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Subjective Social Status is associated with compensation for large meals – a prospective pilot study

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Abstract

Objectives: Subjective social status (SSS) is known to be inversely associated with obesity. Our objective was to determine if SSS is associated with eating behaviors that would predispose to weight gain, specifically, with inadequate compensation for excess energy consumed during a single large meal. Therefore, we conducted a pilot study to determine the association of SSS with 24-hour energy balance, 24-hour and post-lunch energy intake, changes in body composition and changes in adjusted resting energy expenditure on days when a high-energy lunch was consumed in free-living human subjects.

Method: Female participants (7 normal weight and 10 overweight) consumed 60% of estimated 24-hour energy requirements as a lunchtime meal in the laboratory for 14 days. Subjective social status was measured at baseline using the MacArthur Scale. Remote Food Photography Method was used to record food intake outside of the lab on days 1–2, 7–8, and 12–13. Associations of 24-hour energy balance, 24-hour and post-lunch energy intake, changes in adjusted resting energy expenditure and changes in percent body fat (measured by dual x-ray absorptiometry) with SSS were studied.

Results: Mean (standard deviation) age and BMI were 36.29(8.25) years and 26.43(2.32) kg/m², respectively. Lower SSS was significantly associated with positive energy balance (p for trend

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0.002), and higher post-lunch energy intake ($p=0.02$) when controlled for age and initial body mass index.

Conclusions: Our pilot data show that lower SSS is associated with higher post-lunch energy intake, which is indicative of poor energy compensation following a large meal. Over a longer time period, this could result in fat mass gain. Studies that are of longer duration and well-powered are warranted to confirm our findings.

Keywords

Subjective social status; Socioeconomic status; Obesity; Energy balance

Introduction

Obesity is a major chronic disease in the United States (U.S.) and 38% of adults have obesity as of 2014 (1). In high-income countries, including the United States, obesity is more prevalent among those with lower socioeconomic status (SES), especially in women (2–5). In high-income countries, women who are food insecure have a 50% higher risk of having a high body weight than those who are food-secure, while no association is present for men (5). The association between low SES and obesity is complex and multiple theories have been suggested.

Nettle et al. described the *insurance hypothesis* where humans increase energy intake over expenditure, resulting in fat storage, when they are uncertain about an adequate supply of food (5). The *resource scarcity hypothesis* is an extension of the insurance hypothesis and proposes that individuals who perceive food insecurity would be in positive energy balance, specifically when there is access to high calorie food, and this effect would be specific to those with low social status only (6). The resource scarcity hypothesis may explain the difference seen in the relationship between social status and obesity in high- and low-income countries. Food insecure individuals consume high energy food and store excess body fat as insurance only when they have access to food, and there is more access to high energy density access food in high-income countries, whereas this is not the case in low income countries (5, 6). The *life history theory* proposes that exposure to an unpredictable environment during childhood impacts eating behavior, and explains in part the effects of low SES during childhood on obesity as an adult (7). Individuals with lower childhood SES tend to have marked impulsivity and a focus on short-term goals as adults, and this may result in problems with weight-management behaviors (7). Hence, studies that suggest social status may influence our decision-making, combined with theoretical frameworks from evolutionary biology, suggest that social status may play a causative role in weight gain.

The association between low SES and obesity may not be a simplistic function of financial resources. Lower SES is associated with food, employment and housing insecurities, which affect the diet of the individual and the family (8). Affluence is associated with the consumption of nutrient-rich, high quality diets, whereas poverty is associated with the consumption of more affordable, low cost, energy-dense and nutrient-poor diets (9). However, the provision of extra resources in the form of cash transfers has resulted in an *increased* prevalence of overweight and obesity in adults and children (10, 11). Briefly, a

large-scale, Mexican conditional cash transfer (CCT) program was conducted to alleviate poverty and the participants received cash transfers. Unexpectedly, higher BMI and increased prevalence of overweight and obesity were associated with receiving more money (10). Similarly, participation in the Supplemental Nutrition Assistance Program (SNAP, previously and still commonly referred to by ‘food stamps’) is associated with higher BMI in adults, independent of perceived food insecurity; this may be due to disordered eating patterns that result from receiving monthly SNAP funds or could be due to increased consumption of energy-dense food (12).

