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Experimentally Manipulated Low Social Status and Food Insecurity Alter Eating Behavior Among Adolescents: A RCT

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Abstract

Objective: This randomized trial experimentally manipulated social status to assess effects on acute eating behavior and 24-hour energy balance.

Methods: Participants (n=133 Hispanics; 15–21y; 60.2% females) were randomized to LOW or HIGH social status conditions in a rigged game of Monopoly™. Acute energy intake in a lunchtime meal was measured by food scales. 24-hour energy balance was assessed via summation of resting metabolic rate (metabolic cart), physical activity energy expenditure (accelerometer), thermic effect of food, and subtraction of 24-hour energy intake (food diary).

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Results: In the total sample, no significant differences were observed by study condition at lunchtime. LOW females consumed a greater percent of lunchtime daily energy needs (37.5%) relative to HIGH (34.3%); however, this difference was not statistically significant (p=0.291). Whereas in males, LOW consumed significantly less (36.5%) of their daily energy needs than HIGH males (45.8%;p=0.001). For 24-hour energy balance, sex differences were nearly significant (p=0.057; LOW Females:Surplus +200kcals; HIGH Males:Surplus +445kcals). Food insecure individuals consumed a nearly significant greater lunchtime percent daily energy than those with food security (40.7% vs. 36.3%;p=0.0797).

Conclusion: Our data demonstrate differential acute and 24-hour eating behavior responses between Hispanic male and female adolescents in experimentally manipulated low social status conditions.

Keywords

obesity; social status; adolescent; food insecurity; Hispanic

Introduction

In the United States (US), Hispanic American (HA) youth have the greatest prevalence of obesity (28.0% of boys, 23.6% of girls) as compared to Whites (14.6% of boys, 13.5% of girls), Blacks (19.0% of boys, 25.1% of girls), and Asians (11.7% of boys, 10.1% of girls)[1]. This is concerning given that 80% of adolescents with obesity will have obesity as adults[2], thus increasing cardiometabolic disease risk[3]. Among HA adolescents, socioeconomic status (SES) and neighborhood economic factors are associated with increased body mass index (BMI)[4] attributed, in part, to associations between low SES and poor dietary patterns[5] and food insecurity, a condition that occurs when households are at risk of hunger due to inability to afford food[6]. However, among youth, SES is often operationalized by parental levels of income and education and may not fully capture the internalized social positioning of youth. Moreover, it appears one's perception of social rank and objective SES independently correlate to SES-related health disparities[7].

Subjective social status (SSS) assesses perceived social standing, determined by an individual's rank of their social standing when compared to others within one's community or broader US society[8]. SSS is informed by concepts developing during adolescence including self-esteem, popularity, social desirability, social mobility, and peer norms[8,9]. SSS has been associated with food insecurity[10] and discrimination[11], which are disproportionately experienced by racial/ethnic minorities[11]. SSS, SES, and food insecurity are independently associated with weight status and a variety of health-related outcomes in adults[12,13], and SSS is associated with mental health, self-rated health, and general health during adolescence[7]. Among adolescents, healthier diet and activity patterns are positively associated with SSS[7], and SSS is a better predictor of weight than parental SES. The relationship between SSS and weight differs by sex and race/ethnicity, with associations stronger among females and Latinos[14]. Yet, mechanisms driving the relationships between SES, SSS, and food insecurity with weight status, and differences by sex, remain unclear[15].

SSS is thought to influence health outcomes through psychological processes and associated biological processes and behaviors[7]. Recently, our group and others manipulated social status in laboratory settings and lower SSS increased acute intended or actual food intake[15-18] and increased secretion of ghrelin[19]. However, other studies have found inconsistent associations between social status, perceived power or scarcity, and eating behavior[20]. Together, this work suggests SSS may influence eating behavior and risk for obesity, but additional research is needed. In line with these findings and earlier observational studies of the association between SES and weight among females, our group and others have also proposed the "Insurance Hypothesis" and "Resource Scarcity Hypothesis", each of which broadly states that low SSS (e.g., in the case of food insecurity) engenders psychological and physiological responses promoting increased energy intake as a means of buffering against potential shortfalls in food availability[21-23]. We believe SSS and other factors contributing to "energetic uncertainty" (i.e., housing, food insecurity) may promote long-term positive energy balance and risk of obesity via both energy intake and expenditure, particularly among females[24].

The objective of this study was to assess the effects of experimentally manipulated social status on acute dietary intake and energy balance over a 24-hour period among HA adolescents. We hypothesized participants, particularly females, randomized to a low social status condition (LOW) would consume more energy (kcals) and percent of daily energy needs, and would be more likely to be in positive energy balance when compared to those randomized to a high social status condition (HIGH). We also hypothesized that individuals with food insecurity would consume significantly more of their daily energy needs (%EN) than individuals who are food secure, and that any observed associations would be independent of stress.

