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Bi-Directional Relationship Between Self-Regulation and Improved Eating: Temporal Associations With Exercise, Reduced Fatigue, and Weight Loss

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ABSTRACT. Severely obese men and women (body mass index $\geq$ 35 $\leq$ 55 kg/m^2; $M_{age} = 44.8$ years, $SD = 9.3$) were randomly assigned to a 6-month physical activity support treatment paired with either nutrition education ($n = 83$) or cognitive-behavioral nutrition ($n = 82$) methods for weight loss. Both groups had significant improvements in physical activity, fatigue, self-regulation for eating, and fruit and vegetable intake. Compared to those in the nutrition education group, participants in the behavioral group demonstrated greater overall increases in fruit and vegetable intake and physical activity. These group differences were associated with changes that occurred after Month 3. Increased physical activity predicted reduced fatigue, $\beta = -.19, p = .01$. A reciprocal relationship between the mediators of that relationship, which were changes in self-regulation and fruit and vegetable intake, was identified. There was significantly greater weight loss over six months in the behavioral nutrition group when contrasted with the nutrition education group. Self-regulation for eating and fruit and vegetable intake were significant predictors of weight loss over both three and six months. Findings enabled a better understanding of psychosocial effects on temporal aspects of weight loss and may lead to more effective behavioral treatments for weight loss.

Keywords: fatigue, nutrition, obesity, physical activity, self-regulation

TRADITIONAL OBESITY INTERVENTIONS THAT FOCUS ON TEACHING individuals how to create a negative energy balance for weight loss through a reduction in calorie intake and, possibly, an increase in physical activity have

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been largely ineffective beyond the first several months (Mann et al., 2007). It is possible that motivation to control one's eating decreases as early reductions in weight begin to plateau, and self-regulation is not strong enough to overcome ensuing barriers such as social pressure to overeat and limited time for proper food preparation. Thus far, both psychosocial and temporal aspects of weight loss remain poorly understood and are often addressed in clinical practice in an atheoretical manner (Mann et al.). Although regular physical activity is generally considered a desirable *adjunct* to nutritional treatments, research indicates that it is the strongest predictor of long-term success with weight reduction (Fogelholm & Kukkomen-Harjula, 2000; Svetkey et al., 2008). This may be attributable to factors well beyond the number of calories burned because energy expenditures through physical activities are minimal in individuals who are physically unfit (American College of Sports Medicine, 2009). Both theory (Baker & Brownell, 2000) and direct investigation (Mata et al., 2009; Teixeira et al., 2010) have suggested that physical activity impacts psychosocial predictors of improved eating. There is, however, a need to understand the dynamics of such relationships to clarify the foci and processes of improved treatments in the future.

Psychosocial Effects on Overeating

There has been considerable research attention on overeating in response to negative mood (i.e., emotional eating) (Geliebter & Aversa, 2003). A classic psychosomatic interpretation is that emotional eating is a learned behavior associated with the reduction of an aversive state (Kaplan & Kaplan, 1957). More specifically, the early review by Kaplan and Kaplan proposed an anxiety-reduction model where overeating by obese individuals reduces anxiety, and that maintains (or even increases) eating behaviors beyond what is required for satiety. More recent research suggests that obese individuals lack an ability to self-regulate their overeating in response to negative mood, even when they are well aware of the future aversive consequences to their health (Davis, Levitan, Muglia, Bewell, & Kennedy, 2004). This is especially true, "... in a culture dominated by so many, and such varied, sources of palatable and calorically dense sources of energy" (Davis et al., p. 929). Physical activity has been shown to positively affect mood states such as depression and anxiety (Landers & Arent, 2007). These improvements in mood may mitigate emotional eating (Melanson, Dell'Olio, Carpenter, & Angelopoulos, 2004) which has been associated with an increased consumption of sweet and high-fat foods, and reduced intake of fruits and vegetables (Konttinen, Männistö, Sarlio-Lähteenkorva, Silventoinen, & Haukkala, 2010). Although the positive influence of physical activity on fatigue has been addressed far less often than effects on depression and anxiety (Landers & Arent), it may be an important factor that affects both self-regulation and eating (Baumeister & Heatherton, 1996; Oaten & Cheng, 2006). This is important because self-regulation is viewed as critical for improving eating behaviors such as increased intake of fruits and vegetables, a proxy for an adequate diet (Rolls, Ello-Martin, & Tohill, 2004). In addition, success with improved eating may simultaneously reinforce (motivate) the use of self-regulatory skills (Kitsantas, 2000).

