Health Behavior Research

Volume 1 | Number 1 Article 9

October 2017

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Keywords

weight loss, physical activity, cognitive behavioral, social cognitive, nutrition, self-regulation

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Abstract

Behavioral weight-loss treatments have typically been unsuccessful and atheoretical. Even when treatments were scientifically derived, theory has rarely been used to decompose, and understand the bases of, their effects. This 2-year study evaluated mediation of the prediction of nutritional changes by changes in physical activity, through social cognitive theory variables. Data from women with Class 1–2 obesity, classified as "insufficiently active" (N = 50; M_{age} = 47.6 years), were extracted from 2 initial trials of a new cognitive-behavioral intervention. That treatment sought to improve self-regulation, mood, and self-efficacy through increased physical activity, to then induce improved eating and long-term weight loss. Data showed significant improvements in self-regulation for controlled eating, mood, self-efficacy for eating, physical activity/exercise outputs, and intake of fruits/vegetables and sweets. In the prediction of changes in fruit/vegetable intake over 6, 12, and 24 months by physical activity changes, changes in the 3 psychosocial variables were significant mediators. For each of those significant overall models (R^2-values = .31, .30, and .25, respectively), self-regulation and self-efficacy change were independent mediators. When change in sweets was substituted for fruits/vegetable intake in otherwise identical models, although overall significance was not found, change in mood was a significant mediator. Changes in intake of fruits/vegetables and sweets significantly predicted a 2-year mean weight loss of 5.4 kg (-5.7% reduction). Results generally supported the basis for the architecture of the new cognitive-behavioral treatment. Based on findings, much of the effect of physical activity/exercise on weight loss could be explained through its impact on psychosocial correlates of healthier eating.

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Behavioral (non-surgical, non-pharmacological) treatments for obesity have generally had disappointing long-term effects.[1-3] Most concentrate on providing information about the need to eat healthier and, in some cases, be more physically active.[4] These educational approaches place little attention on hypothesized mechanisms of health behavior-change processes.[4] Based on the length of treatment (longer being more advantageous), body weight loss typically occurs over the initial 6–9 months.[1-3] After that, a brief plateau in weight ensues, after which there is a sustained trajectory toward complete or near-complete regain.[1-4] In consideration of the consistency of the aforementioned pattern for decades, some researchers have suggested that future efforts to facilitate long-term weight loss through behavioral means will likely be of little value, and should be eliminated.[5] Health risks associated with weight loss-regain cycling has also been cited as a concern for the ongoing use of ineffective treatments.[6]

Although acknowledging considerable innovation would be required, other researchers have reasoned that reliable behavioral solutions to reducing energy intake and enabling weight loss over the long term could ultimately be found.[2,7,8] However, recent attempts to (1) lengthen interventions,[9] (2) emphasize self-management skills for the retention of weight change from treatment start,[5] (3) modify state-of-the-art cognitive-behavioral methods through the addition of acceptance and mindfulness strategies,[10] and (4) provide Internet-based support[11] also demonstrated only transient effects. Nevertheless, 2 initial trials incorporating novel behavioral methods were associated with sustained 6.1% to 6.3% weight losses over 2 years in women with obesity within a low-cost community-based intervention.[12] In consideration of findings that physical activity/exercise is the strongest predictor of sustained weight loss,[13,14] this atypically successful treatment first focused on the challenge of adherence to physical activity[15] through the use of a well-validated protocol.[16] The self-regulatory skills that were the bases of that protocol were next adapted, and leveraged to control eating during the nutrition-change components. Thus, as suggested in review of the experimental research literature, self-regulation was treated in a manner analogous to a muscle that could be strengthened through repeated use in one context (ie, physical activity), to then be carried-over to another (ie, controlled eating).[17] Improved self-regulatory skill usage was also intended to promote self-efficacy through highlighting a participant's effective management of life's barriers.[12] Also, expected exercise-induced improvements in mood[18] were used to target emotional eating.[19]