Methods

Subjects

HA adolescents ages 15-21 (n=133) were recruited via flyers and participant referral. For study inclusion, participants self-identified as HA, BMI ≥18.5 and ≤40 kg/m^2, born in the US. We excluded participants who had never played Monopoly™, and those who reported 1, 2, 9, or 10 on the community SSS scale during screening[25], since it may be difficult to experimentally manipulate acute social status of individuals with extremely low/high SSS.

Additional exclusions included tobacco use, dietary restrictions, ≥10 pounds gain/loss in previous 6 months, severe clinical depression, uncontrolled psychiatric disease, known substance abuse or eating disorder, pregnancy, or any major health condition or medication use known to affect body composition, appetite, metabolism, or cardiac function.

Protocol

After a telephone screen, participants were instructed to fast for 12 hours and avoid strenuous exercise for 24 hours prior to visit. Upon arrival, fasting status was confirmed and informed consent/assent, approved by the Institutional Review Board, was given (Figure 1). The study protocol is displayed in Figure 2. Anthropometries were assessed and participants rested for 10 minutes prior to blood pressure (BP) and heart rate (HR) measurements. Next, resting metabolic rate (RMR) and percent body fat were assessed and participants were provided with an accelerometer and HR monitor. The HR monitor was worn around the chest through the remainder of their visit.

Measurements of BP and HR were taken again and then participants completed visual analog scales (VAS; 1-100) assessing subjective feelings of stress, powerfulness, and hunger. Participants consumed a standardized breakfast, followed by additional VAS assessment and a series of questionnaires. Salivary cortisol was collected and then staff told the participant they were leaving to score their questionnaires. However, they opened an envelope providing randomization status (HIGH or LOW). Participants, stratified by sex, were block randomized using random block sizes of two and four. The participant was notified of their assignment for the Monopoly™ game with one of the following statements: if randomized to HIGH, "Congratulations, based on your test scores, you have been given the Rolls Royce piece", and if randomized to LOW, "I'm sorry, based on your test scores, you have been given the shoe piece." The participant played a 40-minute game of Monopoly™ with a confederate player with the opposite social status condition. Rules of the game were explained and a physical copy of the rules provided.

Similar to our previously published pilot[15], rules for the Monopoly™ game differed by condition. Rules for HIGH: Rolls Royce piece, beginning the game with $2000, rolling both dice at each turn, collecting $200 when passing "Go", and assigned the role of banker throughout the game. Rules for LOW: shoe piece, beginning the game with only $1000, rolling only one die each turn, and collecting $100 when passing "Go". Other standard rules applied and participants were instructed not to assist each other. Through social position manipulation, the rigged Monopoly™ game promoted internalization of social standing and subjective potential for social mobility[15].

After 40 minutes, participant and confederate player returned to respective rooms. Salivary cortisol was assessed and measurements of BP, HR, and VAS were collected. The weighed *ad libitum* lunch was delivered and the participant was left alone to eat. After 20 minutes, the food was collected and BP, HR, and VAS were assessed. Participants were given a food diary to use for 24-hours. Participants were blinded to the main aim of the study to minimize confounding resulting from potential expectation. Upon completion of the study, participants were informed of the true nature of the study via email.

Anthropometries and body composition

Each participant was weighed to the nearest 0.1 kg on a digital scale (Health O Meter 2600KL Wheelchair Scale, McCook, IL, USA). Height was recorded to the nearest 0.1 cm using a wall-mounted stadiometer (Holtain Limited Harpenden, Crosswell, Crymych, UK; Veeder-Root, Elizabethtown, NC, USA). Percent body fat was assessed using BodPod (Life Measurement, Inc., Concord, CA, USA).

Subjective measures of stress, powerfulness, and hunger

Perceived feelings of stress, powerfulness, and hunger were assessed using validated VAS[18,20,26]. VAS assessments were taken 4 times throughout the study: before breakfast, after breakfast/before game, after game/before lunch, and after lunch.

Objective measures of stress

BP and HR were measured with an automated monitor (Omron BP710N, Omron Europe, Netherlands). These measures were taken in duplicate with 2 minutes between each measure and averaged at each of the 4 time points. Objective stress indicators were measured with salivary cortisol via SalivaBio Oral Swab (Salimetrics, LLC, Carlsbad, CA, USA) before and after Monopoly™. For analysis of salivary cortisol, we used the American Laboratory Products Company (ALPCO, Salem, NH) Cortisol ELISA (Saliva) Cat. No. 11-CORHU-E01-SLV.