Subjective social status (SSS) is defined as “a person’s belief about his / her location in a status order” (13). The MacArthur Scale of Subjective Social Status is a commonly used method to measure SSS at the society or community level. This scale is represented by a ladder; at the top of the ladder are people who are best off with the most amounts of money, education and best jobs, while the people who are the worst off are at the bottom of the ladder (14). Education, occupation, household income, feeling of future financial security, satisfaction with living standards, physiological functioning, strength and sickness contribute to SSS (15, 16). Interestingly, SSS appears to mediate the association between objective measures of SES (education and income) and BMI (17). According to a prospective cohort study, SSS is a strong predictor of ill health, irrespective of education, occupation and income (15). Lower SSS is also associated with increased risk of hypertension, dyslipidemia, coronary artery disease, diabetes and obesity (16, 18). Such associations between SSS and health outcomes may be due to the effects of perceived social status on the underlying physiology of feeding behavior, which may impact body size and body fatness (12, 19–22). It is often hypothesized that dietary factors associated with SES may drive obesity in low SES populations. However, this has recently been challenged by the idea that social status may be a fundamental driver, or cause, of these dietary behaviors and weight gain (5, 6, 23). Furthermore, the lack of effectiveness of interventions (10–12) that seeks to manipulate material resources on obesity also suggests that perceived social status, not simply SES, may cause weight gain. Considering these findings, SES may be a better indicator of access to valued resources while SSS may be a better indicator of security and sense of control.

Recent studies have experimentally induced lower or higher SSS (24, 25). Cheon et al. conducted four studies where low (vs. high or neutral) socioeconomic status was experimentally induced in the participants. They observed that the subjective experience of low social class resulted in a preference for high energy foods and increased intake of energy from meals and snacks independent of financial resources (24). Cardel et al. also conducted a randomized crossover study in Hispanic young adults to experimentally manipulate social status conditions using a game of Monopoly™. Fasted participants consumed a standardized breakfast and were randomly assigned to either a high or low social status condition. Next, high vs. low status participants played a rigged game of Monopoly™ where the rules were different for each group (e.g., double the resources were given to those in the high status group). Following the game, the participants consumed lunch ad-libitum. Individuals reported decreased feelings of pride and powerfulness and consumed approximately 130 more kilocalories when placed in the low social status condition when compared to the high social status condition (25). Pavea et al. used a different strategy to experimentally induce

higher or lower social status by assigning participants to be a leader or follower in a partner activity (26). However, they did not observe any difference in energy intake between the two groups as in the previous studies and this method to induce a relative difference in SSS may have not been effective. In another randomized social experiment, the intervention group moved from a high-poverty neighborhood to a low-poverty neighborhood. Interestingly, prevalence of obesity was reduced only in the intervention group (19), again highlighting the potential connection between SSS and obesity.

In theory, energy balance can be achieved by controlling energy intake or energy expenditure and one is said to be in “energy balance” when energy intake is equal to energy expenditure, which results in a stable body weight (27). However, when energy intake is greater than expenditure, it is known as “positive energy balance” and this results in weight gain (27). Generally, compensatory mechanisms to defend against negative energy balance and weight loss may be stronger than for those against positive energy balance with weight gain. In American culture, individuals are frequently exposed to large meals in social or restaurant settings, and their ability to recognize these occasions and adjust their energy intake or expenditure to account for them may be an important indicator of obesity risk. Indeed, certain individuals are more predisposed to have inadequate compensation for excess energy and weight gain (28).

