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Byte by Bite: Use of a mobile Bite Counter and weekly behavioral challenges to promote weight loss

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Abstract

The goal of this study was to examine the usability and feasibility of the mobile Bite Counter (a watch-like device that detects when a user consumes food or beverage) and the impact of weekly behavioral challenges on diet and physical activity outcomes. Overweight (mean BMI 31.1±4.9 kg/m^2) adults (n=12) were recruited to participate in a four-week study to test both the usability and feasibility of using the device as part of a behavioral weight loss intervention. Participants were instructed to self-monitor number of bites/day using the Bite Counter, attend weekly group sessions, and listen to weekly podcasts. Participants were given weekly challenges: use a daily bite limit goal (wk1), turn off Bite Counter when fruits/vegetables are consumed (wk2), self-monitor kilocalories vs. bites (wk3), and receive a 10 bites/day bonus for every 30 minutes of exercise (wk4). Participants lost a mean of −1.2±1.3 kg. Only the wk3 challenge produced significant differences in kcal change (wk3 1302±120 kcal/day vs. baseline 2042±302 kcal/d, $P<0.05$). Bite Counter use was significantly correlated with weight loss ($r= -0.58$, P<0.05). Future studies should examine the use of the Bite Counter and impact of behavioral challenges over a longer period of time in a controlled study.

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Keywords

mobile health; personal health device; dietary self-monitoring; weight loss; mobile technology

1. Introduction

Obesity is associated with a number of chronic diseases including type 2 diabetes, hypertension, and cardiovascular disease (Mokdad et al., 2003; Must et al., 1999), as well as an increased risk of several cancers (Calle, Rodriguez, Walker-Thurmond, & Thun, 2003; Pischon, Nothlings, & Boeing, 2008). Behavioral interventions are an effective way to help people lose weight and decrease chronic disease risk factors (Dombrowski, Avenell, & Sniehott, 2010). Dietary self-monitoring is effective for weight management (Burke, Wang, & Sevick, 2011) and is considered the cornerstone of behavioral treatment for weight loss (Wing, 2004). Adherence to self-monitoring (Warziski, Sereika, Styn, Music, & Burke, 2008) and receiving personalized feedback on self-monitoring behaviors (Turk et al., 2012; Venditti & Kramer, 2012) are both associated with improved weight loss. Because self-monitoring can be burdensome (Burke, Swigart, Warziski Turk, Derro, & Ewing, 2009), adherence to self-monitoring can be low and may decrease over time (Burke et al., 2011). Therefore, finding ways to make self-monitoring unobtrusive, easy, engaging, more automated, and able to provide feedback may enhance adherence to self-monitoring and improve weight loss.

Emerging research has examined mHealth technologies as a way to help people achieve a healthy weight and hold promise as a way to improve self-monitoring efforts (Thomas & Bond, 2014; Tufano & Karras, 2005). While most mobile technology for dietary self-monitoring has focused on using mobile apps (Lieffers & Hanning, 2012; Gabrielle M Turner-McGrievy et al., 2013), new technology has been developed to allow for wearable dietary self-monitoring methods. The Bite Counter is worn like a watch and tracks wrist motion using a microelectromechanical systems gyroscope (Dong, Hoover, Scisco, & Muth, 2012). It detects a pattern of wrist roll motion and increments a counter on the detection of each such pattern. Bite count can be converted to an average approximation of energy intake using a kilocalories per bite (KPB) formula based upon subject demographics (height, weight, age, and sex). During eating, the Bite Counter displays bite count for the current eating activity in real-time, as well as estimated kilocalories (kcals). The device provides data for meal level diet self-monitoring, daily self-monitoring, and long term analysis over weeks/months by connecting the device to a computer. This allows for the potential for behavior change to be targeted at the single meal (e.g., a cue to stop eating before overeating), as well as at longer term eating patterns (e.g., eliminating overeating on weekends compared to weekdays). The device has been shown to accurately detect bites with a sensitivity of 75% and a positive predictive value of 89% (Shen, Salley, Muth, & Hoover, 2016). The KPB formula was previously validated among 263 individuals eating a meal in a university cafeteria finding it to estimate calories consumed in an individual meal to ±50 kcals (Salley, 2013). In an additional two-week validation study, 77 participants wore the Bite Counter to assess all eating occasions and also completed a 24-hour dietary recall each day. The mean per-individual correlation between bite count and kcals was 0.53 (Scisco, Muth, & Hoover, 2013).

