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A comparison of bite size and BMI in a cafeteria setting

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ABSTRACT

Our study investigated the relationship between BMI and bite size in a cafeteria setting. Two hundred and seventy one participants consumed one meal each. Participants were free to select any food provided by the cafeteria and could return for additional food as desired. Bite weights were measured with a table embedded scale. Data were analyzed with ANOVAs, regressions, Kolmogorov-Smirnov tests, and a repeated measures general linear model for quartile analysis. Obese participants were found to take larger bites than both normal ($p = 0.002$) and overweight participants ($p = 0.017$). Average bite size increased by 0.20 g per point increase in BMI. Food bites and drink bites were analyzed individually, showing 0.11 g/BMI and 0.23 g/BMI slopes, respectively. Quartiles of bites were also analyzed, and a significant interaction was found between normal and obese participants ($p = 0.034$) such that the lower two quartiles were similar, but the upper two quartiles showed an increase in bite size for obese participants. The source of these effects could be the result of a combination of several uncontrolled factors.

1. Introduction

The study of the microstructure of eating investigates physiological actions during consumption such as bite size (g), chewing rate (chews/swallow), eating rate (g/min or bites/min), and meal duration (min) [13,27]. Differences in these measures between the lean and obese are sought to provide a basis for recommending behavior changes to treat obesity [25]. Example behaviors that have been studied include slowing eating rate [29,30], chewing food more slowly [31], reducing visible portion size [1], and controlling bite size [26]. Many of these eating behaviors, including eating rate, bite size, and time each bite spends in the oral cavity, are inter-related [9,10,21].

This paper considers one specific component of the microstructure of eating, bite size, and relates this component to BMI. Previous studies have shown trends of larger sized bites for the obese compared to the lean, but were conducted in a laboratory setting and differences did not show statistical significance. For example, Hill and McCutcheon found a 0.8 g increase in bite size of donuts between the obese and non-obese, but the distributions of 7.1 ± 2.3 g (obese) and 6.3 ± 2.0 g were not statistically significantly different [14]. Spiegel reports a range of 0.2 to 2 g increase in average bite size of five different foods (chips, sandwich, bagel, cake, and cookie) between obese and non-obese participants, but again none of the differences reached statistical significance [25]. Park and Shin found a 0.2 to 0.4 g decrease in bite size of rice between obese and non-obese, but the study was designed to compare differences in gender and only compared 12 subjects in each group [20]. As noted by the authors of these studies, the inability to detect a bite size vs BMI difference may be due to a combination of the small size of the difference and an insufficient sample size to detect it. It may also be confounded by the limited number of foods tested.

The purpose of this study is to examine if the relationship between bite size and BMI seen in a laboratory setting can be observed in a less controlled environment. The secondary goal was to characterize the difference in bite size in terms of grams per BMI. The study took place in a cafeteria setting, and participants were free to select any food option available in the cafeteria that day. Each of the 271 participants' meals were continuously weighed through use of scales embedded in the table with a cafeteria tray adhered to their tops. Video recording was used to provide visual verification of when bites were consumed.

2. Methods

2.1. Subjects

A total of 271 subjects (130 males, 141 females; age 18–75; BMI 17–46 kg/m^2; ethnicity 189 Caucasian, 27 African-American, 2 American Indian or Alaska Native, 29 Asian or Pacific Islander, 11 Hispanic, and 13 Other) participated in the study. The participants were categorized into BMI groups, with 4 underweight (BMI < 18.5), 162 normal weight (18.5 ≤ BMI < 25), 66 overweight (25 ≤ BMI < 30), and 39 obese (BMI ≥ 30) determined by measured height and weight. Height and weight measures were taken in a laboratory before moving

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as a group to the cafeteria. Because only four underweight participants took place in this study, these four were excluded from categorical analysis of BMI. Each subject provided informed consent. The study was approved by the Clemson University Institutional Review Board for the protection of human subjects.

2.2. Food selection

The data used in this study were recorded in the Harcombe Dining Hall of Clemson University. The facility seats up to 800 guests and provides hundreds of different foods and beverages. Subjects were free to select any available foods or beverages and make as many return trips as desired to obtain more food. Each such trip was referred to as a course. Participants selected 374 unique foods and beverages, and the most commonly selected items are summarized in previous articles [23,24].

2.3. Procedure

The main purpose of the data collection was to support algorithm development in wrist motion tracking to automatically detect and count bites [6,24]. Participants wore wrist motion trackers on their dominant wrist. The trackers were tethered to external computers; this data is not used in this paper. A second purpose of the data collection was to compare an estimate of kilocalories consumed to kilocalories predicted by the participant. A prior work estimated kilocalories consumed through use of a digital photography technique [23,32], and this estimate is used in this work to facilitate meal level analysis. The full details of participant recruitment and scheduling are described in these previous works. A third purpose of the data collection was to support algorithm development for detecting and weighing individual bites using a table embedded scale [18]. These weights are analyzed in this paper and their calculations are described below. The following focuses on the aspects of the procedure most pertinent to the analysis reported in this paper.

