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Examining the pattern of new foods and beverages consumed during obesity treatment to inform strategies for self-monitoring intake

Hollie A Raynor, PhD, RDN¹, J Graham Thomas, PhD², Chelsi C. Cardoso, MS, RD¹, Alexis C Wojtanowski, BS³, and Gary D. Foster, PhD^{3,4}

¹Department of Nutrition, University of Tennessee, Department of Nutrition, Knoxville, TN, USA

²Department of Psychiatry and Human Behavior, Warren Alpert Medical School of Brown University, The Miriam Hospital/Weight Control and Diabetes Research Center, Providence, RI, USA

³Weight Watchers International, Inc. New York City, NY, USA

⁴Center for Weight and Eating Disorders, University of Pennsylvania Perelman School of Medicine, Center of Obesity Research and Education, Temple University, Philadelphia, PA, USA

Abstract

Maintaining dietary self-monitoring during obesity treatment may improve outcomes. As dietary variety is associated with energy intake, understanding the pattern of when new foods and beverages are consumed may assist with identifying when self-monitoring should occur. This study examined dietary variety (total number of differing foods and beverages consumed) from the first 40 days of self-monitoring records reporting 3 eating occasions and > 600 kcal/day from 60 adults (55.9 ± 9.1 yrs, 35.1 ± 5.3 kg/m², 80.0% female, 95.0% white) participating in a smartphone-based, lifestyle intervention. Dietary variety was coded using an ingredient-based approach. Additionally, new flavors of previously consumed items, and modified and nonmodified items contributed to variety. Total number of different foods and beverages consumed over 40 coded days (cumulative variety [cv₄₀]); number of days to reach 50%, 75%, and 100% of cv₄₀; cv₄₀ by eating occasions; and mean number of new items consumed on weekdays and weekend days were calculated. CV₄₀ was 145.4 ± 33.5 . Number of coded days to consume 50%, 75%, and 100% of cv₄₀ was 12.7, 25.1, and 40.0, respectively. Dinner was greater ($p < 0.0001$) in cv₄₀ (58.6 ± 18.5 different items) than other eating occasions, and lunch was greater ($p < 0.0001$) (38.8 ± 10.7 different items) than breakfast and snack. Weekend days had a greater mean number of new items consumed than weekdays, (3.8 ± 1.0 items vs. 3.6 ± 0.9 items, $p = 0.035$). Variety of items consumed during obesity treatment is high, and to capture the majority of differing items

Corresponding Author: Hollie A Raynor, PhD, RDN, 1215 Cumberland Ave, Department of Nutrition, University of Tennessee, Knoxville, TN 37996; phone: 865-974-6259; fax: 865-974-3491; hraynor@utk.edu.

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consumed, at least 4 weeks of detailed recording is needed. After this, to capture new foods and beverages consumed, self-monitoring dinners, lunch, and weekend days may be helpful.

Keywords

Variety; self-monitoring; diet; obesity treatment

Self-monitoring of dietary intake is believed to be a critical behavior for successful weight loss¹ and weight loss maintenance,² as it assists with adherence to dietary goals designed to reduce energy intake.³ Unfortunately, participants report that dietary self-monitoring can be burdensome⁴ and the occurrence of dietary self-monitoring decreases over time during treatment of overweight and obesity.¹ As research has found that frequency (engaging in selfmonitoring at least 50% of the time when active weight loss and weight loss maintenance is occurring) and consistency (self-monitoring at least three days per week), rather than comprehensiveness (self-monitoring time, food name, amount, and energy intake for all meals), of dietary self-monitoring is important for successful weight management,⁵ one potential method to reduce the burden of dietary self-monitoring is to decrease the level of detail that is included in the monitoring. Reducing the detail in dietary self-monitoring could decrease the time and cognitive effort needed for self-monitoring of diet, which may help with maintaining dietary selfmonitoring frequency and consistency.⁵ If dietary intake is not comprehensively monitored, ideally what is monitored is related to and assists with identifying when excessive energy intake may be occurring. As dietary variety is positively associated with energy intake,⁶ understanding the number of days of monitoring required to capture the majority of differing foods and beverages consumed, as well as ascertaining when new foods and beverages are more likely to be consumed, may assist with identifying when self-monitoring should occur if dietary intake is not comprehensively monitored.

