

Dietary lapses are associated with meaningful elevations in daily caloric intake and added sugar consumption during a lifestyle modification intervention

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Abstract

Objective: Lapses from the dietary prescription in lifestyle modification interventions for overweight/obesity are common and impact weight loss outcomes. While it is expected that lapses influence weight via increased consumption, there are no studies that have evaluated how dietary lapses affect dietary intake during treatment. This study examined the association between daily lapses and daily energy and macronutrient intake during a lifestyle modification intervention.

Methods: This study used an intensive longitudinal design to observe participants throughout a 6-month lifestyle modification intervention. Participants ($n = 32$) were adults with overweight/obesity (body mass index 25–50 kg/m²) and a diagnosed cardiovascular disease risk factor (e.g., hypertension) with a desire to lose weight. Participants underwent a gold-standard individual in-person lifestyle modification protocol consisting of 3 months of weekly sessions with 3 months of monthly sessions. Each participant's dietary prescription included a calorie target range that was based on their starting weight. Participants completed ecological momentary assessment (EMA; repeated daily smartphone surveys) every other week to self-report on dietary lapses and telephone-based 24-h dietary recalls every 6 weeks.

Results: On days with EMA and recalled intake ($n = 210$ days), linear mixed models demonstrated significant associations between daily lapse and higher total daily caloric intake ($B = 139.20$, $p < 0.05$), more daily grams of added sugar ($B = 16.24$, $p < 0.001$), and likelihood of exceeding the daily calorie goal ($B = 0.89$, $p < 0.05$). The associations between daily lapse and intake of all other daily macronutrients were non-significant.

Conclusions: This study contributes to literature suggesting that dietary lapses pose a threat to weight loss success. Results indicate that reducing lapse frequency could reduce overall caloric intake and added sugar consumption.

Abbreviations: BMI, body mass index; DPP, diabetes prevention program; EMA, ecological momentary assessment; ID, identification number; NDSR, University of Minnesota Nutrition Data System for Research.

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KEYWORDS

24-h dietary recall, adherence, behavioral weight loss, dietary intake, dietary lapses, ecological momentary assessment

1 | BACKGROUND

Lifestyle modification is the gold-standard non-surgical approach to reducing overweight/obesity via clinically meaningful weight loss of 5%–10% of one's initial body weight.¹ Lifestyle modification interventions involve a daily calorie prescription and physical activity goal, which serve to create a negative energy balance.² Lifestyle modification also typically involves provision of behavioral and cognitive strategies to facilitate adherence to the prescribed diet and activity goals (e.g., stimulus control, meal planning, coping with stress).¹⁻³

Research has shown that the dietary prescription serves as one of the most important drivers of weight change in lifestyle modification.⁴ Adherence to prescribed dietary goals, as measured by doubly labeled water or self-reported food diaries, has been robustly associated with overall rates of weight loss during lifestyle modification interventions.⁵⁻¹² Consistent with these findings, research on dietary lapses (i.e., specific instances of nonadherence to one or more of the dietary goals set forth in lifestyle modification interventions) indicates that momentary deviations from the prescribed diet can have a meaningful deleterious impact on weight loss. Previous studies have shown dietary lapses occur anywhere from 2.7 to 11.8 times per week during lifestyle modification interventions.¹³⁻¹⁷ Having more lapses has been associated with less weight loss in a given week of treatment, as well as less weight lost overall at the conclusion of lifestyle modification protocols.^{15,18} These studies benefit from using ecological momentary assessment (EMA) to repeatedly prompt individuals to report on lapses directly in the moment or very soon after.¹⁹ EMA represents a substantial improvement over non-momentary measurement methods (e.g., retrospective recalls), as the near real-time nature of assessment improves the ecological validity and reliability of self-reported eating behavior.²⁰⁻²² By studying dietary lapses in precise moments, rather than measuring overall dietary (non)adherence via doubly labeled water or food diary, EMA can elucidate temporal patterns of (non)adherence and help researchers to hone precision approaches for improving adherence to lifestyle modification diets.²³

Given the robust research on the association between dietary nonadherence and poorer weight loss outcomes during lifestyle modification, it stands to reason that dietary lapses likely influence weight via increased caloric intake. However, there are virtually no studies that examine whether instances of self-described non-adherence objectively impact caloric intake or key macronutrient intake (e.g., protein, fiber, saturated fat). One study of dietary lapses throughout a 12-month lifestyle modification intervention posited that, based on participant food records kept during treatment, lapses may incur an additional 600–750 kcals of intake per week; but this estimate was never empirically assessed.¹⁵ Because lapses are

broadly defined (i.e., non-adherence to one or more dietary goals, not necessarily referring to a calorie goal specifically) and can be comprised of a broad set of intake behaviors (e.g., overall energy intake, but also eating specific types of food one was intending to avoid),²⁴ it is not a certainty nor a requirement that self-identified lapses are meaningfully reflective of overall caloric intake. For example, lapses could instead be more indicative of the macronutrient make-up of the foods consumed (e.g., high in fat).²⁵ Thus, empirical research on the roles of dietary lapses and dietary intake is important for concretely establishing a mechanism by which lapses influence weight and will strengthen the argument for more directly targeting lapses to improve dietary adherence and, subsequently, lifestyle modification outcomes.²⁶⁻²⁸

The current study sought to examine the association between lapses and daily caloric and macronutrient intake during lifestyle modification. Participants ($n = 32$) underwent a 6-month in-person lifestyle modification intervention (3 months of active weight loss treatment individually with an interventionist with 3 months of monthly booster sessions). Each participant's dietary prescription included a calorie target range that was based on their starting weight. They completed EMA every other week (biweekly) to self-report on dietary lapses and telephone-based 24-h dietary recalls every 6 weeks throughout the program. This research empirically assessed, for the first time, lapses' contribution to dietary intake. Moreover, the use of multi-modal, repeated assessment throughout lifestyle modification and follow-up allowed for precise and robust estimates of these effects. The aims of this research were three-fold: (1) Examine the association between daily lapse (i.e., whether a participant reported a lapse on a given day or not) and daily recalled caloric intake; (2) Examine the associations between daily lapse and daily recalled macronutrient intake (i.e., grams of added sugars, saturated fat grams, percent daily intake from fat, carbohydrates, and protein, and fiber grams); and (3) Examine the association between daily lapse and whether an individual exceeded their recommended daily calorie goal. It was hypothesized that daily lapses would be associated with higher daily caloric intake, unhealthy dietary intake patterns (i.e., higher grams of added sugar, saturated fat grams, percent daily intake from fat, and percent daily intake from carbohydrates; lower percent daily intake from protein and fiber grams), and greater likelihood of exceeding the recommended calorie goal.

2 | MATERIALS AND METHODS

2.1 | Participants

Eligible participants were men and women who met the following criteria: body mass index (BMI) of 25–50 kg/m², aged 18–70 years,

and had been diagnosed by a physician with one or more cardiovascular disease risk factors (Type 2 diabetes, prediabetes, hypercholesterolemia, or hypertension). Exclusion criteria included: reporting a medical condition contraindicating weight loss, pregnant or breastfeeding within the last 6 months, enrolled in another weight loss program, reporting weight loss $\geq 5\%$ in the last 6 months, taking weight loss medication, history of a weight loss surgical procedure, or reporting a clinically diagnosed eating disorder, excluding Binge Eating Disorder.

