Portion Size Effects on Weight Gain in a Free Living Setting

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Objective: Examine the effect of weekday exposure over 6 months to different lunch sizes on energy intake and body weight in a free-living sample of working adults.

Methods: Adults (n = 233) were randomly assigned to one of three lunch size groups (400 kcal, 800 kcal, and 1,600 kcal) or to a no-free lunch control group for 6 months. Weight and energy intake were measured at baseline, and months 1, 3, and 6.

Results: Lunch energy was significantly higher in the 800 and 1,600 kcal groups compared with the 400 kcal group (P < 0.0001). Total energy was significantly higher for the 1,600 kcal group compared with the 400 and 800 kcal groups (P = 0.02). Body weight change at 6 months did not significantly differ at the 5% level by experimental group (1,600 kcal group: +1.1 kg (SD = 0.44); 800 kcal group: −0.1 kg (SD = 0.42); 400 kcal group: −0.1 kg (SD = 0.43); control group: 1.1 (SD = 0.42); P = 0.07). Weight gain over time was significant in the 1,600 kcal box lunch group (P < 0.05).

Conclusions: Weekday exposure for 6 months to a 1,600 kcal lunch caused significant increases in total energy intake and weight gain.

Introduction

The food environment in the US has been transformed during the past two decades concurrent with the epidemic rise in obesity (1). The pervasive availability of food and large portion sizes are aspects of the food environment that are potential contributors to overeating and excess weight gain (2,3). However, at present, there is little experimental evidence available to evaluate the potential public health impact of exposure to large portion sizes on energy intake or body weight.

Large portion sizes have been studied extensively in highly controlled laboratory settings and consistently show increases in energy intake over a short time frame (4-6). This effect is robust across gender, body mass index, age, and individual differences in measures of stable eating behaviors such as dietary restraint and disinhibition. In the longest-duration laboratory study conducted to date, participants were exposed to 50% larger portion sizes than usual for 11 days (6). Energy intake during this period increased by 423 kcal per day and was sustained for the entire 11-day period. Body weight change was not reported.

Three cross-sectional studies examined the effects of portion size on a single eating episode in a naturalistic environment (7-9). These cross-sectional studies neither examined effects within the same people over time nor effects on total energy intake.

Portion size effects on total energy intake and body weight over time within the same individuals have been examined in only one study, conducted by our research team (10). In a within-subjects counterbalanced cross-over design, participants received an 800 kcal and a 1,600 kcal box lunch weekdays for 4 weeks for each condition. Mean 24-h energy intake was 278 kcal/day higher in the large portion compared with the standard portion condition (P < 0.001). Average weight change was 0.64 kg during the large portion and 0.06 kg during the standard portion conditions (P = 0.13).

Clearly, the effects of large portion sizes on energy intake appear to be robust in the laboratory and in the few cross-sectional field studies conducted to date. However, studies have yet to examine the effects of large portion sizes in the context of the entire day’s energy intake in a free-living population. The effect of large portion size exposure on body weight change over a longer time period is still unknown.
unknown. Are people able to self-regulate energy intake over time despite exposure to large portion sizes, and thus maintain a stable body weight? An answer to this question is critical to understand whether the current food environment is contributing importantly to the obesity epidemic.

This article reports the results of a randomized trial that examined the effects of weekday exposure to one of three different lunch energy sizes on energy intake and body weight in a free living sample of adults over 6 months. It was hypothesized that exposure to large energy sizes at lunch would cause increases in lunch energy intake, total energy intake, and body weight during the 6-month experimental period compared with exposure to smaller portion sizes.

Methods
Study design overview
The study design was a randomized controlled trial. Individuals were randomized to one of three conditions: a free box lunch of one of three calorie sizes; or to a no-free-lunch control group. Evaluation data were collected at baseline before randomization, and at 6 months. Dietary recalls and measured body weight were collected additionally at months 1 and 3. The study was conducted from September 2010 through February 2013 and approved by the University of Minnesota Institutional Review Board.