Fruit and Vegetable Consumption

Research suggests that a focus on specific (e.g., number of servings of fruits and vegetables), rather than general (e.g., overall energy intake), behaviors may be advantageous for advancing behavioral change (Gollwitzer, 1999). Fruit and vegetable consumption has previously been shown to be the only significant nutrition-related predictor of both weight loss and weight-loss maintenance (Champagne et al., 2011). If improvements in self-regulation and fruit and vegetable intake emanating from physical activity-induced changes in fatigue are found to reinforce one another (i.e., possess a reciprocal relationship), interventions may be accordingly adapted to maximize their effect. For example, treatments might highlight small gains in fruit and vegetable consumption to reinforce the use of self-regulatory skills such as cognitive restructuring and managing cues to overeating, while also carefully attending to the development of an array of self-regulatory skills to maximize fruit and vegetable intake.

Temporal Aspects of Weight Loss

With few exceptions (e.g., Cooper et al., 2010; Teixeira et al., 2006), temporal (or timing) patterns of weight loss, and implications based on physical activity and psychological and behavioral changes, have also been understudied. This is especially true in the initial months of treatment when as many as 77% of the participants drop out (Inelmen et al., 2005). It is possible that weight loss is most likely to occur during the initial weeks and months because strong motivations are present at treatment outset. Thus, when subsequent weight loss becomes more challenging and additional barriers are emerging, self-regulatory skills might be most critical. It is also possible, however, that self-regulatory techniques require considerable time for an individual to develop and, therefore, their impact on weight loss is deferred. Some plateauing of weight loss over time is also predicted from physiological factors such as the body's adaption to reduced energy intake (Hall et al., 2011). Thus, clinical expectations and optimally selecting and timing intervention components to maximize effects require targeted research for clarifications.

Although treatments based on tenets of social cognitive theory (Bandura 1986, 2004) have successfully increased physical activity, and improved mood, self-regulation for eating, and eating behaviors (Annesi, 2011; Annesi & Marti, 2011), associated effects of fatigue and the impact of physical activity on fatigue have not been sufficiently assessed. Temporal aspects of weight loss and its behavioral predictors have also received minimal research attention. Therefore, this study was conducted over six months to address these gaps in research. Adults with severe obesity (body mass index [BMI] $\geq$ 35 kg/m^2; World Health Organization, 2000) were selected for participation because of a great need for treatment improvements in these individuals. Consistent with recent suggestions to conduct research in practical settings in order to rapidly generalize findings for large scale application (Glasgow & Emmons, 2007; Green, Sim, & Breiner, 2013), a venue common to many communities (i.e., YMCAs) was selected for use.

Hypotheses

Hypothesis 1: Fatigue, fruit and vegetable intake, self-regulatory skills for eating, and physical activity volume would significantly improve over both three and six months, with greater improvements associated with a treatment emphasizing cognitive-behavioral methods over providing education in healthy eating (with both treatments having the same support for physical activity).

Hypothesis 2: Increase in physical activity would be related to a reduction in fatigue.

Hypothesis 3: A reciprocal relationship between changes in self-regulatory skills for eating and fruit and vegetable intake would be demonstrated based on the following: (a) self-regulation change would significantly mediate the relationship between changes in fatigue and fruit and vegetable intake, and (b) fruit and vegetable intake change would significantly mediate the relationship between changes in fatigue and self-regulation (see Palmeira et al., 2009).

Hypothesis 4: Weight loss would be significant for groups emphasizing both cognitive-behavioral and educational nutrition methods, with greater loss in the cognitive-behavioral treatment group.

Hypothesis 5: Because an emphasis on self-regulation has produced positive long-term effects on weight loss (McKee, Ntoumanis, & Smith, 2013), it was expected that the cognitive-behavioral group would have an overall greater loss in weight attributable to weight reductions occurring from Month 3 to Month 6.

Hypothesis 6: Reduction in weight over both three and six months would be predicted by changes in self-regulation and fruit and vegetable intake over the same time frames. Also, weight reduction over both three and six months would be predicted by self-regulation and fruit and vegetable intake scores at Month 3 and Month 6, respectively.

