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ABSTRACT

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Purpose: The purpose of this study was to examine the effects of long-term (24 weeks) physical activity on attention allocated toward food in college freshmen women. Methods: Seventy-nine freshmen college women wore a multi-function pedometer for 24 weeks after being randomly assigned to a daily step level: 10,000; 12,500; or 15,000. After at least 16 weeks of intervention, participants were given a cognitive viewing task (pictures of food and flowers) with the neural response measured using electroencephalogram (EEG) and event-related potentials (ERPs). P300s and LPPs are components of the ERP indicating increased attention to stimuli. Results: There was a significant difference in daily step counts between groups. No interaction between step group and picture condition (food vs. flowers) was found for any of the three ERP (event-related potential) variables (P300 amplitude, P300 latency, LPP amplitude). The 12,500 group showed a significantly elevated response in comparison to the other groups for both food and flowers (F=8.84; P=0.0002). Additionally, subjective rating of hunger was significantly lower in the 15,000 step group (F=4.72; P=0.0030). Conclusion: It appears that long-term increases in physical activity are capable of reducing neural orientation toward hedonic food cues as well as subjective hunger ratings. In addition to increasing energy expenditure, increases in long-term physical activity may also influence the physiological drive to consume food.

Keywords: long-term physical activity, food motivation, food attention allocation, event-related potential (ERP), college students

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Introduction

Attempting to lose or maintain body weight is common in the United States.[1-4] More than two-thirds of US adults participate in weight control behaviors.[4] However, losing weight and maintaining weight loss is difficult.[5-9] Although weight loss can be achieved, most research indicates a high percentage of those who lose weight tend to regain the lost weight.[6,7,10] Because losing and maintaining weight loss is difficult, viable and sustainable approaches for the prevention of weight gain are needed.

Risk of weight gain is elevated during the first year of college.[11] College freshmen tend to gain weight at a rate that is higher than the general population.[11-14] This increased rate of freshmen weight gain is likely because of the many environmental and social changes they experience during this transitional period of life.[1,15,16]

One health-related behavior that may partially be responsible for the weight gain seen in college freshmen is decreased physical activity.[17] A significant decline in physical activity among 18 to 29 year olds has been found in several studies.[1,12,15,17-23] Additionally, a decrease in physical activity has also been observed in the transition from high school to college.[23] University freshmen report significantly more barriers to physical activity than do grade school or high school students.[24] In addition, while studying first year college students, Racette et al. found that 30% reported no exercise during their freshman year.[15]

One method of measuring habitual physical activity is by pedometry. Pedometers have been used extensively in research and have been found to be a reliable and effective method to measure free living physical activity in college students. [25-27] Pedometers are also a very effective method of influencing habitual physical activity and there is now an extensive research base that supports the use of pedometers for increasing physical activity.[25,27]

While physical activity is an important part of weight management, the influence of physical activity on weight loss is often less than expected.[5-7,28,29] This is because energy intake also plays an important role in energy balance and consequently body weight. One reason why energy intake may have an influence on body weight and energy balance may be because physiological changes, as a result of modifications in energy expenditure, may change attention allocation toward food. These changes could make resistance to food cues more difficult, thus altering energy consumption and attenuating the impact of physical activity on body weight.

Most of the literature measuring attention toward food has been conducted in the short-term, often using visual analog scales (VAS) to rate subjective appetite, satiety, and hunger in response to a bout of exercise.[30-35] The majority of these studies report no effect or suppressed attention toward food following exercise.

Although subjective measures suggest an interaction between exercise and attention allocation toward food, objective measures may be more sensitive to change and better describe this relationship. Two methods for objectively measuring brain activity are functional magnetic resonance imaging (fMRI) and electroencephalogram (EEG) recording. However, differences in measurement techniques should be noted: fMRI indexes blood flow in the brain and has good spatial resolution but poor temporal resolution, whereas EEG measures the electrical activity of the brain and has good temporal resolution but poor spatial resolution. One method used to measure the time course of neural electrical activity is through event-related potential (ERP) amplitudes. ERPs represent the averaged electrical activity of the brain time-locked to the presentation of stimuli.[36] Therefore, using EEG to measure ERP amplitudes may be the most appropriate measurement to assess the magnitude and timing of the brain's electrical response toward food cues.

Objective measures have been used to examine change in attention allocation toward food following exercise. [33,37,38] However, these measures have been employed less frequently. Evero et al. found in a short-term crossover study, that fMRI scans showed reduced neural response to acute exercise in brain regions involved in 'food reward and visual attention'.[33] Hanlon et al. similarly tested the response of exercise on food motivation using EEG.[38] The results confirmed that of Evero; namely, following an acute bout of exercise, a decreased neural response was observed.