Sample and recruitment. The study was conducted at a large metropolitan medical complex that employed over 2,000 full time staff of diverse demographic backgrounds. The study purpose was described as “a study to examine the feasibility of offering box lunches at the worksite.” Interested participants were screened by telephone to determine eligibility. Eligibility criteria were: 1) age 18-60 years; 2) nonsmoker; 3) speak and read in English; 4) not taking medications that affect appetite or body weight; 5) able to pick up lunches at the medical complex Monday through Friday during the lunch hours; 6) not allergic to the foods in the study lunches; 7) willing to eat the foods in the study lunches (examples were provided of the types of foods); 8) not currently on a diet to lose weight; 9) no diagnosed eating disorder; 10) not planning to move or pregnant in the last 12 months. Two-hundred thirty-three participants were randomized to one of three conditions: a free box lunch of one of three calorie sizes; or to a no-free-lunch control group. Evaluation data were collected at baseline before randomization, and at 6 months. Dietary recalls and measured body weight were collected additionally at months 1 and 3. The study was conducted from September 2010 through February 2013 and approved by the University of Minnesota Institutional Review Board.

Box lunch intervention exposure procedure. The intervention consisted of Monday-Friday lunch box pick-ups by participants at the worksite for a 6-month period. Staff distributed lunch boxes at a central location during the hours 11:00 am to 1:00 pm. Participants were required to pick up their own lunch boxes, but were not further instructed about consumption of the lunch. Overall, 91% of the lunches were picked up by participants (85% up on time; an additional 6% 1 day late). Participants randomized to the control condition did not receive a box lunch and were instructed to continue their usual lunch patterns.

Box lunch experimental conditions. This experiment was a community-based intervention to examine portion size effects on energy intake and body weight in a free-living setting among a working population-based sample. It was not a feeding study and its focus was not on the metabolic or clinical aspects of macronutrient or energy density variations on energy intake. The research team collaborated with a grocery/catering retailer to develop the study menus and prepare the foods. The overall goal was to develop menus with specific energy content and highly similar foods of sizes that accommodated the energy requirements of each experimental condition.

The energy sizes of the experimental conditions were 400 kcal, 800 kcal, and 1,600 kcal. There was some variation in the types of foods provided across the energy size conditions. However, overall the menus were planned to be similar and the foods were for the most part identical across conditions (see Supporting Information Appendix 1 and 2 for menus). Fifteen different box lunch menus were created and pilot tested before the beginning of the study. Menus were implemented on a 3-week repeating cycle. However, the conditions were on different cycles, so that participants assigned to different conditions could not directly compare their lunch box items on any given day. The same size box was used in all three conditions. Only water was served as a beverage.

Box lunch quality control. Every day an extra box lunch was ordered to conduct quality control measures. The research staff disassembled each box lunch item into ingredient components, weighed, and measured them, and the energy intake values for each food item were calculated using the NDS-R software system (11-13). The goal was to ensure that the box lunches did not deviate by more than 5% kcals above or below the kcal goal for each box lunch condition. This quality control process was conducted daily throughout the 27-month study period (a total of 515 box lunch meals). Over all, the menu meals evaluated, the median deviation in kcals was small (23 kcals, 33 kcals, and 16 kcals, in the 400, 800, and 1,600 kcal conditions, respectively). Quality control analyses showed that 52% of the lunches measured were within the 5% kcal range. Ten percent of the lunches were below 95% kcals and 37% were above 105% kcals.

Data collection protocol. Data were collected by trained research staff blinded to study condition at a University research building located about a mile from the medical complex. Similar data collection procedures took place at 6 months when the intervention ended. Participants were paid $125 for each of the baseline and 6-month measurements (two clinic visits at each of baseline and 6 months) and $50 each for the 1 month and 3 months set of three dietary recall interviews and measured body weight.