Method

Participants

Men and women volunteers from the southeast United States were solicited through print media for a study incorporating physical activity and nutrition methods for weight loss at a local YMCA. One hundred seventy-five individuals were accepted into the study based on the following criteria: age $\geq$21 years, BMI $\geq 35 \leq 55$ kg/m^2, and no regular exercise (<20 min/week) in the previous year. Exclusion criteria were: planned or present pregnancy, use of medications for weight loss or a psychological condition, and present participation in a medical or commercial weight-loss program. A written statement of adequate health to participate was required from a medical professional. Appropriate institutional review board approval and written informed consent were obtained from all participants. There was no significant difference in percentage of women (overall 79%), age (overall $M = 44.8$ years, $SD = 9.3$), BMI (overall $M = 40.7$ kg/m^2, $SD = 5.0$), and racial/ethnic make-up (overall 53% White, 44% African American, and 3% of other racial/ethnic groups) between those randomly assigned to either nutrition education (education group; $n = 83$) or cognitive-behavioral methods applied to nutritional change (behavioral group; $n = 82$). Participants were almost all middle-class. There was minimal attrition from initial acceptance into the study to actual treatment participation (6%) due to reported illnesses, problems with transportation, and an inability of study staff to make contact by phone or e-mail. Attrition did not differ by group. There was no cost or compensation for participation.

Measures

Fatigue was measured by the Profile of Mood States Short Form (McNair & Heuchert, 2005). Its 5-item scale of Fatigue required responses to 1- to 3-word items (e.g., worn-out) from 0 (*Not at all*) to 4 (*Extremely*) to indicate how the respondent has been, "... feeling during the past week including today." Item scores were summed. Internal consistency was reported to be $\alpha = .91$, and test-retest reliability over three weeks was .70 (McNair & Heuchert). For the present sample, internal consistency was $\alpha = .87$.

Quality of eating was assessed through a self-report survey of fruit and vegetable intake. It was measured by participants' self-reporting their combined servings of fruits and vegetables consumed "in a typical day" over the past month. It was based on the U.S. Food Guide Pyramid's descriptions of foods and their corresponding portion sizes (that was indicated within each item). Responses to the one item for fruits and the one item for vegetables were summed. Research suggests that fruit and vegetable intake alone is a good predictor of quality of the diet (Epstein et al., 2001; Rolls et al., 2004), and in the present type and context of measurement single items may be fully appropriate (Cummings, Dunham, Gardner, & Pierce, 1998). In previous research (Sharma et al., 2004), test-retest reliability over two weeks averaged .82, and concurrent validity was indicated through strong correlations of the present measure with lengthier food frequency questionnaires.

Self-regulation for eating was measured by a modified version of a recently published scale of 10 items (Saelens et al., 2000). Items were intended to measure a participant's use of specific self-regulatory skills associated with the content of the present treatment (e.g., "I say positive things to myself about eating well") (Annesi & Marti, 2011). Responses ranged from 1 (*Never*) to 5 (*Often*) and were summed. Previous research found that the instrument had an internal consistency of $\alpha = .81$, and test-retest reliability over two weeks was .74 (Annesi & Marti). For the present sample, internal consistency was $\alpha = .80$.

Physical activity volume was measured by the Godin-Shephard Leisure-Time Physical Activity Questionnaire (Godin, 2011). It incorporated metabolic equivalent of tasks (METs) or the energy cost based on physical activity intensity. A single

MET approximates the use of 3.5 ml of O_2/kg/min (Jetté, Sidney, & Blumchen, 1990). The Questionnaire required entry of number of weekly sessions of strenuous (approximately 9 METs; e.g., running), moderate (approximately 5 METs; e.g., fast walking), and light (approximately 3 METs; e.g., easy walking) physical activity for "more than 15 minutes." Thus, METs per week was the measure of volume of physical activity. Previous research found test-retest reliability over two weeks to be .74 (Godin & Shephard, 1985). Also in previous research (Jacobs, Ainsworth, Hartman, & Leon, 1993; Miller, Freedson, & Kline, 1994), construct validity was supported through strong correlations of Questionnaire scores with both accelerometer and peak volume of oxygen uptake measurements.

Weight was measured in kg using a recently calibrated digital scale.