While adherence to dietary self-monitoring is an important component of behavioral weight loss treatment, so is finding ways to maintain user engagement and adherence to behaviors important for weight loss. One potential way to address this is to build in novelty, which has not been used extensively in previous behavioral weight loss research. Previous studies show that novelty (using a different or new element or approach) assists with reinforcement learning and reward processing (Houillon et al., 2013) and adherence to medication use when using an mHealth approach (Cook, Carrington, Schmiege, Starr, & Reeder, 2015). In addition, the use of varying behavioral challenges helps to build in gamification, which includes challenges but can also include points, leaderboards, and social engagement (Miller, Cafazzo, & Seto, 2014). Adding elements of gamification, such as challenges, has been shown to assist with better self-management among individuals (Miller et al., 2014) and to encourage online users to be more physically active (Hales, Grant, Barr-Anderson, & Turner-McGrievy, 2016).

This study aimed to examine the user experience (Stewart, 2015) of the Bite Counter as a dietary self-monitoring tool in a one-month, behavioral weight loss usability and feasibility intervention delivered via weekly face-to-face sessions and twice weekly audio podcasts, coupled with weekly behavioral challenges. While most mHealth usability studies last under an hour (Zapata, Fernández-Alemán, Idri, & Toval, 2015), the present study aimed to test both usability and feasibility of the Bite Counter with adequate time to conduct four weekly challenges. The present study had three hypotheses. Hypothesis one was that use of the Bite Counter (assessed via total days of usage) would be associated with weight loss at one month. Hypothesis two was that there would be significant improvements in measures of self-efficacy and positive eating behaviors from pre- to post-intervention and that also measures of usability, novelty, cognitive load, and user control would receive high (positive) post-assessment ratings. In addition, the study aimed to examine the relationship of weekly behavioral challenges with Bite Counter use and so hypothesis three was that use of weekly challenges would be associated with improvements in the targeted, related outcomes, such as increases in fruit and vegetable intake or physical activity.

2. Materials and Methods

Overweight adults (n=12, BMI 31.1±4.9 kg.m^2) were recruited to participate in a four-week pilot trial to assess the use of the Bite Counter device for dietary self-monitoring in order to promote weight loss. The goal was to recruit 12 participants in order to have at least 10 complete the study as that has been shown to be a sufficient sample for usability testing purposes (Bastien, 2010; Nielsen, 2012). Participants were recruited through workplace listservs and newspaper advertisements. To enroll, participants must have been overweight or obese (BMI 25–49.9 kg/m^2), between the ages of 18 and 65 years, and have access to the Internet to complete surveys. Participants were excluded if they had an unstable medical condition, uncontrolled thyroid condition, eating disorder, or a psychiatric illness, or were in treatment for alcohol or drug dependency; on medication for diabetes or insulin resistance; currently participating in a weight-loss program; or pregnant, breastfeeding, or planning on becoming pregnant within the next six months. Upon meeting study criteria, participants were e-mailed a link to complete a 24-hour dietary recall collected using the Automated Self-administered 24-hour Dietary Recall (ASA24™) (Subar et al., 2010). Participants then attended an orientation session held in a computer laboratory at a large research university in the southeastern United States and completed remaining questionnaires online, including another day of dietary recall. While obtaining more than two recalls per week would be more optimal to capture overall dietary pattern (Ma et al., 2009), two recalls were chosen in order to reduce user burden (completing 10 vs. 15 recalls in one month) and ensure compliance. Two dietary recalls are considered to be the minimum that can be used in dietary research (NCI). Additional validated questionnaires assessed weight loss-related eating behaviors (Eating Behavior Inventory (EBI)) (Patrick Mahlen O'Neil et al., 1979; P. M. O'Neil & Rieder, 2005), self-efficacy around weight loss (Weight Efficacy Lifestyle Questionnaire (WEL-Q)) (Clark, Abrams, Niaura, Eaton, & Rossi, 1991), and physical activity (International Physical Activity Questionnaire (IPAQ)) (Hagstromer, Oja, & Sjostrom, 2006). The EBI assesses both positive and negative behaviors associated with weight loss or gain, with scores ranging from 26 (very few eating behaviors supporting weight loss) to 130 (many eating behaviors related to weight loss). The WEL-Q assesses an individual's confidence in his or her ability to lose weight on a scale of 0 (not confident) to 9 (very confident) and contains five domains (with each scale score ranging from 0 to 45): negative emotions, availability, social pressure, physical discomfort, and positive activities. These measures were collected at both baseline and at the end of the four-week study via online survey in a computer lab. Each week, participants completed one unannounced ASA24 at home and one at the weekly meetings, along with a weekly questionnaire to assess any outcomes related to the weekly behavioral challenges (such as physical activity).