Measures
Body weight and height. All anthropometric measures were conducted by trained and certified research staff according to standardized protocols (14). Body weight was measured to the nearest 0.1 kg using a calibrated electronic scale (Befour, Saukville, WI). Height was measured to the nearest 0.1 cm with a wall-mounted stadiometer. Body weight was measured with participants in light clothing and without shoes. All measures were performed in duplicate. If there was greater than or equal to 1 cm or 0.5 kg deviation between the two measures, a third measurement was taken. The mean values of the two measures in closest agreement were used in analysis.
Dietary intake. Energy intake was measured using three unannounced 24-h dietary recalls measured at baseline, 1, 3, and 6 months (12 dietary recalls per person during the 6-month study). Dietary recalls were conducted on nonconsecutive days (two weekdays and one weekend day; all three within a time window of 21 days maximum) over the telephone using Nutrition Data System for Research (NDSR) software (Nutrition Coordinating Center (NCC), University of Minnesota, Minneapolis, MN). Trained and certified staff at NCC collected the recalls.

Physical activity. Physical activity (PA) was measured objectively at baseline and at 6 months using a commercially available ActiGraph GT1M accelerometer (ActiGraph, Pensacola, FL) (15,16). Study participants were instructed to wear the GT1M monitor on the right hip for seven complete days except while sleeping or during water activity (e.g., bathing, swimming, showering, and sleep).

Demographic variables. Demographic information was self-reported, and included household income before taxes, age, ethnicity, race, education level, job type, and marital status.

Statistical analysis
Planned intent-to-treat analysis of baseline to 6-month changes. Two-hundred thirty-three participants provided data at baseline and were randomized. Two hundred twenty-nine (99.1%) participants were weighed at 6 months. Unless otherwise specified, analyses of baseline to 6-month changes were performed in the intent-to-treat framework, including all randomized participants with available measurements at both time points. Analyses were conducted using SAS (Cary, NC) and R (17).

The planned primary analysis for the trial was an intent-to-treat comparison of the 6-month change in body weight between the four randomized groups (control and the three box lunch sizes). The same intent-to-treat approach was used to assess the secondary outcomes of lunch energy intake and total energy intake. A secondary analysis used the longitudinal measurements collected at baseline, months 1, 3, and 6 to examine the rate of change in body weight and energy intake over the 6-month intervention period.

Linear regression models were used to evaluate differences in outcomes at 6 months. Despite randomization, job type and education were not balanced between groups, so they were adjusted for in the regression models. Models were also adjusted for baseline values of the outcomes (weight or energy intake) to achieve a possible gain in precision. For the analysis of the rate of change, using all four data points (baseline, months 1, 3, and 6), generalized estimating equations (18) with an independence working correlation structure were used. Differences in the rate of change of outcomes over time were investigated via the interaction term of continuous time (in months) and a four-level categorical variable designating the experimental groups. Main effects for time and experimental condition were considered, as were the adjustment covariates job type and education.

Results
Demographic and baseline variables
Demographic and baseline variables by treatment group are shown in Table 1. The proportion of college-educated individuals and clerical workers differed by study condition. As noted above, analyses were adjusted for education and job type to account for these chance imbalances.

Baseline lunch energy intake and nutrient values compared with box lunches
Participant baseline lunch energy intake and nutrient values based on three 24-h dietary recalls are shown in Table 2, along with the computed average mean energy and nutrient values for each of the box lunch energy groups (400, 800, and 1,600 kcal). These data show that the percent fat, protein, and carbohydrates in the three portion conditions were similar to participants’ baseline lunch intake. However, the fruit and vegetable servings provided in the lunch boxes were higher compared with participants’ usual lunch intake.

Lunch energy intake change over 6 months box lunch intervention
Table 3 shows adjusted mean lunch energy intake at 6 months by intervention group. In paired contrasts, the 1,600 kcal box lunch group reported significantly higher lunch energy intake compared with each of the other groups (including the control group; \( P < 0.0001 \)). Lunch energy intake increased significantly over time in the 1,600 kcal lunch box group and decreased significantly over time in the 400 kcal box lunch group (\( P < 0.05 \) to reject the null hypothesis of no change in lunch energy intake over time for both groups; Table 4).

Total energy intake change over 6 months box lunch intervention
Table 3 shows adjusted mean total energy intake at 6 months by intervention group. The 1,600 kcal box lunch group reported significantly higher total energy intake compared with the 800 kcal and 400 kcal box lunch groups (\( P = 0.02 \)). Total energy intake decreased significantly over time in both the 400 kcal and 800 kcal box lunch groups (\( P < 0.05 \); Table 4).