Procedure

Physical Activity Support

Each participant was provided access to a YMCA center and received an orientation to study processes. Support of physical activity was identical in both the education and behavioral groups. It consisted of six, 45- to 60-min meetings with a trained YMCA wellness leader over six months (Annesi, Unruh, Marti, Gorjala, & Tennant, 2011). These one-on-one sessions included a physical activity plan based on each participant's preference and tolerance. Physical activity sessions could be completed either in or outside of the YMCA, and were not directly supervised by a wellness leader. Participants were informed that the current minimum volume of weekly physical activity recommended for health benefits was 150 min of moderate cardiovascular activity (Garber et al., 2011), but that *any* volume was likely to be beneficial for health, especially in the beginning. Moderate-intensity walking was the most frequent physical activity selected. Much of the meeting times, however, were spent learning self-regulatory methods intended to promote adherence. For example, long-term physical activity goals were identified, documented, and broken down into process-oriented short-term goals where ongoing progress feedback was tracked. Additional self-regulatory methods such as cognitive restructuring, stimulus control, self-reward, and relapse prevention were also taught during the sessions.

Nutrition Education

The nutrition component of the treatments differed by group. Both were conducted in groups of a combination of 10 to 15 men and women participants. In the education group, a previously developed protocol of six, 45-min group sessions of nutrition education (Kaiser Permanente Health Education Services, 2008) was administered over 12 weeks. Sessions began approximately six weeks after initiation of the physical-activity support component, and were led by trained YMCA wellness leaders. Protocol components provided education in the following areas: (a) understanding macronutrients, (b) stocking healthy foods, (c) incorporating healthy recipes, (d) menu planning, (e) healthy eating outside of the home, and (f) healthy snacking.

Cognitive-Behavioral Nutrition

The behavioral group had the same format for time of treatment administration as the nutrition group. However, the protocol used by the behavioral group was developed specifically for this study, and primarily focused on cognitive-behavioral techniques that were consistent with social cognitive theory. Thus, components emphasized the following methods: (a) setting caloric goals and logging daily food and calorie intake, (b) regular self-weighing, (c) relapse prevention training, (d) cognitive restructuring, and (e) recognizing and managing cues to uncontrolled eating.

Wellness leaders administering the treatments were blind to the purposes of the investigation. Approximately 10% of treatment sessions were monitored by study administrators for their adherence to each aspect of the treatment protocols. Problems with treatment-administration fidelity rarely arose, and were quickly rectified in cooperation with YMCA supervisors. Surveys were administered in a private area at baseline, and at the end of Month 3 and Month 6.

Data Analysis

Of the 165 participants initiating a treatment, 139 (84%) completed it. Completion rate did not differ significantly by group. An intention-to-treat format was used that retained data from all participants initiating treatment. Statistical significance was set at $\alpha = .05$ (two-tailed), throughout. To detect a small–moderate effect ($f^2 = .08$) at the statistical power of .80, a minimum of 122 participants was required. The anticipated effect size was estimated based on pilot research. The expectation-maximization algorithm (Schafer, 1997; Schafer & Graham, 2002) was used to impute data for the 16% of missing scores. It was suggested that up to 20% missing data is acceptable, especially when data appear to be missing at random and statistical power is adequate (Peng, Harwell, Liou, & Ehman, 2006), as was the case in this study. Consistent with previous suggestions for the present research context (Glymour, Weuve, Berkman, Kawachi, & Robins, 2005), gain (change) scores were unadjusted for their baseline value.

A series of mixed-model repeated measures ANOVAs were first computed to determine if there were significant improvements in fatigue, fruit and vegetable intake, self-regulatory skills for eating, and volume of physical activity over three and six months, and whether those changes differed by treatment group. After aggregating data, the association of changes in physical activity with changes in fatigue was assessed through a bivariate regression analysis. Mediation analyses (controlling for group and baseline scores) using a bootstrap procedure with 10,000 resamples (Preacher & Hayes, 2008) then evaluated if changes in self-regulation significantly mediated the relationship between changes in fatigue and fruit and vegetable intake; and whether changes in fruit and vegetable intake significantly mediated the relationship between changes in fatigue and self-regulation. If both self-regulation and fruit and vegetable intake were significant mediators in those corresponding equations, a reciprocal relationship would have been identified indicating that change in fruit and vegetable intake both mediates, and is mediated by, self-regulation change (Palmeira et al., 2009). In a mediation analysis, if a significant relationship between a predictor and outcome variable (Path c) is rendered insignificant after entry of a mediator (Path c'), complete mediation has occurred.

After aggregating data, the effects of changes in fruit and vegetable intake and use of self-regulatory skill on predicting weight changes occurring from baseline to Month 3 and baseline to Month 6 were assessed using multiple regression analyses with simultaneous entry of the predictors over the corresponding time frames.

