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Psychosocial predictors of decay in healthy eating and physical activity improvements in obese women regaining lost weight: translation of behavioral theory into treatment suggestions

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ABSTRACT

Regain of lost weight is a universal problem for behavioral treatments. An increased understanding of theory-based psychosocial predictors of decay in behavioral correlates of weight loss might improve treatments. Data were derived from a previous weight loss investigation of 110 women with obesity. A subsample from the experimental treatment who lost ≥3 % body weight and regained at least one third of that over 24 months ($N = 36$) was assessed. During months 6 through 24, there were unfavorable changes in behavioral (fruit/vegetable and sweet intake; physical activity) and psychosocial variables. Mood change predicted change in fruit/vegetable and sweet intake, with emotional eating change mediating the latter relationship. Change in self-regulation predicted changes in sweet and fruit/vegetable intake and physical activity, with self-efficacy mediating the self-regulation–fruit/vegetable intake and self-regulation–physical activity relationships. Findings suggest that after treatment-induced weight loss, addressing indicated theory-based psychosocial variables might mitigate decay in behavioral predictors of healthier weight.

Implications

Practice: Practitioners should expect a decay in healthy eating and physical activity after weight loss in many individuals and plan follow-ups to improve deteriorations in psychological predictors of those behavioral changes such as mood, emotional eating, self-regulation, and self-efficacy.

Researchers: Future research is warranted to further evaluate methods in which decays in post-behavioral intervention eating and physical activity behaviors, that are expected for many individuals, might be improved in order to better-enable sustained losses in weight.

Policymakers: Resources should be focused on scalable evidence-based methods designed to sustain behaviors that are consistent with maintaining loss of weight after behavioral intervention.

KEYWORDS

Weight loss, Maintenance, Treatment, Self-regulation, Self-efficacy, Physical activity

Although behavioral (non-pharmacological/non-surgical) treatments have consistently been associated with a 5–8 % loss in initial body weight, even more consistent has been a gradual climb toward baseline weight after approximately 6 months [1–3]. Although as little as 3 % weight loss can have health benefits [4, 5], from one third to two third regain of weight is expected over 2 years [2, 6]. Often, regain will continue beyond a participant's initial weight [1]. Repeating a pattern of weight loss and regain might increase individuals' health risks [7]. Researchers suggest that weight loss maintenance differs considerably from weight loss and thus should be distinctly studied and addressed [8]. In a recent trial incorporating a year-long, state-of-the-science behavioral weight management protocol directed primarily at reductions in energy intake [9], an initial weight loss of 9 % demonstrated a 91 % regain of baseline weight over the subsequent 3 years [10]. Because of the failure of this seemingly comprehensive protocol that was highly focused upon maintaining weight loss from its outset, along with the long history of behavioral treatments' association with weight regain [1–3], its developers questioned the merits of any further pursuits of such weight management interventions [10]. Although other researchers disagreed [11–13], it seemed clear that new and different approaches were needed.

As a reaction to this and (a) a consensus that exercise is a primary predictor of maintained weight loss [6, 14, 15], (b) suggestions that the development of self-regulation *prior to* pursuing reductions in energy intake is advisable [8], (c) proposed behavioral models of the relationship between exercise and weight loss [11, 16, 17], and (d) indications that physical activity affects weight loss more through its impact on psychosocial predictors of controlled eating than energy expenditure [11], a novel experimental intervention was

recently tested with women with obesity [18]. This treatment administered a component of supported exercise to improve psychosocial factors such as self-regulatory skills, self-efficacy, and mood 2 months *prior to* the administration of group nutrition-change sessions. The nutrition sessions then focused upon generalizing and reinforcing those gains for long-term maintenance of controlled eating and weight loss [18].

For example, for improving both physical activity and eating, there was a concentration on the use of self-regulation for overcoming common behavioral barriers and building self-efficacy to persevere. Also, the impact that exercise-induced mood change has on emotional eating [19] was leveraged. This impact is a factor previously shown to be associated with fruit and vegetable intake and consumption of sweets in women [20]. It was thought that this focus on building resilient self-regulatory skills, and accounting for psychosocial factors such as self-efficacy, mood, and emotional eating, would mitigate expected decays in the behaviors that are predictive of maintained weight loss [18, 21].