Weight change over 6-month box lunch intervention
Table 3 shows adjusted mean change in body weight over 6 months by treatment group. Overall, the differences between groups were not statistically significant at the 5% level (\( P = 0.07 \)). Increase in weight over time was statistically significant in the 1,600 kcal box lunch group (\( P < 0.05 \); Table 4).

Physical activity change over 6-month intervention period
PA change over 6 months did not significantly differ by treatment group. Adjusted for baseline value, job type, and education, PA means (se) (moderate/vigorous mins/day) at 6 months were: control: 27.5 (1.9); 400 kcal: 28.0 (1.9); 800 kcal: 31.8 (1.9); 1,600 kcal: 26.1 (2.0) (\( P = 0.20 \)).
energy sizes on energy intake and body weight change over 6 months in a naturalistic setting among a sample of working adults. The naturalistic setting of the experiment was designed to shed light on the potential effects of the widespread increases in portion sizes in both packaged and restaurant foods on energy intake and weight gain, and ultimately the population-wide obesity epidemic.

The original hypothesis was that the 1,600 kcal lunch group would increase lunch and total energy intake, and gain weight, over the 6 months exposure. The 800 kcal condition was hypothesized to represent a typical lunch energy exposure and the 400 kcal condition was thought to represent a smaller than typical exposure. The control group was not expected to increase energy intake or body weight.

The results of the study were surprising and informative. As hypothesized, lunch energy intake was significantly higher in the large box lunch condition (1,600 kcal) and in the medium box lunch condition (800 kcal) compared with the smallest box lunch condition (400 kcal). These results are consistent with experimental laboratory studies conducted over short time periods (4-6) and cross-sectional studies conducted field settings (7-9). Thus, relative to small box lunch energy sizes, larger box lunch energy sizes delivered over 6 months led to higher energy lunch intake, and this effect persisted for up to 6 months.

Higher energy intake at lunch would not be problematic if people spontaneously reduced their intake at other meals. The study results suggest that over 6 months, people may have compensated to some extent, but not entirely. Interestingly, the comparison group’s change in total energy intake did not differ from the 1,600 kcal box lunch group. It appears that in this study’s comparison group, change in total energy intake was the same as that of people exposed to a large free box lunch every weekday. Also of interest is the significant reduction in the total energy intake of the 400 kcal box lunch group, relative to the 1,600 kcal and no-free-box-lunch comparison group.

Most importantly, does exposure to large energy sizes at lunch over a 6-month period lead to excess weight gain? Participants in the large box lunch group gained significant weight over the 6-month period, but weight changes in the 400 kcal and 800 kcal box lunch conditions were not significantly different from zero.

The control group gained more weight than expected over the 6-month study. Their energy intake and weight change may reflect the normal intake of this sample of working people who live in an obesigenic environment. The stability of body weight and decrease in energy intake observed in the small lunch condition might mitigate the rate of weight gain in such an environment. These findings are consistent with the