Results

Descriptive statistics are given in Table 1. There were no significant group differences in any measure at baseline (ps $> .15$). In response to Hypothesis 1, mixed-model repeated measures ANOVAs (dfs $= 1, 163$) indicated significant improvements in fatigue ($F = 133.35$, $p < .001$, $\eta^2_{\rm p} = .450$), fruit and vegetable intake ($F = 75.10$, $p < .001$, $\eta^2_{\rm p} = .315$), self-regulation ($F = 270.03$, $p < .001$, $\eta^2_{\rm p} = .624$), and physical activity ($F = 481.13$, $p < .001$, $\eta^2_{\rm p} = .747$) over six months, with the behavioral treatment associated with significantly greater changes in fruit and vegetable intake ($F = 9.06$, $p = .003$, $\eta^2_{\rm p} = .053$) and physical activity ($F = 4.43$, $p = .037$, $\eta^2_{\rm p} = .026$). Changes in physical activity ($F = 0.42$, $p = .517$, $\eta^2_{\rm p} = .003$) and fruit and vegetable intake ($F = 0.54$, $p = .465$, $\eta^2_{\rm p} = .003$) from baseline to Month 3 did not, however, significantly differ by group. Post hoc exploratory analysis indicated that when only Month 6 data were considered, self-regulation for eating was also significantly greater in the behavioral treatment group, $F = 8.09$, $p = .005$.

In response to Hypothesis 2, the relationship between physical activity change and change in fatigue was significant, $\beta = -.192$, $SE = .029$, $p = .014$.

In response to Hypothesis 3, self-regulation for eating change fully mediated the relationship between changes in fatigue and fruit and vegetable intake (Paths $a \times b = -.026$, 95% CI $= [-.056, -.007]$), and fruit and vegetable intake change significantly mediated the relationship between changes in fatigue and self-regulation (Paths $a \times b = -.044$, 95% CI $= [-.119, -.004]$) (Figure 1). Based on the aforementioned criterion, a reciprocal relationship between changes in self-regulation for eating and fruit and vegetable intake was identified.

In response to Hypothesis 4, over the six-month duration of the study, weight loss was significant overall ($F = 143.43$, $p < .001$, $\eta^2_{\rm p} = .468$), and significantly greater for the behavioral treatment group ($F = 5.93$, $p = .016$, $\eta^2_{\rm p} = .035$). Follow-up t tests indicated significant within-group reductions in weight for both

TABLE 1. Changes in Study Measure Over 3 and 6 Months, by Treatment Group

			Baseline–Month 3				Month 3–Month 6			
	Baseline		Month 3		Change		Month 6		Change	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Fatigue										
Education group	8.49	4.74	4.01	3.84	−4.48	5.63*	3.66	3.66	−.35	1.90
Behavioral group	9.56	4.93	3.83	3.69	−5.73	5.21*	3.82	4.35	−.01	2.22
Fruit and vegetable intake/day										
Education group	4.53	1.98	5.49	2.18	.96	1.96*	5.30	1.89	−.19	1.15
Behavioral group	4.16	1.90	5.35	1.78	1.18	1.99*	5.76	1.97	.41	1.23*
Self-regulation for eating										
Education group	20.75	5.77	28.78	5.43	8.04	5.47*	28.47	5.91	.31	4.21
Behavioral group	22.11	5.78	30.38	5.61	8.27	7.00*	30.91	5.09	.54	3.49
Physical activity (METs/week)										
Education group	10.05	9.20	36.77	16.37	26.72	14.61*	34.15	17.58	−2.62	13.96
Behavioral group	7.89	7.58	36.17	15.82	28.28	16.29*	37.11	16.16	.94	12.86
Weight (kg)										
Education group	115.76	14.71	112.37	13.44	−3.39	4.26*	111.53	13.02	−.84	2.47*
Behavioral group	112.98	15.38	108.50	14.32	−4.49	4.01*	106.60	13.78	−1.90	3.65*

Note. Education group, $n = 83$; Behavioral group, $n = 82$.
*denotes a significant ($p < .05$) within-group change over the designated range of time.