There has only been one study that has attempted to measure neural response toward food cues following long-term exercise. Cornier et al. employed VAS and fMRI before and after a progressive 6-month exercise program on 12 overweight or obese participants (5 women, 7 men).[37] Neural response to food was found to decrease, while there were no changes in hunger, satiety, or prospective food consumption. However, it is difficult to come to any firm conclusion about these relationships given the limited sample size and lack of a comparison group. To our knowledge, a long-term physical activity study using EEG to measure neural response toward food cues with a large sample had not been done. The purpose of this study was to examine the effects of long-term physical activity on neural attention toward pictures of food in freshmen college women.

Methods

Research Design

A randomized three group post-test experimental design was employed for this study. Participants were randomly assigned to one of three recommended step groups: 10,000; 12,500; or 15,000. Tudor-Locke and Bassett suggest step indices for healthy adults: ≥10,000 steps/day being considered 'active' and >12,500 being considered 'highly active'.[39] Further, Tudor-Locke et al. reports interventions using an increase of 2,000-2,500 steps/day.[40] We wanted all groups to be physically active, while separating progressive recommended levels by a large enough margin to discover health differences due to activity level. The 2,500 step difference between the three progressive groups requires approximately an extra mile per day. Participants were instructed to accumulate their step recommendation daily for 24 weeks. Between week 16 and 24, cognitive food attention testing was performed. Details of the testing measures are included below.

Participants

Participants were studied in 2 cohorts; spanning the university school year. All participants were freshmen women during their first term or semester at college at time of recruitment. Recruitment was through flyers, a booth at the new student orientation fair, and word of mouth. Participants were required to be able to participate in physical activity without restriction, not be taking metabolic-altering medications of any kind, and have a BMI $\geq$ 20 (kg/m^2). Those accumulating higher than 11,500 steps/day during baseline testing were excluded. The study was previously approved by the Institutional Review Board. All study participants signed a consent form and were asked for understanding before any testing or treatment was conducted.

Following the study, participants were asked if they had a history of a head injury resulting in unconsciousness or a neurological disorder. Three participants were excluded from the analysis for history of head injury (10,000 – n=1; 12,500 – n=1; 15,000 – n=1). Two participants were not able to be contacted.

Procedures

Following inclusion screening, participants were given a pedometer to wear for four days (2 weekdays and 2 weekend days) as a baseline testing period to decipher their average daily step count. Those individuals who averaged less than 11,500 steps/day were randomized into to one of three step groups: 10,000; 12,500; or 15,000 steps/day. Participants were expected to achieve their step recommendation 6 days of the week. Although not required to make their steps on the seventh day, participants were instructed to still wear the pedometer the entire day. Additionally, participants were instructed not to discuss their step group with other participants. For the course of the study, participants came to the Human Performance Research Center at the university every other week to download their pedometer data.

After at least 16 weeks of intervention, participants were scheduled on a weekday morning between 8 and 10 AM for food attention allocation testing; measured through an EEG completed at the Clinical Cognitive Neuroscience and Neuropsychology Lab at the university. In an 8-hour fasted state, brain activity was objectively measured by the EEG through a passive-viewing task. In 3 blocks of 80 pictures each, the participant observed 40 pictures of flowers and 40 pictures of plated food in random order. Excepting one picture, (single picture of noodles), all pictures of food contained multiple foods per plate. A broad breakdown of the pictures of food include: salads (6 pictures), fruits (2 pictures), meat-based meals (15 pictures), sandwiches (5 pictures), pizza/tacos/nachos (3 pictures), dessert (3 pictures), pasta-based meals (5 pictures), and pancakes (1 picture). Due to similarity in color and appearance to pictures of plated food, flower pictures were chosen to control for increased attention toward food. Change in level of pleasantness or arousal in reaction to these pictures is therefore directly due to the object of the picture. Previous research has used these pictures to examine neural response and consequential food motivation.[41] Following the EEG, participants were then asked to rate each picture on a 9-point scale concerning the level of valence (pleasantness) and the level of arousal (attention) the picture produced for them, thus measuring the viewing task subjectively as well. A similar protocol was used by Hanlon et al.[38]

After 20 weeks of step intervention, participants were emailed a web link to an online Visual Analog Scale (VAS) for 5 consecutive days. Web-based VAS were to be completed each of the 5 days following receipt of each email. VAS are a subjective method of assessing hunger (see below for details). The time of day in which to complete the questionnaire the following day was also indicated.

In addition to compensation for participation, incentives were offered to encourage participants to maintain the study protocol and achieve the required daily step count.

