

one-sixteenth of an inch. Fat mass and fat-free mass will be assessed using the BOD POD. The BOD POD tracking system is a technologically sophisticated method of determining body composition [3]. The BOD POD relies on whole body air displacement plethysmography to measure body volume. Reliability for the BOD POD is high [30]. Additional studies have further examined the efficacy of the BOD POD among various populations and conditions and determined it is both reliable and valid [7].

Energy Intake. Energy and macronutrient intake will be tracked for 24-hours during each experimental condition. To do this, each participant will be given a food log spreadsheet to record all food and beverages consumed, amount consumed, time of day the food item was consumed, and any other pertinent details about the food or beverage such as the brand name and nutrition labels. To improve accuracy of food logs, participants will use food scales to more objectively assess their intake. Participants will be encouraged to record all food or beverages consumed immediately after it is ingested and to include as much detail as possible about each food or beverage. Participants will be provided a food scale to weigh the food or beverage in order to accurately assess amount consumed.

Following completion of each experimental condition and recording of food intake, a trained student will review each food item with the participant to ensure accuracy of their recording. Subsequently, each dietary record will be analyzed for energy and macronutrient intake using the Food Processor SQL nutrition software (ESHA Research, Inc. Salem, OR).

Computerized Tasks To Determine Food Motivation. During each experimental laboratory session, participants will complete the following computerized task that assesses food motivation while brain activity data are collected (event-related potentials). For this task we will replicate the study procedures used by Blechert et al., [6] in their study of food motivation in

restrained eaters. For this task participants are shown a continuous stream of visual pictures. Pictures are presented for 1000 ms each without a noticeable inter-stimulus gap. Pictures will be presented during two separate task conditions. In the first condition, food and flower pictures are presented. In the second condition pleasant, neutral, and unpleasant pictures are presented from the International Affective Picture System IAPS; [6]. Emotional (pleasant and unpleasant) and non-emotional (neutral) pictures are used in order to maintain consistency with the previous literature on physiological responding and because the IAPS pictures are standardized along dimensions of emotional valence and arousal. Forty pictures from each category will be presented in random order. Consistent with Blechert et al., [6] all pictures will be presented twice.

ERP and EEG Data Acquisition and Reduction. Electroencephalogram (EEG) data will be recorded from 128 scalp sites using a geodesic sensor net and Electrical Geodesics, Inc., (EGI; Eugene, Oregon) amplifier system (20K gain, nominal bandpass= .10-100 Hz). Electrode placements will enable recording vertical and horizontal eye movements reflecting electro-oculographic (EOG) activity. Data from the EEG will be referenced to Cz and digitized continuously at 250 Hz with a 16-bit analog-to-digital converter. A right posterior electrode approximately two inches behind the right mastoid serves as common ground. Electrode impedance will be maintained below 50k Ω . Electroencephalographic data will be segmented off-line and single trial epochs rejected if voltages exceeded 100 μ V, transitional (sample-to-sample) thresholds were greater than 100 μ V, or eye-channel amplitudes were above 70 μ V. Data will be digitally re-referenced to an average reference then digitally low-pass filtered at 15Hz.

Physical Activity. Physical activity will be assessed objectively over a 24-hour period of time utilizing accelerometry. Accelerometers are small-computerized devices that measure

primarily, the number vertical accelerations (changes in movement) over a given period of time. Based upon the number of accelerations per unit of time (epochs), sedentary time, intensity of activity, as well as total physical activity can be determined. As it has been suggested that accelerometers be worn on the hip, all participants in this study will wear the accelerometer in this way and on the right side for consistency [43]. Accelerometers have previously been shown to have high reliability and validity and are thus appropriate as an objective measure of physical activity [43, 10]. Physical activity will be monitored for a 24-hour period of time during each experimental condition in order to determine if there is activity compensation following the exercise bout compared to the non-exercise condition. Following completion of each 24-hour period of data collection, accelerometers will be downloaded as an excel spreadsheet, briefly reviewed for completion, and saved on a laptop computer for future analysis. Coinciding with the wearing of accelerometers, participants will be asked to record any time in which the accelerometer was removed.

For a valid day, accelerometers must be worn at least 80% of the time between the hours of 7am and 11pm. Non-wear time will be considered to be a string of at least 20 consecutive zero counts.

Data Analysis. Analyses will be completed using the statistical software PC-SAS (version 9.1, SAS Institute, Inc., Cary, NC). Descriptive data for body weight, BMI, body fat percentage, energy intake, and physical activity will be reported in standard deviations and means. To further characterize physical activity data via accelerometry, the following categories, based upon a report by Troiano et al., will be utilized to describe sedentary time, light-intensity activity time, moderate-intensity activity time, and vigorous-intensity activity time: 249 counts or less per minute; 250-2019 counts per minute; 2020-5998 counts per minute,

and 5999 or greater counts per minute, respectively [43]. Mixed effects models will be utilized to test differences in the exercise and non-exercise condition within each BMI condition and to test for a group*condition interaction in energy intake and physical activity.

