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ORIGINAL ARTICLE

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A randomized trial examining the effect of yoga on dietary lapses and lapse triggers following behavioral weight loss treatment

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Abstract

Background: Dietary lapses can hinder weight loss and yoga can improve self-regulation, which may protect against lapses. This study examined the effect of yoga on dietary lapses, potential lapse triggers (e.g., affective states, cravings, dietary temptations), and reasons for initiating eating following weight loss treatment.

Methods: Sixty women with overweight/obesity (34.3 ± 3.9 kg/m^2) were randomized to a 12 week yoga intervention (2x/week; YOGA) or contact-matched control (cooking/nutrition classes; CON) following a 12-week behavioral weight loss program. Participants responded to smartphone surveys (5x/day) over a 10-day period at baseline, 12, and 24 weeks to assess lapses and triggers.

Results: At 24 weeks, YOGA and CON differed on several types of lapses (i.e., less eating past full, eating more than usual, loss of control when eating, self-identified overeating, difficulty stopping eating in YOGA), and YOGA was less likely to eat to feel better or in response to stress (ps < 0.05). YOGA also reported less stress and anxiety and more positive affect (ps < 0.01); dietary temptations and cravings did not differ from CON.

Conclusion: Yoga resulted in fewer dietary lapses and improved affect among women with overweight/obesity following weight loss. While preliminary, findings suggest that yoga should be considered as a potential component of weight loss treatment to target dietary lapses.

KEYWORDS
ecological momentary assessment, lapse, weight loss, yoga

1 | INTRODUCTION

Behavioral weight loss treatment can effectively reduce body weight in the short-term; however, the rates of long-term weight loss success remain less than optimal.[1] Although there are many factors which contribute to poor long-term outcomes, emerging research suggests that frequent dietary lapses (i.e., discrete episodes of dietary non-adherence) are of concern and can hinder short- and long-term weight loss and lead to abandonment of weight loss goals.[2–4] Conversely, improvements in self-regulation (i.e., the ability to manage thoughts, emotions, and behaviors) may help to enhance weight loss and reduce dietary lapses by facilitating greater adherence to dietary goals, even in the presence of life stressors or common lapse triggers (e.g., negative emotions, cravings, dietary temptations).[5–7] Therefore, intervention approaches, and specifically those which target multiple aspects of self-regulation, should be tested in the context of behavioral weight loss treatment to determine whether greater reductions in dietary lapses and weight can be observed.

Hatha yoga is a multicomponent spiritual practice with its earliest origins in India. Modern yoga variants (termed yoga from here on out) predominantly consist of postures with less emphasis on breathwork, relaxation, and meditation. Yoga has been shown to strengthen various dimensions of self-regulation (e.g., mindfulness self-efficacy, self-compassion) and can also improve psychological factors that tend to trigger dietary lapses (e.g., affect, stress, and psychological well-being), thereby presenting as a potential strategy to reduce dietary lapses.[8–12] Yoga has been effectively applied within a variety of health disciplines (e.g., pain management, depression, cardiometabolic health, etc.),[13–16] but has been largely overlooked within the context of weight loss treatment, possibly because it has traditionally been viewed as a form of exercise with a low energy expenditure. However, this viewpoint fails to consider the psychological and self-regulatory benefits of yoga, apart from the calories burned, which could have an impact on dietary behaviors and weight. While data from observational and cross-sectional studies suggest a favorable effect of yoga on weight[17–20] and aspects of eating behavior (e.g., disordered eating, mindful eating, binge eating, and dietary intake),[21–24] research testing the combination of yoga within behavioral weight loss treatment is limited. A systematic review conducted in 2021[25] identified only two randomized trials that prescribed both yoga and calorie reduction for adults with overweight/obesity. Jakicic et al.[26] reported that yoga could be implemented within a behavioral weight loss program with high feasibility and acceptability and Yadav et al.[27] reported that yoga plus calorie reduction led to greater improvements in waist circumference, metabolic syndrome parameters, and dietary intake compared with calorie reduction alone. While these findings are initially promising in terms of adding yoga to a weight management program, neither of these studies examined the impact of yoga on dietary lapses.