Food security, SES, and SSS

Food security was measured using the 2-item clinical screener for food insecurity[27]. Participants reported their highest level of education and household income as assessments of SES and their SSS using validated MacArthur scales[25]. Participants under the age of 18 used youth MacArthur scales[8]. Community SSS was used in all statistical models.

RMR

RMR was assessed using the validated Parvo Medics TrueOne 2400 machine (Sandy, UT, USA). Participants laid in an active resting state for 30 minutes while metabolic measurements were taken in 30-second increments. When calculated, 5 minutes of measurements at the beginning and end of the test were dropped and all measurements between those points were averaged to determine RMR[28].

Dietary intake assessment

After 12+ hours of fasting prior to the visit, all participants consumed the same standardized breakfast: 500 g water and a bacon, egg, and cheese flatbread breakfast sandwich (190 kcal, 9 g/12% total fat, 17 g/6% total carbohydrate, 11 g/21% protein, 4 g sugar, 580 mg sodium, 1 g fiber).

The *ad libitum* buffet lunch included a variety of options for a total of 1970 kcal (nutritional composition described in Table S2). All foods were weighed to the nearest 0.01 g before and after the *ad libitum* buffet lunch and data were entered into the Nutrition Data System for Research 2017 (Nutrition Coordinating Center, University of Minnesota). %EN was analyzed by first calculating total energy expenditure using RMR, objectively measured daily physical activity energy expenditure, and diet-induced thermogenesis of 10%. Calories consumed during the *ad libitum* lunch buffet meal were presented as a percent of the total energy expenditure, %EN consumed. To assess 24-hour dietary intakes, objectively measured breakfast and lunch consumption were totaled with the self-reported diet in the food diary for the remainder of the 24-hours. It is important to note that some study authors have raised significant issues regarding self-reported data for 24-hour intakes. However, diet data were objectively measured in our laboratory for both the breakfast and lunch, presumably reducing measurement error associated with 24-hour self-report data.

Physical activity

Physical activity was assessed using an ActiGraph wGT3X-BT accelerometer placed at the waist above the right hip. The accelerometer was set to record at a sampling rate of 30 Hz and data was collected in 60-second epochs. Each participant was instructed to wear it for 24-hours, except while sleeping and in water. Physical activity data were wear-time validated using the Choi 2011 algorithm[29]. Moderate to vigorous physical activity was calculated using the Freedson VM3 2011 algorithm[30] and physical activity energy expenditure was calculated using a regression equation published by Ekelund et al[31].

24-hour energy balance

24-hour energy balance was assessed with the summation of RMR, physical activity energy expenditure, thermic effect of food, minus daily energy intake.

Monopoly™ winnings

Monopoly™ winnings were calculated at the end of each game. Cash, property, and total values of the participant’s winnings were recorded.

Power and Sample Size

To determine power and sample size calculations, POWERLIB version 2.2., a SAS/IML based software was used[32]. Using the primary outcome of adjusted calorie intake, power curves with 95% confidence interval were plotted. Based on our pilot study[15], we estimated the standard deviation of the adjusted calorie intake at lunch to be 0.11. We needed n=50 per group (n=100 total) to detect a significant difference between groups if the true mean difference is at least 0.06 (SD=0.11) with 80% power and an alpha level of 0.05 with a two-tailed test.

Statistical analysis

All statistical analyses were conducted using SAS 9.4 (SAS Institute, Cary, NC). Descriptive statistics were reported as mean±SD for continuous variables and n(%) for categorical variables. Categorical outcomes were compared between groups using the chi-square test, and continuous outcomes were compared using either two-sample t-test or non-parametric Wilcoxon test. A general linear regression model was used to estimate the effect of treatment assignment on %EN and 24-hour energy balance. For this model, after breakfast/before game was used as baseline, representing a more analogous hunger level across participants.

The general linear regression model was used to estimate the association between explanatory variables and outcomes. Residual analyses were conducted to ensure residuals met the model assumptions. Collinearity between explanatory variables was checked, and reductant explanatory variables that caused collinearity were eliminated from the model (conditional index >10). Interaction terms involving very small counts (<5) in subgroups were also eliminated from the model. Thus, covariates included sex, BMI, food security, and community SSS. Given the relationship between food insecurity and risk for obesity[33], we decided *a priori* to include food insecurity in the model as a more relevant proxy for SES in our study design. We conducted a backward model selection and further eliminated insignificant interaction terms. Outcomes that were measured multiple time points were compared between two study groups using general linear mixed model with repeated measures, controlling for the baseline value of the measure before the game. A test was considered statistically significant if its p-value<0.05. All data was complete, with the exception of one subject missing BP and HR measurement after lunch, and there are 1-3 missing in VAS depending on time of measurement. Except for the testosterone analysis, which was conducted post-hoc, all analyses were decided *a priori*. The raw code, de-identified data, and analyses were re-run and double-checked by another analysis team.