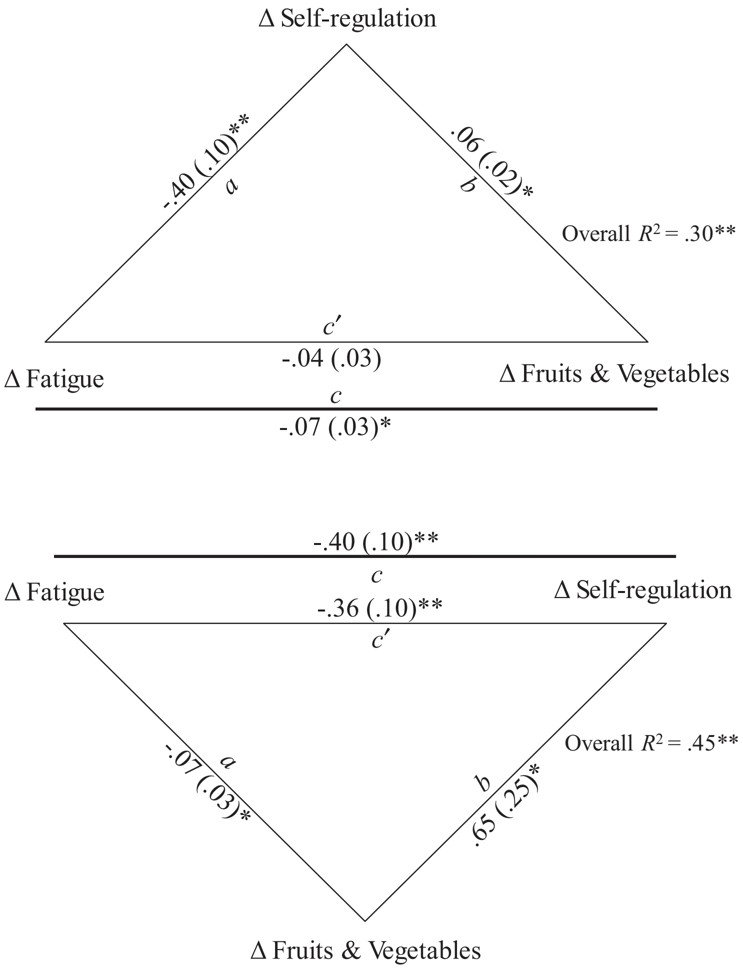

FIGURE 1. Mediation analyses for reciprocal effects between changes in scores on self-regulation for eating and fruit and vegetable intake. The Delta symbol (Δ) denotes score change from baseline to Month 6. Path *a* = predictor → mediator; Path *b* = mediator → outcome; Path *c* = predictor → outcome; Path *c′* = predictor → outcome, controlling for the mediator. Standard error (*SE*) is given in parentheses adjacent to each interrelationship coefficient. **p* < .05. ***p* < .001.

groups. There was a mean loss of 5.6% of original body weight in the behavioral group and 3.8% loss in the educational group.

In response to Hypothesis 5, although there were no significant group differences from baseline to Month 3 ($F = 2.91$, $p = .090$, $\eta^2_p = .018$), the behavioral treatment group continued to lose over half of its baseline to Month 3 weight change from Month 3 to Month 6, where the education group lost less than one-third of its baseline to Month 3 weight change over the same period. This difference was significant ($F = 4.78$, $p = .030$, $\eta^2_p = .029$).

In response to Hypothesis 6, for fruit and vegetable intake, changes over the initial 3 months did not significantly differ by group ($F = 0.54$, $p = .465$, $\eta^2_p = .003$), where changes from Month 3 to Month 6 were significantly greater for the behavioral group ($F = 10.34$, $p = .002$, $\eta^2_p = .060$). There was no significant group difference in self-regulation change for either baseline to Month 3 or Month 3 to Month 6. Considering aggregated data over the six months, increases in fruit and vegetable intake and self-regulation for eating accounted for a significant portion of the variance in weight loss (Table 2). Over the initial 3 months, increases in fruit and vegetable intake and self-regulation also accounted for a significant portion of the variance in lost weight (Table 2). In both equations, changes in both fruit and vegetable intake and self-regulation for eating contributed uniquely to the explained variances in weight change. When changes in self-regulation for eating and fruit and vegetable intake were replaced with self-regulation for eating and fruit and vegetable intake scores at Month 6 and Month 3 as predictors of weight changes over six and three months, respectively, significant portions of the variance in weight loss were accounted for (Table 2). Both self-regulation and fruit and vegetable intake were significant unique contributors.

