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Week-to-Week Predictors of Weight Loss and Regain

Kathryn M. Ross, Ph.D., M.P.H.[1,2], **Peihua Qiu, Ph.D.**[3], **Lu You, B.S.**[3], **Rena R. Wing, Ph.D.**[2]

[1]Department of Clinical & Health Psychology, College of Public Health and Health Professions, University of Florida, Gainesville, Florida [2]Department of Psychiatry and Human Behavior, Warren Alpert Medical School of Brown University, The Miriam Hospital/Weight Control and Diabetes Research Center, Providence, Rhode Island [3]Department of Biostatistics, College of Public Health and Health Professions & College of Medicine, University of Florida, Gainesville, Florida

Abstract

Objectives: Despite increased interest in the development of individually-tailored weight management programs, little is known about what factors proximally predict weight change.

Method: The current study investigated proximal (week-to-week) predictors of weight loss/regain in 74 adults during a 3-month, Internet-based behavioral weight loss program followed by a 9-month “maintenance” period (during which no additional intervention was provided). Participants were asked to self-weigh daily using scales which transmitted weight via the cellular network and to answer a brief questionnaire each week querying mood, behaviors, and cognitions hypothesized to be associated with weight loss/regain.

Results: Longitudinal multilevel models demonstrated that weight loss during initial intervention was proximally predicted by greater frequency of self-monitoring weight and caloric intake, consistency between eating choices and weight loss goals, and importance of “staying on track” with these goals, and less negative mood, boredom with weight control efforts, hunger, and temptation to eat foods “not on plan” (*p*s<.05). Greater weight regain after intervention was also proximally predicted by these factors (with effects in the opposite direction), and additionally by less physical activity, less positive mood, more stress, greater temptation to skip planned physical activity, and higher ratings of the amount of effort required to stay on track (*p*s<.05).

Conclusions: Results confirmed the importance of self-monitoring for weight loss/maintenance and identified other key week-to-week predictors of weight change. Results also supported efforts to develop intervention approaches specifically focused on weight loss maintenance. Future research should investigate whether using identified predictors to tailor intervention content/timing can improve weight outcomes.

Corresponding author information is below: Kathryn M. Ross, Ph.D. M.P.H., Department of Clinical & Health Psychology, College of Public Health & Health Professions, University of Florida, PO Box 100165, Gainesville, FL 32610-0165, Phone: 352-294-8433, kmross@phhp.ufl.edu.

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Keywords

weight loss; weight gain; weight reduction programs; behavior and behavior mechanisms; obesity/therapy

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Behavioral weight management interventions have been demonstrated to produce average weight losses of 8–10% of initial body weight (Butryn, Webb, & Wadden, 2011); however, there exists substantial individual variability in weight change experienced by participants during and after intervention (MacLean et al., 2014). This pattern, coupled with the proliferation of smartphones and digital health monitoring tools, has led to increased interest in the development of flexible, individually-tailored interventions. Newer treatment frameworks, such just-in-time adaptive interventions (JITAIs), offer promise to improve intervention outcomes by utilizing these technological advances to dynamically adapt the timing and content of intervention based on individuals' changing behaviors, cognitions, and environment (Nahum-Shani et al., 2018, 2014). For example, JITAIs have been developed that tailor intervention provision to times when an individual is identified to be at "high risk" for behaviors such as smoking (Naughton et al., 2016) or overeating (Forman et al., 2018).

A key step necessary for the development of individually-adaptable weight management programs is the selection of "tailoring variables," or factors that can be monitored and used to trigger intervention (Nahum-Shani et al., 2014). Previous research has demonstrated a host of behavioral and psychological factors associated with weight change during and after intervention. On the behavioral side, successful weight loss and weight loss maintenance have been associated with greater frequency of self-monitoring of weight and dietary intake (Burke, Wang, & Sevick, 2011; Butryn, Phelan, Hill, & Wing, 2007; Laitner, Minski, & Perri, 2016; Peterson et al., 2014; Wing, Tate, Gorin, Raynor, & Fava, 2006; Zheng et al., 2015, 2015), continued adherence to a reduced calorie diet (Johns, Hartmann-Boyce, Jebb, & Aveyard, 2014; Klem, Wing, McGuire, Seagle, & Hill, 1997; McGuire, Wing, Klem, Lang, & Hill, 1999; Sacks et al., 2009), and high levels of physical activity (Donnelly et al., 2009; Johns et al., 2014). Further, psychological factors such as higher levels of stress (Elfhag & Rössner, 2005; Gormally & Rardin, 1981; Kayman, Bruvold, & Stern, 1990), hunger (Cuntz, Leibbrand, Ehrig, Shaw, & Fichter, 2001; Elfhag & Rössner, 2005; McGuire et al., 1999; Pasman, Saris, & Westerterp-Plantenga, 1999), boredom (Grilo, Shiffman, & Wing, 1989; Walfish, 2004), perceived effort required for weight control (Byrne, Cooper, & Fairburn, 2003; Klem, Wing, Lang, McGuire, & Hill, 2000), and negative affect or, conversely, lower levels of positive affect (Carels, Douglass, Cacciapaglia, & O'Brien, 2004; Cuntz et al., 2001; Grilo et al., 1989; Walfish, 2004) have been associated with less weight loss/greater weight regain.