We previously conducted a randomized trial to assess the feasibility and acceptability of a 12-week yoga program delivered following a 12-week behavioral weight loss program among women with overweight or obesity.[28] Findings demonstrated excellent retention, attendance at yoga sessions, and satisfaction with the yoga program. Moreover, among those who achieved a clinically significant weight loss within the initial behavioral weight loss program, those randomized to yoga had greater weight loss, self-regulation (assessed via distress tolerance, mindfulness, and self-compassion), and lower negative affect at 24 weeks compared to a contact-matched control condition.

This manuscript contains secondary analyses of the above-mentioned randomized trial. While the primary outcome paper focused on the feasibility, acceptability, and preliminary efficacy of adding yoga following behavioral weight loss treatment on weight change, this manuscript reports on the effect of yoga on dietary lapses and lapse triggers. Ecological momentary assessment (EMA) was used to assess several types of dietary lapses (e.g., eating past full, eating more than usual, loss of control when eating), lapse triggers (e.g., cravings, dietary temptations, affective states), and reasons for initiating eating under free-living conditions (e.g., because stressed, couldn't resist, wanted to feel better) at three time points: before weight loss treatment, after weight loss treatment, and following a 12-week yoga or contact-matched control condition. The primary hypotheses were that those randomized to yoga would experience fewer dietary lapses and triggers at 24 weeks compared with the control condition. Treatment groups were also compared on reasons for eating, with the hypothesis that yoga would be less likely to eat for non-homeostatic reasons (e.g., stress or feeling that one deserved to eat). Study findings are an important initial step for aiding in our understanding of how yoga may impact eating behaviors within the context of weight loss treatment.

2 | MATERIALS AND METHODS

2.1 | Participants

Sixty women with overweight or obesity (BMI: 25 to <40.0 kg/m^2) between 18 and 60 years of age participated in this study. Full exclusion criteria have been reported previously.[28] In short, participants were required to be stable in weight and free of any orthopedic or psychiatric condition that would limit exercise or weight loss. The current or recent pregnancy or enrollment in a weight loss or mindfulness-based program (e.g., Tai-Chi, yoga) were not allowed. All participants were required to own a smartphone and have ≥80% compliance to the EMA surveys at baseline. Only participants who completed the 12-week assessment (n = 51), which followed the WL program, moved on to receive the yoga or cooking and nutrition education classes.

2.2 | Overall study design

Participants were randomized to one of two conditions at baseline: 1) a 12-week standard behavioral weight loss program followed by a

12-week Iyengar yoga intervention (YOGA) or 2) 12-week standard behavioral weight loss program followed by a 12-week cooking and nutrition education program, which served as the contact-matched control (CON). Iyengar yoga[29] is a form of hatha yoga, which incorporates breathing, postural, and meditation practices and utilizes 'props' (e.g., straps, blocks, blankets, chairs) to assist individuals in maintaining the proper alignment and to reduce the risk of injury. Participants and weight loss instructors were not informed of the randomization assignment until after completion of the behavioral weight loss program and participants remained with the same group of individuals throughout the 24-week intervention period. Dietary lapses, lapse triggers, and reasons for eating were assessed using smartphone surveys over a 10-day period at three time points: (1) before the start of the weight loss program (baseline), (2) after the completion of the behavioral weight loss program (12 weeks), and (3) after the completion of the 12 weeks of yoga or cooking/nutrition classes (24 weeks). Written informed consent was obtained prior to enrollment and all study procedures were approved by The Miriam Hospital Institutional Review Board.