We hypothesize that the experience of low SSS may be one determining factor that predisposes an individual to inadequate compensation for excess energy and weight gain. Even though experimentally induced lower SSS results in acute increases in energy intake, the association between actual SSS and energy-intake has not been observed in long-term studies, and the external validity of the various operationalization of social status (e.g., being randomly assigned as a “leader” or “follower” in a partner activity) have not been verified. Furthermore, there is a gap in the current literature regarding the effect of SSS on energy balance and eating behavior. Therefore, we conducted a novel observational, large meal challenge pilot study wherein female participants of varied SSS consumed a large lunchtime meal for 14 days, and we then monitored their post-lunch energy intake to determine how SSS is associated with their ability to adjust their energy intake to maintain energy balance despite the large meal challenge. Another purpose of this pilot study is to help to determine sample size for a larger scale study in the future.

Our primary objective is to understand the association of SSS with 24-hour energy balance during the large meal challenge, as an indicator of weight gain propensity, and our secondary objectives are to identify the association of SSS with 24-hour energy intake, post-lunch energy intake, changes in body composition and adjusted resting energy expenditure (REE) following a high-energy lunch for 14 days in free-living human subjects. Our central hypothesis is that lower SSS will be associated with inadequate compensation for excess energy consumed during a single large meal (i.e., the large meal provided to participants as part of the study). Further, we hypothesize that lower SSS will be associated with positive energy balance, to the extent that it leads to body fat gain in response to daily large meals over a 14-day period.

Material and Methods

We have used the CONSORT 2010 checklist of information to include when reporting a pilot or feasibility randomized trial (Appendix A-Table S1) (29). The trial was registered at clinicaltrials.gov, protocol number NCT03510364.

Ethical concerns

The protocol to protect our human subjects was approved by the Institutional Review Boards of University of Alabama, Birmingham (Protocol number F131010007) and Texas Tech University, Lubbock, TX (Protocol number IRB2016–571). We obtained informed consent from participants at the time of enrollment in the study.

Study design

This is a prospective feeding pilot study with convenience sampling and the study was conducted over 14 days. Figure 1 illustrates the study design. Participants were blinded regarding the aim of the study and were debriefed at the end of the study. Participants were told that the effect of diet macronutrient composition on resting metabolic rate was being measured.

Participant recruitment

Fliers were posted in community locations around the University of Alabama at Birmingham campus, which is situated in the central part of the city. Twenty one women were recruited from the University of Alabama at Birmingham and surrounding area and data was collected between June 2014 and June 2015. First, a script-based telephone screening was used to identify eligible participants and was followed by in-person screening. Inclusion criteria included: between 20–50 years old, with BMI between 23–30 kg/m², no food allergies or food restrictions, not engaged in any weight reduction program within the past 3 months, not experienced any weight loss or gain of more than 5% of body weight in the past 6 months other than due to post-partum weight loss, not on appetite suppressant or stimulant medication, not having undergone prior surgical procedures for weight control or liposuction, does not smoke or has not smoked in over 6 months, does not have any major diseases such as cancer at present or had cancer that was treated in the past 2 years (except non-melanoma skin cancer), active or chronic infections (e.g., HIV or TB), cardiovascular disease, gastrointestinal disease, kidney disease, chronic obstructive airway disease that requires oxygen (e.g., emphysema or chronic bronchitis), diabetes (type 1 or 2) and on anti-diabetic medications and/ or controlling with dietary modifications, uncontrolled psychiatric disease, not have a recent or ongoing problem with drug abuse or addiction, does not consume more than three alcoholic drinks per day and has not had 7 or more alcoholic beverages in a 24 hour period in the last 12 months, currently pregnant or within 3 months post-partum, not currently nursing or completed nursing within the last 6 weeks, and not anticipating a possible pregnancy during the study.

Dietary intervention

For the feeding intervention, participants consumed a meal containing 60% of their estimated energy daily energy requirement as a lunchtime meal for 14 consecutive days under observation. On weekends, participants were allowed to bring the packed lunches home if necessary but were encouraged to consume them under observation in a tertiary location outside UAB's Bionutrition Unit, which was closed on weekends. To ensure the participant receives 60% of the daily energy requirement as a lunch meal we added a supplemental shake to a standard 1200 kcal meal (Details of the shake and meals are in the Appendix B -Table S2 and S3). We determined the lunch calories to be provided to each participant based on their daily energy requirement calculated using basal metabolic rate (BMR) measured via indirect calorimetry at the baseline. We used a physical activity level value (PAL) of 1.4 (30), and we assumed that our participants were sedentary. Thus, target lunch calorie intake was calculated as $BMR \times 1.4 \times 0.6$.