An instrumented table was constructed consisting of four place settings. Each setting had a scale embedded in the table with a cafeteria tray adhered to its top. After collecting foods and beverages, each participant placed their dishes on top of the fixed tray to facilitate continuous weighing of the tray's contents during consumption. Digital cameras in the ceiling were positioned to record each participant, including the tray, upper torso and head.

The actions of participants were unrestricted, meaning they could eat with either or both hands, consume foods and beverages in any order, mix foods, and remove foods from the tray and consume multiple bites without returning it to the tray in between bites. Foods were not preselected nor were they pre-cut into controlled sizes. Portion sizes were provided according to the standards served in the dining hall, but participants were free to request multiple portions. Participants were seated in groups of up to 4 to encourage socializing, and other activities such as talking on the phone were not prohibited. In summary, the environment was intended to be as natural as possible while still affording the ability to collect data.

2.4. Measures

The main measure used in this paper is bites that could be individually weighed by the scale. The times of bites were determined by reviewers watching the synchronized video of the participants eating and marking the times at which a bite of food or drink was consumed, identified as the time when placed into the mouth [24]. For all 271 subjects, a total of 24,101 bites were annotated. However, not all these bites could be individually weighed. Because our environment was not controlled, multiple bites could be taken without scale interaction, actions could be taken too quickly for the scale to stabilize, and interactions with non-food items (such as a utensil, napkin, and dish) could interfere with weighing individual bites.

Our group developed an algorithm based upon the concept of the universal eating monitor (UEM) [15] that uses a more sophisticated signal analysis to identify bites during unrestricted eating [18]. The algorithm identified time periods when the scale weight is stable and analyzed the surrounding weight changes. The series of preceding and succeeding weight changes was compared against patterns for single food bites, food mass bites, and drink bites to determine if a scale interaction was due to a bite or some other activity. Our algorithm correctly detected and weighed 39% of bites [18]. An analysis of bites that could not be weighed compared to those that could revealed no statistically significant difference in average weight [18].

2.5. Statistical analyses

Statistical analyses were performed using Statistical Product and Service Solutions (SPSS version 24.0). Descriptive statistics were performed on all data including means, standard deviations, and standard error of the means. An analysis of variance (ANOVA) was used to analyze differences between bite weights for normal, overweight, and obese groups. Regressions were performed to find the relationship between participant BMI and bite weight for all bites, food bites, and drink bites. A repeated measures general linear model was used to determine the interaction between BMI categories and mean quartile bite weights with three between-subjects BMI levels (normal, overweight, and obese) and 4 within-subjects bite quartiles (0–25th percentile, 25–50th percentile, 50–75th percentile and 75th–100th percentile). Finally, Kolmogorov-Smirnov tests were used to compare distributions of meal level variables for each BMI group including total grams consumed, kilocalories consumed, number of bites, number of courses, and duration of meal.

3. Results

Fig. 1 shows each participant's average bite weight plotted against their BMI. The regression for this data has a slope of 0.20 (indicating an increase of 0.20 g in bite size per single BMI point increase) with $R^2 = 0.035$.

Fig. 2 plots the average bite weight of normal weight, overweight and obese participants with standard errors and number of participants per category. We found a significant main effect of BMI in which obese individuals had higher bite weights than normal weight individuals and overweight individuals. The mean bite sizes and standard errors for normal weight, overweight, and obese are 12.0 ± 0.39 g/bite, 12.4 ± 0.64, and 15.0 ± 1.1, respectively. Significant differences were found between normal and obese ($p = 0.002$) and overweight and obese ($p = 0.017$). No significant difference was found between normal and

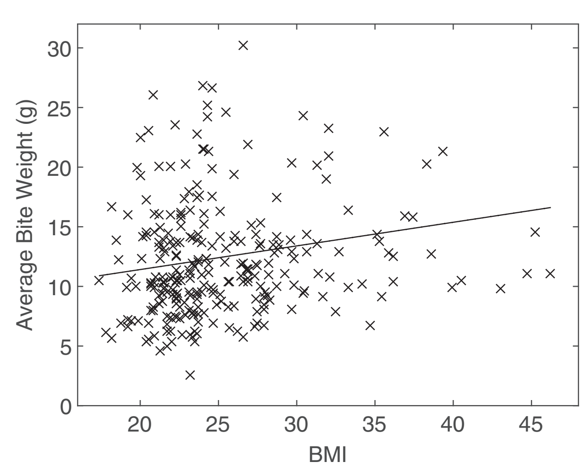

Fig. 1. Plot comparing BMI to average bite weight per participant and trend line.