Weight (baseline and each week; SECA 869, Hamburg, Germany) and height (baseline; SECA 213) were measured. At the end of the study, participants answered additional questions on a 7-point Likert scale that assessed user control (3 questions with score range of 3 to 21 and 21 representing highest user control or freedom in using the Bite Counter) (Eveland & Dunwoody, 2001), cognitive load (2 questions with score range of 2 to 14 and 14 representing highest cognitive load or degree of cognitive burden felt when using the Bite Counter) (Brunken, Plass, & Leutner, 2003), novelty (2 questions with score range of 2 to 14 and 14 representing highest perceived novelty or how innovative using the Bite Counter was), and one question assessing ease of use (scale of 1 to 7 with 7 being very easy to use). These measures have been used in previous work (Ko, Turner-McGrievy, & Campbell, 2013; G. Turner-McGrievy & Tate, 2011; G. M. Turner-McGrievy et al., 2009). A university Institutional Review Board approved the study, and all the participants gave written informed consent.

Intervention components

Each participant was instructed on how to use their Bite Counter device. A kilocalories per bite (KPB) for each participant was calculated based on the Mifflin-St Jeor formula for resting metabolic rate (Mifflin et al., 1990) and refined in prior studies (Scisco et al., 2013). Participants were given a bites/day goal for weight loss based on calorie goals for weight loss (Jakicic, Tate, Lang, & et al., 2012). If weight loss did not occur each week, participants were provided with a lower daily bite limit.

Participants attended a one-hour group session each week for four sessions plus the orientation session. At these sessions, a study counselor (registered dietitian with extensive training in health behavior and weight loss interventions) led a group session that included participants updating the group on how the previous week had gone with using the Bite Counter. Each week had a different topic: Week 1) Increasing fruits and vegetables, Week 2) Goal setting, Week 3) Planning for social cues and using the Bite Counter at social gatherings, and Week 4) Review and wrap-up. Participants also downloaded two 15-minute podcasts each week that have been used to assist with weight loss in previous studies (G. Turner-McGrievy & Tate, 2011; G. M. Turner-McGrievy et al., 2009). Participants were provided with four different weekly challenges with the goal of facilitating regular Bite Counter adherence and weight loss. These four weekly challenges included: use a provided bite limit goal for diet self-monitoring (bites, week 1), ability to turn off Bite Counter when fruits and veggies are consumed (F&V, week 2), use a provided kcal/day goal (vs. bites/day goal used in previous weeks) to self-monitor caloric intake (vs. daily bites) by switching the Bite Counter view to display kcals vs. bites (kcals, week 3), and receive an extra 10 bites/day bonus on top of their daily bite limit for every 30 minutes of moderate/vigorous physical activity a participant completed per day (PA, week 4).

2.1. Statistical analysis

Descriptive statistics were used to present results of demographic data and weight loss. For hypothesis one, Pearson correlation was used to examine the relationship between weight loss (kg) and Bite Counter adherence (continuous measure assessed via number of days of use). For hypothesis two (related to psychosocial variables), paired-samples *t* tests were used to examine changes from pre- to post-scores for EBI and WEL-Q and descriptive statistics were used for post-only usability data (e.g., ease of use, cognitive load, etc.). For hypothesis three examining outcomes of weekly behavioral challenges, repeated measures within-subject General Linear Models were used to examine differences among relevant outcomes for each of the behavioral challenges. For this, the outcome of interest for the examined weekly behavioral challenge (e.g., fruit and vegetable intake) was a single factor with three to five levels representing the time points where each measure was assessed (e.g., baseline and week's one through four). Differences in main effects among all time points with one another were examined with pairwise comparisons using the Least Significant Difference test. Only complete data were used in the analyses. For example, if a participant did not complete two days of dietary recall, he/she was excluded from the dietary recall analyses. All analyses were conducted using SPSS for Windows software, version 22.0.0, with a *p*-value of 0.05 used to indicate significant differences.

3. Theory/Calculation

The present study was informed by User Control Theory and Cognitive Load Theory. User Control Theory states that an increase in the variety of different ways to learn and access information adds to the control a user feels and therefore increases learning (Eveland &

Dunwoody, 2001). Cognitive Load Theory states that the more cognitive burden, or mental effort, a user feels when learning, the less able they will be to retain and act upon what they learned (Brunken et al., 2003; Paas, Tuovinen, Tabbers, & Van Gerven, 2003). The Bite Counter was chosen because of its potential to increase user control and decrease cognitive load. Because Bite Counters have a simple interface, provide the ability to view bites taken or kcals consumed, show data in real time as meals are being consumed, and allow users to view or upload their data when they want to, we hypothesize that this combination of features will help facilitate feelings of high user control and low cognitive load—thereby potentially leading to greater adherence and weight loss. In addition, the study examined the role novelty and variation might play with improving dietary and physical activity behaviors. Novelty may play a role in reinforcement learning and reward processing (Houillon et al., 2013), which in turn could improve adherence and engagement in a weight loss intervention.