Food motivation will be examined using a 2-Group x 2-Condition x 2-Picture (food versus flower) mixed model ANOVA on ERP amplitudes and latencies. Tests of simple effects will be used to decompose significant main effects and interactions. The relationship between indices of food motivation, indices of health (e.g., BMI) and ERP amplitudes will be assessed using zero-order correlations.

References

1. Akio I, Meguid M, Laviano A. Satiety and Appetite as Regulators of Food Intake. *Encyclopedia of Gastroenterology* 2004: 329-334.
2. Babiloni C, Del Percio C, Valenzano A, et al. Frontal attentional responses to food size are abnormal in obese subjects: An electroencephalographic study. *Clinical Neurophysiology* 2009;120:1441-8.
3. Ball SD, Altena TS. Comparison of the Bod Pod and dual energy x-ray absorptiometry in men. *Physiological Measurement* 2004;25:671-8.
4. Basal Energy Expenditure: Harris-Benedict Equation. Cornell Medical University, 2000. 29 January 2010. <http://www-users.med.cornell.edu/~spon/picu/calc/beecalc.htm>
5. Blaak EE, Westerterp KR, Baror O, Wouters LJM, Saris WHM. TOTAL ENERGY-EXPENDITURE AND SPONTANEOUS ACTIVITY IN RELATION TO TRAINING IN OBESE BOYS. *American Journal of Clinical Nutrition* 1992;55:777-82.
6. Blechert J, Feige B, Hajcak G, Tuschen-Caffier B. To eat or not to eat? Availability of food modulates the electrocortical response to food pictures in restrained eaters. *Appetite* 2010;54:262-8.
7. Blundell JE, Stubbs RJ, Hughes DA, Whybrow S, King NA. Cross talk between physical activity and appetite control: does physical activity stimulate appetite? *Proceedings of the Nutrition Society* 2003;62:651-61.
8. Colley R, Byrne N, Hills A. Quantifying the effect of physical activity on total energy expenditure in obese women. *Obesity Research* 2005;13:A24-A.
9. Davis JA, Dorado S, Keays KA, Reigel KA, Valencia KS, Pham PH. Reliability and validity of the lung volume measurement made by the BOD POD body composition system. *Clinical Physiology and Functional Imaging* 2007;27:42-6.
10. Field AE, Coakley EH, Spadano JL, et al. Impact of overweight on the risk of developing common chronic diseases during a 10-year period. *Archives of Internal Medicine* 2001;161:1581-6.
11. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and Trends in Obesity Among US Adults, 1999-2008. *Jama-Journal of the American Medical Association* 2010;303:235-41.

12. Forbes GB, Kreipe RE, Lipinski B. BODY-COMPOSITION AND THE ENERGY-COST OF WEIGHT-GAIN. *Human Nutrition-Clinical Nutrition* 1982;36:485-7.
13. George VA, Morganstein A. Effect of moderate intensity exercise on acute energy intake in normal and overweight females. *Appetite* 2003;40:43-6.
14. Hubert P, King NA, Blundell JE. Uncoupling the effects of energy expenditure and energy intake: Appetite response to short-term energy deficit induced by meal omission and physical activity. *Appetite* 1998;31:9-19.
15. Ilse, M.T., et al., Differences in attention to food and food intake between overweight/obese and normal-weight females under conditions of hunger and satiety. *Appetite*, 2010. 54: 243-254.
16. Imbeault P, SaintPierre S, Almeras N, Tremblay A. Acute effects of exercise on energy intake and feeding behaviour. *British Journal of Nutrition* 1997;77:511-21.
17. King NA, Blundell JE. HIGH-FAT FOODS OVERCOME THE ENERGY-EXPENDITURE INDUCED BY HIGH-INTENSITY CYCLING OR RUNNING. *European Journal of Clinical Nutrition* 1995;49:114-23.
18. King NA, Burley VJ, Blundell JE. Exercise-induced suppression of appetite: effects on food intake and implications for energy balance. *European journal of clinical nutrition*;48:715.
19. King NA, Caudwell P, Hopkins M, et al. Metabolic and behavioral compensatory responses to exercise interventions: Barriers to weight loss. *Obesity* 2007;15:1373-83.
20. King NA, Snell L, Smith RD, Blundell JE. Effects of short-term exercise on appetite responses in unrestrained females. *European Journal of Clinical Nutrition* 1996;50:663-7.
21. King NA. What processes are involved in the appetite response to moderate increases in exercise-induced energy expenditure? *Proc. Nutr. Soc.* pp 107-13.
22. Kissileff HR, Pisunyer FX, Segal K, Meltzer S, Foelsch PA. ACUTE EFFECTS OF EXERCISE ON FOOD-INTAKE IN OBESE AND NONOBESE WOMEN. *American Journal of Clinical Nutrition* 1990;52:240-5.
23. Lluch A, King NA, Blundell JE. Exercise in dietary restrained women: no effect on energy intake but change in hedonic ratings. *European Journal of Clinical Nutrition* 1998;52:300-7.
24. Manson JE, Willett WC, Speizer FE. Body weight and mortality among women - Reply. *New England Journal of Medicine* 1996;334:733-.