Most research examining dietary variety consumed in free-living situations has assessed dietary variety comprehensively over short periods of time (i.e., three days of intake collected via 24-hr dietary recalls or food records) or less comprehensively over long periods of time (i.e., food frequency questionnaires [FFQs] that capture usual intake over 6 months).⁶ However, these methods of assessment may underestimate the number of different foods and beverages consumed (dietary variety).⁶ While 24-hr dietary recalls or food records provide a large amount of detail regarding the varying foods and beverages consumed at different eating occasions and on different days, the time frame of consumption is limited and most likely is not long enough to truly capture usual intake regarding the number of unique food and beverages in the diet. Alternatively, while the FFQ captures a longer time frame of consumption, the number of differing foods and beverages consumed can only be assessed from the list of provided food and beverage groupings on the questionnaire. The list of food and beverage groupings is fairly limited in most FFQs, and most likely does not capture all foods and beverages consumed. Furthermore, what is actually consumed in eating occasions and on differing days cannot be determined.

Only one study has examined dietary variety more comprehensively, in which one 24-hr dietary recall and 14 days of food records were collected.⁷ While the number of new foods

introduced within eating occasions was not examined, the number of new foods consumed by day was analyzed. This study suggested that at least 10 days of monitored intake was needed to determine overall dietary variety, but no results were provided regarding the number of new foods consumed by different days of the week (weekday vs weekend day).⁷ Additionally, this investigation examined usual intake in individuals of a healthy weight, and our research has found that individuals with overweight or obesity generally consume a diet with a greater number of differing foods than individuals of a lower weight.^{8,9} Furthermore, no study has examined dietary variety, or the total number of differing foods and beverages consumed, comprehensively during obesity treatment. Thus, to better understand the pattern of introduction of new foods and beverages consumed that contribute to variety in the diet during obesity treatment to inform strategies for self-monitoring intake, this study examined dietary variety, defined as the total number of differing foods and beverages consumed, over 40 coded days of electronic self-monitoring in individuals with overweight or obesity starting a smartphone-based, 18-month, lifestyle intervention in which a reduced-energy diet was prescribed. The aim of this investigation was to describe dietary variety in several ways: cumulative dietary variety (total number of differing foods and beverages consumed) over 40 coded days, cv_{40} , of electronic self-monitoring; number of days of self-monitoring needed to capture 50%, 75%, 80%, and 100% of cv_{40} ; and how eating occasions, breakfast, lunch, dinner and snack, and weekdays and weekend days contribute to variety in regards to introducing new foods and beverages into the diet. A secondary aim was to examine the relationship between dietary variety and energy intake.

Methods

Study design and participants

This was a secondary data analysis of dietary self-monitoring data collected during an 18-month lifestyle intervention (R01DK095779). This analysis used 40 days of self-monitored dietary data from 60 adults with overweight or obesity participating in a randomized controlled trial (RCT) investigating a smartphone-based, 18-month, lifestyle intervention. To be eligible for the RCT, participants needed to be between the ages of 18 and 70 years, with a body mass index (BMI) between 25–45 kg/m². Ineligibility criteria, based upon self-reported information, included: currently in another weight loss program; taking weight loss medication; weight loss of $\geq 5\%$ of body weight during the past six months; currently pregnant, lactating, less than 6 months post-partum, or plans to become pregnant during the next 18 months; report of a heart condition, chest pain during periods of activity or rest, or loss of consciousness on the Physical Activity Readiness Questionnaire (PAR-Q);¹⁰ report of a medical condition that would affect the safety of participating in unsupervised physical activity; inability to walk 2 blocks without stopping; report conditions that in the opinion of the investigators would render them potentially unlikely to follow the protocol including terminal illness; plans to relocate; or a history of substance abuse, bulimia nervosa, or other significant psychiatric problems.