2.2 | Procedure

Individuals were recruited on a rolling basis from October 2018 to September 2020 via advertisements in local newspapers, the research center's website, email newsletters through the Miriam Hospital and by physician referrals. Interested participants were contacted by phone and screened for eligibility. All assessments and treatment sessions occurred in-person until the beginning of the COVID-19 pandemic in March 2020, when regular in-person assessment visits were discontinued and participants received the remainder of their weight loss counseling via telephone. After confirming eligibility, participants provided informed consent at an in-person orientation, which was immediately followed by a baseline assessment. During the baseline assessment height and weight were measured, questionnaires completed, and participants were shown how to self-monitor dietary intake using either a paper record or the MyFitnessPal smartphone application, per their preference. Participants were asked to complete a 7-day run-in, in which the minimum criteria for starting treatment included tracking dietary intake (≥ 2 meals/day for 7 days) and gaining their physician's confirmation of eligibility (cardiovascular disease risk factor diagnosis) and permission to participate in the study.²⁹ Participants who met the run-in requirements began their initial treatment session approximately 1 week after their baseline appointment and continued weekly sessions for the first 12 weeks with monthly boosters during the final 12 weeks. Participants were asked to complete regular EMA surveys and phone-based 24-h dietary recalls (schedule for each assessment described below). The current study utilized data from the EMA surveys and phone-based dietary recalls, and the timing of these assessments were predeclared at the outset of this trial. All study procedures followed were in accordance with the ethical standards of the Miriam Hospital Institutional Review Board and in accordance with the Helsinki Declaration of 1975 as revised in 1983.

2.2.1 | Ecological momentary assessment protocol

At the first treatment session (week 1) participants were trained in how to complete EMA surveys, with once-per-month training refreshers throughout the 24-week study. Participants who did not own a smartphone were provided one. Ecological momentary assessment surveys were delivered through LifeData, a HIPAA-

compliant platform with iOS/Android compatible smartphone application ("app"). Participants were instructed to complete 7 days of EMA every other week starting on week 1, ending on week 23. Participants were prompted via app notification to complete EMA surveys semi-randomly throughout the day around 5 anchor times (9:00 a.m., 11:00 a.m., 2:00 p.m., 5:00 p.m., 8:00 p.m.), within ± 1 h of the anchor time. Semi-random prompting ensured an even distribution of assessment points throughout the day while minimizing reactivity.¹⁹ Participants had 1 h to complete the survey and received a reminder after 30 min. Ecological momentary assessment surveys measured dietary lapses and non-lapse eating occasions.²⁹ Note that analyses for this study only utilized EMA completed on days in which 24-h food recalls were conducted (see below).

2.2.2 | Dietary assessment

Reported dietary intake was measured via 24-h dietary recalls, a well-established dietary assessment tool, with demonstrated validity and reliability in estimating energy and macronutrient intake.³⁰⁻³² Telephone-based, 24-h dietary recalls were collected during weeks 1, 5, 11, 17, and 23 to coincide with the weeks of EMA surveys. Dietary recalls were collected by trained by research staff using the University of Minnesota Nutrition Data System for Research (NDSR) software (version 2018; Nutrition Coordinating Center, Minneapolis). On the week of assessment, participants provided their general availability and recalls were conducted on three random, non-consecutive days (2 weekdays, 1 weekend day) via telephone. Nutrition Data System for Research employs an automated multiple-pass method and a standardized portion-size manual, which has been shown to reduce measurement error.^{33,34} Participants were taught how to use the portion-size manual during their first treatment session (week 1) and were provided with a copy for use during the subsequent recalls. Nutrition Data System for Research also required the assessor to ask if the rating of recalled intake is more, less, or a typical amount of food for them (intake amount) and this variable was included in the below-described models. Nutrition Data System for Research output files were used to determine reported energy intake, as well as reported intake of grams of added sugars, saturated fat, and fiber, and percent daily intake from fat, carbohydrates, and protein.³⁵

2.3 | Lifestyle modification intervention

Both content and session structure of the lifestyle modification intervention were based on the Diabetes Prevention Program (DPP) and LookAHEAD trials.^{36,37} Consistent with DPP and LookAHEAD, each participant was given a calorie goal based on their starting weight (< 250 lbs, 1200–1500 kcals per day, and > 250 lbs, 1500–1800 kcals per day). In addition, participants were asked to follow the Mediterranean diet due to its association with improved cardiovascular health as well as successful weight loss.^{38,39} The Mediterranean

diet focuses on eating whole vegetables, whole grains, nuts and fruits, with a moderate intake of fish and poultry and low intake of dairy products, and red meat.³⁸ Participants were also provided with a physical activity prescription, with weekly goals for aerobic activity (i.e., a minimum of brisk walking) that worked up to 200 min/week of moderate intensity activity by week 12 of the program. Participants measured and tracked their daily calorie intake, physical activity and weight using My Fitness Pal. Treatment sessions were 30 min in length and conducted individually with postdoctoral level clinicians supervised by a licensed clinical psychologist. Each session covered personalized feedback on dietary intake and physical activity, and behavioral and cognitive strategies for meeting weight loss goals (e.g., meal planning, stimulus control, restaurant eating, stress management).

2.4 | Measures

2.4.1 | Dietary lapse

Each EMA survey assessed dietary lapses, defined as any “eating or drinking likely to cause weight gain, and/or put weight loss/maintenance at risk”,¹⁵ by asking participants to report whether they had experienced a lapse since the last survey. For the proposed analyses, reports of daily lapses were dichotomized by day; any day in which a participant reported a lapse (regardless of the number of lapses reported) was coded as a “lapse day” for that participant, conversely, any day in which a participant did not report a lapse was coded as a “non-lapse day” for that participant.

2.4.2 | Daily caloric intake, usual intake, and likelihood of exceeding daily calorie goal

Total daily caloric intake estimates were determined for each 24-h dietary recall using NDSR. Calorie goal differences were calculated by subtracting the upper limit of the prescribed daily calorie goal (i.e., 1500 kcals/day for <250 lbs and 1800 kcals/day for >250 lbs) from the NDSR total daily caloric intake; a dichotomous variable indicating whether the calorie goal was exceeded or not was created from these data and used in the below analyses. Usual intake was calculated using an average of weighted daily calorie intake estimates by weekend versus week day, and used as a covariate to account for between-subjects differences in day-to-day intake.

2.4.3 | Daily macronutrient intake

The following daily macronutrient estimates were determined for each 24-h dietary recall using NDSR: grams of added sugars, grams of saturated fat, percent daily intake from fat, percent daily intake from carbohydrates, percent daily intake from protein, and grams of fiber.

2.4.4 | Demographic information

A baseline assessment questionnaire collected participant demographics, including age, sex, race, and ethnicity.

2.4.5 | Weight and height

Baseline weight (kg) was measured to the nearest 0.1 kg using a calibrated digital scale. Height (mm) was measured during the baseline assessment using a wall-mounted stadiometer. Height and weight measurements were used to calculate BMI (kg/m²). Participants who completed the trial during the COVID-19 pandemic were encouraged to attend their final assessment in-person, with the appropriate precautions in place to reduce risk of exposure (e.g., sanitization, surgical-grade face masks), so that they could be weighed by the research staff. Those who declined an in-person appointment were permitted to self-weigh at home and report their weight to the research staff during a remote final assessment.