Results

Participant characteristics are reported in Table S1 (mean age 19.1; 60.2% female; mean BMI 24.4 kg/m^2). Mean percent body fat of participants was 25.7±9.7. Mean RMR was 1196.3±260.3 kcal and estimated energy needs were 1983.7±457.9 kcal/day.

Monopoly™ Winnings

Monopoly™ winnings are depicted in Figure S1. Relative to HIGH, LOW had significantly lower cash winnings ($158 vs $1030; p<0.0001), lower property winnings ($960 vs $2600; p<0.0001), and lower total value winnings ($1172 vs $3786; p<0.0001). Winnings served as one of the manipulation checks.

Ad libitum lunch buffet meal

In the total sample, manipulated social status condition was not significantly related to total energy, %EN consumed, or macro- or micro-nutrient intakes at lunch (Table 1). HIGH consumed an average of 36.9% of their energy needs during lunch, while LOW consumed 35.7% of their energy needs at lunch (p=0.075).

After covariate adjustment, the effect of manipulated social status on %EN consumed at lunch significantly differed by sex (p=0.009; Table 2a). Predicted means for %EN consumed at lunch by sex and status group are presented in Table 2b. Females randomized to LOW consumed greater %EN (37.5%) at the *ad libitum* lunch buffet meal relative to HIGH (34.3%); however, this difference was not statistically significant (p=0.291). In males, the opposite was true, with LOW consuming significantly less %EN (36.5%) than HIGH males (45.8%; p=0.001).

After controlling for sex, BMI, community SSS, and experimental manipulation, we found that food security was nearly significantly associated with %EN consumed at lunch (p=0.080), such that those who reported food insecurity consumed greater %EN (40.7%) relative to those who identified as food secure (36.4%).

24-hour energy balance

Effects of experimentally manipulated social status on 24-hour dietary intakes, 24-hour energy expenditure, and 24-hour energy balance in the total sample are presented in Table 3.

Experimentally manipulated social status was not a significant predictor of 24-hour energy balance or %EN consumed. Individuals in the LOW condition consumed a significantly greater percentage of their calories from fat (p=0.043), while individuals in the HIGH condition consumed a significantly greater percentage of their calories from carbohydrate (p=0.046).

After covariate adjustment, the effect of manipulated social status on 24-hour energy balance was nearly significantly different by sex (p=0.057; Table 4a). Predicted means for 24-hour energy balance are described in Table 4b. Though the total sample was in positive energy balance, differences by sex were notable with LOW females in positive energy balance of +848 kcals and HIGH females in positive energy balance of +646 kcals daily, equating to +200 surplus of kcals in a 24-hour period for LOW females relative to HIGH females; however this difference was not statistically significant (p=0.344). Conversely, LOW males were in positive energy balance of +596 kcals and HIGH males had +1041 kcal positive energy balance, equating to +445 surplus of kcals in a 24-hour period for males in HIGH relative to the males in LOW; this difference was nearly statistically significant (p=0.092).

Perceptions of powerfulness, frustration, stress, and hunger

Perceptions of powerfulness, frustration, stress (Figure S2 and Table 5), and hunger (Table 5) are displayed. There were no differences in subjectively measured stress or hunger by experimental condition at any time point. In Figures S2B and S2C, being randomized to LOW was significantly associated with reports of greater feelings of frustration (p=0.059) and decreased feelings of powerfulness (p=0.035) after game/before lunch.

Objectively measured stress

Objectively measured stress (salivary cortisol) is shown in Figure S2D and demonstrates no significant differences in salivary cortisol by manipulated social status condition (p=0.53). Similarly, there were no significant differences in other objective markers of stress (BP and HR) by manipulated social status condition.

Discussion

This is the first study to examine the effects of experimentally manipulated social status and food insecurity on acute dietary intakes, 24-hour energy balance, and acute stress-related outcomes. LOW participants experienced a significant decrease of perceived powerfulness and increased frustration and ended the game with significantly less cash, property, and total winnings. Together, these two components suggest our paradigm was successful in altering short-term feelings of social status. Though we did not observe significant differences by social status condition in the total sample at the lunchtime meal, females and males randomized to LOW responded differently relative to those randomized to HIGH in their consumption of daily energy needs at lunch following the rigged game. When looking at 24-hour energy balance in the total sample, individuals in LOW consumed significantly more fat, whereas those in HIGH consumed significantly more carbohydrate but no differences in total calories were observed. When looking at the relationship of sex in 24-hour energy balance, sex differences were nearly significant (p=0.057; LOW Females: Surplus +200 kcals; HIGH Males: Surplus +445 kcals). Almost one-quarter of participants reported food insecurity, aligning with previous literature highlighting high prevalence of food insecurity as a major issue among college students[34]. Individuals who were food insecure consumed a greater %EN in the *ad libitum* meal, regardless of randomized condition. Interestingly, all results appear to be independent of stress, as no stress-related markers (objective via salivary cortisol, BP, and HR; subjective via VAS assessments) differed by social status condition. Together, this suggests a lower SSS position, even for a short duration, can have differential effects on eating behavior by sex and may have an effect on obesity by promoting excess calorie consumption and positive energy balance among individuals with food insecurity.