4. Results

A total of 26 individuals completed screening and 12 qualified and participated in the study. All participants provided a final weight assessment. Demographic characteristics are presented in Table 1.

Participants lost a mean (±SE) of −1.2±0.4 kg. Bite Counter use was significantly correlated with weight loss over the course of the study (r=−0.583, P=0.047). Participants' EBI scores significantly increased from baseline (77.2±9.2) to follow-up (90.3±8.8, P<0.01), indicating a significant increase in positive weight management behaviors. From baseline to follow-up, WEL-Q subscales showed significant increases for resisting overeating when in physical discomfort (23.8±5.3 to 26.1±6.7, P<0.05) and resisting overeating while engaging in positive activities (24.1±6.3 to 26.5±6.9, P<0.01). There were no significant changes in the other WEL-Q subscales of negativity, social pressure, and food availability.

Participants found the Bite Counter easy to use (5.4±1.6; scale of 1 to 7 with 7 being very easy to use) and novel (12.6±1.8; score range 2–14 with 14 representing highest perceived novelty). Participants also reported low levels of cognitive load (12.6±1.4; score range 2–14 with 14 representing lowest cognitive load), indicating little mental effort used to process the information, and high levels of user control (16.8±4.7; score range 3–21 with 21 representing highest user control), indicating a perception of being able to control the content of the information received and use of intervention components.

4.1. Weekly behavioral challenges

Table 2 presents the baseline results for dietary variables, physical activity, weight, results during each weekly behavioral challenge, and mean bites/day. Table 2 also shows the number of participants who attended each weekly session (displayed as n's for each week) and mean number of podcasts participants listened to each week (out of two). The only weekly behavioral challenge that had a significant impact on the examined outcome was the week 3 (kcals) challenge, with energy intake (kcals/day) being significantly lower (1302±120 kcal/day) compared to prior to starting the intervention at baseline (2042±302 kcal/day, P<0.05). Body weight was significantly lower compared to baseline at each time point. Total days of self-monitoring with the Bite Counter (mean 20.3±9.7 days out of 28) was significantly correlated with four-week weight loss ($r = -0.58$, $P<0.05$).

5. Discussion

Adherence to dietary self-monitoring tends to decrease even when less burdensome mHealth methods are used (Gabrielle M Turner-McGrievy et al., 2013). Frequency of and adherence to diet self-monitoring for weight loss may be more important than recording detailed dietary intake or accuracy (Yon, Johnson, Harvey-Berino, & Gold, 2006). The goal of the present study was to examine the Bite Counter as a self-monitoring tool during a behavioral weight loss intervention and examined the use of weekly behavioral challenges associated with Bite Counter adherence.

The present study found that use of the Bite Counter was significantly associated with weight loss. The mean weight loss of 1.2 kg (0.3 kg/week) was slightly lower than what has been observed in most other behavioral weight loss programs, which is usually around 0.4 to 0.5 kg/week (Butryn, Webb, & Wadden, 2011). However, most of the behavioral content of the current intervention was delivered via mHealth approaches, and remotely-delivered weight loss interventions typically see lower weight loss outcomes. Systematic reviews of mHealth interventions have shown total weight loss outcomes ranging from 0.08 to 5.4 kg (Aguilar-Martínez et al., 2014; Flores Mateo, Granado-Font, Ferre-Grau, & Montana-Carreras, 2015; Levine, Savarimuthu, Squires, Nicholson, & Jay, 2015). In addition, there were improvements in eating behaviors conducive to weight management (EBI scores) and increased self-efficacy in resisting overeating when in physical discomfort and doing positive activities (WEL-Q scores). Participants found the counter novel and easy to use. In addition, while only the week 3 (kcal) challenge impacted the examined outcome for that week (change in kcals), the weekly behavioral challenges may be a way to keep participants engaged and increase novelty during a behavioral weight loss intervention. Research on the impact of novelty during weight loss interventions has been limited. Previous research has shown that varying goals over time may improve weight loss (versus static goals) (Jeffery et al., 2009) and that varying exercise type is associated with greater moderate-to-vigorous physical activity (Bond et al., 2012). Other research has shown that novelty may help with adherence to medication use when using an mHealth approach (Cook et al., 2015). Because a previous research study indicated that varying behavioral goals over time may impact weight loss maintenance (Jeffery et al., 2009), future studies should examine the impact of longer behavioral challenges over a longer period of time, particularly on weight loss maintenance.