Eligible participants were randomized within recruited cohorts and within sex to one of the three 18-month treatment arms: 1) a group-based behavioral obesity treatment in which treatment was delivered in face-to-face sessions and participants self-monitored weight, diet

and physical activity via paper-pencil methods; 2) a primarily smartphone-based behavioral obesity treatment in which participants self-monitored weight, diet, and physical activity with MyFitnessPal; and 3) a control condition in which participants also self-monitored weight, diet, and physical activity via paper-pencil methods. The dietary prescription was 1,200–1,500 kcal/day with 30% energy from fat, with no guidance regarding dietary variety. Self-monitoring data from MyFitnessPal was stored electronically for the trial, and thus was available for the secondary data analysis. Thus, participants for this secondary data analysis were the first 60 participants that had been randomized to the smartphone-based, lifestyle intervention that had completed > 40 days of the intervention by September 2014. The protocol for this analysis was approved by the Institutional Review Board at the University of Tennessee, Knoxville, TN. The original trial is registered at [ClinicalTrials.gov](https://clinicaltrials.gov/ct2/show/study/NCT01724632) as NCT01724632.

Procedures

Participants in the smartphone-based lifestyle intervention used the free commercially available MyFitnessPal app to self-monitor daily weight, dietary intake, and physical activity minutes. For each day of self-monitoring, participants were instructed to enter the type and amount of foods and beverages consumed for breakfast, lunch, dinner, and snacks (thus eating occasions were participant defined) as soon as items were consumed. MyFitnessPal only records one “snack” per day, thus for the items coded as being consumed as a snack it is not clear from the self-monitoring data if foods and/or beverages consumed were in one snack or several snacks.

Measures

To be eligible for coding for this investigation, a daily self-monitoring record had to include at least three different eating occasions and total energy reported needed to be > 50% of the prescribed energy goal of 1,200 kcal/day.¹¹ The first 40 days of self-monitoring during the intervention meeting these criteria were coded.

There is no standard way to code dietary variety, defined as the number of different food and beverages consumed. However research that has been conducted on dietary variety and energy intake suggest that coding variety with an ingredient-based approach may be more associated with energy intake than other methods of coding variety.⁶ Variety was coded by hand by a M.S.-level nutritionist. Using an ingredient-based approach, foods and beverages composed of one ingredient (i.e., apple, milk) counted towards contributing to variety. In addition, combination foods and beverages, in which individual ingredients could be identified, were broken into their ingredients (i.e., sandwich = bread, turkey, lettuce, tomato, cheese; coffee and half-n-half = black coffee, half-n-half), and each ingredient contributed to variety. As consuming the same item in differing flavors has been a type of variety associated with increased intake,⁶ flavor was also coded to contribute to variety (i.e., BBQ, sour cream, and plain potato chips were counted as three items contributing to variety; root beer, cola, and ginger ale sugar-sweetened sodas counted as three items contributing to variety). Finally, as modified foods and beverages (i.e., reduced-fat and/or reduced sugar foods or beverages) are commonly increased during weight management,^{12,13} modified foods and beverages were counted separately from their non-modified counterparts (i.e.,

regular mayonnaise was counted as a separate item from fat-free mayonnaise; cola was counted as a separate item from diet cola). Variety was coded as food and beverages combined.

Inter-rater reliability was determined by having a M.S.-level registered dietitian recode 30 participant records that were randomly selected. Kappa coefficients were determined for each day of coding (i.e., agreement of number of items contributing to variety on day 1, day 2, etc.) and percent agreement for daily totals contributing to cumulative variety was calculated.