Although the treatment's foundation in social cognitive theory[20,21] – and thus control over psychological, environmental, and behavioral predictors of weight loss – was clear, the proposed relationships of changes in physical activity leading to healthier eating behaviors through improvements in eating-related self-regulatory skill usage, self-efficacy to control eating, and overall mood had not been directly evaluated. Although viewed to be advantageous,[22-24] such a decomposition of treatment effects had rarely occurred, and represented a gap in the extant research. By determining salient mediators of effects, such process-sensitive assessment could benefit the architecture of future treatments, extensions of existing treatments, and weight-loss intervention theory, in general. These analytic methods could further be enhanced by accounting for directionality within the dynamic relationships between intervention components, psychosocial mediators, and behavioral effects. For example, experimental designs could model change in self-efficacy over 3 months as a predictor of change in a behavior over 6 months. Although some reciprocality between changes in the variables would no doubt exist, such methods would represent an improvement over *assuming* directionality through the common practice of measurement over the same interval or at a single point. Accounting for temporality in outcome measures would even further enhance the utility of findings. For example, if it were found that initial changes in eating behaviors are impacted differently over the short term (eg, 6 months) than the longer term (eg, 24 months), treatment curricula could accordingly be adjusted to optimize effects. Entry of different types of foods (eg, sweets, fats, fruits and vegetables [F/V]) into analyses would also be beneficial because of their different impact on weight and associations with psychosocial factors.[19]

The assessment of eating behaviors has taken various forms (eg, blood tests, food frequency questionnaires, urine tests).[25,26] Field-based research has been considered advantageous because it enables rapid generalizability of findings for applied uses,[27] however eating-behavior assessment can be invasive, expensive, and difficult to accommodate in practical settings. Because the intake of F/V has been considered a proxy for an overall healthy diet,[28,29] and sweets have been categorized as a calorie-dense, nutrient-poor food,[30,31] they represent

DOI: 10.4148/2572-1836.1001

(positively and negatively based) measures of treatment effects that can be more readily incorporated into field research.

Thus, the aim of this study was to assess the theory-based prediction of improvements in the intake of F/V and sweets by physical activity change, through mediation of treatment-associated improvements in self-regulatory skills usage, mood, and self-efficacy to control eating. Directionality in the prediction of eating behavior changes over various time frames was accounted for using a cross-lagged approach incorporating psychosocial and physical activity changes occurring *prior to* the nutritional changes. It was expected that improvements in the consumption of F/V and sweets, and reduction in weight, would be continuous through the 12-month treatment process. The psychosocial measures were also expected to demonstrate significant improvements, with effects primarily occurring within the initial 3 months of treatment. It was hypothesized that treatment-supported physical activity/exercise would significantly predict changes in F/V and sweets intake over 6, 12, and 24 months, with changes in self-regulation, mood, and self-efficacy demonstrating significant mediation of that relationship. Although less than 4% of U.S. adults meet the minimum requirement of weekly physical activity/exercise to promote health (ie, 150 minutes),[32] roughly one-fourth are largely sedentary.[33] They might present the greatest challenge to a weight-management intervention centered around physical activity. Also, research indicates that even 2 sessions of exercise per week (less than half the minimum recommendation for improved health[34]) can induce stable psychosocial improvements.[35] Inclusion of individuals already completing that amount of weekly physical activity would challenge further improvements in psychosocial variables and compromise the planned evaluation of theory.[17,20,21] Therefore, only this most sedentary subgroup were included in the present re-analysis of 2 studies' data using the above-described treatment.[12] Results of the present field-based design could facilitate an improved understanding of physical activity/exercise in the weight-loss/behavior-change process over both the short and longer terms, and produce findings that could be rapidly translated for large-scale application.