Outcomes of this experimental treatment were considerably stronger than a comparison condition of theory-based education and most other behavioral weight loss treatments. At the end of its second year, 89 % of participants' initial mean weight loss of 5.8 kg was maintained [18]. Also, this experimental treatment was relatively inexpensive to administer. Theoretical tenets of social cognitive [22] and self-efficacy [23] theory were supported. However, as has been the case with most weight management studies [8], behavioral changes and the resulting mean weight regain of only 0.6 kg over 2 years varied greatly between participants (SD = 4.6 kg).

Although there are a few exceptions, which also suggest the importance of building self-efficacy (e.g., perceptions of ability and competence) and addressing eating in response to emotional cues [24, 25], there is little actionable research on theory-based psychosocial factors that might influence success at *maintaining* weight management behaviors. Analyses of dynamic patterns of changes in psychosocial correlates of eating and physical activity trajectories in participants who were unsuccessful at maintaining their weight loss might be especially instructive beginning *just after* the time when most weight loss is expected (e.g., after the initial 6 months of treatment [1–3]). Thus, the aim of this preliminary, small-sample study was to develop a better understanding of changes within malleable psychosocial factors as they relate to their association with changes in fruits/vegetable consumption, intake of sweets, and physical activity outputs after the completion of a 6-month period of expected weight loss. Based on theory [16, 22, 23] and previous research over primarily brief time frames [11, 25], changes in self-regulation, self-efficacy, mood, and emotional eating were incorporated as predictors of behavioral changes within this research because of their respective roles in (a) overcoming inevitable life-related barriers, (b) perceiving success that motivates persistence, (c) establishing a positive mental climate that is advantageous for persistence, and (d) overcoming emotion-based triggers for lapses into past unproductive eating behaviors.

The ultimate goal of the research was to advance behavioral treatments to better-facilitate *sustained* weight loss in all participants. Data from a subsample of participants of the aforementioned experimental treatment [18], who were initially successful at weight loss by losing at least the 3 % of their initial weight required for a reduction in health risks [4, 5] but regained a minimum of one third of that weight over 2 years (which is indicative of a failure to sustain long-term effects [2, 6]), were assessed. After considering previously suggested relationships between changes in psychosocial and behavioral correlates of weight [8, 10, 11, 16, 17, 20, 25], and incorporating suggestions for the use of mediation analyses to inform the architecture of interventions [26], the following hypotheses were provided:

1. Measures of eating, physical activity, and their psychosocial predictors will proceed in the unfavorable direction from month 6 to month 12, month 6 to month 24, and month 12 to month 24.
2. Over the above temporal periods, there will be a significant inverse relationship between changes in negative mood and fruit/vegetable intake that will be mediated by emotional eating change. That relationship will be positive when change in the consumption of sweets is the measure of eating.
3. Over the aforementioned temporal periods, there will be a significant positive relationship between changes self-regulation and fruit/vegetable intake that will be mediated by self-efficacy change. That relationship will be negative when change in the consumption of sweets is the measure of eating.
4. Over the aforementioned temporal periods, there will be a significant positive relationship between changes in self-regulation and physical activity that will be mediated by change in exercise self-efficacy.

METHODS

Participants

Participants were a subsample of a recent study of 110 women with obesity (body mass index (BMI) = 30–40 kg/m^2) [18]. That sample type and size was established a priori to match a study being contrasted within that report [10]. For inclusion in the present research, at least 3 % of initial body weight must have been lost over the first 6 months after treatment initiation, and at least one third (≥33.3 %) of the lost weight must have been regained over 24 months while participating in the experimental group. Exclusion criteria were under 21 years of age, pregnancy, current use of medications for weight loss or a psychological/psychiatric condition, participation in a medical or commercial weight loss program, and exercise of ≥20 min/week.

The mean age of this subsample ($N = 36$) was 45.9 years (SD = 9.2), with a mean BMI of 34.5 kg/m^2 (SD = 3.2). There were 72 % White, 19 % African-American, and 9 % of other races/ethnicities. This approximates the racial make-up of the USA, as a whole. Nearly all self-reported a middle family-income range. Mean weight loss at month 6 was 7.3 % of original body weight (SD = 3.1). Mean weight loss at month 24 was 4.1 % (SD = 5.2). Institutional review board approval and written informed consent were obtained from each participant. The research protocols followed requirements of the Helsinki Declaration.