Measurements

Physical Activity: Steps were recorded for each participant using an Omron pedometer (Omron Healthcare, Inc., Bannockburn, IL). The Omron HJ720ITC multi-function downloadable pedometer can store 41 days of data and is capable of distinguishing aerobic steps from total step counts while worn at multiple places on the body. Validity and reliability of this pedometer model have been documented.[42] For validity, the absolute percent error (APE) of steps (number of actual compared with pedometer-determined steps) were calculated for accuracy. Across three self-paced walking speeds (means= 2.7 mph (slow), 3.3 mph (moderate), and 4.1 mph (very brisk)) and six placement positions (midback, backpack, right pocket, left pocket, right hip, left hip) for this model, APE was 2.3% $\pm$ 2.8%. All placement positions were found to be valid, excepting the backpack position. For convenience, participants were instructed to wear the pedometer over their right hip or in pockets that restrict the pedometer from flipping over (e.g. such as jean pockets that would hold the pedometer to the body). For reliability, coefficients of variance (CoV) were calculated. Under self-paced walking conditions, CoV was 1.4%. There was no significant difference in CoV across walking speeds using repeated-measures ANOVA.[42]

Attention Allocation Toward Food: A Geodesic sensor net (128 scalp sites) and Electrical Geodesics, Inc., (EGI; Eugene, OR) amplifier system (20K gain, nominal bandpass=.10-100Hz) was used to record EEG data. The protocol is similar to that of Stockburger et al.,[41] studying allocation of attention toward food through ERP levels. Neural activity time-locked to a specific stimulus are known as ERPs, which measure electrical activity directly.[36] P300 is the nomenclature describing a positive deflection in an ERP peaking around 300 ms following a stimulus. P300s suggest initial increased attention to specific stimuli.[36] The LPP, measured in microvolts (μV), portion of the ERP shows continued attention to stimuli, though not increasing attention.[36] The electrical activity of the brain surrounding a specific stimulus, known as ERP, measured amplitudes of attention allocation toward food through positive association with the food pictures. ERPs were examined for both intensity (amplitude) and timing (latency) of response. For data analysis, mean amplitudes were used for P300 and LPP variables between 200 and 300 ms and 600 and 700 ms, respectively. These scores were then matched to the corresponding assigned activity level of the participant. The amplitude and latency of the P300 and LPP potentials were compared for the food and flower pictures between activity groups.

Visual Analog Scale (VAS): VAS were administered through Qualtrics (Provo, UT) on-line surveying software. Reproducibility and validity of VAS have been confirmed as effective for research.[43] There have been many reputable studies that have used the VAS as a subjective measure of hunger and eating desires.[30,32,33,37] This scale is used as another component to verify inclination toward food at the end of the long-term physical activity phase. For 5 consecutive weekdays (Monday-Friday), participants were sent an email each night including the link for a

VAS to be completed the following day. In addition to the link for the on-line survey, this email also indicated the time they were to complete the survey (e.g. before breakfast or 9:00 AM, whichever comes first). For each visual analog question, participants were required to slide a marker along a 100mm line, therefore rating their answer from 1 to 100. The results were recorded on the research Qualtrics account in a central location for easy downloading for data collection and analysis (Table 4).

Data Analysis

The statistical software PC-SAS (version 9.3, SAS Institute, Inc., Cary, NC) was used to analyze the data. Alpha was set at $p < 0.05$. Means and standard deviations were calculated for all independent, dependent and control variables. A 3-Group (10,000; 12,500; 15,000 steps) x 2-Picture Type (food vs. flower) mixed model ANOVA was used to measure the effect of long-term step activity on ERP amplitudes in response to type of picture. Mixed model analysis was used to determine *within* and *between* group interactions of activity level (steps/day) and neural indices of food motivation. Influence of potential confounding variables on primary relationships was determined using partial correlation. Control variables for ERP analysis included: age, baseline weight, weight change, day of week, duration in study, and time of day. Subjective hunger was examined using 3-Group (10,000; 12,500; 15,000 steps) x 3-Meal (breakfast; lunch; dinner) mixed model ANOVA. Control variables that were used when analyzing subjective hunger included: age, baseline weight, weight change, time of day, and previous-day step count adherence.

Results

One hundred twenty-five participants were randomized. Ninety three participants completed EEG testing, with seventy nine participants included in the final analysis (Figure 1).

Approximately 89% of participants were Caucasian, 8% Hispanic, and 3% Asian. Collectively, participants were studying 62 different majors. Demographics at baseline are reported for all randomized participants (Table 1). A slight difference in age (yr) between the 12,500 and 15,000 groups was found (P=0.012). In addition, a difference in weight (kg) for the 10,000 and 12,500 groups was also found (P= 0.046), however there was no difference in BMI between groups. When evaluating characteristics for only those participants who were included in the final data analysis there was no difference for any measured variable (Table 2). Drop out across groups was unequal, however, there was no within group difference in age, BMI, or baseline steps for women who completed the study compared to those who did not.