Data collection

A questionnaire was administered at baseline to collect sociodemographic data. We inquired about income, debt and food insecurity. These questions are provided in Appendix B. In the same questionnaire, we determined subjective social status of the participants, using the MacArthur scale of Subjective Social Status (SSS) (14) which uses an image of a ladder with ten rungs (Appendix B Figure.S1). The description provided regarding the ladder was, "At the top of the ladder are the people who are the best off – those who have the most money, the most education and the most respected jobs. At the bottom are the people who are the worst off – who have the least money, least education, and the least respected jobs or no job. The higher up are on this ladder, the closer you are to the people at the very top; the lower you are, the closer you are to the people at the very bottom". Participants were asked to mark a "X" on the rung where they "thought" they stood at that particular time in their lives, relative to the other people in the United States (14).

We measured height using a stadiometer with the participant standing straight, facing forward, looking straight ahead, heels touching the stadiometer, and the horizontal headpiece touching the crown of the head. Height was recorded in cm and rounded to the nearest 0.1 cm. Weight was recorded to the nearest 0.1 kg. BMI was calculated as height divided by height squared. If it did not fall between 23 and 30, the participant did not qualify and was excluded. Both pre-and post-intervention body fat percentage was measured using dual energy X-ray absorptiometry (DXA) (GE-Lunar Radiation Corp. Madison, WI) and resting metabolic rate was measured using indirect calorimetry (Vmax ENCORE 29N Systems, SensorMedics Corporation, Yorba Linda, CA).

Each food item provided in the lunchtime meal in the laboratory was weighed before consumption, and any remaining food was weighed using electronic weighing scales. Participants were allowed to eat *ad-libitum* outside the laboratory. On days 1 and 2 (early), 7 and 8 (middle), and 12 and 13 (late), food intake outside the lab was recorded using remote food photography (31, 32). For this, participants were first trained to use the SmartIntake application, an iPhone app to track their food intake, over a three-day period prior to the feeding intervention. In addition, participants used a food diary as a backup method if they

forgot to record their food intake using the RFPM method. Thus, we assumed that the energy intake recorded during meals and snacks outside the laboratory are complete and that there are no missing data.

Statistical analysis

Data are presented as mean $\pm$ standard deviation (SD). We used IBM® SPSS version 25 and R 3.5.0 statistical software for our analyses; please see below for further detail. Our primary outcome measure was 24-hour energy balance. Our secondary outcome measures included 24-hour energy intake, post-lunch energy intake, and difference in adjusted REE and changes in body composition.

In our data, there were missing values for some lunchtime energy intakes; corresponding calculations of energy intake and energy balance were also missing for those subjects on those days. These missing values were handled through massive multiple imputation using the *mice* R package. Default settings were used (e.g., predictive mean matching) except that we increased the number of imputations to 30 and increased the maximum number of iterations to 20. These parameters were set to these higher values to make sure that we were compensating for the relatively small fractions of missing information exhibited by our data. Additionally, there was a single missing value in the results from each of the instruments measuring income and total debt; the tau-b extension to Kendall's tau functionally ignores such an individual.