Research in animal models and humans demonstrates low social status predicts obesity more strongly in females than males[35-37]. Similarly, we observed a differential sex response to experiencing a low social status condition on eating behavior, which could impact obesity development. Specifically, we observed that females consumed a numerically greater, but not statistically significant, %EN when placed in LOW while males did the exact opposite, consuming a statistically significantly greater %EN in HIGH relative to LOW. These differences were demonstrated in the acute *ad libitum* lunchtime meal and extended over the 24-hour period. Our hypothesis was that randomizing females to LOW would acutely result in excess calorie consumption. This hypothesis is derived, in part, from research in animal models and humans, demonstrating that low social status predicts obesity more strongly in females than males[35,36], and from theories utilizing adaptive evolutionary logic[21-24]. Briefly, these evolutionary-informed theories suggest that when individuals are in a subordinate position, they are more likely to encounter insecurity in their environment and are more likely to experience unpredictability. To protect themselves and buffer fat stores during times of instability (and to protect reproductive capacity in females), social animals in a subordinate position have adapted to consume and store more energy[35,38]. For example, when experiencing 5% energy restriction, female mice paradoxically respond by increasing fat stores[38]. This hypothesis has been supported in experimental studies in human models where individuals who were randomized to low social status conditions, consumed significantly greater intended or actual calories[15-18]. Additionally, Sim and colleagues observed an increase in ghrelin in individuals placed in a low SSS position[19]. In a social species like humans, social status is typically associated with access to food[21]. One potential explanation for sex differences in energy intake in response to social manipulation is that the differences reflect sex-specific adaptive responses to potential risks associated with lower social status. Women face greater threats than men to reproductive potential when food availability is scarce or unpredictable[39], which could increase motivation to eat during insecure times. This is supported by observational and experimental data demonstrating that among individuals with food insecurity across the world, males' risk for obesity appears insensitive to food insecurity, but the same data reveals a robust positive association for females[21],[40]. For males, however, unpredictability in early life may prompt behaviors that promote status enhancement rather than fat accumulation, as fat accumulation is not likely advantageous in that environment[41]. Moreover, food insecurity among females has been linked to development of obesity in observational studies and has been a driving force in theories underlying the pathways driving low social status and obesity[21],[23]. A recent study in a controlled feeding environment found individuals who are food insecure have higher body weight and consume more total calories and %EN in 3 days of *ad libitum* intake following a 5-day, weight-maintaining diet[37]. This is consistent with our findings that individuals reporting food insecurity ate a numerically greater %EN during our lunchtime *ad libitum* meal, regardless of randomized social status condition. Yet, with limited exception and inconsistent findings[16,40,42], experimental manipulations of social status on eating behavior among humans have not tested for effects of gender or sex. Thus, it is difficult to compare our observed sex differences, as experimental data of social status on eating behaviors is relatively new[15,16,18,40,42].

The "Insurance Hypothesis" or “faster life history developmental paths” are but two of several explanations for the well-known association between SES and weight. Other explanations for the association between SES and obesity may relate to the symbolic value of food across cultures. Given the important role of food beyond its basic function as a source of energy, there is potentially an interplay between biological and social/cultural imperatives, with sex-specific consequences. The mechanisms underlying the significant differences in energy intake in response to LOW and HIGH social status conditions between males and females and amongst other racial/ethnic groups and cultures require further investigation.

Various types of stress have been associated with excess calorie consumption, particularly among females and those in low SES[43-45]. Therefore, we questioned whether the observed relationship between low social status and eating behavior in experimental studies[16-18] was a result of stress rather than a change in social status. However, we found in the present work, as in our pilot study[15], perceived stress and physiological measures of stress (i.e., salivary cortisol) did not differ by experimental social status condition. This suggests the results observed were independent of stress, but further research is warranted.

It is possible that experimental manipulation of social status does not have a causal effect on energy intake. In this study, there were no statistically significant differences in %EN consumed by experimental social status condition in the total sample. Other studies have found inconsistent associations between social status, perceived power or scarcity, and eating behavior[20]. This may be due, in part, to lack of a single, agreed upon method for social status manipulation in the laboratory, which limits overall impact of the literature. Additionally, we were not able to account for personality differences, such as competitiveness. However, as we would expect competitiveness (and all other observed and unobserved characteristics) to be balanced across groups over repeated trials due to randomization, our statistical inferences remain valid. Thus, additional research with a more nuanced view on the influence of perceptions of social status, scarcity, and inequality on eating behavior, particularly by sex, is needed.