| TABLE 1 Baseline demographic variables (unadjusted mean (SD) or percent) (N = 233) |
|-----------------|---------|------|------|------|------|
|                 | Total   | Control | 400  | 800  | 1600 |
| n               | 233     | 61     | 57   | 59   | 56   |
| Age, y          | 42.6 (11.2) | 42.8 (10.4) | 40.4 (10.8) | 44.1 (12.0) | 42.9 (11.6) |
| Sex, % female   | 67.4    | 68.9   | 73.7 | 67.8 | 58.9 |
| BMI, kg/m²      | 29.8 (6.4) | 29.3 (6.4) | 30.9 (6.9) | 30.5 (6.7) | 28.7 (5.6) |
| Weight, kg      | 85.4 (19.7) | 84.6 (20.3) | 87.5 (20.5) | 86.6 (20.5) | 82.9 (17.3) |
| Race, % white   | 69.1    | 73.8   | 62.5 | 71.9 | 67.9 |
| Married/living with (%) partner | 58.8 | 49.2   | 57.9 | 50.9 | 51.8 |
| Education, %    |        |        |      |      |      |
| <College        | 15.0   | 11.5   | 24.6 | 10.1 | 14.3 |
| Some college    | 33.5   | 27.9   | 33.3 | 49.2 | 23.2 |
| College degree  | 33.5   | 39.3   | 29.8 | 30.5 | 33.9 |
| College +       | 18.0   | 21.3<sup>a,b</sup> | 12.3<sup>b</sup> | 10.2<sup>d</sup> | 28.6<sup>a</sup> |
| Job type, %     |        |        |      |      |      |
| Patient care    | 33.3   | 38.3   | 27.8 | 31.6 | 42.3 |
| Administration  | 11.1   | 13.3   | 7.4  | 15.8 | 7.3  |
| Clerical        | 38.5   | 41.7<sup>a</sup> | 51.9<sup>a</sup> | 38.8<sup>a,b</sup> | 21.8<sup>b</sup> |
| Service/labor   | 4.9    | 1.7    | 9.3  | 1.8  | 7.3  |
| Other           | 9.3    | 5.0    | 3.7  | 12.3 | 16.4 |
| Income, %       |        |        |      |      |      |
| ≤$40,000        | 21.4   | 18.6   | 24.6 | 24.1 | 18.2 |
| $40,000-$80,000 | 41.9   | 37.3   | 49.1 | 39.7 | 41.8 |
| >$80,000        | 36.7   | 44.1   | 26.3 | 36.2 | 40.0 |
| Moderate/vigorous PA, mins/d | 27.5 (17.2) | 26.4 (15.2) | 24.5 (14.6) | 27.3 (16.7) | 31.8 (21.3) |
| Energy intake, kcal/d | 2012 (679) | 1981 (630) | 1953 (554) | 2111 (717) | 2002 (800) |
| Lunch energy, kcal/d | 516 (262) | 540 (278) | 519 (223) | 534 (305) | 468 (233) |

Different superscripts (alphabets) show significantly different means; post hoc analysis (P < 0.05).
*P < 0.05 difference between treatment groups.
TABLE 2 Baseline participant lunch intake ($N = 233$) and the intervention box lunch nutrients

| Nutrient values | 400 kcal Box lunch | 800 kcal Box lunch | 1600 kcal Box lunch |
|-----------------|-------------------|-------------------|-------------------|
| kcal            | Mean (SD)         | Mean (SD)         | Mean (SD)         |
|                 | 516 (262)         | 413 (11)          | 821 (20)          |
| % Fat           | 35 (14)           | 32 (5)            | 36 (4)            |
| % Protein       | 19 (9)            | 21 (5)            | 21 (4)            |
| % Carbohydrate  | 47 (17)           | 48 (5)            | 45 (5)            |
| Fiber, g        | 5.2 (3.6)         | 6.1 (3.0)         | 9.1 (4.1)         |
| Added sugar, g  | 12.5 (19.3)       | 9.0 (6.8)         | 15.2 (11.7)       |
| Fruit servings, cups | 0.15 (0.35)       | 0.56 (0.33)       | 0.83 (0.36)       |
| Vegetable servings, cups | 0.62 (0.69)       | 1.17 (0.90)       | 1.60 (1.24)       |
| Energy density, kcal/g | 0.9 (0.7)        | 0.5 (0.1)         | 0.8 (0.1)         |

*Calculated from three nonconsecutive day, unannounced telephone-administered 24-h recalls (1 weekday; 1 weekend day).

TABLE 3 Change in lunch energy, total energy, and body weight over 6 months by treatment group

| Treatment Group | No box lunch Mean (SE) | 400 kcal Mean (SE) | 800 kcal Mean (SE) | 1600 kcal Mean (SE) |
|-----------------|------------------------|--------------------|--------------------|--------------------|
| Lunch energy, kcal* | 492 a,b (28)          | 417 a (30)        | 557 b (29)        | 636 c (30)         |
| Total energy, kcal** | 1938 a,c (66)       | 1718 b (70)       | 1792 a,b (68)     | 1996 c (71)        |
| Weight change, kg | 1.1 (0.42)            | -0.1 (0.43)       | -0.1 (0.42)       | 1.1 (0.44)         |

NOTE: Lunch and total energy: Least squared mean at 6 months, adjusted for baseline value, education, and job type. Weight change: Least-squared mean increase at 6 months, adjusted for baseline value, education, and job type.
Different superscripts (alphabets) differ at $P < 0.05$ in pairwise comparisons.
*Significant difference, $P < 0.00001$.
**Significant difference, $P = 0.02$.

