Examining the Utility of a Bite-Count–Based Measure of Eating Activity in Free-Living Human Beings

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ABSTRACT
The obesity epidemic has triggered a need for novel methods for measuring eating activity in free-living settings. Here, we introduce a bite-count method that has the potential to be used in long-term investigations of eating activity. The purpose of our observational study was to describe the relationship between bite count and energy intake and determine whether there are sex and body mass index group differences in kilocalories per bite in free-living human beings. From October 2011 to February 2012, 77 participants used a wrist-worn device for 2 weeks to measure bite count during 2,975 eating activities. An automated self-administered 24-hour recall was completed daily to provide kilocalorie estimates for each eating activity. Pearson's correlation indicated a moderate, positive correlation between bite count and kilocalories (r=0.44; P<0.001) across all 2,975 eating activities. The average per-individual correlation was 0.53. A 2 (sex)×3 (body mass index group: normal, overweight, obese) analysis of variance indicated that men consumed 6 kcal more per bite than women on average. However, there were no body mass index group differences in kilocalories per bite. This was the longest study of a body-worn sensor for monitoring eating activity of free-living human beings to date, which highlights the strong potential for this method to be used in future, long-term investigations.
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OBESITY IS A SIGNIFICANT PUBLIC HEALTH PROBLEM affecting millions of adults worldwide.[1] The sharp rise in obesity in recent decades is partially due to an obesogenic environment that promotes energy imbalance: energy intake from eating and drinking is greater than energy expenditure from physical activity.[1] To fully understand the energy intake and expenditure patterns that contribute to weight change, energy intake and expenditure must be studied over long periods of time (weeks to months) outside of the laboratory in free-living settings. Years of research and practical use have demonstrated that long-term energy expenditure patterns can be approximated with accelerometry methods, despite difficulties in precisely equating measured activity with energy expenditure.[2] However, similarly accurate and practical methods for measuring long-term energy intake are still lacking.

Self-report tools for measuring energy intake in free-living include diet records, 24-hour recalls, food frequency questionnaires, and food photography methods.[3] These methods require time-consuming data entry, recording food types and portion sizes, and linking data with extensive dietary databases, limiting their use for long-term monitoring of intake except in the most well-funded, well-staffed studies.[4] Hence, whereas self-report tools are a viable solution for short-term monitoring of eating activity (days) or as periodic probes, they are less useful for continuous long-term monitoring of intake (weeks to months).

To reduce user burden and make long-term eating activity monitoring a more tenable proposition, new methods are being developed to measure the movements and sounds associated with eating and drinking, such as intake gestures, chews, and swallows.[5,6] Although these methods can detect eating activity using body-worn sensors in laboratory settings, they have not been used in free-living conditions for longer than a single meal.[7] Furthermore, the necessary body-worn sensors for these methods, including ear-pad microphones, upper back sensors, or sensors on the neck, are currently too obtrusive or uncomfortable for long-term use.[8]

In contrast with other body-worn sensors, a wrist-worn device that measures eating activity with a bite-count method has made unobtrusive, practical ambulatory monitoring of eating activity possible.[9,10] Unlike chewing, which involves repeated mastication of the same piece of food, a bite is defined as food placed into the mouth for consumption.[11] Prior research has demonstrated that a wrist-roll motion associated with taking a bite can be detected with a wrist-worn gyroscope and simple algorithm.[9] This method detects 94% of bites in controlled laboratory settings and 86% of bites in uncontrolled laboratory settings, with approximately one false positive per every five bites.[9] Here, the utility of this bite count based measure of eating activity is examined. This measure is relevant for dietetics practitioners seeking objective eating activity data from clients, patients, or research participants.

Previous laboratory studies of single-food meals have demonstrated a positive relationship between bite count and ad libitum energy intake, with men and individuals with higher body mass indexes (BMIs) consuming more kilocalories per bite (KPB).[12-14] However, in free-living conditions where foods consumed and eating environments are free to vary, it is unknown whether bite count and energy intake are related, or if average KPB varies by sex or BMI. Therefore, the purpose of our study was twofold: describe the relationship between bite count and energy intake for eating activities, and determine whether there are sex and BMI differences in KPB in free-living conditions.