2.3 | Standard behavioral weight loss program

Both treatment groups received an identical 12-week group-based in-person standard behavioral weight loss program, which has been described in detail elsewhere.[28] Participants were given a calorie intake goal of 1200–1800 kcals/day and a moderate-intensity aerobic exercise prescription which progressed from 75 to 200 min/week, with a goal of inducing a 1–2 pound weight loss per week. Participants were also taught a variety of behavioral strategies (e.g., stimulus control, problem solving, goal setting) for modifying diet and exercise behaviors via didactic content and group discussions. Participants were also instructed to record food intake, weight, and exercise minutes daily and written feedback was provided periodically by the intervention staff.

2.4 | Yoga intervention

YOGA participants received a 12-week group-based Iyengar yoga intervention following the 12-week standard behavioral weight loss program. A full description of the yoga intervention has been described in detail previously.[28] In brief, classes were held twice per week for 60 min and led by two certified Iyengar yoga instructors. Yoga classes consisted of a brief warm-up (~5–7 min), a period of more intense poses (~35 min), a cool-down consisting of more relaxing poses (~3–7 min), breath work (~7–10 min), and savasana (supine relaxation, ~2–10 min). Further, participants were encouraged to engage in self-initiated yoga practice at home, provided with resources for home-based practice, and given weekly notecards to help them apply the learned yoga skills to weight-control behaviors. Due to the COVID-19 pandemic, Cohort 1 yoga classes were conducted in-person while Cohort 2 yoga classes were conducted remotely – cohorts did not differ in attendance at yoga classes or program satisfaction ratings.

2.5 | Culinary and nutrition education intervention

Participants randomized to CON received 12 weeks of culinary/nutrition education classes (2x/week), led by dieticians or culinary experts, following the 12-week standard behavioral weight loss program. This group served as a contact-matched control condition in which participants were provided with intervention content relevant to weight loss (to promote attendance) but content which would not likely influence weight or psychological constructs targeted by yoga (e.g., mindfulness, stress, distress tolerance). Furthermore, no behavioral strategies for changing diet or inducing weight loss were discussed; rather basic education surrounding healthy eating and cooking was provided. Example topics included culinary skills (e.g., proper knife cutting), antioxidants, fiber, fluid, sodium, and macronutrient guidelines, and cooking demonstrations were also provided. Similar to YOGA, the method of intervention delivery differed by cohort.

2.6 | Measures

Demographic information was collected at baseline. Ecological momentary assessment (EMA) was used to assess dietary lapses, lapse triggers, and reasons for eating at baseline, 12 weeks (following behavioral weight loss treatment), and 24 weeks (following yoga or cooking classes).

2.6.1 | EMA protocol

Participants were asked to respond to surveys via their smartphones for 10 consecutive days at each assessment period. Given that the first YOGA or CON session was held on the week immediately following the last weight loss session, EMA monitoring for the 12-week assessment began several days prior to the end of the weight loss intervention to ensure that all monitoring was complete prior to the start of YOGA or CON. Surveys were in the form of 5 semi-random prompts (i.e., occurring every 2–3 h) delivered between 8:00 AM and 10:00 PM via text message. Participants were instructed to respond to the survey as soon as possible upon receiving the text message, but had 45 min to respond before it was considered a missed survey. To promote adherence to surveys, participants were compensated $0.50 for each completed survey and were provided with an additional $25 bonus if the survey completion rate was >85% at follow-up. At each prompt, participants were asked specific questions related to potential lapse triggers (e.g., affective states, cravings, dietary temptations) and were also asked to report any eating episodes since the last prompt. If eating was endorsed, follow-up questions regarding the nature of the eating episode were

asked (e.g., reasons for eating and questions to determine whether the eating episode would be considered a type of dietary lapse). If eating was not endorsed, additional 'filler' questions were asked to ensure that the number of questions was consistent and independent of participant response.