Measures

Because of the large number of self-report survey responses required, abbreviated instruments that were appropriately validated were used to minimize participant burden and maximize quality of responses where possible [27].

Fruits/vegetables and sweets–As suggested as applicable for the present research context [28], single items were used to measure typical daily intake of servings of fruits (e.g., apple, orange [1 small or 118 mL canned], 100 % fruit juice [118 mL]), vegetables (e.g., broccoli, carrots, green beans [118 mL], raw spinach [236 mL]), and sweets (e.g., candy [one small piece or 27 mL], cake [one small piece or 59 mL]) corresponding to both the U.S. Department of Agriculture's Food Plate and its earlier Food Guide Pyramid [29]. Scores from fruits and vegetables were summed (i.e., fruits/vegetables). Correlations with comprehensive food frequency questionnaires and the full-length Block Food Frequency Questionnaire [30] were reported to be strong at .70–.85 [30, 31]. Test-retest reliabilities over 3 weeks were .77–.83 for women [11].

Physical activity–The Godin-Shephard Leisure-Time Physical Activity Questionnaire [32] was used to measure weekly physical activity. Its measurement unit is metabolic equivalent of tasks (METs) per week, where 1 MET ~ 3.5 mL of O_2/kg/minute [33]. Participants' self-reported numbers of weekly sessions of strenuous (~9 METs; e.g., running), moderate (~5 METs; e.g., fast walking), and light (~3 METs; e.g., easy walking) physical activities for "more than 15 min" were summed. Test-retest reliability over 2 weeks was reported to be .74 [34]. Construct validity was indicated through strong correlations reported with both accelerometer and VO_{2max} measurements [35, 36].

Negative mood–The Total Mood Disturbance scale of the Profile of Mood States Short Form [37] was used to measure negative mood. Its 30 items assess feelings related to depression, tension/anxiety, vigor, fatigue, anger, and confusion (e.g., "sad," "tense," "energetic") occurring during the past week. Responses range from 0 (*not at all*) to 4 (*extremely*) and are summed (after reversing the scores on vigor). A lower score indicates less negative mood. Internal consistencies (all reported as Cronbach's α) were reported to be .84–.95 across factors [37] and were .79–.89 for the present sample [18]. Reported 3-week test-retest reliabilities averaged .69 [37].

Emotional eating–A 15-item version of the Emotional Eating Scale [38] was used to measure emotional eating. Items assess the extent a feeling related to anxiety, depression, and anger/frustration leads to an urge to eat (e.g., "nervous," "irritated"). Item responses range from 0 (*no desire to eat*) to 4 (*an overwhelming urge to eat*) and were summed. A higher score indicated more emotional eating. Internal consistencies were reported to be $\alpha = .72–.78$, and test-retest reliability over 2 weeks was .79 [38]. For the present sample, $\alpha = .70–.79$ [18].

Self-regulation for controlled eating and self-regulation for exercise–Consistent with previous research [11], a validated scale [39] that was adapted for the present context separately measured self-regulation for exercise and self-regulation for controlled eating through 10 items each. Responses range from 1 (*never*) to 5 (*often*) and assess the degrees specific self-regulatory skills/methods are presently incorporated to manage barriers to controlled eating (e.g., "I say positive things to myself about eating well") and completing exercise/physical activity (e.g., "I set physical activity goals"). Scores within each scale are summed, with a higher score indicating greater use of self-regulation to manage either eating or exercise/physical activity. Internal consistency of the original instrument was reported to be .75 [39] and was .83 and .80, respectively, for the present versions and sample [18]. Test-retest reliabilities over 2 weeks were .74 and .78, respectively [17].

Self-efficacy for controlling eating–The 20-item Weight Efficacy Lifestyle Scale [40] was used to measure self-efficacy for controlling eating when negative emotions, food availability, physical discomfort, positive activities, and social pressure might be challenging (e.g., "I can resist eating even when I have to say 'no' to others"). Item responses range from 0 (*not confident*) to 9 (*very confident*) and are summed. A higher score indicates greater self-efficacy. Internal consistencies were reported to be $\alpha = .70–.90$ [40] and were .74–.81 for the present sample [18].