25. Maraki M, Tsofliou F, Pitsiladis YP, Malkova D, Mutrie N, Higgins S. Acute effects of a single exercise class on appetite, energy intake and mood. Is there a time of day effect? *Appetite*;45:272.
26. Marra C, Martinez EC, Barros Junior OS, Candia FD. Effects Of Different Intensities Of Aerobic Exercise On Acute Changes In Biochemical Analysis And Appetite Of Adults With Overweight. *Medicine & Science in Sports & Exercise*;39:S383.
27. Martins C, Kulseng B, King NA, Holst JJ, Blundell JE. The Effects of Exercise-Induced Weight Loss on Appetite-Related Peptides and Motivation to Eat. *Journal of Clinical Endocrinology & Metabolism* 2010;95:1609-16.
28. Martins C, Truby H, Morgan LA. Short-term appetite control in response to a 6-week exercise programme in sedentary volunteers. *British Journal of Nutrition* 2007;98:834-42.
29. Martins C, Morgan LM, Bloom SR, Robertson MD. Effects of exercise on gut peptides, energy intake and appetite. *The Journal of endocrinology*;193:251.
30. McCrory MA, Mole PA, Gomez TD, Dewey KG, Bernauer EM. Body composition by air-displacement plethysmography by using predicted and measured thoracic gas volumes. *Journal of Applied Physiology* 1998;84:1475-9.
31. Meijer EP, Westerterp KR, Verstappen FTJ. Effect of exercise training on total daily physical activity in elderly humans. *European Journal of Applied Physiology and Occupational Physiology* 1999;80:16-21.
32. Mela DJ. Food choice and intake: the human factor. *Proc. Nutr. Soc.* pp 513-21.
33. Physical Activity and Public Health Guidelines. American College of Sports Medicine, 2007. 11 Dec 2010. <http://www.acsm.org/AM/Template.cfm>
34. Speakman JR, Stubbs RJ, Mercer JG. Does body mass play a role in the regulation of food intake? *Proceedings of the Nutrition Society* 2002;61:473-87.
35. Stubbs RJ, Hughes DA, Johnstone AM, et al. Rate and extent of compensatory changes in energy intake and expenditure in response to altered exercise and diet composition in humans. *American Journal of Physiology-Regulatory Integrative and Comparative Physiology* 2004;286:R350-R8.
36. Stubbs RJ, Sepp A, Hughes DA, et al. The effect of graded levels of exercise on energy intake and balance in free-living men, consuming their normal diet. *European Journal of Clinical Nutrition* 2002;56:129-40.
37. Stubbs, R.J., Whybrow, S., Blundell, J.E. Psychobiological and Behavioral Aspects of Appetite. *Enc Human Nutr.*, 2005, 27(6): p. 154-163.

38. Taylor AH, Oliver AJ. Acute effects of brisk walking on urges to eat chocolate, affect, and responses to a stressor and chocolate cue. An experimental study. *Appetite* 2009;52:155-60.
39. Thomas DP, Belko AZ, Mulroy GL, Haas JD, Roe DA. Combined effects of exercise and restriction of energy intake on moderately obese women. *British Journal of Sports Medicine*;20:84.
40. Thompson DA, Wolfe LA, Eikelboom R. Acute effects of exercise intensity on appetite in young men. *Medicine and science in sports and exercise*;20:222.
41. Thompson JK, Blanton P. ENERGY-CONSERVATION AND EXERCISE DEPENDENCE - A SYMPATHETIC AROUSAL HYPOTHESIS. *Medicine and Science in Sports and Exercise* 1987;19:91-9.
42. Tremblay A, Almeras N. EXERCISE, MACRONUTRIENT PREFERENCES AND FOOD-INTAKE. *International Journal of Obesity* 1995;19:S97-S101.
43. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical Activity in the United States Measured by Accelerometer. *Medicine and Science in Sports and Exercise* 2008;40:181-8.
44. Verger P, Lanteaume MT, Louis-Sylvestre J. Free food choice after acute exercise in men. *Appetite*;22:159.
45. Westerterp Plantenga MS, Verwegen CRT, Ijedema MJW, Wijckmans NEG, Saris WHM. Acute effects of exercise or sauna on appetite in obese and nonobese men. *Physiology & Behavior* 1997;62:1345-54.