As shown in Table 1, several types of dietary lapses and reasons for eating were assessed. Specifically, if participants indicated an eating episode, follow-up questions were asked related to whether one ate past the point of feeling full, ate more than usual, or had unplanned eating. Individuals were also asked to rate the degree of overeating, any difficulty stopping eating, or loss of control when eating (reflective of six different types of dietary lapses). Various reasons for initiating eating were also assessed. Of specific interest were non-homeostatic reasons for eating (e.g., chose to eat because: stressed, couldn't resist, wanted to feel better, or deserved to eat), as this may be one mechanism through which yoga could aid in weight control. Homeostatic reasons for eating (e.g., hunger, scheduled time to eat) were also assessed even though it was not expected that YOGA and CON would differ on these variables.

2.7 | Statistical analysis

As a preliminary step, intervention conditions (YOGA vs. CON) were compared with respect to baseline socio demographics using *t*-tests (for continuous variables), chi-squared tests (for categorical variables) and non-parametric tests (for skewed variables) as appropriate.

Among the aggregate sample ($n = 51$), changes from baseline to 12 weeks were assessed within the condition using *t*-tests or chi-squared tests as appropriate. Between-group comparisons were made at 24 weeks, controlling for baseline and 12-week time points. Specifically, a series of longitudinal models implemented with Generalized Estimating Equations (GEEs) with robust standard errors were used to examine between-group differences over time in key eating behaviors and psychosocial outcomes assessed via EMA. Models were specified to allow for nesting of repeated responses within a day within the assessment period. Further, models controlled for cohort and baseline values of the reported outcome. Next, for continuous outcomes, a series of mixed effects models

TABLE 1 Summary of ecological momentary assessment (EMA) variables.

Variable	Measures of dietary lapse	Response options/coding
Eating past full Eating more than usual Unplanned eating	During your last eating episode did you experience any of the following? (check all that apply)	a) I ate past the point of feeling full, b) I ate more than usual, c) I had unplanned eating (i.e., consumed food when I don't usually eat and was not making up for a missed meal), or d) None of the above.
Self-identified overeating	While you were eating, to what extent did you feel that you overate?	1 = not at all, 4 moderately, 7 = extremely
Difficulty stopping eating	While you were eating, to what extent did you feel that you could not stop eating once you started?	
Loss of control when eating	While you were eating, to what extent did you feel a sense of loss of control?	
Inability to resist dietary temptation	Did you eat the tempting food? (only asked when a dietary temptation was reported)	If response was 'yes' this was coded as an inability to resist the temptation
Variable	**Dietary lapse triggers**	**Response options/coding**
Anxiety	Right now I feel anxious	1 = not at all, 7 = very much so
Stress	Right now I feel stressed	
Affect	Right now I feel	Feeling Scale: −5 = very bad, 0 = neutral, +5 = very good
Dietary temptation	Since the last prompt, a) I was tempted to overeat, b) I had a sudden urge to eat a tempting or forbidden food, c) I was exposed to tempting foods or beverages, or d) None of the above (check all that apply).	If the response was a,b,or c, it was classified as a 'dietary temptation'.
Food craving	Right now I am craving food	1 = strongly disagree, 7 = strongly agree
Variable	**Reasons for eating**	**Response options/coding**
Hunger	I ate because I was hungry	1 = strongly disagree, 4 = neutral, 7 = strongly agree
Stressed	I ate because I was stressed	
Scheduled time	I ate because it was time to eat	
Couldn't resist	I ate because I could not resist eating	
To feel better	I ate because I wanted to feel better	
Reward-driven	I ate because I deserved to eat	

were used to compare. Models included a subject-specific intercept and adjusted standard errors for repeated measures within participants (nested within day within assessment period). Mixed effects models allow for a range of outcome distributions (e.g., Normal) and specifications of the time effect (e.g., linear, non-linear). Higher order time effects were tested (quadrative and cubic) and found non-significant and thus, all models had linear effects only. All analyses were run in SAS 9.3 with significance level set at 0.05 a priori.