We calculated the adjusted REE values by correction for lean mass ($\text{REE corrected} = (\text{REE} / \text{lean mass})$). The difference in adjusted REE over time was calculated as $(\text{Final REE} / \text{Final LM}) - (\text{Initial REE} / \text{Initial REE})$. Percent change in BMI, fat mass and visceral fat were calculated as $[100 * (\text{final value} - \text{initial value}) / \text{initial value}]$. Post-lunch energy intake was calculated as the sum of energy intake consumed at dinner, afternoon snacks, and evening snacks recorded by the RFPM method. If a meal was not recorded via photos app, participants were immediately reminded to record their meal using a food diary and those data were used in place of photography data. Twenty-four hour energy intake was calculated as the sum of calories consumed during all meals and snacks during a 24-hour period. We calculated the energy expenditure as resting energy expenditure (REE) multiplied by 1.4 (a sedentary physical activity level) (30). Energy balance was calculated as follows: $\text{Energy balance} = 24\text{-hour Energy intake} / \text{Energy expenditure}$. For the early (Day (D)1 and 2) and middle (D7 and 8) time points, we used baseline REE value and for the late time point we used post-feeding REE (D12, D13) REE values for the above calculation.

To identify association of race with SSS and adjusted REE, we used Mann Whitney U tests. For comparison of BMI, body fat, lean mass, REE and adjusted REE at basal and post feeding time points, we used paired t-tests after confirming normality using the Shapiro-Wilk test. Energy balance was modeled as a function of period (1–2, 7–8, and 12–13 days) using a mixed linear effects model, while adjusting for subject as a random intercept using the *lme4* and *lmerTest* packages in R to study if energy balance change with time while on a high calorie lunch; here and for all analyses, when missing values were present, a pooled analysis was obtained from the massive multiple imputation.

Associations between SSS and energy balance, 24-hour total energy intake, and post lunch energy intake were assessed using linear models, controlling for age and baseline BMI using a mixed model (with subject as a random intercept). Because an energy balance percentage of 100% corresponds to perfect energy balance, and 50% and 200% are the same magnitude but in different directions, the natural log of energy balance as a proportion was used in all analyses involving energy balance (e.g., 100% becomes 0, 200% becomes 0.69315 and 50% becomes -0.69315). SSS could be treated as a continuous variable or a factor whenever it was used in a linear or mixed linear effects model; the p-values for trend that we will report treat it as a continuous variable.

Furthermore, associations between SSS and difference in adjusted REE and percent changes in body composition (BMI, fat mass and lean mass) were studied using linear models while controlling for age. Kendall's tau-b correlation analysis was performed between SSS and income, education, debt, body composition and food insecurity measures.

Results

We recruited 21 participants and 17 completed the study. Details of study participation, handling of missing data, compliance and respective analysis are illustrated in Figure 2. All participants were compliant, with each participant having an average lunch intake of 80% or more of their intended lunch intake (i.e. 60% of their daily energy requirement) over the 14 days (for this determination, averages over imputed values were used when lunch values were missing). All $n=17$ subjects were used in the analyses.

Baseline characteristics and associations with subjective social status

Our participants had SSS ranging from 3 to 8 out of a scale of 10. SSS was not significantly correlated with indicators of socioeconomic status including income ($T_b = 0.346$, $p = 0.11$, $n=16$), debt ($T_b = -0.206$, $p = 0.33$, $n=16$) and education ($T_b = -0.102$, $p = 0.33$, $n=17$). In addition, SSS was not significantly correlated with food insecurity (Question 4: $T_b = -0.154$, $p = 0.49$, $n=17$ and Question 5: $T_b = -0.211$, $p = 0.35$, $n=17$). We did not observe significant differences in SSS between non-Hispanic whites and non-Hispanic blacks (two-sample Wilcoxon $p=0.63$, $n=17$ (12 and 5, respectively)).

Furthermore, we did not observe significant correlations of SSS with BMI ($T_b = 0.080$, $p = 0.67$, $n=17$) and body fat percentage ($T_b = 0.177$, $p = 0.35$, $n=17$) at baseline.

Effects of high calorie meal on body composition and energy balance

The socio-demographics and pre-and post-feeding measurements are summarized in Table 1. Even though a high calorie lunch was provided over 14 days, participants did not show significant increases in BMI, lean mass or fat mass (all $p > 0.05$) (Table 1).

We observed that average resting energy expenditure increased by ~ 73 kCal/ 24 hours by the end of the intervention but was not statistically significant ($p>0.05$) (Table 1). Similarly, pre- and post-intervention adjusted REE were not significantly different ($p>0.05$) (Table 1).