Variety was calculated in several ways. First, the number of new foods and beverages consumed each day (so items that were not consumed on a previous coded day) was determined. Second, a cumulative variety score was calculated. For the cumulative variety score, the number of new items consumed each day (without having been consumed on previously coded days) was summed. Thus, the number of new items consumed for each consecutive day (i.e., sum for day 1 [cv_1], sum for day 2 [which is sum for day 1 + sum for day 2 = cv_2], etc.) was determined. Cumulative variety on day 40 (cv_{40}) was the total number of different foods and beverages consumed over the 40 coded days. This type of calculating variety has been conducted previously.⁷ The number of days for which a mean of 50%, 75%, and 100% of all different items were consumed (percent of cv_{40}) was also determined.

To better understand how the type of eating occasion may be related to the number of new food and beverages consumed, all days were also coded to determine the number of new foods and beverages consumed at breakfast, lunch, dinner, and snack. An overall cumulative variety for the 40 coded days, cv_{40} , was calculated for each eating occasion.

Variety in foods and beverages consumed on weekday and weekend days was also calculated. The number of new food and beverages consumed for each coded day was determined. From there, days were identified as weekday and weekend based upon the date on the monitoring record. As there were fewer weekend days than weekdays represented in the 40 days, rather than using a cumulative variety score, a mean was determined for the number of new items consumed on weekdays and weekend days.

Finally, as variety in the diet has been related to energy intake, this relationship was examined. To establish energy intake, all MyFitnessPal records were re-entered into Nutrition Data System for Research (NDSR) (Minneapolis, MN), so that energy intake per day could be established using this database (research quality nutrient database).

Data analyses

Pearson product correlations examined the relationship between the number of days examined to code 40 days and cv_{40} for foods and beverages consumed, and variety of foods and beverages consumed on day 1 (cv_1) and cumulative variety of foods and beverages consumed (cv_{40}). Along with the previously described descriptive statistics of variety, a repeated measures analysis of variance (ANOVA), with the within-subject factor of eating occasion (breakfast, lunch, dinner, and snack), was conducted on cv_{40} for the eating

occasions to examine differences in number of new foods and beverages consumed during the 40 coded days between the eating occasions. Post-hoc comparisons with bonferroni corrections were used to examine differences in variety between eating occasions. A paired t-test was used to examine for differences in the mean number of new food and beverages consumed on weekdays vs weekend days. Pearson product correlations were conducted to examine relationships between cv_{40} , mean number of new items consumed per day, summed energy intake over 40 days, and mean daily energy intake over the 40 days. Analyses were conducted with SPSS version 23, with alpha set at 0.05.

Results

Participants

Participants were aged 55.9 ± 9.1 yrs, had a BMI of 35.1 ± 5.3 kg/m², and were 80.0% female, 95.0% white, and 98.3% non-Hispanic. The majority of the participants were married (78.3%), and had some college education (83.4%).

Dietary data

The mean number of days examined per participant to be able to code 40 days was 46.8 ± 8.9 . A Pearson product correlation found no significant relationship ($p > 0.40$) between number of days examined to code 40 days and cv_{40} for foods and beverages consumed. As participants started self-monitoring at different time points, each coded day could be represented by any day of the week. However, when each coded day was examined, day 1 was represented by all days except Saturday and day 2 was represented by all days except Monday and Sunday. Days 3 to 40 were represented by all seven days of the week. The mean daily energy and percent energy from fat intake over the 40 days was 1443 ± 226 kcal and $31.8 \pm 5.4\%$, respectively.

Inter-rater reliability

Kappa coefficients for days 1 to 40 ranged from 0.73 to 1.00. Only days 11 and 20 had kappa coefficients below 0.80 (0.73 and 0.79, respectively), with all other days 0.80. These coefficients indicate “substantial” to “almost perfect” agreement.¹⁴ Percent agreement of daily totals contributing to cumulative variety was $90.6 \pm 4.0\%$.