2.5 | Statistical approach

Given the nested structure of study days within individuals, multilevel modeling ([generalized] linear mixed models) was employed to acknowledge that both individual-level and day-level effects might contribute to variation in our dependent variables of interest (i.e., daily caloric intake, daily macronutrient intake, and exceeding the prescribed goal). Individual-level effects on dependent variables were considered using a test of significance for variance in a null model where participant identification number (ID) was the clustering variable. Data were analyzed with R version 4.0.2.⁴⁰ Descriptive statistics included means and standard deviations of dependent variables, as well as the independent variable of interest, daily dietary lapses. Assumptions of linearity were evaluated and met for independent variables and dependent variable of interest over time (days in the study). Assumptions of normality were tested for each dependent variable of interest and non-normal dependent variables (i.e., daily intake of saturated fat grams and daily intake of fiber grams) were log transformed.

Multilevel analyses were performed for all continuous dependent variables using linear mixed models with the “nlme” package.⁴¹ An autoregressive [AR (1)] correlation structure was used to account for greater correlations between caloric and macronutrient intake across adjacent days.⁴² Mixed effects logistic regression, with a binomial distribution and logit link function, was used to model the dichotomous dependent variable (exceeding one’s calorie goal) with the “lme4” package.⁴³ Maximum-likelihood estimation was used to account for missing data (days in which recall was completed but there were no EMA surveys completed). Analyses proceeded via an iterative model

building approach using a stepwise examination of a series of four nested models. First, a null model (Model 0) was assessed to examine the variation in dependent variables across participant ID (random effect) and estimate the intraclass correlation coefficient (ICC). Then, study day (i.e., numbered day on which assessment occurred) was added (Model 1) to determine whether the dependent variables varied linearly as a function of time. Within Model 1, study day was evaluated as both a fixed linear effect and as a random effect to determine whether individuals vary with regard to their rate of change over time. Third, individual-level predictors (i.e., age, sex, race, ethnicity, baseline BMI, usual intake) and day-level predictors (i.e., percent of EMA surveys completed, rating of recalled intake as more/less/typical amount of food [intake amount], and day of the week coded from 1 to 7) were added as fixed effects to control for their potential impact on the dependent variables (Model 2). In all models, intake amount and the day of the week of intake were not significant covariates; therefore, model building proceeded without them. All other covariates, regardless of whether they were significant, were retained in the model due to conceptual relevance. Fourth, a “lapse day” variable was added to the model as a fixed effect (Model 3). Dichotomizing a day as either having a lapse (i.e., “lapse day”) or not (i.e., “non-lapse day”) ensures that individuals reporting many more lapses do not skew the results.

2.5.1 | Sample size considerations

As detailed in Goldstein et al.²⁹ the target sample size ($N = 40$) was derived via a Monte Carlo simulation using data from prior work studying lapses and weight loss in the context of lifestyle modification (primary aim of the main trial). According to rules of thumb for multi-level modeling, the recruited sample of $N = 32$ (with an average of ~ 7 – 8 repeated observations per person [5 food recall assessment weeks, 3 daily recalls occurring each week, accounting for expected attrition and data loss]) was 80% powered to detect a minimum effect size between 0.25 and 0.26 at $\alpha = 0.05$, assuming a medium (ICC) of 0.3–0.5.⁴⁴ Because minimum detectable effects fall in the small-to-medium range in Cohen's effect size taxonomy,⁴⁵ this trial adequately powered to evaluate day-level effects of lapses on intake (a secondary aim of the main trial).²⁹

3 | RESULTS

3.1 | Participant characteristics

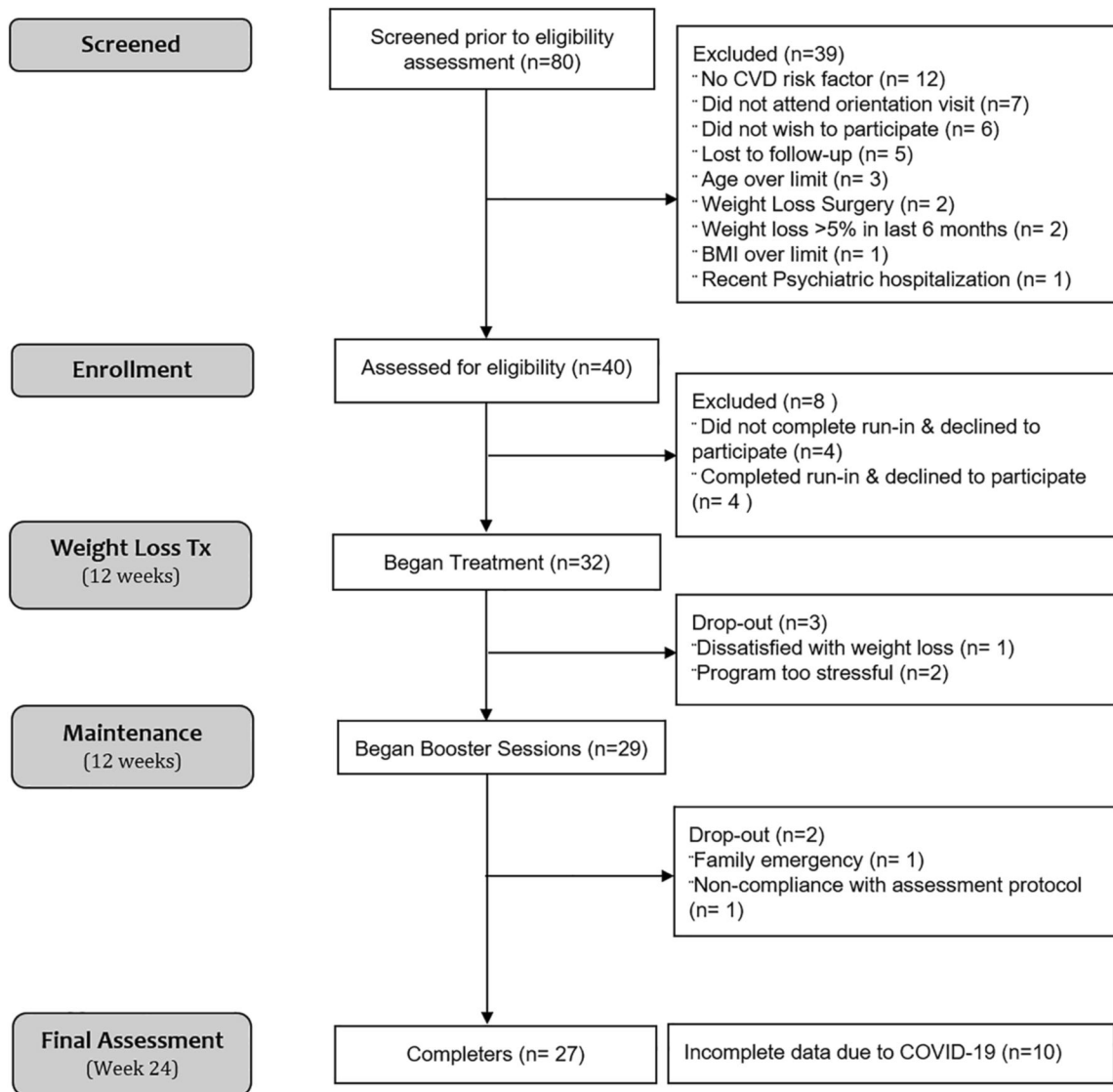
See Figure 1 for the CONSORT diagram, depicting participant flow through the trial. Analyses represent available data from 32 participants who attended and completed their first treatment session. As specified prior to the trial start, participants who dropped out of the program were no longer followed because assessment of dietary lapse (primary independent variable of interest) is dependent on

adhering to a dietary prescription.²⁹ Participants were majority female (68.8%), with an average BMI of 38.37 ($SD_{BMI} = 4.89$) and average age of 54.50 ($SD_{age} = 10.70$). The sample self-identified as 75.0% White, 9.4% Black or African American, and 15.6% “other”. Participants self-identified as 18.8% Hispanic or Latino. The majority of participants reported being college-educated (71.8%), working full- (50.0%) or part-time (43.8%), and having $> \$75,000$ per year annual income (56.3%). Participants self-reported diagnoses of high cholesterol (65.6%), hypertension (65.6%), and Type 2 diabetes (34.3%). Participants lost an average of 6.5% of their initial body weight ($SD_{\%weight\ loss} = 6.1\%$, $range_{\%weight\ loss} = -7.120.4\%$) during the 24-week intervention. Two participants self-reported their final weight using a home scale during the COVID-19 pandemic, and the remainder of participants attended an in-person assessment to provide their final study weight as described above. Missing data from participants who dropped out were imputed via baseline weight carried forward.