Exercise self-efficacy–The 5-item Exercise Self-Efficacy Scale [41] was used to measure self-efficacy for completing exercise/physical activity or "… how confident you are that you can persist with exercising (continue with exercising) under the listed conditions" (e.g., "I feel I don't have the time," "I have more enjoyable things to do"). Responses range from 1 (*not at all confident*) to 11 (*very confident*) and are summed. A higher score indicates greater self-efficacy. Internal consistencies were reported to be $\alpha = .76–.82$, and test-retest reliability over 2 weeks was .90 [42]. For the present sample, $\alpha = .80$ [18].

Procedure

The treatment setting was small community-based wellness/fitness centers in the eastern USA. Processes and procedures are more fully explained elsewhere [18]; however, an overview will be provided here. The weight loss treatment consisted of two

components. The exercise support component incorporated the previously validated Coach Approach protocol [43] which was administered via six individual meetings (treatment initiation–month 7; Fig. 1). The nutrition behavior change component was administered through small group sessions (months 2–14; Fig. 1). Both treatment components were based on social cognitive [22] and self-efficacy [23] theories where individuals are viewed as being capable of self-organization, managing their environments, and being self-reflective of their abilities. Wellness leaders with at least one national certification (e.g., American Council on Exercise) received training in, and administered, all treatment sessions.

Within the exercise support component, physical activity plans were based on each participant's ability and preferences. However, the officially recommended minimum volume for health (i.e., 150 min/week of moderate-intensity physical activity [44]) was also described. Most session time was spent on the development of distinct self-regulatory skills including goal setting/progress monitoring, stimulus control, cognitive restructuring, relapse prevention, behavioral contracting, and how to best address behavioral cues and triggers. Physical activity-induced mood change was assessed both in response to a single bout of physical activity and over 1- to 2-month intervals. The individual one-on-one sessions were conducted in a private office supported by the use of a dedicated computer program [43].

The experimental nutrition component began after 2 months of focusing on exercise only. As diagrammed in Fig. 1, module 1 of the weight loss treatment component consisted of two, one-on-one sessions that introduced all participants to food and kcal tracking. Energy-intake limits were assigned based on each individual's present weight (e.g., 1500 kcal/day limit for a body weight of 79–99 kg). Module 2 of the treatment consisted of 10 group nutrition sessions of 60 min each. They were each spaced by 2 weeks. Consistent with previous research [11], its goal of active weight loss focused upon generalizing and adapting self-regulatory skills developed and practiced in the context of supporting regular physical activity, to regulating eating behaviors. For example, dissociation from exercise-induced discomfort was extended to dissociating from cues to overeating. Module 3 of the nutrition component consisted of four group sessions of 45 min each that again focused on the use of self-regulatory skills but were adapted to a required goal of *maintaining*, rather than seeking continuation of, lost weight. A final nutrition module provided content from module 2 tailored for either obtaining additional weight loss, or maintenance of lost weight, based on each participant's goals.

Throughout, the treatment processes emphasized the need to (a) maintain regular physical activity, (b) increase consumption of fruits and vegetables and minimize sweets, (c) incorporate self-regulatory skills to overcome behavioral barriers, and (d) develop self-efficacy through acknowledgement of enhanced capabilities to persevere. Because the emphases on behavioral change processes required considerable time within sessions, participants were referred to a United States Department of Agriculture website [29] for further evidence-based nutrition information. Study staff completed fidelity checks on approximately 15 % of treatment sessions. They indicated the need for only minor, easily implemented, corrective actions. Surveys were completed in a private area.

Data analyses

The intention-to-treat format that was used incorporated the expectation-maximization algorithm [45] for imputation of the 12 % of missing scores within the present data set. Based on consistent directionality of score changes and relationships in earlier related research [11], statistical significance was set at $\alpha = .05$ (one-tailed). Statistical analyses were conducted using SPSS Version 22 (IBM, Armonk, NY).

Repeated measures ANOVAs assessed changes in scores at months 6, 12, and 24. This was followed-up with *t* tests to evaluate all possible pairwise contrasts. Consistent with suggestions for this research context, change scores were unadjusted for baseline values [46].