Mean step counts across the entire study are reported in Table 3. There was a statistical difference between all groups for step count at study completion (P=<0.0001). Additionally, the difference in steps from baseline to study completion for all groups was significant (P=<0.0001). Table 3 shows the change in steps and weight from baseline for each step group. There was not a difference in weight gain between groups at follow-up (P=0.8385).

Table 4 summarizes amplitudes and latencies of the event-related potentials (P300 and LPP) of the EEG. No interaction between step group and picture condition was found for any of the three ERP variables (P300 amplitude, P300 latency, LPP amplitude). The 12,500 group had a significantly higher response in LPP amplitude to both food and flower pictures compared to the other groups (P=0.0002). These results were not altered when controlling for age, baseline weight, weight change, day of the week, duration in the study, or the time of day the ERP assessment was conducted.

Table 5 states the values for two questions related to subjective hunger and restraint assessed using a visual analog scale. For the question, 'How hungry are you right now?' there was a borderline significant difference, with the 15,000 group reported to be less hungry than either the 10,000 or 12,500 step groups (P=0.0991). However, after controlling for both the time of day the questionnaire was completed and the previous-day step count adherence, the difference between the 15,000 group and the other two groups was significant (P=0.0030). Controlling for age, baseline weight, or change in weight had no impact on this relationship. There was no interaction between meal and step group.

Discussion

The purpose of this study was to examine the effects of long-term physical activity on attention allocated toward food in freshmen college women. Findings from our study indicate that there was no *preferential* increase in attention allocation to food over flowers due to increased long-term habitual physical activity. It does appear that attention allocation (specifically LPP) to *both* food and flowers was influenced by long-term physical activity; thus, this relationship appears to be complex. Based on the findings from our study, LPP amplitudes for both food and flowers were highest in the 12,500 step group and lowest in the 15,000 step group. This indicates that the neural response to visual cues increases with increased long-term physical activity to a certain volume and that physical activity beyond this volume results in reduced neural response to visual cues. Therefore, the influence of long-term physical activity on attention allocation to visual cues may be dose dependent and that the impact is not specific to food.

There are few studies that have evaluated the neural response to food. Of the studies that have examined this relationship, the majority have been conducted following acute bouts of physical activity. Collectively, these studies have shown a decrease in neural response to visual food cues following acute exercise.[33,37,38] While understanding the impact of acute bouts of exercise on the neural response to visual cues is important in helping to understand the interplay between physical activity and attention toward food, these results do not take into account the body's ability to adapt.

Long-term physical activity studies measuring neural response to food are even more rare. To our knowledge, only one study has attempted to measure neural attention to food following chronic activity.[37] In this study the authors used a pre-experimental pre-test post-test design and measured change in neural function (evaluated using fMRI) following a progressive 6-month treadmill intervention. To determine exercise prescription, 12 participants (5 women, 7 men, mean BMI 33.3 ± 4.3 kg/m^2, and mean age 38.2 ± 9.5 years) were given a maximal aerobic capacity test and prescribed a tailored exercise load accordingly. This exercise load targeted an additional 2,500 kcal/week. Sub-maximal exercise tests were given every 6 weeks to ensure exercise load was appropriate for a 500 kcal/day increase. Intensity (60 to 75% of VO2 max) and duration (~15 to 20 min/day to 40-60 min/day) increased until week 18 and was sustained at that level for the duration of the study.

Following the exercise intervention, Cornier found that the neural response to food cues decreased compared to non-food cues, particularly in the bilateral insular cortices, which are known to be important in regulation of food intake. While the design of our study was different, the results of both studies taken together do support the possibility that chronic physical activity reduces the neural response to food cues. However, our study indicates that there may be a threshold at which this neural suppression to food cues occurs and that the suppression of neural response was not specifically limited to food.

It was surprising that there was no differential neural response to food cues and flowers. It may be that the physical activity intervention heightened attention to all pleasant visual cues, not solely to food-related ones. This may explain why the difference in neuronal response between conditions (food or flowers), regardless of LPP amplitude, revealed a similar margin for all step groups. It is also possible that foods presented were unappetizing or less familiar to participants, resulting in lower observed amplitudes for food.