Unfortunately, methodological issues limit the ability to use this existing evidence to select intervention tailoring variables. Previous research has largely utilized data collected via self-report, retrospective recall measures collected at sparsely-spaced follow-up visits (often scheduled at 3 to 6-month intervals). Beyond potential bias introduced by social desirability (Krumpal, 2013; Sitzia & Wood, 1997), research has indicated that retrospective recall measures may be biased by emotions, appraisals, and behaviors at the time of recall

(Durante & Ainsworth, 1996; Dwyer & Coleman, 1997; Kihlstrom, Eich, Sandbrand, & Tobias, 2000; Levine & Safer, 2002). In particular, two studies have demonstrated that retrospective recall data collected after the end of a weight management program can be biased by treatment outcome, such that participants that lost less or regained more weight exhibited greater negative recall biases (Ross & Wing, 2018; Wadden, Stunkard, & Smoller, 1986). Further, the sparse nature of data collected only at follow-up assessment visits precludes the development of “decision rules” to serve as thresholds or cut-offs for intervention tailoring variables (Spruijt-Metz et al., 2015).

More recently, studies have implemented ecological momentary assessment (EMA) methods to collect more proximal data (Shiffman, Stone, & Hufford, 2008; Stone & Shiffman, 1994). In these studies, participants are often prompted throughout the day (e.g., via phone call or a text/alert on a mobile device) and asked to complete questionnaires assessing environmental, behavioral, and psychological factors hypothesized to predict health behaviors. Researchers have used EMA methods to identify factors proximally associated with dietary lapses, such as positive and negative mood, hunger, reports of cravings/temptation, and use of coping mechanisms such as whether an individual thought of their long-term weight loss goal in the face of temptation and whether they considered that long-term weight loss goal important (Carels et al., 2004; Forman et al., 2017; McKee, Ntoumanis, & Taylor, 2014).

Due to the intensity of data collection and accompanying response burden for participants, EMA methods are often used for short periods only (e.g., a few days to a week). This limits the utility of these data for assessing more distal outcomes (e.g., weight change versus just a single dietary lapse) and for assessing patterns of associations over time. One study, conducted by Kwasnicka and colleagues (2017) attempted to overcome this barrier when assessing weight regain after initial weight loss. In this study, eight adults who had intentionally lost a clinically-significant amount of weight (defined as ≥ 5% of initial weight) were asked to complete questionnaires daily for 6 months. Results demonstrated that lower self-reported adherence to weight management plans was proximally associated with lower ratings of motivation, less appreciation for the benefits of weight loss, lower ratings of importance of following weight management plans compared to other activities/goals, reduced confidence in ability to follow weight management plans, greater temptation to break weight loss maintenance plans, and greater number of barriers reported. The authors also reported that visual inspection of graphs suggested that adherence to weight management plans corresponded with weight change; however this was not examined statistically. Overall, this study demonstrated preliminary evidence for several proximal predictors of weight regain, but interpretation of results was limited due to the small sample size.

The current study attempted to overcome existing methodological issues to identify the factors proximally associated with weight loss during and weight regain after a 3-month behavioral weight management program. Participants were asked to weigh themselves daily using “smart” scales which used the cellular network to send weights directly back to research servers, and to complete a questionnaire each week that assessed mood, behaviors, and cognitions which previous research suggested may be associated with weight loss/regain. First, it was hypothesized that greater weight losses on a given week during initial intervention would be associated with greater frequency of self-weighing and self-monitoring caloric intake, higher ratings of positive mood, consistency between eating/activity choices and weight loss goals, and importance of staying on track with weight loss goals relative to other competing life demands, and lower ratings of negative mood, stress, hunger, boredom with weight management efforts, temptation to eat foods not consistent with weight loss goals or to skip physical activity, and perceived effort of staying on track with weight management goals. Second, it was hypothesized the inverse association between these factors and weight regain would be observed during a 9-month post-intervention maintenance period. Third, it was hypothesized that the patterns of associations observed in these correlational models (with mood, behaviors, and cognitions assessed on the same week as weight change) would also be observed in predictive models (with mood, behaviors, and cognitions assessed on one week predicting weight change the next week).