Positive energy balances of intake at 106.6%, 111.7% and 108.9% of energy needs were observed at early (Day 1 and 2), middle (Day 7 and 8) and late (Day 12 and 13) time periods, respectively (n=17); however, the latter two energy balance numbers are not significantly different than the 106.6% of the early period (p=0.49 and p=0.76, respectively).

Associations between subjective social status, energy balance, and body composition following a high calorie meal

When controlling for age and baseline BMI, we observed that lower SSS was associated with increased log energy balance (p for trend = 0.002). This association between SSS and logged energy balance is shown in Figure 3, with a linear trend superimposed over the best estimates obtained by treating SSS as a factor. We did not control for race since there was no significant difference in baseline adjusted REE between non-Hispanic whites vs non-Hispanic black (two-sample Wilcoxon p=0.23, n=17).

Average post lunch energy intake was significantly inversely associated with SSS (Figure 4) in the full sample (p for trend = 0.02) when controlled for age and baseline BMI. Exhibiting a similar pattern, 24-hour energy intake was not significantly inversely associated with SSS (p for trend = 0.20) when controlled for age and baseline BMI. In general, these results are being driven by the subjects with the lowest and highest observed SSS (scores of 3 and 8, respectively), as these subjects have the highest leverage in the data set.

When controlling for age, SSS was not associated with *percent change* in BMI, fat mass or visceral adipose tissue (VAT) (p= 0.84, 0.68 and 0.52, respectively). Furthermore, SSS was not associated with change in lean mass adjusted REE, when controlling for age (p=0.67).

DISCUSSION

In this pilot study, we employed a novel approach to identify associations between SSS and energy balance and energy intake in free-living females with normal and overweight status. While controlling for age and baseline BMI, we assessed the association between *ad-libitum* meal intake and energy balance following a high calorie meal challenge, which was 60% of participant's energy requirements, over 14 days. We selected the duration as 14 days since it is relatively longer duration that may be needed for persistent effects on energy balance to result in measurable changes in energy stores.

We report that SSS was inversely associated with 24-hour energy balance during 14 days of high calorie lunch in free-living females. 24-hour energy intake was not significantly inversely associated with SSS, so any influence on energy balance through energy intake is only apparent after adjusting for an individuals' energy needs. Changes in lean mass adjusted REE similarly did not show an association with SSS. Thus, the inverse association between SSS and 24-hour energy balance is likely to be driven by the 24-hour energy intake.

These findings are consistent with previous research findings that experimentally induced lower social status resulted in higher energy intake in humans and primates (33, 34). It has been previously shown that selection of high calorie food is predicted by perception of scarcity, and not taste (35). Hence, participants with lower SSS may continue to consume

more calories because of their perception of low social status and perception of scarcity. Sim et al., have shown that both acute and chronic subjective deprivation of non-food resources are associated with increased consumption food and stronger desire to consume large portion sizes (36). Our findings are also in line with previous research that demonstrates individuals with food insecurity tend to consume poor quality, energy dense food and tend to have disinhibited eating or are prone to overeat (8).

The association of lower SSS with positive energy balance in our study may be driven by differences in acute energy intake following the consumption of a much larger meal than what is normally consumed. We observed a statistically significant association between SSS and post-lunch energy intake at the meals immediately following the large lunch, specifically, such that individuals with lower SSS consumed more energy following a large lunch. Thus, individuals with lower SSS may not experience the same inhibition and sensation of satiety as higher SSS individuals for eating meals later the same day. However, we did not measure satiety, fullness, gastric emptying, or any satiety hormones in this study. Measuring differences in physiological regulation of acute eating behaviors between social status categories would be a logical next step in understanding the physiological roots of this difference in eating behavior.