TABLE 4 Rate of change in lunch energy, total energy, and body weight over 6 months by treatment group

| Treatment Group | No box lunch Mean | 400 kcal Mean | 800 kcal Mean | 1600 kcal Mean |
|-----------------|-----------------|--------------|--------------|---------------|
| Lunch energy, kcal/month | -7.9           | -16.2*       | 0.5          | 16.9*         |
| Total energy, kcal/month | -11.1          | -40.1*       | -33.2*       | -0.66         |
| Weight change, kg/month | 0.24*          | -0.01        | -0.01        | 0.19*         |

Note: Results of longitudinal analysis using marginal linear regression model (GEE) with independence working correlation, adjusted for baseline BMI, education, and job type.
*Significantly different from zero ($P < 0.05$).
single laboratory study on small portion size exposure over a 2-day period that resulted in lower energy intake (4). The use of portion-controlled prepackaged meals also is associated with larger weight losses in clinical weight loss trials (19-21). Because the participants in this free-living working adult sample were overweight, the small box lunch condition may have provided support for lower energy intake at lunch that was not compensated later during the day. This effect, if replicated, could be a promising strategy to support overweight adults’ effort to reduce energy intake and promote weight stability or weight loss over long time periods. Results from the weight loss literature show that the effects of portion controlled food provision are limited to the period during which food provision is provided (21).

The mechanisms that explain the relative decrease in energy intake and weight stability are not clear, but are important questions to pursue in future studies. A better understanding of how people consciously attend to and self-regulate portion sizes in their natural environment is critical to development of effective eating behavior interventions in the community that could help prevent excess energy intake and weight gain (22-24). If people are not paying attention to or consciously self-regulating intake in the face of large portion size exposures, then package size regulation appears to be an even more critical intervention to prevent excess energy intake at meals.

The strengths of this study are many. Its 6-month duration, randomized experimental design, use of state of the science dietary intake measures, direct measures of body weight, high intervention exposure rates (91% dose delivered), and high rate of cohort retention (99% at 6 months) also support the validity of the results. Limitations include the lack of interpretive consistency for the control group in relation to the three box lunch groups. Participants randomized to the control group did not receive daily free lunches for 6 months. It is not clear whether this may have led to changes in eating behaviors as a result of knowledge of being assigned to the control condition (no free lunch; e.g., compensatory rivalry or resentful demoralization) (25). In addition to energy, the lunch conditions differed in composition in ways that might have affected satiety and energy intake. The fruit, vegetable, and fiber composition of the box lunches was high relative to the participants’ baseline lunch intake, and the foods across conditions, although similar, were not identical. The validity of the dietary intake assessments may have been higher for the box lunch groups than for the control group during the experimental period because objective information was available on the food ingredients and sizes for the box lunches (12,13,26). Therefore, food types and portion sizes consumed could be estimated more accurately for participants in one of the three box lunch conditions compared with those in the control group. Under-reporting of dietary intake is a well-established shortcoming of self-report dietary intake methods such as recalls (26). However, assuming the magnitude of under-reporting is similar across experimental groups, between group comparisons should not be affected by this bias in reporting.

The main conclusion of this study is that chronic exposure to a high energy lunch weekdays for 6 months may represent a risk for excess energy intake and weight gain. Exposure to small lunch sizes is associated with relative decreases in energy intake and with weight stability. Future studies are needed to clarify whether chronic exposure to large portion sizes across several settings presents a risk for excess energy intake and weight gain. Also of interest is whether chronic exposure to smaller energy meals can enhance weight control in a free-living overweight population, and specification of the mechanisms of this effect.

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