This study builds significantly on previous literature by looking at the effect of experimentally manipulated social status condition on %EN consumed and 24-hour energy balance, as well as inclusion of stress-related markers. Though we have not captured the many real-life factors affecting social status, food security, and life experience through a rigged game of Monopoly™, this study provides evidence that perceptions of social status can be manipulated and studied in a laboratory setting. Despite limitations, this work is an important step into beginning to identify underlying mechanisms driving the relationship between low social status, food insecurity, and development of obesity, and how those relationships may differ by sex.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

Individual participant data will be available (including data dictionaries). In particular, individual participant data that underlie the results reported in this article, after de-identification (text, tables, figures, and appendices) will be shared. Other documents that will be available include the study protocol. Investigator whose proposed use of the data has been approved by an independent review committee (learned intermediary) identified for this purpose will be allowed access for individual participant data meta-analysis. Proposals may be submitted up to 36 months following article publication. After 36 months, the data will be available in our University's data warehouse but without investigator support other than deposited metadata.

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Study Importance

- Social status perception is thought to influence health outcomes through biological, physiological, and behavioral processes, but the extent of these associations is unclear and thus far, inconsistent.
- This data demonstrate that males and females have differential acute and 24-hour eating behavior responses when experimentally manipulated to a low social status condition.
- Individuals with food insecurity may be at increased risk for excess energy consumption, when compared to their food secure counterparts.
- This work is an important step into identifying underlying mechanisms driving the relationship between low social status, food insecurity, and development of obesity, and how those relationships may differ by sex.

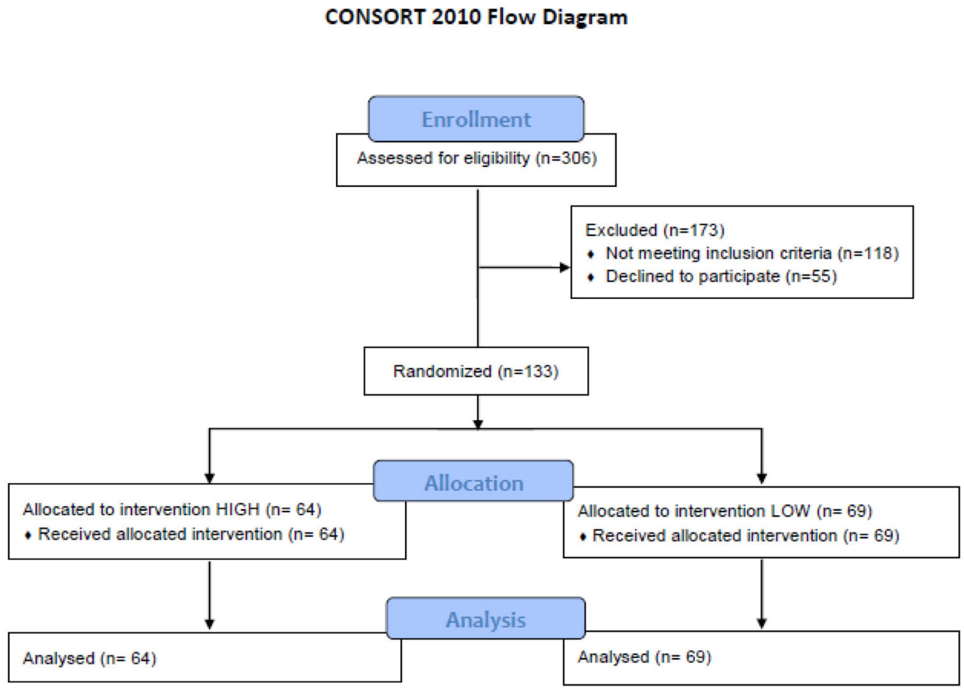

Figure 1.

CONSORT Flow diagram of participation.