Mediation analysis was then used incorporating 20,000 bootstrapped resamples [47]. The direct

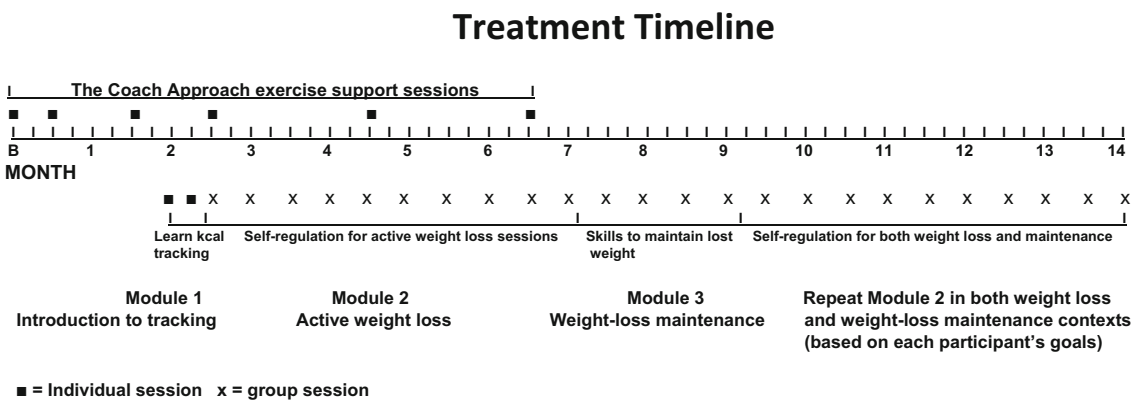

Fig. 1 | Weight loss treatment timeline

relationship between a predictor and outcome measure was first calculated (path *c*). Then, a potential mediator of that relationship was added to the model. Based on previous suggestions [48], a significant relationship between the predictor and outcome variable was not required for proceeding with mediation analyses. Statistical significance of mediation is identified when its corresponding 95 % confidence interval does not include zero. The relationships of mediator to predictor (path *a*), mediator to outcome (path *b*), and predictor to outcome while accounting for the effect of the mediator (path *c′*) were also calculated. Temporal periods for changes (month 6–month 12, month 6–month 24, and month 12–month 24) were consistent for variables within each equation. However, to assess directionality vs. bi-directionality in relationships, a procedure for assessment of reciprocal relationships [45] was used. Within this procedure, a reciprocal, mutually reinforcing, relationship between an outcome and mediator variable is identified if, after reversing their positions in a complementary mediation model, *both* equations demonstrate significant mediation [49].

RESULTS

Score changes

Each of the behavioral predictors of weight measured in this study–fruit/vegetable intake, consumption of sweets, and physical activity output–significantly changed in the undesirable direction starting 12 months after treatment initiation (Table 1). The proposed psychosocial correlates of these behavioral changes, however, demonstrated a more linear unfavorable trajectory starting at month 6. Only self-efficacy for controlling eating did not show a significant degradation over the course of this study (Table 1).

Psychosocial predictors of behavioral changes

Results for all mediation analyses are shown in Table 2. Statistically significant relationships between changes in mood and fruit/vegetable intake were not significantly mediated by changes in emotional eating (models 1a, 4a, and 7a). However, during months 6–24, the significant prediction of changes in the intake of sweets by mood change was significantly mediated by changes in emotional eating (model 4b). Change in self-efficacy for controlling eating significantly mediated the significant relationship between changes in self-regulation for controlled eating and fruit/vegetable intake only when month 24 data were included (models 5a and 8a). However, self-efficacy for controlled eating change was not a significant mediator of the prediction of changes in the consumption of sweets by self-regulation for controlled eating changes. In all temporal intervals tested, change in exercise self-efficacy significantly mediated a statistically significant relationship between changes in self-regulation for exercise and physical activity (models 3, 6, and 9).

Table 1 | Descriptive statistics and change scores from month 6 to month 24 ($N = 36$)