3 | RESULTS

A full description of the study sample has been presented previously.[28] In brief, randomized participants had an average baseline BMI of 34.3 ± 3.9 kg/m^2 and were approximately 48 years of age (SD = 10.1), and the majority self-reported their race and ethnicity as White (83.3%) and non-Hispanic (90%). There were no differences between conditions in baseline variables (ps > 0.05; Table 2). As previously reported, participants lost an average of 5.86 ± 3.18 kg following the 12-week behavioral weight loss program prior to the start of yoga or cooking classes and mean weight change from 12 to 24 weeks did not differ between YOGA (0.30 ± 2.48 kg) and CON (0.37 ± 3.32 kg; $p = 0.93$).

3.1 | Compliance and baseline to 12-week changes

Compliance to smartphone surveys was 91.3 ± 6.0%, 90.2 ± 9.3%, and 90.0 ± 12.6% at baseline, 12, and 24 weeks respectively. Attendance at YOGA and CON classes were similar (YOGA: 75.4 ± 24.6% vs. CON: 75.9 ± 27.1%). To examine the effect of the behavioral weight loss intervention on dietary lapses, lapse triggers, and reasons for eating, baseline to 12-week changes were assessed. Averaged across groups, reductions were observed in all variables at 12 weeks except 'eating because I deserved to eat'. A full description is presented in Table 3.

TABLE 2 Baseline characteristics of the study sample by the treatment arm.

	Yoga (n = 30)	CON (n = 30)
Age (years)	48.2 ± 10.1	48.0 ± 10.2
Height (cm)	161.9 ± 5.7	162.8 ± 6.7
Weight (kg)	89.4 ± 12.9	90.6 ± 11.0
BMI (kg/m^2)	34.0 ± 4.0	34.5 ± 3.8
% White (n/%)	25 (83.3%)	25 (83.3%)
% Hispanic (n/%)	4 (13.3%)	2 (6.7%)
MVPA (min/wk)	92.2 ± 109.1	84.1 ± 89.9

Abbreviation: MVPA, moderate-to-vigorous intensity physical activity.

3.2 | Dietary lapses

Adjusted GEE models indicate significant differences between YOGA and CON on total lapses, eating past full, and eating more than usual. Specifically, at 24 weeks, YOGA participants reported a 14% reduction in the odds of a lapse (OR = 0.86, 95% CI: 0.76-0.98). Further, at 24 weeks, YOGA participants reported a 61% reduction in the odds of reporting eating past full (OR = 0.39, 95% CI: 0.18-0.85) and a 49% reduction in the odds of eating more than usual (OR = 0.51, 95% CI: 0.29-0.92) compared to CON. Longitudinal mixed effects models indicate that YOGA participants reported significantly less loss of control when eating (b = −0.25, SE = 0.08, $p < 0.001$), less self-identified overeating (b = −0.43, SE = 0.11, $p < 0.001$), and less difficulty stopping eating once initiated (b = −0.28, SE = 0.11, $p = 0.01$) compared to CON. There were no significant differences between conditions with respect to the number of unplanned eating episodes or one's self-reported ability to resist dietary temptations (ps > 0.05).

3.3 | Dietary lapse triggers

Adjusted models indicated significant between-group differences at 24 weeks (controlling for baseline and 12 weeks) in dietary lapse triggers. Specifically, those randomized to YOGA reported significantly less anxiety (b = −0.30, SE = 0.10, $p < 0.01$), less stress (b = −0.28, SE = 0.07, $p < 0.01$), higher overall affect (b = 0.67, SE = 0.18, $p < 0.001$) and significantly lower odds of reporting a dietary temptation (OR = 0.67, 95% CI: 0.48-0.94) compared to CON. There were no significant differences between conditions with respect to food cravings at 24 weeks ($p > 0.05$).

3.4 | Reasons for eating

Finally, models of reasons for eating suggest significant differences between conditions with respect to eating to feel better (b = −0.68, SE = 0.12, $p < 0.01$), and eating due to stress (b = −0.21, SE = 0.07, $p = 0.002$), such that YOGA participants reported significantly lower frequency of these reasons at 24 weeks compared to CON. At 24 weeks, treatment groups did not differ on eating because one couldn't resist, feeling like one deserved to eat, eating due to hunger, or because it was time to eat (ps > 0.05).