This study has several strengths. It is one of the first studies to test the use of a wearable device to self-monitor diet during a weight loss intervention, as well as testing the use of weekly behavioral challenges. The study also used validated questionnaires to assess eating behavior-related outcomes. There are also some limitations, including the short duration, single-arm design, two vs. three days of dietary recalls collected each week, and a small sample that was mostly white, female, and educated. In addition, most of the data collected were self-report. Even though Bite Counter data were objectively downloaded from each participant's device each week, participants still had to remember to use the device in order to capture all data. In addition, Bite Counters had to be connected to a computer in order to sync. Future versions of the Bite Counter would be improved if they could wirelessly sync to a smartphone. Lastly, the Bite Counter was just part of a multi-component behavioral intervention so it is possible that other aspects of the study, such as face-to-face meetings or podcasts, also contributed to the outcomes.

6. Conclusions

The present study examined the use of the Bite Counter as a diet self-monitoring device during a behavioral weight loss intervention. Findings from the study demonstrate that participants found the Bite Counter easy to use and that use was associated with weight loss. This work will help inform future research in the area of using wearable devices to assist with diet self-monitoring during behavioral weight loss interventions.

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Highlights

- Bite Counter use during a weight loss intervention was associated with weight loss.
- Bite Counters were rated as highly easy-to-use and novel with low user burden.
- Using the Bite Counters to track kcal intake was associated with lower kcal intake.
- Participants had improvements in weight-related eating behaviors and self-efficacy.

Table 1

Demographic characteristics of the Bite Counter Study

Demographic characteristics	
n	12
Age (mean years ± SD)	54.1 ± 11.29 years
Sex (n (%))	
Female	11 (92%)
Male	1 (8%)
Race (n (%))	
Black	1 (8%)
White	11 (92%)
Education (n (%))	
High school, partial or graduate	0 (0%)
College, partial or graduate	7 (58%)
Graduate degree	5 (42%)
Marital Status (n (%))	
Married	7 (58%)
Other	5 (42%)
Mean BMI (kg/m^2 ± SD)	31.1 ± 4.9

Table 2

Outcomes of weekly behavioral challenges during the Bite Counter study

	Baseline (n=12)	Week 1: Use bite counter with bite limit (n=11)	Week 2: Fruit and veggie challenge (n=9)	Week 3: Track kcals vs. bites (n=10)	Week 4: 10 bites/day bonus for every 30 minutes of moderate-to-vigorous physical activity (n=11)
Bites/day (±SE)	*	96.0 ± 8.5	88.9 ± 7.5	91.0 ± 7.5	102.2 ± 8.8
Kcals/day (±SE)	2089 ± 198	2042 ± 302	1440 ± 160[a,b]	1302 ± 120[a]	1452 ± 150[a]
Fruits and vegetables (servings±SE)	3.2 ± 0.7	4.2 ± 0.8[a]	3.9 ± 0.9	3.1 ± 0.6	3.5 ± 0.8
Minutes of Vigorous PA/week (±SE)	110.0 ± 27.6	*	*	176.0 ± 51.1	142 ± 28.0
Minutes of Moderate PA/week (±SE)	144.5 ± 55.6	*	*	144.1 ± 28.9	125.9 ± 27.0
Minutes of walking/week (±SE)	125.0 ± 45.4	*	*	250.9 ± 65.0[a]	180.5 ± 31.7
Minutes spent sitting per weekday over past 7 days (±SE)	2018.2 ± 176.7	*	*	2890.9 ± 932.4	1718.2 ± 157.1
Body weight (kg) ±SE	80.9 ± 6.4	80.4 ± 6.5[a]	79.4 ± 6.2[a,b]	79.1 ± 6.3[a]	79.5 ± 6.5[a]
Weight loss from baseline (kg) ±SE	*	−0.7±0.2 kg	−1.3±0.3 kg	−1.7±0.5 kg	−1.2±0.4 kg
Mean number of podcasts participants downloaded (out of two/week) ±SE	*	1.6±0.2	1.1±0.3[a]	1.2±0.3	1.1±0.3

[a] Significantly different from baseline (P<0.05)

[b] Significantly different from prior week (P<0.05)

[*] Outcome not assessed at this time point