Methods

Participants.

The current study analyzed data collected for a full year during and after the implementation of a 3-month, Internet-based behavioral weight management intervention in a worksite setting. Full inclusion/exclusion criteria, information regarding participant recruitment, and intervention weight loss outcomes have been published previously (Ross & Wing, 2016). Briefly, participants in the parent study were 75 employees (or dependents of employees) of a large healthcare corporation in Providence, Rhode Island who elected to take part in a worksite wellness program. Within this sample, 70.6% of participants had obtained at least one college or university degree and 67% of participants had household incomes above $75,000 year. Eligibility criteria for the parent study included age between 18 and 70 years old and body mass index (BMIs) equal or greater to 25 kg/m^2 (but weight < 150 kg due to restrictions of the study-provided body weight scale), and access to a computer and Internet at home. All participants provided written informed consent prior to completing in-person screening for these eligibility criteria.

To be eligible for the current study, participants were required to have weighed themselves using the study smart scale and reported questionnaire data for at least one week. Of the 75 participants in the initial intervention, 74 met these additional criteria and were included in the current study. These participants were an average (mean ± SD) of 50.65 ± 10.41 years old, weighed an average of 86.65 ± 16.76 kg, and had an average BMI of 31.20 ± 4.51 kg/m^2 (Ross et al., 2019). Moreover, 68.9% were female and, in terms of race, 86.5% of participants reported identifying as White, 9.5% as African American or Black, 2.7% as Asian, 1.4% as American Indian or Alaskan Native, and 5.4% selected “other” (participants could self-select more than one race category, thus totals may exceed 100%). In terms of ethnicity, 2.7% of participants identified as Hispanic or Latino. The parent study was approved by The Miriam Hospital Institutional Review Board and the current analyses were also approved by the University of Florida Institutional Review Board.

Intervention.

After completing baseline assessment measures, participants were asked to return for a one-time "Weight Loss 101" educational session. At this session, participants were taught how to use the study website and were given initial goals for caloric intake (1200 – 1800 kcal/day, based on baseline weight) and physical activity (to gradually increase engagement in moderate-intensity physical activity to an eventual goal of 200 minutes/week). Participants were also taught how to self-monitor caloric intake (using paper self-monitoring records and a printed calorie reference book), physical activity (using the same paper self-monitoring record, recording total minutes of moderate- or vigorous-intensity physical activity that lasted for at least 10 minutes per bout), and weight (using the paper records and study-provided BodyTrace "smart" scales, weighing first thing in the morning, before eating/drinking but after voiding, and recording this weight in the same paper self-monitoring record). Participants were given the option self-monitoring caloric intake and physical activity via alternative methods (e.g., using websites/smartphone application or commercial fitness monitors), but these tools/services were not provided by the study. Participants were asked to self-monitor caloric intake, physical activity, and weight daily. After the initial introductory session, participants were asked to log into a study website once each week to view an interactive education module (lasting between 12 and 15 minutes). New modules released each Monday. Participants were also asked to log in each Sunday to submit self-monitoring data (caloric intake, and minutes of physical activity, and weight for each day of the previous week) and answer a brief 11-item self-report questionnaire. At their next log in (starting the following morning), participants were provided automated feedback based on self-monitoring data (no feedback was given in response to the 11-item questionnaire responses). After the end of the 3-month program, participants were asked to continue to log into the website each Sunday to complete the 11-item self-report questionnaire and to report the number of days that they self-monitored caloric intake and weight and their total minutes of physical activity for the week, but no automated feedback was provided and participants no longer had access to any of the intervention website components.

Measures.

At baseline, demographic information was collected via self-report questionnaire and participant height was measured to the nearest 0.1 cm using a wall-mounted stadiometer, with participant shoes removed. Weight was measured at baseline and follow-up assessment visits to the nearest 0.1 kg using a calibrated digital scale, with participants in light indoor clothing and with shoes removed. Participant body mass index (BMI) was calculated using assessment height and weight data. Weight data over the study year was also collected from study smart scales (collected in lb and converted to kg), and frequency of self-weighing was calculated as a count of the number of days that participants used the smart scale each week. Frequency of self-monitoring caloric intake and total minutes of physical activity each week were collected via the study website. During the 3-month intervention, participants were asked to log into the study website at the end of each week and self-report their total caloric intake and minutes of physical activity for each day. From this data, a count of the number of days each week that caloric intake was self-monitored was calculated and total minutes of physical activity per week were summed. During the 9-month maintenance period, participants were asked at the end of each week to self-report the number of days that they monitored their caloric intake and their total minutes of physical activity for the previous week, producing count variables on the same scale as those calculated from intervention data. Weekly minutes of physical activity over the entire study were converted into hours to ease interpretation of results.