Measure	Month 6		Month 12		Month 24		Month 6–12 change		Month 6–24 change		Month 12–24 change	
	M	SD	*M*	SD	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Fruit/vegetable intake (servings/day)	6.40	2.41	6.31	2.33	5.43	1.99	−.97	1.21	−.97	2.33**	−.88	2.23*
Consumption of sweets (servings/day)	1.06	.83	1.11	.78	1.44	.97	.06	.64	.38	1.25*	.32	1.01*
Physical activity/week (METs/week)	36.14	14.95	35.79	14.77	22.96	15.45	−.34	8.13	−13.18	16.83***	−12.84	16.44***
Negative mood	2.44	10.23	6.94	12.29	9.56	15.37	4.50	7.84***	7.12	13.69**	2.61	13.66
Emotional eating	17.47	9.61	18.67	11.59	20.43	11.14	1.19	5.37	2.96	10.05*	1.76	10.07
Self-regulation for controlled eating	33.14	4.14	31.81	4.43	28.97	6.34	−1.33	3.94*	−4.17	6.31***	−2.83	5.90**
Self-efficacy for controlling eating	130.57	25.25	128.26	25.37	124.11	30.34	−2.31	14.93	−6.46	32.17	−4.15	27.37
Self-regulation for exercise	33.67	4.08	32.58	4.24	29.58	6.21	−1.08	3.45*	−4.09	4.69***	−3.00	5.41**
Exercise self-efficacy	36.44	9.43	34.69	10.98	30.33	11.04	−1.75	7.31	−6.11	10.86***	−4.36	9.06**

Significance of change within the labeled temporal interval is based on paired one-tailed *t* tests (dfs = 35)

METs metabolic equivalent of tasks (a measure of energy costs)

*$p < .05$, **$p < .01$, ***$p < .001$

Table 2 | Results from mediation and reciprocal effects analyses (N= 36)

Predictor	Mediator	Outcome	Model R^2 p	Path a β (SE) p	Path b β (SE) p	Path c β (SE) p	Path c' β (SE) p	Indirect effect β (SE) [95% CI]
Changes from month 6 to month 12								
Model 1a								
ΔNegative mood	ΔEmotional eating	ΔFruit/vegetable	.17	−.15 (.06)	.07 (.04)	−.02 (.01)	−.01 (.01)	−.01 (.01)
			.047	.006	.038	.042	.183	−.03, .00
Model 1b								
ΔNegative mood	ΔEmotional eating	ΔSweets	.00	−.15 (.06)	.01 (.02)	.00 (.01)	.00 (.01)	.00 (.01)
			.968	.006	.419	.439	.412	−.01, .01
Model 2a								
ΔSelf-regulation-eating	ΔSelf-efficacy-eating	ΔFruit/vegetable	.20	−.06 (.71)	−.02 (.01)	−.11 (.05)	−.12 (.05)	.00 (.03)
			.023	.466	.032	.021	.016	−.04, .04
Model 2b								
ΔSelf-regulation-eating	ΔSelf-efficacy-eating	ΔSweets	.09	−.06 (.71)	.00 (.01)	−.05 (.03)	−.05 (.03)	.00 (.01)
			.223	.466	.448	.041	.043	−.01, .01
Model 3								
ΔSelf-regulation-exercise	ΔExercise self-efficacy	ΔPhysical activity	.23	.78 (.26)	.35 (.22)	.93 (.35)	.65 (.38)	.27 (.18)
			.007	.003	.061	.006	.050	.04, .67
Model 3 (reciprocal analysis)								
ΔSelf-regulation-exercise	ΔPhysical activity	ΔExercise self-efficacy	.23	.26 (.09)	.65 (.38)	.52 (.20)	.35 (.22)	.17 (.11)
			.014	.003	.050	.008	.061	.02, .41
Changes from month 6 to month 24								
Model 4a								
ΔNegative mood	ΔEmotional eating	ΔFruit/vegetable	.12	.24 (.12)	−.07 (.04)	−.05 (.03)	−.03 (.03)	−.02 (.02)
			.050	.025	.040	.044	.135	−.06, .01
Model 4b								
ΔNegative mood	ΔEmotional eating	ΔSweets	.30	.24 (.12)	.06 (.02)	.03 (.01)	.01 (.01)	.01 (.01)
			.003	.025	.002	.032	.161	.01, .03
Model 4b (reciprocal analysis)								
ΔNegative mood	ΔSweets	ΔEmotional eating	.31	.03 (.01)	3.80 (1.22)	.24 (.12)	.13 (.11)	.11 (.08)
			.002	.032	.002	.025	.122	.03, .30
Model 5a								
ΔSelf-regulation-eating	ΔSelf-efficacy-eating	ΔFruit/vegetable	.24	2.63 (.75)	.02 (.01)	.15 (.06)	.09 (.07)	.06 (.04)
			.010	.001	.040	.006	.084	.01, .15