Discussion

This research was intended first to assess and contrast changes in fatigue, fruit and vegetable intake, self-regulatory skills for eating, and physical activity in response to a treatment of physical activity support paired with either nutrition education or cognitive-behavioral nutrition methods. Next, it was to evaluate if a reciprocal relationship between changes in self-regulation and fruit and vegetable intake occurred in response to physical activity-induced improvements in fatigue. Finally, it examined changes in the aforementioned variables, along with weight change, over both three and six months so that practical implications for treatment designs might be realized. Results provided an improved understanding of how moderate physical activity positively affects fatigue, and how improvements in self-regulation and eating could reinforce one another to increase weight loss. The finding that a significant reduction in fatigue was associated with an average of approximately 27 METs of physical activity per week (the equivalent of approximately five moderate walks per week) was consistent with changes in depression

TABLE 2. Multiple Regression Analyses Predicting Changes in Weight ($N = 165$)

Outcome	Predictors	β	SE_B	R^2	F	df	p
Δ Weight baseline–Month 6				.10	9.02	2, 162	<.001
	Δ Self-regulation for eating from baseline–Month 6	−.20	.07				.008
	Δ Fruit and vegetable intake from baseline–Month 6	−.20	.25				.009
Δ Weight baseline–Month 3				.10	8.87	2, 162	<.001
	Δ Self-regulation for eating from baseline–Month 3	−.18	.05				.024
	Δ Fruit and vegetable intake from baseline–Month 3	−.22	.16				.006
Δ Weight baseline–Month 6				.16	15.22	2, 162	<.001
	Δ Self-regulation for eating at Month 6	−.27	.08				<.001
	Δ Fruit and vegetable intake at Month 6	−.22	.22				.004
Δ Weight baseline–Month 3				.14	13.14	2, 162	<.001
	Δ Self-regulation for eating at Month 3	−.24	.06				.001
	Δ Fruit and vegetable intake at Month 3	−.24	.16				.002

Note. The Delta symbol (Δ) denotes change in score.

and anxiety associated with similar volumes (Landers & Arent, 2007). The average effect size for reduction in fatigue ($d = 1.09$) was even larger than that of depression and anxiety (Landers & Arent, 2007), which suggested strong favorability for initiating moderate physical activity in the present population. Although some research suggests a biochemical basis for physical activity-induced mood improvements, the lack of a dose-response effect (i.e., more physical activity associated with a more improved mood) supports a behavioral explanation (e.g., good feelings associated with sustaining a positive health behavior that is challenging for most individuals) (Landers & Arent, 2007; Morgan, 1997).

The finding that the cognitive-behavioral nutrition treatment was associated with greater effects than with the educational approach on self-regulation for eating and fruit and vegetable consumption supports related research on adults with lower degrees of obesity (Annesi & Marti, 2011). Self-regulation is thought to be a powerful process for dealing with everyday barriers to physical activity and healthy eating (Bandura, 2004; Baumeister & Heatherton, 1996). It was unclear, however, to what degree self-regulatory skills that were established in the exercise support treatment component "carried over" to self-regulated eating. Although the transfer of self-regulation from an exercise to eating context has been suggested in previous research (Annesi & Marti, 2011; Mata et al., 2009; Oaten & Cheng, 2006), the directionality and extent of such a relationship remains unclear. It is also unclear whether adhering to a program of regular physical activity itself is associated with enhanced self-regulatory abilities, or if the addition of cognitive-behavioral support is required for (or moderates) such effects. Extensions of this research are needed to resolve these questions that have strong implications for treatment.

Temporal aspects of treatment-associated psychosocial changes and their effects on eating and weight loss have rarely been assessed. The finding that reductions in weight from Month 3 to Month 6, but not baseline to Month 3, were superior in the behavioral nutrition group suggests that cognitive-behavioral intervention effects may require several months to establish superiority over traditional educational approaches. Because drop out from physical activity (Annesi et al., 2011) and nutrition (Inelmen et al., 2005) programs might be as high as 60%–80% in initial months, strong adherence components are suggested as a part of future obesity treatments. For example, consistent with other research (Annesi et al., 2011), the cognitive-behavioral physical activity support component in this research was associated with less than 20% attrition. Consistent with the identified relationship between physical activity and long-term success with weight loss (Fogelholm & Kukkomen-Harjula, 2000; Svetkey et al., 2008), and based on the plethora of failed treatments (Cooper et al., 2010; Mann et al., 2007); possibly evidence-based adherence methods for physical activity should *precede* behavioral methods to improve eating. The predominant approach of educating individuals on the need and practice of healthy eating and regular physical activity, then expecting them to make difficult changes in their behaviors based on this knowledge, has not been successful (Mann et al., 2007). However, approaches utilizing physical activity and exercise for improving psychosocial predictors of improved eating and weight loss (rather than for their energy expenditures) should be further investigated prior to succumbing to recent suggestions (related to the recurring failures of behavioral obesity treatments) such as, "... psychosocial research on obesity should perhaps shift away from work on treatment ..." (Cooper et al., p. 712).