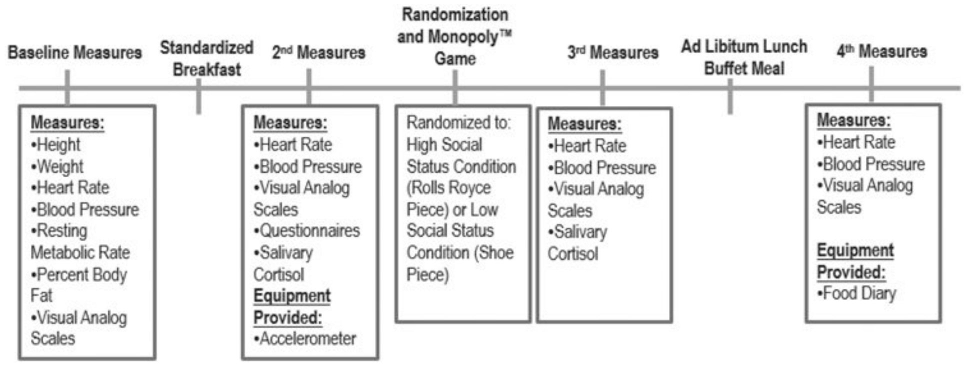

Figure 2.
Study protocol.

Table 1.

Acute *ad libitum* lunch dietary intakes following the social status manipulation among the total sample (mean ± SD)

Variable	Manipulated Social Condition		
	HIGH (n=64)	LOW (n=69)	P-value
Total Energy Consumed, kcal	724.50 ± 321.32	690.32 ± 254.43	0.957
% of Energy Needs*	36.87 ± 14.14	35.69 ± 13.30	0.753
% of calories from fat	33.69 ± 4.45	33.92 ± 4.06	0.787
% of calories from carbohydrate	55.29 ± 5.67	55.66 ± 5.12	0.886
% of calories from saturated fat	10.23 ± 1.67	9.95 ± 1.79	0.761
Total fat, g	27.83 ± 13.81	26.53 ± 10.29	0.907
Total Carbohydrate, g	102.20 ± 46.21	97.97 ± 37.39	0.968
Total sugar, g	40.91 ± 24.43	37.85 ± 19.12	0.694
Added sugar, g	29.23 ± 21.10	26.06 ± 15.59	0.662
Fiber, g	7.05 ± 3.18	6.91 ± 2.79	0.885
Sodium, mg	1327.15 ± 568.70	1287.96 ± 512.94	0.943

*% of energy needs = total energy consumed in lunch at the study visit / (24-hour energy expenditure + resting metabolic rate) × 100

Table 2a.

General Linear Regression model investigating the relationship between sex, body mass index, food security, community subjective social status (SSS), the interaction between sex and experimentally manipulated social status, and % energy needs consumed at lunch.

Variable	Parameter Estimate	Standard Error	P-value (Type I)	ΔR^2
Female	−11.46	3.42	0.070	0.023
BMI	−0.57	0.28	0.071	0.023
Food Security	−4.27	2.71	0.080	0.022
Low community SSS	2.81	2.63	0.314	0.007
LOW manipulated status	−9.33	3.63	0.429	0.004
Female * LOW manipulated status	12.44	4.67	0.009	0.049

Table 2b.

The predicted means of the % energy needs consumed at lunch.

Sex	Manipulated Social status	Predicted Mean of % energy needs	95% Confidence Limits		P-value
Female	LOW	37.45	33.19	41.71	0.291 *
Female	HIGH	34.34	29.81	38.87	
Male	LOW	36.47	31.47	41.47	0.001 *
Male	HIGH	45.80	40.27	51.33	
Food Security		Predicted Mean of % energy needs	95% Confidence Limits		
Secure	-	36.38	33.35	39.41	0.080
Insecure	-	40.65	36.17	45.13	

*The P-values compare low and high social status within females or males, respectively.

Table 3.

24-hour Dietary intakes, energy expenditure, and energy balance following the social status manipulation (mean ± SD)

Variable	Manipulated Social Condition		
	HIGH (n=64)	**LOW (n=69)**	**P-value**
Moderate-to-vigorous physical activity, minutes	56.0 ± 36.1	54.0 ± 49.3	0.305
24-hour energy expenditure, kcal	794.8 ± 277.2	780.6 ± 295.2	0.804
Resting metabolic rate, kcal	1182.1 ± 239.2	1209.4 ± 279.5	0.815
24-hour energy intake, kcal	2690.2 ± 1040.3	2670.7 ± 806.3	0.685
Energy balance, kcal	713.2 ± 1031.5	680.8 ± 882.1	0.549
% of Energy needs *	140.0 ± 53.8	138.8 ± 44.3	0.592
% of calories from fat	34.9 ± 6.3	36.9 ± 5.4	0.043
% of calories from carbohydrate	50.1 ± 8.0	47.7 ± 5.9	0.046
% of calories from saturated fat	11.7 ± 2.8	12.0 ± 2.6	0.558
Total fat, g	104.4 ± 39.4	110.6 ± 33.9	0.168
Total SFA, g	34.4 ± 13.8	35.2 ± 11.0	0.407
Total carbohydrate, g	351.2 ± 175.6	325.0 ± 116.4	0.746
Total sugar, g	140.2 ± 104.5	116.9 ± 53.1	0.488
Added sugar, g	101.8 ± 89.7	82.2 ± 47.0	0.537
Fiber, g	25.5 ± 13.7	22.4 ± 10.3	0.278
Alcohol, g	0.1 ± 0.9	3.3 ± 18.8	0.873
Sodium, mg	5026.4 ± 1921.6	5162.2 ± 1727.6	0.449

* % of energy needs = 24-hour energy intake / (24-hour energy expenditure + resting metabolic rate) × 100

Table 4a.