3.2 | Recalled intake and dietary lapses

There were 231 total food recalls conducted (across 5 timepoints and 32 participants). An average of 7.52 recalls per participant were conducted out of 15 possible recalls ($SD_{completed} = 2.95$, $range [0,12]$). There were 2 significant sources of data loss in this trial: (1) 30 food recalls were collected but were lost to hard-drive failure, and (2) 72 food recalls (and corresponding EMA data) were not collected due to halting study procedures for participant and researcher safety during the COVID-19 pandemic. One food recall was removed for poor intake reliability (i.e., participant could not reliably identify type/quantities of food consumed). Participants completed EMA surveys for 7-day periods every other week, resulting in 12 weeks of EMA in which participants completed 74.8% of all surveys.

Of the 231 recall days, 210 of them had associated EMA data ($M_{days/person} = 6.77$, $SD_{days/person} = 2.91$) and participants completed an average of 79.83% of EMA surveys administered on recall days ($SD_{\% EMA\ complete} = 19.34$). Of the 210 recall days with EMA, there were 60 days in which lapses were reported (“lapse days”) and 150 days in which no lapses were reported (“non-lapse days”). Chi square tests of independence indicated that participants were not significantly less likely to complete dietary recalls on lapse days ($\chi^2 [1] = 0.44$, $p = 0.51$) or significantly less likely to report lapses during weeks of dietary recall compared to non-recall weeks ($\chi^2 [11] = 8.81$, $p = 0.64$). Across the 60 lapse days, participants reported a total of 84 lapses, with an average of 2.71 total lapses per participant ($SD_{lapses} = 3.39$). There were 8 participants who had no “lapse days” that overlapped with recall days. On the 60 lapse days, participants reported an average of 1.28 lapses per recall day ($SD_{lapses} = 0.45$), with 71.67% of lapse days containing 1 lapse, 20.0% of lapse days containing 2 lapses, 5.0% containing 3 lapses, and 3.33% containing 4 lapses. Table 1 characterizes total recalled intake, as well as intake on lapse and non-lapse days. Consistent with the Strengthening the



Citation: Eldridge SM, Chan CL, Campbell MJ, Bond CM, Hopewell S, Thabane L, et al. CONSORT 2010 statement: extension to randomised pilot and feasibility trials. *BMJ*. 2016;355.

FIGURE 1 CONSORT diagram illustrating participant flow

Reporting of Observational Studies in Epidemiology guidelines, Figure 2 illustrates lapses and total caloric intake over time in the study.⁴⁶

3.2.1 | Association between daily lapses and daily caloric intake

Results from model development for the association between daily lapses and daily caloric intake are presented in Table 2. Examination of results from the null model (Model 0) with a random effect of participant ID estimated an ICC of 0.25, which indicates that the between-subjects difference in daily caloric intake is relatively low

(i.e., the majority of the variance in daily caloric intake is attributable to day-to-day variability within a given participant vs. overall differences between one participant and the next). In Model 1, days in the study had a non-significant effect on caloric intake, which is expected given the consistency of the dietary prescription throughout the lifestyle modification. The random effect of study day on caloric intake was not significant, and nested model comparison tests revealed that constraining it to zero did not significantly impact model fit ($\chi^2 [1] = 0.10, p = 0.75$). Thus, Models 2 and 3 included only the fixed effect of study days as a covariate. As expected, Model 2 demonstrated significant positive effects of a participant's usual intake on daily caloric intake. Consistent with hypotheses, a lapse day (compared to a non-lapse day) was

TABLE 1 Raw means of daily energy and macronutrient intake across 24-h food recalls, depicted across “lapse days” and “non-lapse days”

	Lapse days (n = 60)	Non-lapse days (n = 150)	No EMA completed (n = 21)	Total recalled intake (N = 231)	No lapse versus Lapse days unadjusted analysis
Caloric intake M (SD)	1793.85 (486.52)	1496.84 (416.13)	1528.89 (371.09)	1576.48 (448.35)	t (95.35) = -4.16***
Saturated fat grams M (SD)	20.37 (9.22)	19.27 (10.25)	15.81 (6.57)	19.21 (9.73)	t (120.04) = -0.75
Fiber grams M (SD)	24.24 (11.86)	20.89 (8.61)	23.69 (9.26)	22.03 (9.69)	t (85.01) = -1.99*
Percent energy from fat M (SD)	34.84 (9.26)	34.92 (9.71)	33.22 (10.83)	34.73 (9.68)	t (113.55) = 0.06
Percent energy from carbohydrates M (SD)	46.41 (11.48)	44.99 (11.43)	44.27 (12.9)	45.29 (11.57)	t (108.25) = -0.81
Percent energy from protein M (SD)	18.27 (6.03)	19.48 (6.49)	20.92 (5.99)	19.31 (6.35)	t (116.37) = 1.29
Added sugar grams M (SD)	42.47 (32.16)	27.43 (22.57)	21.73 (16.16)	30.73 (25.80)	t (83.26) = -3.13***
Calories exceeding goal M (SD) ^a	253.85 (500.84)	-79.16 (439.55)	-127.35 (364.89)	2.95 (472.89)	t (97.29) = -4.50***
Number of days calorie goal was exceeded N (%)	41 (68.3%)	69 (46.0%)	6 (28.6%)	116 (50.2%)	χ^2 (1) = 7.69**

^aNegative values indicate participants were under daily calorie goal, positive values indicate participants were over daily calorie goal.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

significantly positively associated with greater daily caloric intake in Model 3, such that lapse days conferred 139.20 more calories than non-lapse days.

3.3 | Association between daily lapses and macronutrient intake

Results from model development for the association between daily lapses and daily grams of added sugar intake are presented in Table 3. Examination of results from the null model (Model 0) with a random effect of participant ID estimated an ICC of 0.21, which indicates that the between-subjects difference in daily added sugar intake is relatively low. In Model 1, days in the study had a non-significant effect on added sugar intake, which suggests that participants were consistent in their added sugar consumption throughout the lifestyle modification. The random effect of study day on added sugar intake was significant, and nested model comparison tests revealed that constraining it to zero did significantly improve model fit (χ^2 [1] = 10.9, $p < 0.001$). Thus, Models 2 and 3 included fixed and random effects of days in the study. Model 2 demonstrated significant positive effects of age and ethnicity on added sugar intake, such that older individuals and individuals identifying as Hispanic demonstrated greater daily added sugar intake. Consistent with hypotheses, a lapse day (compared to a non-lapse day) was significantly positively associated with greater daily added sugar intake in Model 3, such that lapse days conferred 16.24 more grams of added sugar than non-lapse days.