Methods

Participants

Participant data were extracted from the initial 2 trials of a new cognitive-behavioral weight-loss protocol.[12] Inclusion criteria for women of at least 21 years of age who volunteered for those trials were: (1) body mass index (BMI) of 30–40 kg/m^2 (Class 1 and 2 obesity), (2) no present participation in a weight-loss program, (3) no use of medications for either weight loss or a psychiatric/psychological problem, (4) not being pregnant or planning a pregnancy within 2 years, and (5) having a goal of weight loss. Although no participant completed the weekly volume of physical activity/exercise recommended for health benefits at baseline (ie, 5 sessions of moderate intensity[34]), many were completing a volume (eg, 2.5–3.5 sessions/week) that was previously identified as sufficient to improve several psychosocial predictors of health behavior changes.[35] Thus, based on the goals of this research, an additional inclusion requirement was the completion of the equivalent of 2 or fewer sessions of moderate–strenuous exercise per week (ie, a score of 14 or less on the Godin-Shephard Leisure-Time Physical Activity Questionnaire, which was termed "insufficiently active"[36]). This reduced the chance of changes in relevant psychological factors having been impacted by physical activity *prior to* baseline (thus, distorting effects of initiating regular physical activity/exercise within the research).

Based on the above inclusion criteria, the present sample included 50 women with the following characteristics: age, *M* = 47.6 years (*SD* = 8.4); BMI, *M* = 34.8 kg/m^2 (*SD* = 3.2); race/ethnicity, 78% white, 16% African American, and 6% other races/ethnicities; education level, 28% high school or some college, 28% bachelor's degree, and 44% greater than a bachelor's degree. Most participants were in the middle family-income range of $50,000 to $100,000/year. Institutional review board approval and written informed consent from all participants was obtained for this research.

Measures

To minimize participant burden and increase accuracy of responses,[37] brief scales with adequate reliability and validity were incorporated. All internal consistency scores are expressed as Cronbach's α, and test-retest reliability values were taken over 2-week to 3-week intervals.

Self-regulation for controlled eating was measured by 10 items that address use of self-regulatory methods to control eating. The items were based on a taxonomy of self-management techniques[38] and self-regulatory skills incorporated in the present treatment. Sample items are: "I say positive things to myself about eating well," and "I keep a record of my eating." Responses ranging from 1 (never) to 4 (often) are summed for a possible score range of 10 to 40. Internal consistency was α = .81,[39] and α = .83 for the study sample. Test-retest reliability was .74.[39]

Overall negative mood was measured by the 30 items of the Profile of Mood States Short Form.[40] It represents the 6 mood factors of depression, fatigue, tension, confusion, anger, and vigor. When items from the first 5 of the aforementioned factors are summed, and items representing vigor subtracted from that score, an aggregate value representing overall negative mood is derived.[40] Sample items are: "sad," "tense," and "energetic." Responses from 0 (not at all) to 4 (extremely) had a score range of -20 to100. Internal consistency across factors ranged from α = .84 to .95[40] and .79 to 0.87 for the study sample. Test-retest reliability averaged .69.[40]

Self-efficacy for eating was measured by the 20 items of the Weight Efficacy Lifestyle Questionnaire.[41] It represents the 5 factors of negative emotions, high food availability, social pressure, physical discomfort, and positive activities (such as viewing television and/or reading) that could impact resistance to eating. Sample items are: "I can resist eating when I am anxious" and "I can resist eating even when others are pressuring me to eat." Responses from 0 (not confident) to 9 (very confident) had a score range of 0 to 180. Internal consistency across factors ranged from α = .70 to .90,[41] and α = .74 to 0.80 for the study sample.

Physical activity/exercise was measured by recall of weekly outputs in metabolic equivalents (1 MET = 3.5 mL of O_2/kg/minute) using the Godin-Shephard Leisure-Time Physical Activity Questionnaire.[36] Each bout of physical activity/exercise "for more than 15 minutes" is recorded as "mild" (3 METs; eg, easy walking), "moderate" (5 METs; eg, fast walking), or "strenuous" (9 METs; eg, running or jogging), and summed. For example, 3 mild sessions (9 METs) and 3 moderate sessions (15 METs) would total 24 METs. Only the total MET score was used for this research. The measure previously demonstrated strong correspondence with accelerometer, maximal oxygen uptake (treadmill test), and body fat testing results.[42-44] To align scores with governmental recommendations for exercise and health benefits, the instrument's developers suggested classifications of "active" (or of "substantial benefit") for a score ≥ 24, "moderately active" (or of "some benefit") for a score of 14 to 23, and "insufficiently active" (or of "low benefit") for a score < 14.[36]