4 | DISCUSSION

This randomized trial examined the effect of a 12-week Iyengar yoga program delivered following 12 weeks of behavioral weight loss treatment (relative to a cooking and nutrition education control group) among a sample of women with overweight or obesity. The primary outcome paper previously reported the feasibility and acceptability of the yoga program and the effect that yoga had on

TABLE 3 Within-person and between-person changes in constructs.

Variable	Baseline (n = 60)	12 weeks (n = 52)	Within-person changes baseline to 12 weeks	24 weeks—Yoga (n = 24)	24 weeks—CON (n = 27)	Between-group adjusted effects at 24 weeks controlling for baseline and 12 weeks
Lapse types						
Ate past point of feeling full[a]	3.17 (3.51)	1.17 (1.80)	OR = 0.37 (0.28-0.49)	0.58 (1,13)	2.44 (3.92)	OR = 0.39, 95% CI: 0.18-0.85
Ate more than usual[a]	3.41 (3.16)	2.21 (2.02)	OR = 0.63 (0.50-0.79).	1.21 (1.32)	3.33 (4.09)	OR = 0.51, 95% CI: 0.29-0.92
Unplanned eating[a]	4.17 (4.51)	2.10 (2.83)	OR = 0.52 (0.41-0.64)	2.08 (3.41)	3.33 (3.49)	ns
Self-identified overeating	2.19 (1.72)	1.66 (1.39)	b = −0.52 (0.05), $p < 0.01$	1.60 (6.03)	2.08 (1.82)	b = −0.43, SE = 0.11, $p < 0.001$
Difficulty stopping eating	2.18 (1.74)	1.71 (1.44)	b = −0.47 (0.06), $p < 0.01$	1.64 (1.35)	2.06 (1.69)	b = −0.28, SE = 0.11, $p = 0.01$
Loss of control when eating	2.08 (1.64)	1.67 (1.39)	b = −0.42 (0.05), $p < 0.01$	1.62 (1.34)	2.04 (1.64)	b = −0.25, SE = 0.08, $p < 0.001$
Inability to resist dietary temptations[a]	9.12 (6.79)	4.50 (3.83)	OR = 0.46 (0.36-0.58)	4.96 (5.11)	5.67 (5.14)	ns
Lapse triggers						
Anxiety	2.30 (1.77)	2.18 (1.82)	b = −0.12 (0.04), $p = 0.02$	2.03 (1.65)	2.03 (1.58)	b = −0.30, SE = 0.10, $p = 0.003$
Stress	2.53 (1.84)	2.47 (1.94)	b = −0.06, $p = 0.01$, $p = 0.04$	2.48 (1.94)	2.29 (1.71)	b = −0.28, SE = 0.07, $p < 0.01$
Affect	7.85 (6.47)	8.29 (4.26)	b = 0.44 (0.15), $p < 0.01$	7.98 (1.03)	8.48 (1.82)	b = 0.67, SE = 0.18, $p < 0.001$
Dietary temptation[a]	30.90 (10.40)	36.60 (8.51)	OR = 0.60 (0.52-0.68)	37.00 (9.27)	39.60 (6.94)	OR = 0.67, 95% CI: 0.48-0.94
Food craving	2.73 (2.02)	2.59 (1.93)	b = −0.14 (0.05), $p = 0.01$	2.59 (1.98)	2.43 (1.86)	ns
Reasons for eating						
Hunger	5.79 (1.54)	6.10 (1.39)	b = 0.31 (0.05), $p < 0.01$	6.07 (1.36)	5.74 (1.77)	ns
Stressed	2.08 (1.62)	1.61 (1.22)	b = −0.47 (0.05), $p < 0.01$	1.53 (1.17)	2.02 (1.52)	b = −0.21, SE = 0.07, p 0.002
Scheduled time	5.41 (1.98)	5.34 (2.06)	b = −0.08 (0.04), $p = 0.04$	5.11 (2.21)	5.25 (2.18)	ns
Couldn't resist	3.46 (2.21)	3.04 (2.25)	b = −0.41 (0.08), $p < 0.01$	2.97 (2.29)	3.01 (2.23)	ns
To feel better	3.69 (2.07)	3.62 (2.20)	b = 0.06 (0.007), $p < 0.01$	3.98 (2.30)	3.22 (2.09)	b = −0.68, SE = 0.12, $p < 0.01$
Reward-driven	3.55 (2.06)	3.60 (2.27)	ns	3.30 (2.24)	3.21 (2.22)	ns