At the end of each week, participants were asked to complete a questionnaire on the study website on which they rated (on a 1–7 Likert-type scale) positive mood, negative mood, stress, hunger, boredom with weight control efforts, temptation to eat foods not on their plan, temptation to skip planned physical activity, the degree to which eating choices were consistent with weight loss goals, the degree to which physical activity choices were consistent with weight loss goals, the amount of effort that it took to stay on track, and the importance of staying on track, compared to other demands in life. Participants were asked to rate these items over the prior week. Higher ratings for each item indicated greater endorsement of that item (e.g., for the question "How positive was your mood during the past week?," 1 = "Not positive at all," 7 = "Very positive"; see online-only supplement for the full questionnaire).

Participants were provided with small financial incentives to encourage weekly self-report of data (and completion of the 11-item questionnaire) during the study year. Incentives ranged from $1–10 per week (with an average of $3.50 per week, and a max of $156 that could be received over the course of the year), and with amounts selected in a pattern unknown to participants. Earned incentives were stored in a digital bank and were redeemed every 3 months at in-person assessment visits. Importantly, incentives were provided based on submission of data, not for the completion of self-monitoring records; participants could still receive the incentive if they reported that they did not self-monitor. Participants were not provided with reminders to log into the study website.

Statistical Analyses.

Analyses were conducted using R version 3.1.3 (R Core Team, 2015) and SAS version 9.4 (SAS Institute Inc., 2013). Missing assessment weight data were imputed with smart scale data; if not available, a missing not-at-random (MNAR) approach was taken wherein participants were assumed to have regained 0.3 kg/month from the last smart scale data point, based on the documented pattern of weight regain after behavioral intervention (Jeffery et al., 2000; Perri et al., 2008; Wadden et al., 2005). At Month 3, in-person assessment weight data were available for 94.6% of participants (of the 4 participants who did not attend this visit, 3 had smart scale data within range of their scheduled assessment, and 1 had a past smart-scale weight value imputed under this MNAR approach). At Month 12, in-person weight data were available for 89.2% of participants (of the 8 participants who did not attend the in-person visit, smart scale weight data were available for 4 participants and the remaining 4 participants had smart-scale weight values imputed under the MNAR approach). Methods for cleaning the smart scale data have been reported previously (Ross, Eastman, & Wing, 2019).

R package *locfit* was used to fit LOESS local regression models by individual, providing an estimated slope of weight change each week (weeks with a negative slope indicated weight loss and weeks with a positive slope indicated weight gain/regain). Overall weight change from baseline through week 12 (3-month initial intervention) and from week 13 through week 52 (9-month observational "maintenance" period) was modeled using these smoothed slopes. Descriptive statistics were used to assess weekly variation in weight, frequency of self-weighing, frequency of self-monitoring of caloric intake and physical activity, and self-report questionnaire ratings during the 3-month intervention and the 9-month maintenance period. Paired samples t-tests were used to investigate mean changes in frequency of self-weighing and self-monitoring caloric intake, hours of physical activity, and self-report questionnaire ratings between the 3-month intervention and 9-month maintenance period. Finally, longitudinal multilevel models (nesting weeks within individuals, using SAS proc MIXED) were used to assess univariate associations between frequency of self-weighing and self-monitoring caloric intake, hours of physical activity, and ratings of the self-report questionnaire items assessed on a given week and weight change both the same week (described as "correlational models") and the *following* week (described as "predictive models"). Associations were modeled separately for the initial 3-month intervention and the 9-month maintenance period.

Results

Rates of Weight Loss and Regain

Using assessment weight data, participants lost on average (mean± SD) −5.78 ± 4.91 kg (−6.42 ± 4.81 % of their baseline weight) during the 3-month intervention, and experienced an average regain of 2.42 ± 3.64 kg (a 2.98 ± 4.50 % increase from Month 3) during the 9-month maintenance period (weeks 13–52). On average, participants self-weighed using the smart scale on 259.11 ± 80.14 days (71.18 ± 22.02% of 364 possible days) and completed the questionnaire on 37.32 ± 14.43 weeks (71.78 ± 27.75% of 52 possible weeks). There was a trend for the amount of incentives received for self-reporting data to be associated with weight change from baseline to Month 12, $r = -0.23$, $p = .045$.