While the correlation between neural response to food cues and subjective appetite measures has generally been weak or non-significant, there does seem to be some agreement between the two in our study.[30,33] The 15,000 group reported the lowest subjective rating of hunger, following a similar pattern as the neural outcomes. Previous studies have shown that exercise has the potential to influence hunger. The majority of these studies have examined subjective hunger following an acute bout of exercise. These studies have generally demonstrated that subjective rating of hunger decreases during or immediately following an acute bout of exercise.[30,33]

While there have been a few studies that have examined the acute relationship between exercise and hunger, to our knowledge only one has examined this relationship following chronic change in physical activity. Contrary to our findings, Cornier et al. found no relationship between chronic exercise and hunger ratings. However, it is difficult to draw firm conclusions from this study given the limited sample size (7 men and 5 women). The small sample makes it difficult to find significant relationships, which is especially true when using a subjective measure of hunger.[37] Our results are in agreement with those of short-term studies,[30,33] revealing that chronic physical activity has the capacity to reduce subjective hunger ratings given the volume of activity is sufficiently high. It is possible that with greater levels of long-term physical activity, hunger levels are attenuated. The present study's results may indicate the existence of a physical activity threshold. When this threshold is exceeded, mechanisms are triggered to decrease hunger.

As with any large study, there are some limitations that should be discussed. First, while all step groups experienced some drop out, there was slightly higher than expected drop out in the 15,000 step group. While the attrition was high in this group, overall, this level of attrition is not uncommon in exercise studies where a high volume of activity is prescribed for a long period of time.[44] However, as the 15,000 group exhibited the lowest neural response, the dropout rate is a concern and should be considered when evaluating our results. In addition, because the study design did not include a pre-test, we were not able to evaluate change in dependent variables. For example, with no pre-test, the results do not show the magnitude of change in hunger ratings. The lack of a pre-test also did not allow us to verify groups were equal at baseline on dependent variables. However the groups were randomly assigned allowing us to assume equal groups at baseline and there was no difference between groups for other variables including BMI, body composition, and steps per day.

Despite these limitations, our study makes some significant additions to the current literature. First, the current study is the only one to use an experimental design to answer the question of a relationship between long-term physical activity and neural response. We not only measured this relationship, but we also used different activity levels to do so. This allowed us to see how neural response varies with differing levels of physical activity. It further enabled us to identify a possible threshold, beyond which further physical activity has a dampening effect on neural response. Additionally, the current study is the largest study to date to measure neural response to chronic physical activity. Because the study was adequately powered we were better able to evaluate the proposed relationships. This is also the only long-term physical activity study that has used EEG to measure neural response. Using EEG as the method of measurement complements and strengthens results found in fMRI studies, as EEG has greater temporal resolution, indicating the timing of neural response to visual cues. Finally, by using both EEG and VAS, this becomes only the second long-term physical activity study to utilize both objective as well as subjective measures.

Conclusion

Based on the findings from this study and other studies, it appears that both acute and chronic physical activity may have the ability to reduce hunger and neural orientation toward food as long as a certain level of chronic physical activity is met. It should be noted that, although neural response to food was reduced with high levels of habitual physical activity, so too was response to flowers, suggesting an impact on attention to visual cue that was not limited to food. These findings suggest that physical activity not only increases energy expenditure but also may help to regulate the physiological drive to consume food. This may be why a certain level of physical activity is important to help regulate body weight and why those who maintain weight loss tend to have a high level of activity. Thus, it seems that the level of habitual physical activity has an impact on attention given to food in college women and that the promotion of activity in young women may have benefits on weight regulation that go beyond energy expenditure. Future research should evaluate these findings in other populations. In addition, future research should also include pre-tests and post-tests, coupled with objective measuring techniques, to help determine the magnitude of change in both neural response and hunger over time. Finally, studies are needed to evaluate how change in neural response to food and subjective hunger relate to actual energy intake.

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Table 1. Baseline demographics of all randomized participants.

	10,000 Step Group n=40	12,500 Step Group n=40	15,000 Step Group n=45	F	P	Total n=125
Age	18.4 ± 0.5[ab]	18.6 ± 0.5[a]	18.2 ± 0.6[b]	4.61	0.012	18.4 ± 0.5
Height (cm)	167.0 ± 5.2	164.7 ± 5.4	166.1 ± 6.0	1.71	0.185	165.9 ± 5.6
Weight (kg)	65.6 ± 7.7[a]	61.4± 6.7[b]	63.6 ± 7.9[ab]	3.15	0.046	63.6 ± 7.6
BMI (kg/m^2)	23.5 ± 2.5	22.6 ± 2.1	23.1 ± 2.5	1.40	0.250	23.1 ± 2.4
Avg. steps at baseline	8090 ± 1565	8345 ± 1508	8161 ± 1503	0.30	0.743	8197 ± 1516

Values are means ± standard deviation. BMI= Body Mass Index.