The reciprocal relationship between improvement in self-regulation for eating and improvement in fruit and vegetable consumption also leads to practical suggestions for treatment improvements. For example, consistent with social cognitive theory and cognitive-behavioral approaches, it is suggested that short-term goal setting and consistent tracking methods are used to document incremental improvements in eating, while self-regulatory skills that are acceptable to each individual are carefully embedded into treatments to support the same. Based on the present findings, both enhanced self-regulatory skills and incremental progress in eating behaviors could be expected to reinforce one other to induce not only greater losses in weight, but improvements in self-regulatory abilities that may sustain weight loss as additional barriers surface. However, the findings that change in self-regulation served to *fully* mediate relationships, where fruit and vegetable intake change did not, suggests that self-regulation is a stronger mediator and should perhaps precede changes in fruit and vegetable consumption. Establishing methods to sustain weight loss past the initial few months of treatment has been a universal challenge that might be positively affected by using manageable volumes of physical activity to improve psychosocial predictors of controlled eating (Mann et al., 2007).

Although enough to induce reductions in health risks (Blackburn, 1995), weight loss in the behavioral group (6.4 kg over six months, or 6%) appeared to be only moderately successful. It should be noted, however, that variability across participants was high, and many related studies have not used the conservative intention-to-treat format incorporated in this study where data from *all* participants (even early noncompliers) were retained. Weight loss tapered off to a lesser extent in Months 3 through 6 in the behavioral group, which again suggested the advantages of a cognitive behavioral treatment. The finding that both self-regulation and fruit and vegetable changes were predictors of weight loss at all measurement points of the study supported the proposed salience and interrelations of those variables. Consideration of these findings will be important for the architecture of future treatments. Practical implications are that supported physical activity, in even manageable amounts, is likely to induce mood and self-regulatory improvements that enhance appropriate eating, a key to long-term weight loss. Future obesity treatments should employ a cognitive-behavioral nutrition approach to extend the findings of this study and confirm that psychosocial and eating changes reinforce one another leading to sustained weight loss.

Limitations of study processes should be noted. Although important information regarding temporal aspects of weight loss and its behavioral predictors were identified, the 6-month time frame of the study was too brief to infer long-term weight-loss maintenance, which has been a problem (Jeffery et al., 2000). Thus, long-term follow-ups should be incorporated into replications. Although required for analyses of change, the use of gain scores compounded measurement errors by combining the error linked to each measure score at multiple times (Nunally & Bernstein, 1994). Also, while considerable validation of the present measurement method of nutritional intake was reported, other types of assessments of the diet (e.g., food diary, food frequency questionnaire) may be more precise, especially when the need for fewer surveys might minimize participant burden. Additionally, the self-report nature of both the eating and physical activity measures could have biased scores through social desirability effects. Factors such as degree of family, work, and peer support; life stressors; and cultural factors might affect behaviors associated with weight and should be accounted for in replications. Testing diverse sample types (e.g., based on age, sex, ethnicity, race, physiological disorder, degree of overweight, availability of healthy foods) will also serve to assess the generalizability of the present findings. While expectation and social support effects may confound findings in field research such as this, and those possible effects should be strongly considered, the ability of field-based research to readily generalize findings to applied venues was thought to, overall, be advantageous (Glasgow & Emmons, 2007; Green et al., 2013).

Conclusion

In summary, for the present sample of adults with severe obesity, fatigue improved with moderate volumes of physical activity, and cognitive-behaviorally based nutrition support increased improvements in self-regulation and eating beyond that of a more traditional approach of nutrition education. Improvements in self-regulation and eating reinforced one another, and each was associated with weight loss in both the first and second half of the 6-month trial. Overall, when paired with a consistent method of exercise support, weight-loss outcomes associated with the cognitive-behavioral nutrition treatment approach was superior to nutrition education. After replications and extensions of this research, behavioral treatments should incorporate findings to improve their outcomes.

AUTHOR NOTES

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