Table 1 provides the weekly averages for self-weighing, self-monitoring of caloric intake, physical activity, and questionnaire ratings during the initial 3-month intervention and the 9-month maintenance period. Compared to the initial intervention, during the maintenance period participants self-weighed and self-monitored caloric intake on fewer days per week and engaged in less physical activity. Further, during the maintenance period participants reported greater boredom with weight control efforts, greater temptation to skip planned physical activity, that their eating and physical activity choices were less consistent with weight loss goals, and that it was less important to stay on track with weight loss goals compared to other life demands.

Weekly Predictors of Weight Loss and Regain

During the initial 3-month intervention, weight loss within a given week was concurrently associated with greater frequency of self-weighing and self-monitoring of caloric intake, higher ratings of positive mood, whether eating choices were consistent with weight goals, and importance of "staying on track" compared to other life demands, and lower ratings of negative mood, hunger, boredom with weight control efforts, temptation to eat foods "not on plan," and effort required to "stay on track" (see Table 2). A similar pattern of effects emerged in models predicting weight regain the *following* week, with the exception that ratings of positive mood and effort required to stay on track were no longer significantly associated with weight change. Model effects listed in Table 2 can be interpreted such that a 1 unit increase in the model parameter (i.e., a 1 day increase in the frequency of self-weighing or self-monitoring of caloric intake, a 1 hour increase in physical activity, or a 1 point increase on the Likert-scale questions) was associated with the weight change listed in the "estimate" column, in kg. For example, during the initial intervention, a 1 day increase in self-weighing was associated with a −0.03 kg greater weight loss that same week and a −0.02 kg greater weight loss the following week.

Table 3 provides model results during the 9-month maintenance period. During this time, weight regain within a given week was concurrently associated with fewer days of self-weighing and self-monitoring caloric intake and fewer hours of physical activity. Further, during this period, all self-report items were proximally associated with weight change the same week; the largest effects were observed for ratings of whether eating choices were consistent with weight management goals and the importance of staying on track compared to other life demands, followed by ratings of boredom with weight control efforts and temptation to eat foods "not on plan" and then by ratings of the amount of effort needed to stay on track and hunger. Conversely, the smallest effect was observed for ratings of stress. A similar pattern of effects was observed when participant self-weighing and self-report behaviors, mood, and cognitions were used to predict weight regain the *following* week during the 40-week maintenance period.

Discussion

The current study was the first to investigate, on a week-to-week basis, the behavioral, cognitive, and affective factors proximally associated with weight loss and weight regain. Across both correlational and predictive models, results demonstrated that greater weight loss during a given week was associated with greater frequency of self-weighing and self-monitoring caloric intake along with self-report ratings indicating greater consistency between eating choices and weight loss goals, greater importance of "staying on track" compared to other life demands, and less boredom, temptation to eat foods "not on plan," hunger, and negative mood. During maintenance, weight *regain* (again across both correlational and predictive models) was associated with the inverse of this pattern (i.e., less frequent self-weighing and self-monitoring of caloric intake, lower ratings of whether eating choices were consistent with weight loss goals and the importance of "staying on track" compared to other life demands, and higher ratings of boredom with weight control efforts, temptation to eat foods "not on plan," hunger, negative mood, and stress) along with lower levels of physical activity, lower ratings of whether physical activity choices were consistent with weight loss goals and positive mood, and higher ratings of temptation to skip planned physical activity and effort required to "stay on track" with weight goals.

The current results have several key implications. While the current study was the first to investigate the impact of self-weighing and self-monitoring of caloric intake on weight change on a proximal, week-to-week basis, results were consistent with previous literature demonstrating the importance of self-monitoring weight and caloric intake for both weight loss and long-term weight loss maintenance (Burke et al., 2011; Klem et al., 1997; Laitner et al., 2016; Peterson et al., 2014; Zheng et al., 2015). These results were also consistent with self-regulation theory, which posits that self-monitoring of behavior (and the comparison between the results of self-monitoring and behavior goals) provides a trigger for individuals to adjust that behavior (Kanfer, 1970). In the case of weight and caloric intake, self-monitoring would provide individuals with key feedback regarding whether they are on track with eating/activity goals or if adjustments need to be made. Observations that show that one has met their goal further provide reinforcement (Kanfer, 1970), promoting future adherence to self-monitoring and thus greater goal attainment. The current results support this theoretical model and extend the research literature by establishing the existence of this association on a proximal, week-to-week basis and by providing data that can be used to develop thresholds to trigger intervention provision within a JITAI framework. With existing digital self-monitoring tools, it is feasible for an intervention to closely monitor adherence to self-monitoring and provide additional support when adherence becomes suboptimal.