F and P values represent differences between step groups at baseline.

Means with different letters are statistically different ($P < 0.05$).

Table 2. Baseline demographics of participants included in analysis.

	10,000 Step Group n=31	12,500 Step Group n=27	15,000 Step Group n=21	F	P	Total n=79
Age	18.5 ± 0.5	18.7 ± 0.4	18.4 ± 0.6	3.09	0.052	18.6 ± 0.5
Height (cm)	167.1 ± 4.6	165.2 ± 5.8	165.1 ± 7.0	1.09	0.343	165.9 ± 5.3
Weight (kg)	64.0 ± 6.1	62.5 ± 7.5	62.2 ± 7.4	0.51	0.601	63.0 ± 6.9
BMI (kg/m^2)	22.9 ± 1.8	22.9 ± 2.4	22.8 ± 1.9	1.01	0.994	22.9 ± 2.0
Avg. steps at baseline	8032 ± 1587	8431 ± 1522	8392 ± 1384	0.61	0.549	8264 ± 1506

Values are means ± standard deviation. BMI = Body Mass Index.

F and P values represent differences between step groups at baseline.

Table 3. Differentials for weight and steps across study.

	10,000 Step Group n=31	12,500 Step Group n=27	15,000 Step Group n=21	F	P
Steps at baseline	8032 ± 1587	8431 ± 1522	8392 ± 1384	0.61	0.549
Steps at study completion	10114 ± 927[a]	11964 ± 1238[b]	12996 ± 1174[c]	47.33	<0.0001
Difference in steps*	2082 ± 1761[a]	3533 ± 1634[b]	4606 ± 1676[c]	13.73	<0.0001
Difference in aerobic steps*	1161 ± 1265[a]	2005 ± 1634[b]	2494 ± 1286[b]	6.49	0.0023
Difference in weight (kg)*	1.4 ± 2.6	1.8 ± 2.1	1.4 ± 2.1	0.18	0.8385

Values are means ± standard deviation.

F and P values represent differences in step groups at study completion.

Means with different letters are statistically different ($P < 0.05$).

* Difference refers to difference between baseline and study completion.

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

	10,000 Step Group n=31	12,500 Step Group n=27	15,000 Step Group n=21	F	P
P300 Amplitude (μV)				0.27	0.7661
-Flower	5.3 ± 3.3	6.4 ± 3.6	5.4 ± 2.1		
-Food	6.3 ± 4.0	7.2 ± 4.1	6.3 ± 2.2		
P300 Latency (ms)				0.08	0.9261
-Flower	235.5 ± 14.9	233.7 ± 16.8	235.8 ± 14.0		
-Food	230.8 ± 13.2	230.5 ± 18.6	230.3 ± 9.9		
LPP Amplitude (μV)				8.84	0.0002
-Flower	0.9 ± 1.1	1.7 ± 1.5	0.7 ± 0.9		
-Food	1.8 ± 1.7	2.8 ± 1.9	1.5 ± 1.0		

Values are means ± standard deviation.

F and P values represent main effects between step groups for given ERP variable.

There was no step group* picture condition interaction.

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

Table 5. Visual analog scale data.

	10,000 Step Group n=31	12,500 Step Group n=27	15,000 Step Group n=21	F	P
How hungry are you right now? (mm)	51.70 ± 24.54[a]	51.21 ± 25.93[a]	46.66 ± 25.65[b]	4.72	0.0030
Yesterday, to what extent did you consciously limit your food intake? (mm)	34.71 ± 24.69	33.77 ± 23.53	31.95 ± 26.17	0.54	0.5857

Values are means ± standard deviation.

F and P values represent differences between step groups for hunger.

Means with different letters are statistically different (P < 0.05).

Values from 5 consecutive-day on-line surveys, measuring hunger at different times of day.