Note: ns = not significant ($p > 0.05$). b(SE) reported for continuous outcomes (b = unstandardized regression coefficients, SE = standard error). OR(95% Confidence Interval) reported for binary outcomes. Note, these are cross-sectional means at each time point and do not reflect within-person changes in constructs. These means are presented for the full description of the study sample.

[a]The mean (SD) number of occurrences over the 10-day EMA period.

weight change.[28] This manuscript focuses on secondary analyses which compare yoga and control on dietary lapses, lapse triggers, and reasons for eating. As hypothesized, yoga had a favorable effect on each of these domains. Specifically, yoga led to reductions in several types of dietary lapses which included lower odds of eating past full and eating more than usual, and less loss of control when eating, self-identified overeating, and difficulty stopping eating. Further, reasons for eating differed between groups such that yoga had a lower frequency of eating to feel better and eating due to stress compared to control. Finally, common lapse triggers were reduced in yoga relative to control - yoga reported less anxiety and stress, more positive overall affect, and lower odds of being tempted at 24 weeks.

This is one of the few trials to examine the impact of yoga on weight control behaviors among weight loss-seeking adults and the

first to assess the effect of yoga on dietary practices within the context of weight loss treatment. While preliminary, current findings suggest that yoga could offer promise as an additive to weight loss treatment and potentially improve long-term weight loss via its favorable impact on dietary lapses and non-homeostatic reasons for eating. To date, prospective studies which assess the effect of yoga on dietary behaviors have been extremely limited. However, consistent with our findings, one study found that 12 weeks of Kripalu yoga resulted in a reduction in calorie intake among individuals reporting high stress and poor dietary habits.[30] Interestingly, these changes were observed among individuals who were not necessarily looking to lose weight and when using a different style of yoga than the current study. Future studies with longer-term follow-up are needed to assess the mechanisms by which reductions in dietary lapses and non-homeostatic eating episodes may impact weight. In the current study, we observed no differences in weight loss at 24 weeks between YOGA and CON. However, it is possible that it could take several weeks or months of yoga practice to produce these dietary changes; thus, there may not have been enough time for substantial weight loss to occur. Further investigation is warranted.

More detailed examination of dietary lapse types revealed that yoga reduced the odds of 'eating past the point of feeling full' and 'eating more than usual' but had no effect on 'unplanned eating'. Interestingly, this is the opposite pattern of what was previously reported following 12 weeks of aerobic exercise training in a prior study. In that study, women with overweight or obesity experienced reductions in unplanned eating, but not eating past full or eating more than usual,[31] thereby suggesting that the mode of exercise may differentially impact lapse type. There may be shared benefits or mechanisms between aerobic exercise and yoga (e.g., increased self-efficacy); however, yoga practice can also include mindfulness and self-compassion training. This is consistent with its historical predecessors, in a fashion more recently adopted by psychotherapeutic interventions such as Acceptance and Commitment Therapy (ACT). Yoga has thus been linked to increased mindfulness and compassion[11,20,28]—like ACT[32,33]—with both in turn having implicated mechanisms on intervention outcome.[33–35] Increased mindfulness could increase one's awareness of craving and satiety mechanisms, while increased self-compassion toward oneself during negative affect could synergistically help one to stop eating, independent of why eating originally began. This is further evidenced by the fact that in the current study, yoga led to less loss of control during eating, less self-identified overeating, and less difficulty stopping eating once initiated, but it had a non-significant effect on one's ability to resist dietary temptations when present or eating because one 'couldn't resist'. Given emerging research which suggests that lapse type may differentially impact weight loss,[36] future studies should not only continue to explore the effect of yoga on different types of lapses, but fully powered trials should also be conducted to evaluate the mechanisms by which yoga may impact dietary lapses and weight. Such work may also wish to consider the integration of yoga with ACT or other multicomponent approaches to synergize the beneficial effects of these strategies on preventing or reducing dietary lapses.[37] Ongoing research has also begun to evaluate different facets of mindfulness and ACT principles to optimize behavioral weight loss treatment.[38] Future studies should consider the integration of yoga into this type of work.