The remainder of the macronutrient models were non-significant with regards to the association between dietary lapses and macronutrient intake. For brevity, the final model results

(Models 3) are briefly summarized here, and the full model development information is presented in Online Supplementary Tables S1-S5. All macronutrient intake variables met assumptions for normality except saturated fat grams and fiber grams, which were log transformed to meet the assumption of normality. The effects of daily dietary lapse on daily intake from fat ($B = -1.57$, $SE = 1.44$, $p = 0.28$), percent daily intake from carbohydrates ($B = 1.82$, $SE = 1.67$, $p = 0.27$), percent daily intake from protein ($B = -0.67$, $SE = 0.98$, $p = 0.49$), daily saturated fat grams ($B = -0.02$, $SE = 0.04$, $p = 0.65$), and daily fiber grams ($B = -0.001$, $SE = 0.03$, $p = 0.98$) were non-significant.

3.4 | Association between daily lapses and exceeding a recommended daily calorie goal

Results from model development for the association between daily lapses and exceeding one's daily calorie goal are presented in Table 4. Examination of results from the null model (Model 0) with a random effect of participant ID estimated an ICC of 0.21, which indicates that the likelihood of exceeding one's calorie goal varied each day within participants. In Model 1, days in the study had a non-significant effect on exceeding a daily calorie goal. The random effect of study day on exceeding a daily calorie goal was significant, and nested model comparison tests revealed that constraining it to zero significantly impacted model fit (χ^2 [2] = 12.12, $p < 0.01$). Thus, Models 2 and 3 included fixed and random effects of days in the study. Model 2 revealed no significant covariates, however they were retained for conceptual purposes. Note that usual intake was not included as a covariate in these models because the outcome variable does not involve estimates of intake. Consistent with hypotheses, Model 3

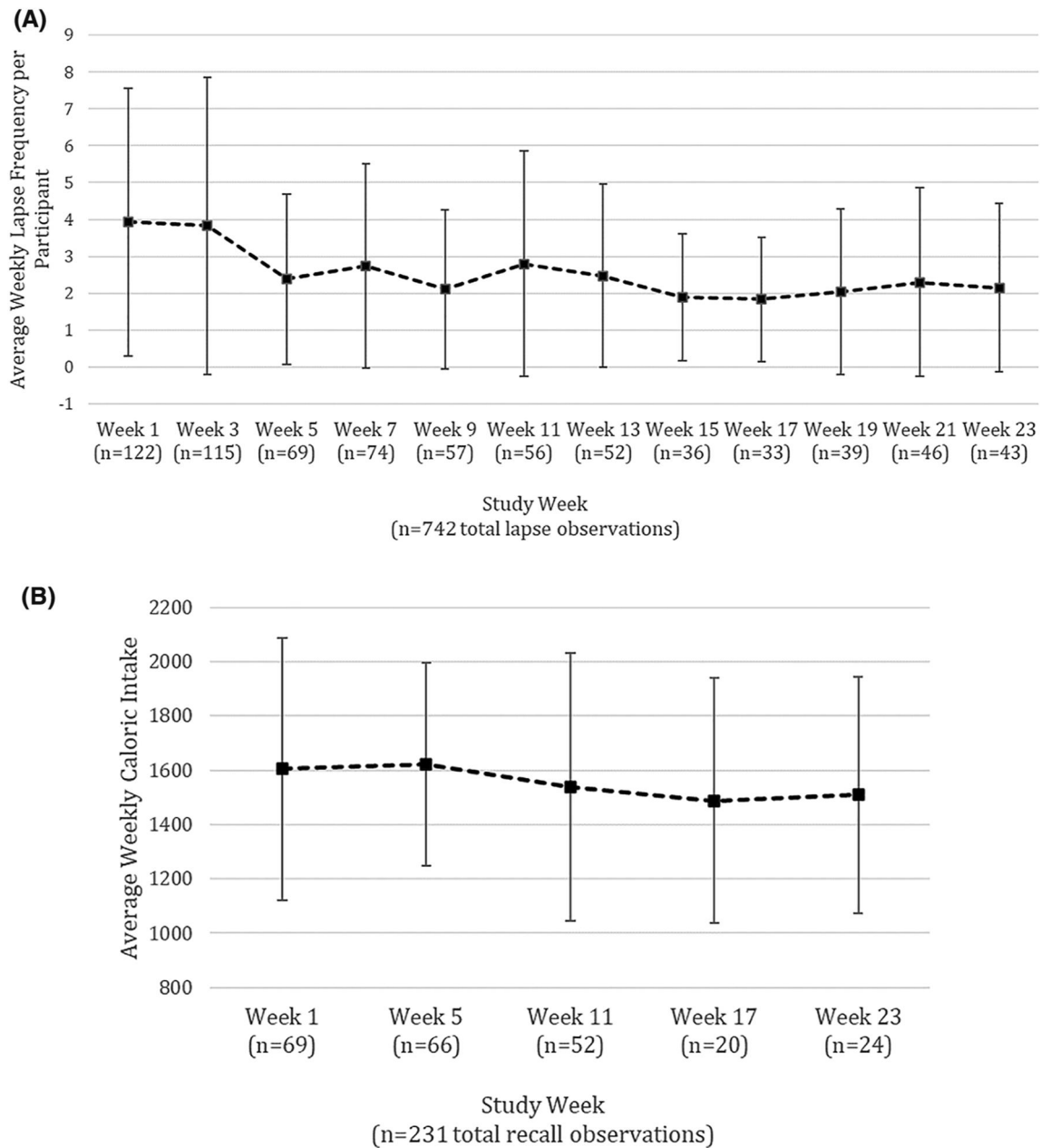


FIGURE 2 Average Weekly Lapse Frequency per Participant (Panel (A)) and Caloric Intake (Panel (B)) Over Time, Error Bars Represent ± 1 Standard Deviation from the Mean, n = total observations for each study week

showed that a lapse day was significantly positively associated with exceeding one's daily calorie goal, such that individuals on lapse days were 2.4 times more likely to exceed their calorie goal.

4 | DISCUSSION

This is the first study to investigate how self-identified dietary lapses, which are defined broadly as eating that is inconsistent with one or more dietary goals, affect reported dietary intake among individuals undergoing a lifestyle modification intervention. It is also the first to explore which macronutrients are implicated in lapse-associated

increased energy intake. Findings suggest that, when controlling for their usual intake, participants consumed significantly more calories and added sugar on days on which they reported dietary lapses. By accounting for one's usual intake, findings illustrate that lapses resulted in an individual consuming more than is usual for themselves, rather than just consuming more than what is typical for the entire sample.

Moreover, results support that increased intake on these days is clinically meaningful, as individuals were 2.4 times more likely to exceed their daily calorie goal if they reported a lapse. In comparison to prescribed calorie goals (1200–1800 kcals/day based on starting weight), participants consumed an unadjusted average of 253.85

	Model 0 B (SE)	Model 1 B (SE)	Model 2 B (SE)	Model 3 B (SE)
Intercept	1567.83 (48.49)***	1621.46 (58.38)***	127.21 (376.83)	124.48 (365.82)
Days in study ^a		-1.06 (0.63)	-0.72 (0.54)	-0.45 (0.52)
Sex ^c			-39.28 (70.23)	-10.53 (70.19)
Age			0.79 (2.92)	0.06 (2.88)
Race ^b			10.96 (93.51)	-12.12 (91.44)
Ethnicity ^b			-48.26 (104.97)	-31.07 (101.21)
Baseline BMI			-3.19 (5.54)	-1.97 (5.48)
EMA compliance			8.38 (119.39)	19.43 (116.34)
Intake amount ^d			-30.61 (33.98)	--
Usual intake			1.09 (0.13)***	0.99 (0.13)***
Day of intake			-7.48 (15.74)	--
Lapse day				139.20 (61.13)*
Fit statistics				
Model	AIC	BIC	Deviance	
Model 0	3488.23	3508.93	-1738.11	
Model 1	3453.08	3470.29	-1721.54	
Model 2	3096.46	3143.32	-1534.22	
Model 3	3091.28	3134.79	-1532.64	

Abbreviations: AIC, Akaike information criterion; BIC, Bayesian information criterion.