Fruit/vegetable and sweets intake were selected as the nutritional measures because fruit and vegetable consumption has been identified as a proxy for an overall healthy diet,[28,29] and sweets have been considered a calorie-dense, nutrient-poor, and unhealthy food type.[30,31] Because of its applicability for field research,[45] and based on previous guidelines[46] and applications,[35] single items enabled recall of daily intakes of servings of fruits (eg, 1 small pear, 118 mL of fruit either canned or as juice), vegetables (eg, 118 mL of peas or carrots, 236 mL of raw spinach), and sweets (eg, 1 small piece of chocolate candy [~ 30 mL], 1 small piece of cake [~ 59 mL]). These corresponded to the current U.S. Department of Agriculture's Food Plate, and its earlier Food Guide Pyramid.[47] Scores from fruits and vegetables were summed. Correlations with the full-length Block Food Frequency Questionnaire[48] and other lengthy and well-validated food frequency questionnaires were strong at .70 to .85.[48,49] The present measures' scores were also associated with the nutritional biomarkers of 4 serum carotenoids.[50] Test-retest reliabilities were .77 to .83 in women.[51]

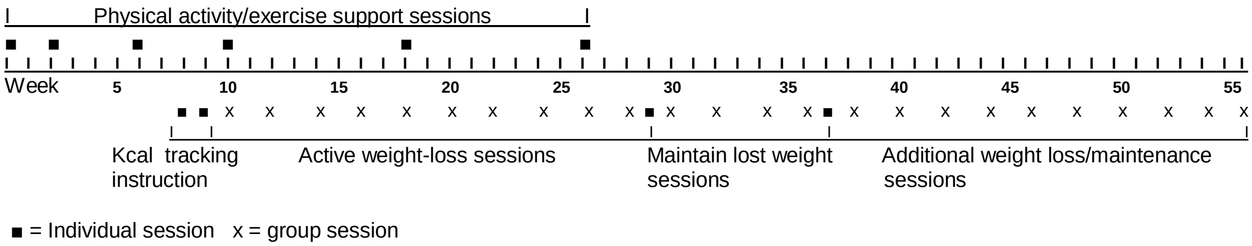
Body weight was measured in kg using a recently calibrated digital scale (Healthometer Professional model 800KL, Buffalo Grove, IL). Heavy clothing such as coats and shoes were first removed. Height was measured in cm using a stadiometer (Detecto model 337, Issaquah, WA). The mean of 2 consecutive measurements was recorded.

Procedure

Physical activity was first initiated as a vehicle for learning and rehearsing an array of self-regulatory skills (eg, goal-setting, relapse prevention, cognitive restructuring) that could facilitate controlled eating behaviors. As these skills enabled barriers (eg, inconvenience, slow progress) to be overcome, it was expected that self-efficacy for healthier eating would increase. Additionally, as increased physical activity improved mood,[18] emotion-based eating might be better controlled.[19] Hence, the curriculum focused on improving eating-related self-regulation, self-efficacy, and mood through behaviorally supported physical activity.[51]