General Linear Regression model investigating the relationship between sex, body mass index, food security, community subjective social status (SSS), the interaction between sex and experimentally manipulated social status, and 24-hour energy balance

Variable	Parameter Estimate	Standard Error	P-value (Type I)	Δ R^2
Female	−396	247	0.958	<0.001
BMI	−35	20.5	0.122	0.018
Food Security	−302	196	0.134	0.017
Low community SSS	7.89	190	0.986	<0.001
LOW manipulated status	−445	262	0.743	0.001
Female * LOW manipulated status	647	338	0.057	0.027

Table 4b.

The predicted means of 24-hour energy balance.

Sex	Manipulated Social status	Predicted Mean of 24-h energy balance	95% Confidence Limits		P-Value
Female	LOW	848	540	1156	0.344 *
Female	HIGH	646	319	973	
Male	LOW	596	235	957	0.092 *
Male	HIGH	1041	642	1441	

* The P-values were to compare low and high social status within females or males, respectively.

Table 5.

Markers of Stress, Powerfulness, and Hunger by Time Point *

Variable	Social Status	TIME															Time Effect (T3 vs. T4)	Time × Intervention
		Before Breakfast (T1)			After Breakfast/ Before Game			After Game/Before Lunch (T3)				After Lunch (T4)						
		n	Mean	SD	n	Mean	SD	n	Mean	SD	P-value[a]	n	Mean	SD	P-value[b]		P-value[c]	P-value[d]
Cortisol	High	-	-	-	64	37.37	12.99	64	30.86	10.48	0.53	-	-	-	--		--	--
	Low	-	-	-	69	37.70	14.27	69	32.45	13.73		-	-	-				
SBP	High	64	112.3	11.1	64	111.4	10.7	64	111.4	12.2	0.768	64	114.7	12.4	0.593		<.001	0.869
	Low	69	112.6	10.9	69	110.9	11.4	69	111.2	12.0		68	115.0	12.3				
DBP	High	64	69.3	8.3	64	73.5	8.9	64	70.9	9.3	0.487	64	72.5	9.2	0.111		0.010	0.368
	Low	69	69.5	6.8	69	72.3	7.0	69	70.7	7.8		68	73.9	11.3				
HR	High	64	67.8	12.6	64	68.1	9.5	64	70.5	10.0	0.196	64	73.7	10.4	0.779		0.002	0.242
	Low	69	66.9	9.8	69	66.3	8.6	69	70.3	11.3		68	71.6	9.6				
Frustrated	High	63	20.2	23.4	64	15.4	20.3	64	15.7	20.1	0.017	64	12.3	17.4	0.798		<0.001	0.059 *
	Low	68	17.6	21.6	68	11.9	17.1	68	18.7	22.5		67	10.2	16.6				
Powerful	High	63	57.0	20.4	64	58.0	19.6	64	61.0	19.2	0.001	64	57.6	21.1	0.884		0.620	0.035 *
	Low	68	53.7	17.3	68	55.5	18.1	68	53.2	20.8		67	54.6	19.9				
Stress	High	63	35.7	26.3	64	31.3	25.3	64	26.8	23.8	0.197	64	24.5	23.2	0.443		0.006	0.144 *
	Low	68	30.8	23.5	68	24.8	23.7	69	25.1	22.2		66	17.9	18.9				
Hunger	High	63	66.5	16.3	64	36.0	21.7	64	48.3	22.1	0.984	64	9.4	13.6	0.236		<0.0001	0.521 *
	Low	68	69.3	17.5	68	38.7	23.8	69	48.6	24.3		67	7.8	10.8				

* A generalized mixed model with repeated measures was fit for each outcome, with baseline, time, social status, and time by social status interaction as the predictors. Cortisol was only measured twice, after breakfast/before game, and after game/before lunch. All other outcomes were measured at all four time points. The measurements conducted at T2 were used as the baseline values in the model.

[a.] The P-value is for the comparison between high and low manipulated social status groups at T3.

[b.] The P-value is for the comparison between high and low manipulated social status groups at T4.

[c.] The P-value is for the comparison between T3 and T4, averaged on manipulated social statuses.

[d.] The P-value is for the effect of the interaction between manipulated social status (high vs. low) and time (T3 vs. T4), controlling for difference at baseline (T2).