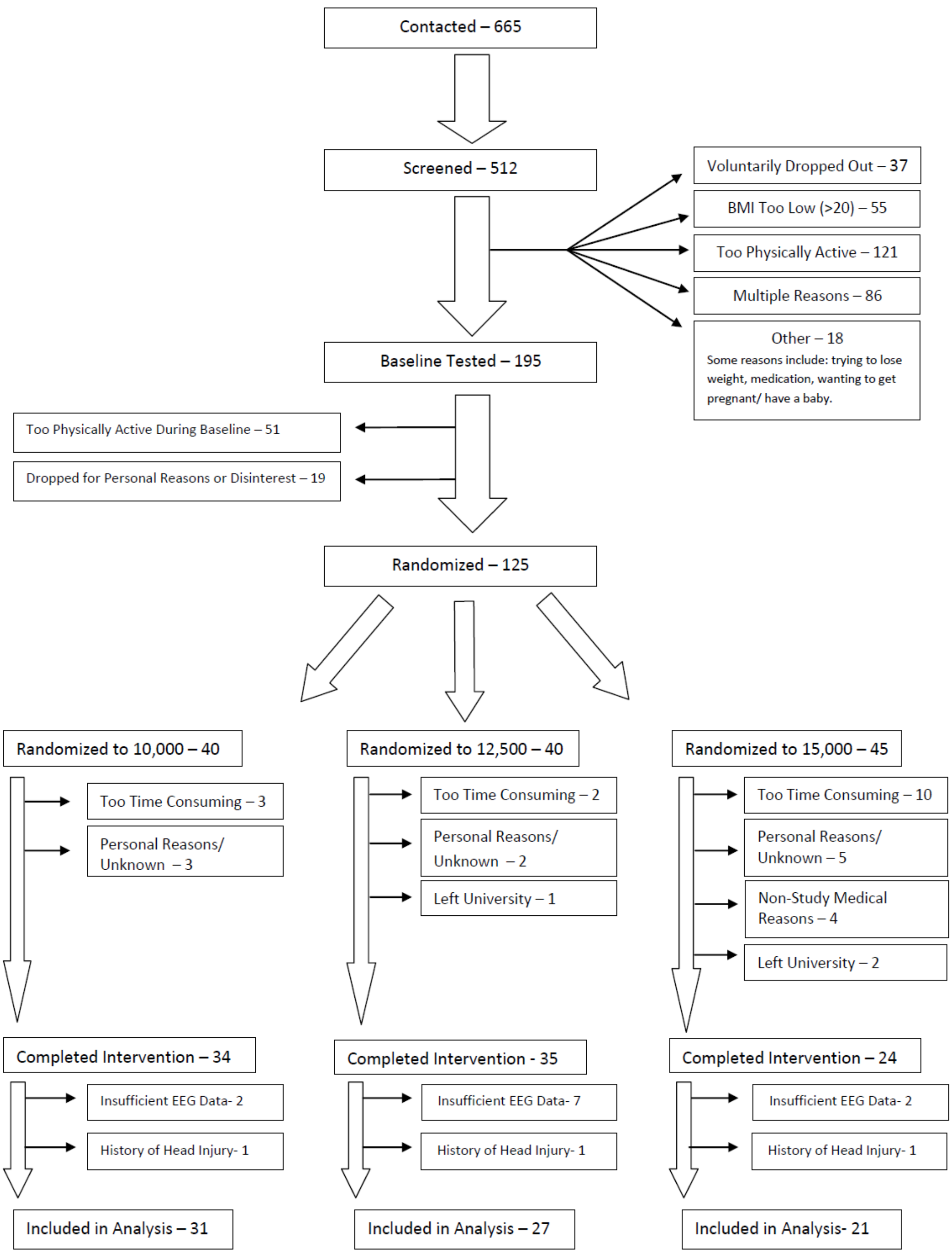

Figure 1. Flowchart of participants.