More specifically, support of increased physical activity consisted of six 45 to 60-minute individual (1-on-1) sessions over 26 weeks using The Coach Approach curriculum of instruction in self-regulatory skills to counter barriers to exercise, leverage social supports, and minimize impediments (eg, physical discomfort).[16] After 8 weeks of exercise-support sessions only, participants were individually instructed in recording daily energy intake, and were provided a daily kcal limit based on present weight (eg, weight of 79–99 kg, 1500 kcal/week). Beginning at week 10, 60-minute nutrition-change sessions were initiated in groups of 10 to 15 participants. Ten such sessions were held every 2 weeks. They aimed to adapt the learned physical activity-related self-regulatory skills for use in controlling eating, with an emphasis on increasing F/V intake and minimizing sweets. Although the focus remained on self-regulatory skills usage throughout, nurturing self-efficacy through the successful mitigation of day-to-day barriers and controlling emotion-triggered eating were also ongoing treatment goals. Group sessions from weeks 30 to 36 then focused on *maintaining* lost weight (ie, no further loss during those weeks, learned skills were to be directed toward weight maintenance). The final 10 group sessions (weeks 38–56) targeted either more loss or maintenance, based on each participant's weight-loss goal. At weeks 29 and 37, there were brief individual meetings to explain the treatment's transition from active weight loss to weight maintenance, and vice versa. A time line of the above processes is given in Figure 1.

Figure 1. Treatment Time Line



Participants were instructed to weigh themselves at least once per week. All treatment components were administered at community wellness centers by wellness leaders with 1 or more national certifications related to health promotion. In addition to their prior 6-hour training in the exercise support component, they completed a 10-hour training in the nutrition-change component. Manuals of 76 pages and 215 pages, respectively, supported the treatment components. Fidelity checks of approximately 15% of randomly selected sessions suggested that the protocol was appropriately administered.

Data Analyses

An intention-to-treat approach[52] was used, which retained data from all individuals who initiated treatment components. For analyses of longitudinal changes, statistical significance was set at $\alpha \leq .05$, 2-tailed. Based on established directionality of relationships among the present variables,[51] 1-tailed tests were used in the planned regression analyses. Statistical calculations were conducted using SPSS version 22.0 (IBM, Armonk, NY).

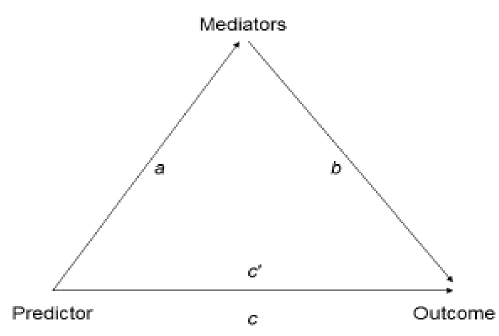
Considering established criteria,[53,54] the 11% of missing data were found to be absent of systematic bias, that is, they were missing at random. Thus, as advocated as appropriate under the present conditions,[55] the expectation maximization algorithm[56] was applied for imputation. For the primary analysis using the anticipated effect size of $f^2 = .25$ from 3 predictor variables at the statistical power level of .80 ($\alpha = .05$), a sample size of 48 was required.[57] Variance inflation factor scores ranged from of 1.26 to 1.97, which suggested an acceptable degree of multicollinearity in the data.[58]

To be sensitive to directionality of relationships, and considering that most changes in the present variables occur early in the treatment process,[51] a cross-lagged approach was used, where earlier temporal changes from baseline were entered as predictors of longer-term changes from baseline, wherever possible given the present data set (eg, changes from baseline–month 3 predicting changes from baseline–month 6).[59] Thus, a series of repeated measures within-subject ANOVAs were calculated based on those intervals, for all study measures. As previously suggested for the present research conditions,[60] change (gain) scores were unadjusted for baseline values (although analyses with baseline adjustments were also calculated, resulting in no appreciable difference from unadjusted data). Bonferroni-adjusted *t* tests were used to follow-up on significant ANOVAs. Effect sizes for ANOVAs were calculated as partial eta-squared ($\eta^2_p = SS_{effect}/[SS_{effect} + SS_{error}]$), and follow-up *t* test effects were calculated as Cohen's *d* ($M_{\text{change from}}$

$_{time1 - time2}/SD_{time1}$). By convention, .02, .13, .26, and .20, .50, .80 are considered to be small, moderate, and large effects, respectively.