^aEntered as fixed effect in the model.

^bWhite is reference.

^cFemale is reference.

^dNormal amount is reference.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

calories (SD = 500.84) above their prescribed goal on lapse days compared to an unadjusted average of 79.16 calories (SD = 439.55) below their prescribed goal on non-lapse days. In the context of lapses occurring approximately 3–4 times per week,^{15,17} these data indicate that lapse days could contribute to an excess of approximately 750–1000 excess kcals per week. Thus, the cumulative effect of lapses over an entire course of lifestyle modification interventions lasting 6–12 months is likely to correspond to several pounds of potential weight loss that is not achieved (and represents potential for weight gain).

Results also indicate that sugar intake was significantly higher on lapse days, and could be responsible for the increase in energy intake on lapse days. However, the causality of this association is unknown. One explanation is that foods consumed during a lapse may contain more added sugar than other “on-plan” foods typically consumed on a lifestyle modification diet. Alternatively, consuming more sugar prior to a lapse could lead to a lapse later in the day. Calories from added sugars tend to provide poor satiation and have been shown to increase appetite in a feed-forward manner, which could lead participants to feel hungrier than usual and consequently lapse by overeating.^{47,48} Analyses in the current study focused on within-day

TABLE 2 Model results for association between daily lapses and daily caloric intake

associations, but future investigations using a more fine-grained temporal analytic approach could explore the causal direction of this relationship.

Despite their known associations with weight change, there was no significant association between lapse reporting and intake of saturated fat, total fat, carbohydrates, protein, or fiber.^{49–54} Notably, the contribution of sugar intake (approximately 16g, or given that added sugars are 4 kcals/g, 64 daily calories per day) is unlikely to account for the entire overall increase in calorie intake on lapse days (average of 139 kcal over non-lapse days). Other macronutrients may have also contributed to calories from lapses, but these associations may have been more difficult to detect as processed foods (which individuals are more likely to lapse on) have a mixed macronutrient profile. Another explanation is that the overall sample size ($n = 32$) did not capture enough variability in intake to reliably detect significant associations among these daily macronutrients. Moreover, analyses were confined to the major macronutrients, but there are many micronutrients (e.g., sodium intake)⁵⁵ not assessed here that could explain the elevated caloric intake on lapse days. In fact, larger daily variations are often observed in micronutrient intake while macronutrient intake tends to be consistent from day to day.⁵⁶

TABLE 3 Model results for association between daily lapses and added sugar grams

	Model 0 B (SE)	Model 1 B (SE)	Model 2 B (SE)	Model 3 B (SE)
Intercept	29.59 (2.67)***	28.89 (2.93)***	-56.96 (32.39)	-49.85 (31.88)
Days in study ^a		0.006 (0.42)	0.002 (0.05)	0.02 (0.05)
Sex ^c			-1.38 (5.65)	2.13 (5.67)
Age			0.72 (0.24)**	0.66 (0.24)*
Race ^b			1.14 (7.48)	1.11 (7.37)
Ethnicity ^b			21.93 (8.34)*	20.69 (8.08)*
Baseline BMI			0.19 (0.49)	0.36 (0.49)
EMA compliance			11.86 (8.19)	10.71 (7.74)
Intake amount ^d			1.52 (2.13)	--
Usual intake			0.004 (0.01)	-0.007 (0.01)
Day of intake			-0.61 (0.98)	--
Lapse day				16.24 (3.74)***
Fit statistics				
Model	AIC	BIC	Deviance	
Model 0	2153.43	2167.23	-1072.71	
Model 1	2127.73	2148.38	-1057.86	
Model 2	1955.02	2005.23	-962.51	
Model 3	1935.51	1982.37	-953.75	

Abbreviations: AIC, Akaike information criterion; BIC, Bayesian information criterion.

^aEntered as fixed and random effect in the model.

^bWhite is reference.

^cFemale is reference.

^dNormal amount is reference.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Overall, additional research with larger sample sizes and additional dietary quality measures is required to replicate and extend these findings.

Results from this study validate prior research indicating that individuals who report more dietary lapses tend to lose less weight,^{15,27} and that this association is likely in part driven by increased caloric intake above a prescribed calorie goal. The finding that lapses are associated with meaningful increases in daily caloric intake is especially interesting in light of the fact that participants were undergoing lifestyle modification intervention, which does employ cognitive and behavioral strategies to reduce lapse and improve adherence. Thus, this work indicates that more robust attempts to target dietary lapses in gold-standard lifestyle modification interventions may be needed to improve weight loss outcomes via reduced caloric intake. For example, outcomes may be strengthened by self-monitoring discrete lapse events in addition to self-monitoring overall daily caloric intake. Self-monitoring such information could improve awareness of lapses, as well as offer participants important insights regarding problem-solving and preventing these eating episodes.⁵⁷ Future work might also consider whether individuals who successfully meet weight loss goals can maintain their weight loss by

only tracking lapses during their weight loss maintenance period,⁵⁸ which would reduce participant burden (a common risk factor for disengagement, nonadherence, and weight regain).^{59,60} Lastly, these findings support the development of interventions that specifically target the prevention of lapse in order to improve weight loss outcomes, such as just-in-time interventions.²⁶

There were several strengths and limitations to this research. This study was strengthened by assessments of diet and eating behavior that maximize both feasibility and rigor relative to retrospective self-reports covering long durations or doubly-labeled water. Furthermore, assessments were conducted repeatedly over the course of a 6-month lifestyle modification protocol and therefore representative of participants' experiences across multiple phases of intervention (i.e., initial weight loss and weight loss maintenance). Lastly, this was the first study to focus on lapses specifically among individuals with overweight/obesity and cardiovascular disease risk. Future research should investigate whether dietary lapses are uniquely detrimental in adults already at increased risk for cardiovascular disease, and also replicate these findings among the general population of individuals with overweight/obesity undergoing lifestyle modification.

	Model 0 B (SE)	Model 1 B (SE)	Model 2 B (SE)	Model 3 B (SE)
Intercept	0.02 (0.23)	0.42 (0.32)	-1.05 (3.27)	-0.20 (2.99)
Days in study ^a		-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)
Sex ^c			1.33 (0.79)	-1.34 (0.75)
Age			0.03 (0.02)	0.02 (0.02)
Race ^b			-0.51 (0.76)	-0.62 (0.72)
Ethnicity ^b			0.45 (0.95)	0.69 (0.87)
Baseline BMI			-0.04 (0.06)	-0.04 (0.05)
EMA compliance			-1.72 (1.01)	-1.23 (0.92)
Intake amount ^d			-0.48 (0.25)	--
Day of intake			-0.09 (0.11)	--
Lapse day				0.89 (0.41)*
Fit statistics				
Model	AIC	BIC	Deviance	
Model 0	308.1	315.0	-152.0	
Model 1	300.2	317.4	-145.1	
Model 2	271.8	315.4	-122.9	
Model 3	270.0	310.2	-123.0	

^aEntered as fixed and random effect in the model.

^bWhite is reference.