One novel aspect of this study is that the experimental design allowed for observation of differences in compensatory mechanisms to maintain energy balance, in spite of a large meal challenge. A common belief is that an individual gains about 5 pounds or more following a holiday, and this is due to the large energy-rich meals consumed with holiday traditions. However, average holiday weight gain is minimal, and is about 0.5 kg or less (37). Energy balance perturbations such as holiday meals, or our large meal challenge, likely result in both metabolic and behavioral compensations. In our study, we were able to measure aspects of both behavioral and metabolic compensation for the large meal. We studied REE pre and post intervention, to detect metabolic compensation, but did not observe any significant changes in REE over the 14-day period. Instead, we measured individual differences in behavioral compensation, in the form of continued high post-lunch energy intake and found that it was associated with SSS. Based on this finding, one would expect to see an increase in body weight of individuals with lower SSS, because they did not compensate for the high calorie meal challenge. However, we did not observe any association between SSS and percent change in BMI or fat mass, and a study period longer than 2 weeks may be needed to observe a change significant association of SSS with change in body composition.

There are several strengths of this pilot study. Unlike the previous studies that investigated SSS and energy consumption by experimentally manipulating SSS, we considered the actual SSS level in our participants. We blinded our participants regarding the real purpose of the study in an attempt to prevent corresponding biases. In order to ensure that the participants got a high calorie lunch we provided 60% of their daily energy requirement as a lunch time meal in the laboratory setting. However, the post-lunch meals were taken in a free-living setting. Hence, our study design allows our findings to be generalized more broadly to free-living settings. We used the RFPM method to track energy intake, which has high accuracy among adults (38), to capture the post-lunch meal intake on selected days. Another important strength is that our study was of longer duration. We conducted our study over 14

days to overcome any day-to day variations that can occur with an individual's food consumption.

There are some limitations in this pilot study. First, we did not measure physical activity and account for its variation among participants in our calculations and assumed everyone had a sedentary physical activity level. Because we did not study the basal food intake in our study participants, we also cannot comment whether provision of high calorie meal changed their feeding behavior. Another limitation is that our sample size is small. Hence, our ability to be confident about the non-significant findings reported in this study is limited. These negative findings may be true negative or false negative results due to type II errors. However, even with a small sample size, we were able to observe significant association of SSS with energy balance and post-lunch energy intake. Furthermore, our study was not a randomized controlled study. Hence, we suggest a larger scale randomized trial in the future that involves strategies to manipulate subjective social status. Our study participants included only females and this was decided during study design because lower socioeconomic status (SES) is associated with obesity in females in developed countries, but the association is not observed in males (39). Also, female sex has a direct relationship with SSS (17). Thus, our findings cannot be generalized to males. Furthermore, we selected our study participants who were either normal or overweight based on BMI despite the noted limitations of using BMI to define obesity (40). There are several theories as to why SSS may have a causal effect on obesity. Financial insecurity and desire for money may increase consumption of palatable, energy dense food that may lead to weight gain over time (16, 41). According to Insurance and Resource scarcity hypotheses, individuals increase energy intake more than the expenditure in the presence of uncertainty about adequate food (5, 6). Evolutionary biology suggests that organisms may respond to perceived energetic insecurity by storing energy as fat as a survival mechanism to ensure longevity and successful reproduction (22). The latter hypothesis suggests that perception of the environment, rather than the environment itself, is critical for regulating eating behavior and body fat stores. Thus, obesity may be an evolutionary adaptive response to food insufficiency and energy storage is increased in response to food insecurity (6, 16).

SES and perceived stress are associated (42), and this is an important consideration in the interpretation of our findings. Adler et al. have reported that subjective social status and chronic stress are significantly associated after controlling for objective SES (43). SSS has shown to be associated with depressive cognition (44). Thus, SES and insecurities that accompany it are stressors that threaten one's well-being, and may cause altered neuroendocrine function due to activation of hypothalamic–pituitary–adrenal axis (8). This may lead to consumption of a highly palatable, energy dense diet poor in quality to help reduce stress response, and stress hormones may favor deposition of excess calories as fat in the central part of the body (8). Even though SSS is related to stress, its effects are distinct from stress. For example, in the Monopoly™ study by Cardel et al., participant's perceived stress did not change significantly when they were placed in high/low social status conditions, but their perceived pride and powerfulness did change significantly and being in a low social status position resulted in significantly higher percentage of daily calorie needs and saturated fat consumed (25).