Beyond adherence to key weight-related behaviors, results identified additional potential tailoring variables for adaptive interventions. In particular, ratings of whether eating choices were consistent with weight loss goals and of the importance of "staying on track" compared to other life demands appeared to have the strongest proximal associations with both weight loss and regain. Ratings of these factors could also be monitored within a weight management program, with additional intervention provided as appropriate. These two constructs, in particular, may suggest utility for newer intervention approaches, such as those informed by Acceptance and Commitment Therapy (ACT; Hayes, Strosahl, & Wilson, 1999). The use of ACT-based techniques to connect individuals with their values (which theoretically could increase "importance of staying on track") and to help them engage in values-consistent behavior even in the face of unpleasant mood states (e.g., making eating choices consistent with one's goals despite experiencing boredom, hunger, and/or temptation to eat other foods) may offer particular promise. Results to date suggest that ACT-based approaches to weight management may improve weight loss outcomes and have potential to improve weight loss maintenance compared to traditional weight loss approaches (Forman et al., 2013, 2016; Lillis et al., 2016).

The current results also support existing efforts to develop intervention approaches specifically adapted to the maintenance period (Kiernan et al., 2013; Leahey et al., 2016; Svetkey et al., 2008; Wing et al., 2006). Based on evidence from previous trials, several researchers have argued that physical activity may be more important for promoting *maintenance* of weight loss in comparison to initial weight loss; the current results support this theory (Johns et al., 2014; Swift, Johannsen, Lavie, Earnest, & Church, 2014). Further, compared to the initial weight loss program, during the maintenance period participants reported more boredom, more temptation to skip physical activity, that their eating choices and physical activity choices were less consistent with weight loss goals, and that staying on track with weight loss goals was less important, compared to other life goals; notably, these constructs were either as strongly or more strongly related with weight change during the maintenance period compared to the initial intervention period. Although participants did not show changes between the initial intervention period and the maintenance period for ratings of hunger, temptation to eat foods not on their plan, and effort, all of these constructs were more strongly associated with weight change during maintenance compared to the initial intervention period. Few maintenance-focused interventions have tailored content specifically to these areas, two previous studies demonstrated improvements in long-term outcomes for maintenance programs aimed at decreasing boredom and the effort required to stay on track (Jeffery et al., 2009; Leahey et al., 2016). Future research should investigate the utility of further tailoring intervention content specifically to the maintenance period.

Finally, in contrast to existing literature (see Elfhag & Rössner, 2005 for a review), results of the current study demonstrated limited associations between stress and weight regain. This discrepancy may be a result of earlier literature relying solely on retrospective recall measures. For example, in addition to the biases discussed earlier in relation to these measures, cognitive dissonance theory (Draycott & Dabbs, 1998) would posit that individuals who lose less weight may attempt to justify these outcomes by reporting greater experience of barriers (such as stress). There also may be variability in individual coping responses to stress that may have affected results. For example, it may be that some individuals managed stress through "stress eating" while others used more active/weight consistent coping mechanisms such as engaging in physical activity (Elfhag & Rössner, 2005). A critical next-step in this line of work would be to investigate between-individual differences in the patterns observed.

An important note is that most of the constructs assessed in this study do not directly affect body weight; rather, many (such as adherence to self-monitoring, hunger, temptation, etc.) likely influence weight regulation indirectly by influence eating and activity habits. Conversely, eating and activity habits may influence other behaviors (e.g., research has demonstrated that individuals are less likely to self-weigh after a day of higher-than-usual caloric intake; Tanenbaum, Ross, & Wing, 2016). There are also likely associations and interactions *between* constructs. As discussed previously, self-regulation theory (Kanfer, 1970) would posit that an individual who self-monitors caloric intake would be more likely to make eating choices consistent with their weight loss goals. Indeed, the conducted by Kwasnicka and colleagues (2017) found that lower adherence to weight maintenance plans was predicted by lower ratings of importance of following these plans compared to other activities/goals and greater temptation to break plans. While the scope of the current study precludes investigating all of the possible associations and interactions, this is an important area for future research.

The current study had several limitations. First, as the current analysis plan was conceptualized as exploratory and hypothesis-generating, a large number of statistical tests were run. Corrections for multiple tests (e.g., Bonferroni adjustments) were not made, thus it is probable that some associations were observed due to chance. As type I and type II errors are inversely related, correcting α for multiple tests (decreasing probability of type I error, or finding false positives) increases the odds of type II error (observing false negatives); with a large number of tests, this means that actual associations may be missed. Given this trade-off, and the exploratory, hypothesis-generating approach used in the current study, the approach described by Perneger (1998) was used, discussing the limitations of these methods without adjusting α/p-values directly.