This study also examined the effect of yoga on affective states which can trigger dietary lapses. Findings revealed that participants randomized to yoga reported less anxiety, less stress, and greater overall positive affect relative to control at 12 weeks. This is consistent with prior studies in other populations who have reported mood-enhancing benefits of yoga.[39] However, the current findings are also unique in that these benefits were observed within a population which has consistently been understudied within yoga research—individuals with overweight/obesity. Clinically, these findings are also significant because less favorable affect is associated with more frequent dietary lapses[2,3,40]; thus, affective improvements may represent another pathway through which yoga could aid in weight control efforts. Mechanistic studies with larger sample sizes are needed to determine whether the impact of yoga on dietary lapses is due to: a) people feeling better (e.g., less stressed and therefore less likely to experience associated dietary temptations), b) reduced likelihood of eating in response to stress or negative feeling states, c) reduced likelihood of overeating, even if eating was initiated due to stress, or d) a combination of all of the above. The current findings suggest it is a combination of all of these factors, as yoga participants had less stress, were less likely to eat in response to stress, and were less likely to overeat once eating was initiated.

This study was strengthened by rigorous methodology, which included a randomized design with a contact-matched control group and the use of EMA, which allowed for repeated assessment of dietary lapses, lapse triggers, and reasons for eating in real time within one's naturalistic setting. Furthermore, EMA compliance (>90%) and adherence (>75%) to the yoga and control interventions were excellent. However, there are also several limitations. First, this was a pilot study with a relatively small sample size, which was conducted in women who were primarily non-Hispanic White; therefore, it is unclear whether study findings would generalize to males or those from other racial or ethnic backgrounds. Furthermore, we do not know whether the favorable improvements observed in dietary lapses, lapse triggers, and reasons for eating were sustained beyond 6 months and whether these improvements would lead to improved weight loss outcomes longer term. A fully powered trial with an extended follow-up period is needed to determine whether dietary lapses mediate the effect of yoga on weight loss.

In conclusion, to our knowledge, this is the first study to test the effect of yoga following behavioral weight loss treatment and it is also the first to examine how yoga impacts dietary lapses among individuals with overweight or obesity. Twelve weeks of Iyengar yoga led to a reduction in several types of dietary lapses and improved affective measures, which have previously been shown to trigger lapses or be associated with weight gain. While findings are preliminary and replication in larger and more diverse samples are

warranted, study results suggest promise for using yoga as an intervention component within a weight control program and as a strategy for targeting dietary lapses.

AUTHOR CONTRIBUTIONS

All authors made significant contributions to this manuscript. Jessica L. Unick, Beth C. Bock, Rena R. Wing conceived of this study, Jacqueline F. Hayes and Sally A. Sherman participated in intervention training or delivery, Shira I. Dunsiger analyzed the data, and all authors were involved in the conceptualization and writing of this manuscript and have approved the submitted version.

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CONFLICT OF INTEREST STATEMENT

Dr. Unick is on the Scientific Advisory Board of Medifast, Dr. Sherman is an ambassador for lululemon, and Dr. Wing is on the Scientific Advisory Board of Noom. All remaining authors have no conflicts of interest to disclose.

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