Model 5a (reciprocal analysis)								
ΔSelf-regulation-eating	ΔFruit/vegetable	ΔSelf-efficacy-eating	.33	.15 (.06)	3.88 (2.15)	2.63 (.75)	2.03 (.80)	.59 (.41)
			.001	.006	.040	.001	.084	.01, 1.35
Model 5b								
ΔSelf-regulation-eating	ΔSelf-efficacy-eating	ΔSweets	.32	2.63 (.75)	−.004 (.01)	−.11 (.03)	−.10 (.03)	−.01 (.01)
			.001	.001	.295	<.001	.002	−.05, .01
Model 6								
ΔSelf-regulation-exercise	ΔExercise self-efficacy	ΔPhysical activity	.52	1.66 (.28)	.64 (.27)	2.36 (.46)	1.30 (.62)	1.06 (.52)
			<.001	<.001	.012	<.001	.022	.30, 1.99
Model 6 (reciprocal analysis)								
ΔSelf-regulation-exercise	ΔPhysical activity	ΔExercise self-efficacy	.58	2.36 (.46)	.23 (.10)	1.66 (.28)	1.11 (.35)	.54 (.24)
			<.001	<.001	.012	<.001	.001	.19, .99
Changes from month 12 to month 24								
Model 7a								
ΔNegative mood	ΔEmotional eating	ΔFruit/vegetable	.52	−.12 (.06)	−.04 (.03)	.06 (.01)	.05 (.01)	.01 (.01)
			<.001	.022	.065	<.001	<.001	.00, .02
Model 7b								
ΔNegative mood	ΔEmotional eating	ΔSweets	.18	−.12 (.06)	.03 (.02)	−.01 (.01)	−.01 (.01)	.00 (.00)
			.039	.022	.057	.022	.077	−.01, .00
Model 8a								
ΔSelf-regulation-eating	ΔSelf-efficacy-eating	ΔFruit/vegetable	.50	1.98 (.72)	.06 (.01)	.08 (.06)	−.04 (.05)	.12 (.06)
			<.001	.005	<.001	.110	.216	.05, .24
Model 8a (reciprocal analysis)								
ΔSelf-regulation-eating	ΔFruit/vegetable	ΔSelf-efficacy-eating	.57	.08 (.06)	7.80 (1.43)	1.98 (.72)	1.36 (.54)	.62 (.54)
			<.001	.110	<.001	.005	.008	−.19, 1.58
Model 8b								
ΔSelf-regulation-eating	ΔSelf-efficacy-eating	ΔSweets	.27	1.98 (.72)	−.01 (.01)	−.09 (.03)	−.08 (.03)	−.01 (.01)
			.005	.005	.189	<.001	.005	−.03, .01
Model 9								
ΔSelf-regulation-exercise	ΔExercise self-efficacy	ΔPhysical activity	.49	1.13 (.21)	.92 (.31)	1.81 (.42)	.78 (.51)	1.04 (.51)
			<.001	<.001	.003	<.001	.070	.32, 2.00
Model 9 (reciprocal analysis)								
ΔSelf-regulation-exercise	ΔPhysical activity	ΔExercise self-efficacy	.57	1.81 (.42)	.23 (.08)	1.13 (.21)	.71 (.24)	.42 (.22)
			<.001	<.001	.003	<.001	.003	.12, .87

Analyses were based on a bootstrapping method for mediation incorporating 20,000 resamples (Preacher and Hayes 2008). A reciprocal analysis was conducted when mediation within the initial model was significant

Path a predictor → mediator, *Path b* mediator → outcome, *Path c* = predictor → outcome, *Path c'* = predictor → outcome, after controlling for the mediator, *95% CI* 95% confidence interval, one-tailed test

In each of the above models, increased negative mood significantly predicted more emotional eating ($ps < .03$), and for intervals where month 24 data were included, increased use of self-regulation significantly predicted greater self-efficacy (see path *a* [predictor → mediator] in Table 2; models 5a, 5b, 6, 8a, 8b, and 9). Also, for each interval tested, there was a reciprocal, bi-directional relationship between changes in exercise self-efficacy and physical activity (Table 2; see reciprocal analyses in models 3, 6, and 9).

Post hoc analysis

Over the duration of the study, participants' change in fruit/vegetable intake was significantly (inversely) associated with change in their consumption of sweets, $r = -.44$, $p = .003$.