Second, participants were asked to self-report data and complete the 11-item questionnaire at the end of each week (by Sunday night). Thus, correlational models (modeling weight change the same week) were unable to demonstrate temporal precedence between the behavioral and psychological factors assessed and weight change and questionnaire results may have been influenced by some of the same biases discussed previously. Overall, a similar pattern of results emerged between the correlational and predictive models (modeling weight change the *following* week), providing evidence that effects observed in the correlational models were not entirely due to bias in self-report from participants observing their level of success (or failure) at weight loss/maintenance. Effect sizes were often smaller, however, in the predictive models. This was not surprising given expected week-to-week variation in factors and the likelihood that many weight-related cognitions and behaviors would be more likely to directly impact weight on the same week than on the following week; however, given that results of the predictive models established temporal precedence, these models may also reflect more robust estimates of effects. To improve this evidence base, future studies should investigate the feasibility of assessing behavioral and psychological constructs more frequently than once-per-week (e.g., using passive monitoring of behaviors when possible, and using methods similar to the EMA approaches discussed in the introduction), and to query current mood, behavior, and cognitions rather than requiring participants to recall these constructs over a previous time period.

Third, participants were given small financial incentives for providing self-monitoring data and answering the 11-item questionnaire each week. It is important to note that these incentives were designed to promote self-report of data, and not self-monitoring itself (i.e., participants could still receive the incentive for reporting that they did not self-monitor). While the benefit of this design is that it minimized the impact of missing data, it also may have altered participant behavior. Future studies should investigate the proximal impact of these factors on weight change without incentivizing self-report each week.

Finally, participants in the current study were all employees or dependents of a large healthcare organization and were predominately white and female; thus, results may not generalize to other samples. Future research should replicate these methods in community samples including more men and individuals from racial/ethnic minority communities.

Despite these limitations, the current study has several notable strengths. Analyses were conducted on a rich dataset providing weekly self-report and questionnaire data and daily smart scale data from participants over a full calendar year, during and after a 3-month weight loss program. While existing research tends to rely on retrospective data collected during sparse assessment visits (e.g., every 3–6 months), the current study was able to investigate much more proximal, week-to-week associations, leading to results that can be used to develop specific thresholds for future adaptive interventions. Further, the current study was the first to investigate proximal predictors of weight change during both initial intervention and a post-intervention observational “maintenance” period, allowing for comparisons between these periods. Given increasing evidence that the processes involved in weight loss maintenance may be distinct from those involved in initial weight loss, collecting data longer periods is critical to investigating potential differences in associations over time.

Conclusion

The current study was the first to investigate proximal (week-to-week) predictors of weight change during and after a behavioral weight management program. Results confirmed the importance of self-monitoring weight and caloric intake for both initial weight loss and weight maintenance, and of physical activity for promoting weight maintenance after initial weight loss. Results further identified additional factors proximally associated with weight change, including ratings of whether eating choices were consistent with weight loss goals, importance of these goals compared with other life demands, boredom, temptation to eat foods not consistent with weight management goals, hunger, and negative mood. Finally, results supported existing efforts to develop of interventions specifically focused on the maintenance period. Future research should investigate whether using the self-report factors identified in the current study to monitor participant progress and tailor intervention content/provision improves weight loss outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Average Weekly Frequency of Self-Weighing and Self-Monitoring Caloric Intake, Hours of Physical Activity, and Ratings of Mood, Behaviors, and Cognitions During the Initial Weight Loss Program (Weeks 1–12) and Maintenance Period (Weeks 13–52).

	Weeks 1–12		**Weeks 13–52**			
	Mean	***SD***	***Mean***	***SD***	***p***	***Cohen's d***
Frequency of Self-Weighing, Days	6.21	1.01	4.85	1.65	**<.0001**	−1.00
Frequency of Self-Monitoring Caloric Intake, Days	5.93	1.56	2.43	2.10	**<.0001**	−1.67
Weekly Physical Activity, Hours	3.24	2.93	2.44	2.72	**<.0001**	−0.70
Positive Mood	4.83	0.81	4.81	0.89	.797	−0.03
Negative Mood	3.04	0.92	3.05	0.91	.900	0.01
Stress	4.09	1.18	4.05	0.94	.738	−0.04
Hunger	4.05	1.10	4.15	1.02	.338	0.11
Boredom with Weight Control Efforts	3.14	1.10	3.65	1.13	**<.0001**	0.53
Temptation to Eat Foods "Not on Plan"	4.79	1.25	4.94	1.02	.146	0.17
Temptation to Skip Planned Physical Activity	3.64	1.60	4.46	1.47	**<.0001**	0.63
Eating Choices Consistent with Weight Loss Goals	4.32	1.09	3.82	0.88	**<.0001**	−0.51
Physical Activity Choices Consistent with Weight Loss Goals	4.47	1.38	3.72	1.37	**<.0001**	−0.58
Effort of "Staying on Track"	4.78	1.08	4.94	1.04	.133	0.18
Importance of "Staying on Track" Compared to Other Life Demands	5.11	1.17	4.56	1.32	**<.0001**	−0.51

Note. p values < .05 are shown in boldface.