Number of new foods and beverages consumed each day

The number of new foods and beverages consumed per coded day is shown in Figure 1. The number of new items consumed per day steadily declined from Day 1 to Day 9. From Day 9 to Day 22 number of new items consumed was around 3 per coded day. From Day 23 forward, all days consistently had < 3 new foods and beverages consumed per coded day. While not shown in Figure 1, the standard deviations are approximately 3 from Day 1 through Day 8 and then approximately 2 for the remaining coded days.

Cumulative variety

Cumulative variety for foods and beverages consumed is shown in Figure 2.

As expected, the number of different foods and beverages consumed increased as a function of time. Mean number of different foods and beverages consumed during the first day (cv_1) was 12.7 ± 3.6 (range 4 to 22 foods and beverages). Mean total number of different foods and beverages consumed by day 40 (cv_{40}) was 145.4 ± 33.5 (range 74 to 217 foods and beverages). A Pearson product correlation found that variety of foods and beverages consumed on day 1 (cv_1) was significantly related to cumulative variety of foods and beverages consumed (cv_{40}) ($r = 0.664$, $p < 0.0001$).

Percent cumulative variety for foods and beverages consumed is shown in Figure 3.

Number of coded days to consume a mean of 50%, 75%, and 100% of cumulative variety on day 40 (cv_{40}) of foods and beverages was 12.7, 25.1, and 40.0, respectively. The first day for a participant to reach 100% cv_{40} for foods and beverages was coded day 36.

Number of new foods consumed in eating occasions and weekdays and weekend days

From the repeated measures ANOVA, a main effect of eating occasion was found ($p < 0.0001$), with dinner being significantly ($p < 0.0001$) greater in cumulative variety than all other eating occasions, lunch being significantly ($p < 0.0001$) greater in cumulative variety than breakfast and snacks, and no significant difference between breakfast and snacks in cumulative variety (number of different foods and beverages consumed over 40 coded days: dinner = 58.6 ± 18.5 ; lunch = 38.8 ± 10.7 ; breakfast = 22.0 ± 8.0 ; and snacks = 25.3 ± 8.9). Figure 4 shows the number of new foods and beverages consumed per eating occasion during the 40 coded days.

The paired t-test found a significant difference in the mean number of new food and beverages consumed on weekdays and weekend days, with weekend days significantly greater than weekdays, (mean number of new foods and beverages consumed: 3.8 ± 1.0 vs. 3.6 ± 0.9 , $p = 0.035$).

Dietary variety and energy intake

The Pearson product correlations found no significant relationship ($p > 0.50$) between cv_{40} , mean number of new items consumed per day, summed energy intake over 40 days, and mean daily energy intake over the 40 days.

Discussion

This is the first investigation to comprehensively examine the pattern of dietary variety, defined as the total number of differing foods and beverages, consumed over 40 coded days from dietary self-monitoring records during obesity treatment. Overall variety in foods and beverages consumed was much higher in this investigation than what has been reported in the only other investigation examining dietary variety using a more comprehensive assessment (15 days of detailed assessment) (145 vs 64 items consumed in total).⁷ The difference in the total number of different items consumed between the two investigations is most likely a consequence of several different methodological factors. This investigation used selfmonitoring food records from participants with overweight and obesity, while the previous investigation used a dietary recall and food records from participants of a healthy

weight. As previous studies have found that individuals with overweight and obesity have greater dietary variety than individuals of a healthy weight,⁶ the differences in findings in the two investigations concur with this research. This investigation also used a longer time frame to determine variety and coded variety using an ingredient-based, as compared to a food-group based, method. Both of these factors are also anticipated to increase amount of dietary variety measured.⁶ Finally, this investigation included beverages in the calculation of variety, while it is not clear if beverages were included in the calculations of variety in the previous investigation.