^cFemale is reference.

^dNormal amount is reference.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

TABLE 4 Model results for association between daily lapses and exceeding the daily recommended calorie goal

Important study limitations must also be considered. First, data collection was interrupted by the COVID-19 pandemic, and some collected data were lost due to hard drive failure. This reduced the amount of data available for analysis, which is particularly important given the small sample size. Second, both lapses and dietary intake were documented via participant self-report, and there may be variability in reporting accuracy and reliability across participants. While analyses accounted for the variance in lapse reporting, results may be less generalizable to participants with limited insight into their lapse behavior or poor EMA compliance. Further, lapses could contribute to increased error in dietary intake reports, thus creating non-systematic error in 24-h food recall data. Third, analyses operationalized lapses as days, rather than momentary instances. This ensured that results remained conservative and robust to outliers (i.e., rare cases in which there were several lapses on a given day). Thus, it is unclear if excess calories or added sugars were consumed during a lapse event, or the extent to which the number of lapses affected intake. Future research examining lapses at the momentary level could investigate the effects of lapse severity (e.g., multiple daily lapses, or a reportedly large deviation from one's dietary prescription vs. a small one) on intake, as well as how lapses affect other proximal outcomes such as intake on subsequent days or treatment drop-out.

Fourth, lapses are difficult to measure among individuals who have dropped out of a lifestyle modification intervention (as they have no diet to lapse from or have substantially changed the diet/program they are following) and so these individuals were not followed. Results should be interpreted with caution, as they are representative of individuals who remain in lifestyle modification programs. Additional research is necessary to understand how patterns of dietary (non)adherence may differ between completers and drop-outs. Fifth, additional research will be required to replicate and extend the presented results to lapses from other types of lifestyle modification interventions with different dietary prescriptions, which could, in turn, impact the operationalization and reporting of dietary lapse.

This study contributes to a growing body of literature suggesting that dietary lapses pose a critical threat to weight loss success during lifestyle modification. Results highlight the importance of reducing lapse frequency to reduce overall caloric intake and added sugar consumption. Future research should explore the individualized nature of lapses via investigation of between- and within-subjects differences in foods consumed during lapses and non-lapse eating, and whether targeting lapse prevention during lifestyle modification interventions can improve dietary intake, weight loss and associated health outcomes.

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CONFLICT OF INTEREST

Dr. Thomas participates in a scientific advisory board and serves as a paid consultant for Lumme Health.

AUTHOR CONTRIBUTIONS

Stephanie P. Goldstein, J. Graham Thomas, and E. Whitney Evans designed research; Stephanie P. Goldstein, Hallie M. Espel-Huynh, and Carly M. Goldstein conducted research; E. Whitney Evans and J. Graham Thomas provided essential materials (access to NDSR software); Stephanie P. Goldstein, E. Whitney Evans, J. Graham Thomas, and Renee Karchere-Sun managed and analyzed data; Stephanie P. Goldstein, Hallie M. Espel-Huynh, Carly M. Goldstein, and Renee Karchere-Sun wrote the paper; Stephanie P. Goldstein had primary responsibility for final content. All authors read and approved the final manuscript.

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REFERENCES

- Wadden TA, Tronieri JS, Butryn ML. Lifestyle modification approaches for the treatment of obesity in adults. *Am Psychol*. 2020; 75(2):235.
- Heymsfield SB, Wadden TA. Mechanisms, pathophysiology, and management of obesity. *N. Engl J Med*. 2017;376(3):254-266.
- Curry SJ, Krist AH, Owens DK, et al. Behavioral weight loss interventions to prevent obesity-related morbidity and mortality in adults: US Preventive Services Task Force recommendation statement. *JAMA*. 2018;320(11):1163-1171.
- Gibson AA, Sainsbury A. Strategies to improve adherence to dietary weight loss interventions in research and real-world settings. *Behav Sci*. 2017;7(3):44.
- Alhassan S, Kim Soowon, Andrea Bersamin, King AC, Gardner CD. Dietary adherence and weight loss success among overweight women: results from the A TO Z weight loss study. *Int J Obes*. 2008;32(6):985-991.
- Warziski MT, Sereika SM, Styn MA, Music E, Burke LE. Changes in self-efficacy and dietary adherence: the impact on weight loss in the PREFER study. *J Behav Med*. 2008;31(1):81-92.
- Calugi S, Marchesini G, El Ghoch M, Gavasso I, Dalle Grave R. The association between weight maintenance and session-by-session diet adherence, weight loss and weight-loss satisfaction. *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity*. 2020; 25(1):127-133.
- Dansinger ML, Gleason JA, Griffith JL, Selker HP, Schaefer EJ. Comparison of the Atkins, Ornish, Weight Watchers, and Zone diets for weight loss and heart disease risk reduction: a randomized trial. *JAMA*. 2005;293(1):43-53.
- Del Corral P, Bryan DR, Garvey WT, Gower BA, Hunter GR. Dietary adherence during weight loss predicts weight regain. *Obesity*. 2011;19(6):1177-1181.
- Heymsfield SB, Harp JB, Reitman ML, et al. Why do obese patients not lose more weight when treated with low-calorie diets? A mechanistic perspective. *Am J Clin Nutr*. 2007;85(2):346-354.
- Thomas DM, Martin CK, Redman LM, et al. Effect of dietary adherence on the body weight plateau: a mathematical model incorporating intermittent compliance with energy intake prescription. *Am J Clin Nutr*. 2014;100(3):787-795.
- Miketinias DC, Bray GA, Beyl RA, Ryan DH, Sacks FM, Champagne CM. Fiber intake predicts weight loss and dietary adherence in adults consuming calorie-restricted diets: the POUNDS lost (preventing overweight using novel dietary strategies) study. *J Nutr*. 2019;149(10):1742-1748.
- Carels RA, Douglass OM, Cacciapaglia HM, O'Brien WH. An ecological momentary assessment of relapse crises in dieting. *J Consult Clin Psychol*. 2004;72(2):341.
- Carels RA, Hoffman J, Collins A, Raber AC, Cacciapaglia H, O'Brien WH. Ecological momentary assessment of temptation and lapse in dieting. *Eat Behav*. 2001;2(4):307-321.
- Forman EM, Schumacher LM, Crosby R, et al. Ecological momentary assessment of dietary lapses across behavioral weight loss treatment: characteristics, predictors, and relationships with weight change. *Ann Behav Med*. 2017;51(5):741-753.
- Forman EM, Goldstein SP, Zhang F, et al. OnTrack: development and feasibility of a smartphone app designed to predict and prevent dietary lapses. *Translational behavioral medicine*. 2019;9(2): 236-245.
- Goldstein SP, Zhang F, Thomas JG, Butryn ML, Herbert JD, Forman EM. Application of machine learning to predict dietary lapses during weight loss. *Journal of diabetes science and technology*. 2018;12(5): 1045-1052.
- Goldstein SP, Brick LA, Thomas JG, Forman EM. Examination of the relationship between lapses and weight loss in a smartphone-based just-in time adaptive intervention. *Translational Behavioral Medicine*. 2021;11(4):993-1005.
- Shiffman S, Stone AA, Hufford MR. Ecological momentary assessment. *Annu Rev Clin Psychol*. 2008;4:1-32.
- Grilo CM, Shiffman S, Wing RR. Relapse crises and coping among dieters. *J Consult Clin Psychol*. 1989;57(4):488.
- Thomas JG, Doshi S, Crosby RD, Lowe MR. Ecological momentary assessment of obesogenic eating behavior: combining person-specific and environmental predictors. *Obesity*. 2011;19(8):1574-1579.
- Tomiya AJ, Mann T, Comer L. Triggers of eating in everyday life. *Appetite*. 2009;52(1):72-82.
- Riley WT, Nilsen WJ, Manolio TA, Masys DR, Lauer M. News from the NIH: potential contributions of the behavioral and social sciences to the precision medicine initiative. *Translational behavioral medicine*. 2015;5(3):243-246.
- Goldstein SP, Dochat C, Schumacher LM, et al. Using ecological momentary assessment to better understand dietary lapse types. *Appetite*. 2018;129:198-206.
- Zellerbach K, Ruiz C. Machine learning to predict overeating from macronutrient composition. Paper presented at: 2019 IEEE International Conference on Bioinformatics and Biomedicine. BIBM; 2019.
- Goldstein SP, Evans BC, Flack D, et al. Return of the JITAI: applying a just-in-time adaptive intervention framework to the development of m-health solutions for addictive behaviors. *Int J Behav Med*. 2017;24(5):673-682.