METHODS AND PROCEDURES

Participants and Recruitment

Participants were recruited from a mid-sized university and surrounding towns with e-mail, flyers, and website announcements. Participants received $50 and an eating activity summary for participating. The eligibility requirements included age 18 to 66 years, no eating disorder history, and daily access to an Internet-capable computer. Based on preliminary data, a large correlation (r=0.6) between bite count and kilocalories was expected.[9] Power analysis (α=.05, power=0.80) indicated that 28 meals per person were needed for within-individual correlations.[15] Participants were measured for 14 days to obtain 28 meals (assuming ≥2 meals per day), and the number of participants was maximized within study constraints to provide a large overall sample of eating activities. Recruitment aimed to sample equal numbers of men and women, and equal numbers of normal weight (BMI=18.5 to 24.9) and overweight/obese (BMI ≥25.0) participants. Ninety-four participants entered the study, 83 completed the study, four were excluded due to device battery problems, and two were excluded due to noncompliance with instructions, resulting in a final sample of 77 participants.

Materials

Bite-Counting Device. The bite counting device (Bite Counter, Bite Technologies) was a 64×38×25 mm black plastic rectangle weighing 75 g with an adjustable wrist band (Figure 1). The device operated as a digital watch when not in use during an eating activity. At the beginning of each eating activity, the user pressed a button to activate "bite-count" mode. The display indicated "on" in bite-count mode, such that no bite-count feedback was provided to the user. At the end of each eating activity, the user pressed a button to return to "time" mode. In addition, the device automatically returned to "time" mode after 1 hour of operating in "bite-count" mode. The device battery provided up to 14 hours of bite counting use and could be fully recharged in 3 hours. The device saved the date, time, duration, and bite count for each eating activity.

Automated Self-Administered 24-Hour Dietary Recall. Total kilocalories and grams of food consumed at each eating activity were obtained from version 1 of the National Cancer Institute's Internet-based automated self-administered 24-hour dietary recall (ASA24).[16] ASA24 uses a modified version of the interviewer-administered automated multiple pass method 24-hour recall. The automated multiple pass method accurately measures energy intake in free-living conditions,[17] but under-reporting energy intake with 24-hour recall methods is possible.[3] Despite this limitation, the ASA24 was a practical, low-cost, low–experimenter-burden tool for obtaining energy intake estimates for thousands of eating activities. In addition, in our study participants did not aim to record complete daily intake with the ASA24; their goal was to record eating activities that were also recorded with the bite counting device. In contrast to an in-person or telephone-administered 24-hour recall, the ASA24 was completed at participants' convenience from their computer. ASA24 staff provided a data file with total duration (minutes) to complete each recall.

Figure 1. The bite-counting device worn on the wrist in "time" mode.

Height, Weight, and BMI Measurements. Body weight and height were measured in street clothes without shoes using the Tanita WB-3000 Digital Beam Scale (Tanita Corp). Weight was measured to the nearest tenth of a pound, and height was measured to the nearest quarter inch. Pounds were converted to kilograms, inches were converted to meters, and BMI was calculated as weight in kilograms divided by height in meters squared.

Study Procedure

The Clemson University Institutional Review Board approved the study, and participants provided written informed consent. To determine eligibility, the participant completed an electronic demographics questionnaire. If the participant was eligible, he or she attended an individual orientation meeting.

Orientation. The experimenter explained the purpose of the study: to investigate whether a new device could estimate the amount of food eaten. Height and weight were measured. Each participant was given a wrist-worn device and written instructions. The experimenter demonstrated proper wearing and use. The participant was instructed to wear the device on the wrist of the hand that they normally ate with for the entire waking day, except when exercising, swimming, showering, or near water (eg, washing dishes) because the device is not waterproof. The participant was instructed to