It has been previously suggested that 10 to 14 days of recording intake may be adequate to capture the majority of different types of items that are usually consumed.⁷ This investigation did find that the number of new items consumed per day was greatest between day 1 and day 9, but the results also suggest that 25 days of recording intake is needed to capture approximately 75% of the different types of foods and beverages consumed. Furthermore, this investigation found that new foods and beverages continued to be introduced daily into the diet during the entire 40 days of coding.

To better understand when new food and beverages are consumed during obesity treatment, this investigation compared the number of new foods and beverages consumed in eating occasions and weekdays vs weekend days. Dinner was the eating occasion in which the greatest number of new foods and beverages were introduced into the diet, followed by lunch. Data from the National Health and Nutrition Examination Survey (NHANES) indicate that dinner, followed by lunch, are the largest, in terms of energy intake, eating occasions of the day.¹⁵ In this investigation, weekend days as compared to weekdays also had significantly more new food and beverages consumed. NHANES data also indicate that greater energy intake occurs on weekend days as compared to weekdays.¹⁶

This investigation did not find a relationship between dietary variety and energy intake, which is not consistent with a large body of research, including that which has examined dietary variety intake during obesity treatment.⁶ As this investigation provides the most comprehensive assessment of dietary variety than has been previously conducted, the methodology used to assess dietary variety may have influenced the relationship between variety and energy intake. Furthermore, the participants in this investigation were in approximately the first forty days of an intervention that prescribed a reduced-energy diet. This may have reduced the variability in reported energy intake as adherence to the diet prescription may have been fairly high. Traditionally, assessments of the diet during an intervention trial occur at a follow-up time point, such as 6-months, in which adherence to the diet may be lower than at the start of the intervention, making intake more variable. A more limited variability in energy intake would make finding a relationship between variety and energy intake more difficult. In support of this, the standard deviation for mean daily energy intake in this investigation was 226 kcal, while the standard deviation of mean energy intake assessed at 6 months via 24-hr recalls during an intervention that a similar diet was approximately 420 kcal, indicating greater variability in energy intake.¹⁷

Limitations of this investigation include the small, homogenous (i.e., predominantly, female, white, non-Hispanic) sample. Investigating dietary variety in a larger, more heterogeneous

sample during obesity treatment would enhance generalizability of these results. Furthermore, it is unclear the level of food neophobia participants experienced, which may impact the overall number of different foods consumed in the evaluated days in this investigation. It is also not clear how well these results translate to other populations with obesity (i.e., children). While the dietary data used in this investigation was self-reported, a strength of the study was the level of detail collected about dietary intake, which allowed the coding of variety using an ingredient-based coding scheme, and the extended period of time in which the data were collected. Furthermore, analyses of the coding methodology indicated a high-degree of reliability.

Conclusion

This investigation suggests that the number of differing food and beverages consumed during obesity treatment is fairly high, and to capture the majority of the different foods and beverages consumed during obesity treatment, at least 4 weeks of detailed recording is needed. If the detail of self-monitoring is reduced after that time, to be more likely to capture when new foods and beverages are being consumed, self-monitoring dinners, lunch, and weekend days may be helpful. Monitoring these eating occasions and days should assist with increasing awareness of items being consumed that participants may not already be familiar with in regards to how these items assist, or not, with meeting dietary goals. Future research should examine if using this self-monitoring guidance increases frequency and consistency of selfmonitoring during obesity treatment, and if this enhances dietary adherence and weight management outcomes.

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Figure 1.
Number of new foods and beverages consumed per day over 40 coded days during treatment of obesity.

Figure 2.
Cumulative variety of foods and beverages consumed over 40 coded days during treatment of obesity.

Figure 3.
Percent cumulative variety of foods and beverages consumed over 40 coded days during treatment of obesity.

Figure 4.
Number of new foods and beverages consumed per eating occasion per day over 40 coded days during treatment of obesity.