This pilot study is useful to plan a larger scale study. We identified that the sample size that is required to detect the largest observed correlation observed in this study. The effect size was 0.34 for the association of energy balance with SSS for this experimental paradigm, which means a sample size of 50 subjects would yield 80% power at an alpha of 0.05. Also, the predicted energy balance in individuals with the lowest SSS (McArthur scale score = 3) was 152.6% while in those with the highest SSS had a predicted energy balance of 81.8% during this experimental feeding challenge paradigm. This degree of positive energy balance in the low social status individuals would conceivably produce up to about 3.2–3.6 kg weight gain over a 14-day period in a subject representing the average subject in this study, according to the NIH-Body Weight Planner Calculator by Hall et al. (45). However, we did not observe this degree of weight gain in our study, potentially because our projections did not account for any changes in spontaneous physical activity or physical activity energy expenditure. Therefore, we recommend 1 month or longer duration would be optimal for future studies to detect weight gain associations with SSS, and we would also recommend that future studies measure energy expenditure via accelerometer or a comparable method.

Conclusions

In our pilot study, we found some evidence to suggest that a lower score on the MacArthur Scale of Subjective Social Status is associated with increased energy balance and reduced ability to compensate for a large meal. Thus, compensation for large meal perturbations in normal caloric consumption may be less accurate in individuals with lower SSS. These findings merit confirmation in larger scale studies in the future.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

BMI	Body Mass Index
BMR	Basal Metabolic Rate

DXA	Dual Energy X-Ray Absorptiometry scan
NHANES	National Health and Nutrition Examination Survey
PAL	Physical Activity Level
REE	Resting Energy Expenditure
RFPM	Remote Food Photography Method
SES	Socioeconomic Status
SSS	Subjective Social Status
US	United States
VAT	Visceral Adipose Tissue

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Figure 1. Study design

Abbreviations: S1 (First phone screening), S2 (Second in-person screening), Q (Questionnaire based data collection), RFPM (Remote Food Photography Method), REE (Resting Energy Expenditure), DXA (Dual Energy X-Ray Absorptiometry scan)

Figure. 2. Flow diagram illustrating study participation, handling of missing data, compliance and respective analysis grouping.

All participants were considered compliant given that their average energy intake at lunch was 80% or more of the intended amount.

Figure 3. Association between subjective social status and log energy balance over 14 days (n=17).

The loess smoothed fit line indicates the trend. We have reported log 24-hour energy balance. Thus, “0” indicates energy balance; positive values indicate positive energy balance, while negative values indicate negative energy balance.

Figure 4.
Association between subjective social status and post lunch energy intake over 6 days
(n=17).

Table 1.

Socio-demographics and pre-and post-feeding measurements (n=17)

	Baseline	Post-feeding period	P value
Race	12:5		
Non-Hispanic white: Non-Hispanic black			
Subjective social status score of:	1		
3	1		
4	4		
5	5		
6	3		
7	3		
8			
Age (years)	36.29 (8.25)		
BMI (kg/m ²)	26.43 (2.32)	26.57 (2.30)	0.194
Lean mass (kg)	42.80 (4.47)	43.08 (4.54)	0.277
Fat mass (kg)	27.61 (6.92)	27.72 (6.78)	0.452
Fat mass %	38.73 (4.64)	38.75 (4.18)	0.940
Visceral fat (kg)	0.50 (0.46)	0.51 (0.43)	0.515
Resting energy expenditure (kCal/ 24hours)	1247.53 (176.36)	1320.53 (209.94)	0.104
Adjusted resting energy expenditure (kCal/ 24hours/per kg of lean muscle)	29.15 (2.80)	30.62 (3.27)	0.119

Data are shown as Mean (SD), proportions or as frequencies.

P values based on paired t-test analyses