Table 2.

Factors Correlated with Weight Loss the Same Week and Predicting Weight Loss the Following Week During the Initial 3-Month Weight Loss Program.

	Weight Change the Same Week Model Fixed Effects				Weight Change the Following Week Model Fixed Effects			
Variable	***Estimate***	***SE***	***t***	***p***	***Estimate***	***SE***	***t***	***p***
Frequency of Self-Weighing, Days	−.030	.006	−4.87	**<.0001**	−.023	.006	−3.70	**<.001**
Frequency of Self-Monitoring Caloric Intake, Days	−.023	.004	−5.21	**<.0001**	−.020	.004	−4.52	**<.0001**
Physical Activity, Hours	.002	.005	0.33	.741	.004	.005	0.76	.447
Positive Mood	−.018	.008	−2.38	**.018**	−.012	.008	−1.52	.128
Negative Mood	.022	.007	3.15	**.002**	.018	.007	2.55	**.011**
Stress	.005	.006	0.88	.379	.006	.006	1.04	.300
Hunger	.020	.008	2.67	**.008**	.018	.008	2.41	**.016**
Boredom with Weight Control Efforts	.045	.007	6.42	**<.0001**	.041	.007	5.79	**<.0001**
Eating Choices Consistent with Weight Loss Goals	−.043	.007	−6.51	**<.0001**	−.037	.007	−5.44	**<.0001**
Physical Activity Choices Consistent with Weight Loss Goals	−.003	.006	−0.47	.641	−.004	.006	−0.67	.505
Temptation to Eat Foods “Not on Plan”	.029	.006	4.61	**<.0001**	.024	.006	3.72	**<.001**
Temptation to Skip Planned Physical Activity	.001	.006	0.19	.850	.003	.006	0.44	.663
Effort of “Staying on Track”	.014	.007	2.17	**.031**	.011	.007	1.64	.100
Importance of “Staying on Track” Compared to Other Life Demands	−.048	.007	−6.57	**<.0001**	−.043	.007	−5.90	**<.0001**

Note. p values < .05 are shown in boldface.

Table 3.

Factors Correlated with Weight Regain the Same Week and Predicting Weight Regain the Following Week During the 9-Month Maintenance Period.

	Weight Change the Same Week Model Fixed Effects				**Weight Change the Following Week Model Fixed Effects**			
Variable	***Estimate***	***SE***	***t***	***p***	***Estimate***	***SE***	***t***	***P***
Frequency of Self-Weighing, Days	−.028	.003	−9.51	**<.0001**	−.018	.003	−6.08	**<.0001**
Frequency of Self-Monitoring Caloric Intake, Days	−.020	.002	−10.27	**<.0001**	−.012	.002	−6.19	**<.0001**
Physical Activity, Hours	−.016	.003	−5.41	**<.0001**	−.012	.003	−4.24	**<.0001**
Positive Mood	−.022	.004	−5.03	**<.0001**	−.012	.004	−2.76	**.006**
Negative Mood	.021	.004	5.11	**<.0001**	.013	.004	3.12	**.002**
Stress	.012	.004	3.17	**.002**	.008	.004	2.35	**.019**
Hunger	.035	.004	7.71	**<.0001**	.019	.004	4.16	**<.0001**
Boredom with Weight Control Efforts	.040	.004	9.72	**<.0001**	.023	.004	5.49	**<.0001**
Eating Choices Consistent with Weight Loss Goals	−.045	.004	−11.61	**<.0001**	−.029	.004	−7.39	**<.0001**
Physical Activity Choices Consistent with Weight Loss Goals	−.023	.003	−6.84	**<.0001**	−.017	.003	−5.12	**<.0001**
Temptation to Eat Foods “Not on Plan”	.039	.004	9.81	**<.0001**	.022	.004	5.48	**<.0001**
Temptation to Skip Planned Physical Activity	.024	.003	7.26	**<.0001**	.015	.003	4.72	**<.0001**
Effort of “Staying on Track”	.036	.004	9.51	**<.0001**	.024	.004	6.37	**<.0001**
Importance of “Staying on Track” Compared to Other Life Demands	−.041	.004	−10.73	**<.0001**	−.025	.004	−6.46	**<.0001**

Note. p values < .05 are shown in boldface.