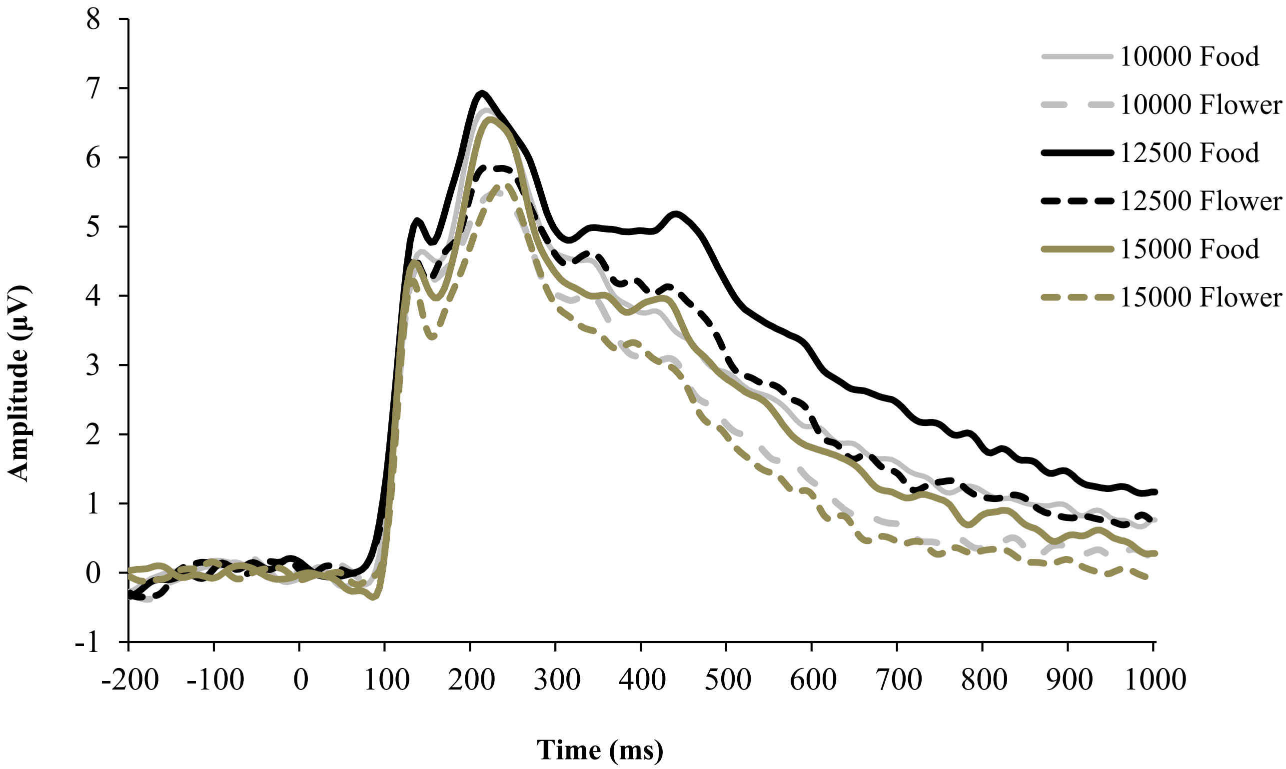

Figure 2. Encephalogram waveform: food and flower values for each group.

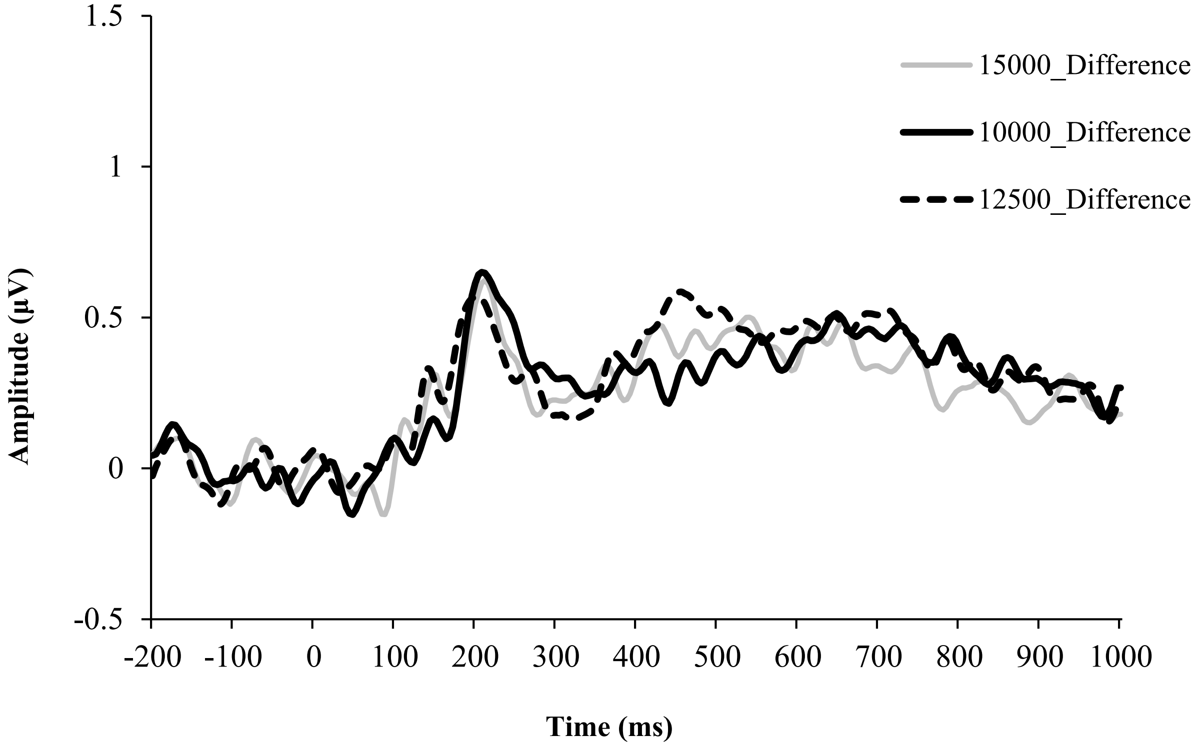

Figure 3. Electroencephalogram waveform: food minus flower difference for each group.