27. Forman EM, Goldstein SP, Crochiere RJ, et al. Randomized controlled trial of OnTrack, a just-in-time adaptive intervention designed to enhance weight loss. *Translational behavioral medicine*. 2019;9(6):989-1001.
28. Tulu B, Ruiz C, Allard J, et al. SlipBuddy: a mobile health intervention to prevent overeating. Paper presented at: Proceedings of the 50th Hawaii international conference on system sciences 2017.
29. Goldstein SP, Hoover A, Evans EW, Thomas JG. Combining ecological momentary assessment, wrist-based eating detection, and dietary assessment to characterize dietary lapse: a multi-method study protocol. *Digital Health*. 2021;7:2055207620988212.
30. Carter RL, Sharbaugh CO, Stapell CA. Reliability and validity of the 24-hour recall. *J Am Dietetic Assoc*. 1981;79(5):542-547.
31. Casey PH, Goolsby SL, Lensing SY, Perloff BP, Bogle ML. The use of telephone interview methodology to obtain 24-hour dietary recalls. *J Am Dietetic Assoc*. 1999;99(11):1406-1411.
32. Jonnalagadda SS, Mitchell DC, Smiciklas-Wright H, et al. Accuracy of energy intake data estimated by a multiple-pass, 24-hour dietary recall technique *J Am Dietetic Assoc*. 2000;100(3):303-311.
33. Steinfeldt L, Anand J, Murayi T. Food reporting patterns in the USDA automated multiple-pass method. *Procedia Food Sci*. 2013;2:145-156.
34. Conway JM, Ingwersen LA, Moshfegh AJ. Accuracy of dietary recall using the USDA five-step multiple-pass method in men: an observational validation study. *J Am Dietetic Assoc*. 2004;104(4):595-603.
35. Schakel SF. Maintaining a nutrient database in a changing marketplace: keeping pace with changing food products—a research perspective. *J Food Compos Analysis*. 2001;14(3):315-322.
36. Diabetes Prevention Program Research Group. The Diabetes Prevention Program (DPP): description of lifestyle intervention. *Diabetes Care*. 2002;25(12):2165-2171.
37. Look AHEAD Research Group. Look AHEAD (Action for Health in Diabetes): design and methods for a clinical trial of weight loss for the prevention of cardiovascular disease in type 2 diabetes. *Contr Clin Trials*. 2003;24(5):610-628.
38. Shai I, Schwarzfuchs D, Henkin Y, et al. Weight loss with a low-carbohydrate, mediterranean, or low-fat diet. *N. Engl J Med*. 2008;359(3):229-241.
39. Poulimeneas D, Anastasiou CA, Santos I, Hill JO, Panagiotakos DB, Yannakoulia M. Exploring the relationship between the Mediterranean diet and weight loss maintenance: the MedWeight study. *Br J Nutr*. 2020;124(8):874-880.
40. Team R. *RStudio: Integrated Development for R*. RStudio, Inc; 2015.
41. Pinheiro J, Bates D, DebRoy S, Sarkar D, Team RC. nlme: linear and nonlinear mixed effects models. *R package version*. 2013;3(1):111.
42. Bolger N, Laurenceau J-P. *Intensive Longitudinal Methods: An Introduction to Diary and Experience Sampling Research*. Guilford Press; 2013.
43. Bates D, Maechler M, Bolker B, et al. Package 'lme4'. *Version*. 2018;1(17):437.
44. Arend MG, Schäfer T. Statistical power in two-level models: a tutorial based on Monte Carlo simulation. *Psychol methods*. 2019;24(1):1-19.
45. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. Academic press; 2013.
46. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Bull World Health Organ*. 2007;85:867-872.
47. Bellisle F, Drewnowski A, Anderson GH, Westerterp-Plantenga M, Martin CK. Sweetness, satiation, and satiety. *J Nutr*. 2012;142(6):1149S-1154S.
48. Low YQ, Lacy K, Keast R. The role of sweet taste in satiation and satiety. *Nutrients*. 2014;6(9):3431-3450.
49. Phillips CM, Kesse-Guyot E, McManus R, et al. High dietary saturated fat intake accentuates obesity risk associated with the fat mass and obesity-associated gene in adults. *J Nutr*. 2012;142(5):824-831.
50. Lissner L, Heitmann BL. Dietary fat and obesity: evidence from epidemiology. *Eur J Clin Nutr*. 1995;49(2):79-90.
51. Hill JO, Melanson EL, Wyatt HT. Dietary fat intake and regulation of energy balance: implications for obesity. *J Nutr*. 2000;130(2):284S-288S.
52. Sartorius K, Sartorius B, Madiba TE, Stefan C. Does high-carbohydrate intake lead to increased risk of obesity? A systematic review and meta-analysis. *BMJ Open*. 2018;8(2):e018449.
53. van Dam RM, Seidell JC. Carbohydrate intake and obesity. *Eur J Clin Nutr*. 2007;61(1):S75-S99.
54. Merchant AT, Anand SS, Vuksan V, et al. Protein intake is inversely associated with abdominal obesity in a multi-ethnic population. *J Nutr*. 2005;135(5):1196-1201.
55. Grimes C, Riddell L, Campbell K, Nowson C. Sugar-sweetened beverage consumption and risk of obesity in Australian children: could dietary salt be contributing to sugar-sweetened beverage consumption? *J Acad Nutr Dietetics*. 2011;11(9).
56. Champagne CM, Han H, Bajpeyi S, et al. Day-to-day variation in food intake and energy expenditure in healthy women: the dietitian II study. *J Acad Nutr Dietetics*. 2013;113(11):1532-1538.
57. Burke LE, Wang J, Sevick MA. Self-monitoring in weight loss: a systematic review of the literature. *J Am Dietetic Assoc*. 2011;111(1):92-102.
58. Gass JC, Funderburk JS, Shepardson R, Kosiba JD, Rodriguez L, Maisto SA. The use and impact of self-monitoring on substance use outcomes: a descriptive systematic review. *Subst Abuse*. 2021;42(4):1-36.
59. Burke LE, Swigart V, Warziski Turk M, Derro N, Ewing LJ. Experiences of self-monitoring: successes and struggles during treatment for weight loss. *Qual health Res*. 2009;19(6):815-828.
60. Befort CA, Stewart EE, Smith BK, Gibson CA, Sullivan DK, Donnelly JE. Weight maintenance, behaviors and barriers among previous participants of a university-based weight control program. *Int J Obes*. 2008;32(3):519-526.

SUPPORTING INFORMATION

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