DISCUSSION

The aim of this preliminary study was to re-analyze a subset of existing data from an earlier investigation [18] to determine psychosocial predictors of decays in healthy eating and physical activity after behavioral treatment-induced weight loss occurred. An additional goal was to translate these findings to inform follow-up treatment processes to better sustain lost weight in individuals vulnerable to regain. A subgroup of experimental treatment participants who lost weight and then began a trajectory of substantial regain from months 6 to 24 were assessed. As hypothesized, findings indicated significant unfavorable changes over time in self-regulatory skill usage, self-efficacy, mood, and emotional eating associated with less healthy eating and reduced physical activity soon after the 6-month period of weight loss. Results suggested a need to bolster some participants' use of self-regulatory skills to maintain healthy behaviors, possibly for years after initial weight loss is attained. The predicted effects of self-regulation on the weight management behaviors of increased fruit/vegetable intake and physical activity outputs were found to be mediated by changes in self-efficacy. Therefore, periodic communications to some participants that not only serve to reinforce previously incorporated self-regulatory skills, but highlight how using these skills can help to overcome challenges and barriers to maintaining their healthy eating and physical activity behaviors, appear to be indicated. Possibly the use of technology will also aid in the reinforcement of self-regulatory skill usage, especially when adherence is challenged. In that manner, lagging feelings of competence (self-efficacy) could be increased through a realization that an enhanced use of self-regulation yields well-earned payoffs for increasing both healthy behaviors and maintaining, or even furthering, loss in weight. The identified reciprocal relationships between gains in self-efficacy and improved behavioral changes could also be reinforced through such processes.

A significant association between increased negative mood and increased intake if sweets was, as expected, mediated by emotional eating over the length of the study. Emotional and binge eating is often related to excess consumption of sweets and fats [20, 50]. Because a minimum of only two to three moderate bouts of exercise per week has been shown to be associated with significant improvements in both mood [11] and emotional eating [19], treatment methods that were previously incorporated to maximize adherence to exercise (e.g., cognitive restructuring, relapse prevention) [42] might be reviewed with a participant to increase her physical activity to a point where mood is improved. Behavioral methods that were previously used to respond to emotion-based cues to overeating should also be re-addressed within follow-ups for participants in need.

Although the need for long-term follow-up is consistent with previous suggestions [2], evidence-based guidance for the content of those processes has been lacking. In two studies that *did* suggest targets for promoting long-term weight loss maintenance, the need for increased self-efficacy, self-regulation strategies, control over emotion-cued overeating, and physical activity was in agreement with the present findings [24, 25]. Continued research will be needed to determine optimal modalities, frequencies, and durations of such follow-up methods, especially because many participants might be averse to engaging in lengthy or intensive treatment sessions over the long term. Although some research indicated the possible helpfulness of phone- and/or Internet-based follow-up messages [51, 52], the associated research is in its early stages and the efficacy of those modalities remains unclear [6]. It is also possible that follow-up protocols should be tailored by individual factors (e.g., amount of weight lost and regained, psychological make-up).

In addition to limitations already stated in the research report where these data were derived such as the use of primarily White, middle-age females with class 1 and 2 obesity with possible expectation biases reflected in survey responses [18], the present preliminary study was also of a particularly small subsample. This modest-size sample was largely due to restrictive participant inclusion criteria that were associated with weight change parameters consistent with the aims of this study. Also, men might respond differently than women on changes in the psychosocial variables tested, especially emotional eating [53]. Therefore, replications with larger sample sizes and more objective measures (e.g., accelerometers) are required to increase confidence in findings, and replications across demographic variables and degrees of overweight/obesity are required to assess their generalizability. The present investigation did, however, serve to foster directed inquiry into actionable steps for the mitigation of weight regain through analyses of theory-based psychosocial predictors of eating and physical activity behaviors–primary behavioral correlates of weight change [11].

In summary, research should continue into the implications of psychosocial predictors of decays in healthy eating and physical activity so that the typical

pattern of weight loss and regain [1–3] might be improved. Additionally, outcomes of the experimental treatment used within this research [18] might be maximized. Because of the efficiency, scalability, and relative success suggested within the initial application of that protocol [18], improvements in its long-term effects might have a considerable impact on community-based weight management efforts. As suggested by Baranowski, the most positive practical effects in weight management might be derived from the effective translation of behavioral theory to practice [54].

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Compliance with Ethical Standards All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000.

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