Following the above analyses of changes, a series of multiple mediation models using a bootstrap procedure with 20,000 resamples[61] were specified. Those models assessed the mediation of the prediction of changes in eating behaviors (ie, outcome variable) by changes in physical activity (ie, predictor) through the change terms for self-regulation for controlled eating, overall negative mood, and self-efficacy for eating (ie, mediators; which were entered simultaneously). Within the multiple mediation models (Figure 2), path a (predictor→mediators), path b (mediators→outcome), and path c′ (predictor→outcome, controlling for the mediators) were calculated. Significant mediation is identified when the range of scores between the upper and lower limits of the corresponding 95% confidence interval does not include 0. Although not universally agreed upon as relevant,[62] if a statistically significant path c (predictor→outcome variable) is no longer significant after entry of the mediators (represented as path c′), then *complete* mediation has occurred (ie, prediction of eating behavior change was completely through the mediators).[63] Results based on suggestions that a significant path c is not required for mediation to be detected were additionally presented, as was suggested.[62]

Figure 2. Representation of a Multiple Mediation Model, Including Proposed Directionality of Relationships



Results

All repeated measures within-subject ANOVAs demonstrated significant overall improvements (Table 1). Follow-up analyses also indicated significant improvements from baseline for each of the measured intervals (Table 2). Additionally, follow-up tests indicated that weight continued to significantly decline, and physical activity continued to significantly increase through month 6. Negative mood significantly improved during months 6 to 12.

Table 1

Descriptive Statistics and Overall Changes within Study Variables (N = 50)

	Baseline *M* (*SD*)	Month 3 *M* (*SD*)	Month 6 *M* (*SD*)	Month 12 *M* (*SD*)	Month 24 *M* (*SD*)	*F*(1, 49)[a]	*p*	η^2_p
Self-regulation	23.36 (5.47)	32.49 (4.78)	32.62 (4.04)	32.04 (4.33)	…	81.55	< .001	.63
Negative mood	26.14 (15.75)	8.57 (15.27)	3.82 (11.58)	7.76 (12.12)	…	52.62	< .001	.52
Self-efficacy	84.42 (30.88)	115.38 (27.52)	127.23 (26.97)	127.47 (26.89)	…	63.64	< .001	.57
Physical activity (METs/week)	7.04 (5.99)	28.72 (13.24)	33.05 (14.95)	…	…	155.20	< .001	.76
Fruits/vegetables (servings/day)	3.69 (2.10)	…	6.46 (2.22)	6.33 (2.27)	5.73 (1.88)	37.05	< .001	.43
Sweets (servings/day)	2.19 (1.54)	…	0.88 (0.70)	0.88 (0.73)	1.12 (0.90)	17.49	< .001	.26
Weight (kg)	94.53 11.72)	91.30 (11.98)	88.46 (11.75)	88.53 (11.95)	89.11 (13.76)	28.71	< .001	.37

[a]Times where measurements were obtained are based on intervals required to accommodate directionality of relationships in the planned regression analyses.

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DOI: 10.4148/2572-1836.1001

Table 2

Change Scores and Effect Sizes Associated with Variables Incorporated Within Mediation Analyses (N = 50)

	Change Score[a] *M* (*SE*)	95% Confidence Interval	Effect Size[b] *d*
Self-regulation			
Baseline–month 3	9.13 (.99)	6.40, 11.86	1.67
Baseline–month 6	9.26 (.87)	6.88, 11.64	1.69
Baseline–month 12	8.68 (.94)	6.09, 11.27	1.59
Negative mood			
Baseline–month 3	-17.57 (2.27)	-23.81, -11.33	1.12
Baseline–month 6	-23.32 (2.45)	-29.05, -15.59	1.42
Baseline–month 12	-18.38 (2.47)	-25.16, -11.60	1.17
Self-efficacy			
Baseline–month 3	29.96 (4.51)	17.55, 42.37	.97
Baseline–month 6	41.81 (4.97)	28.15, 55.47	1.35
Baseline–month 12	42.05 (5.25)	27.61, 56.50	1.36
Physical activity (METs/week)			
Baseline–month 3	21.68 (1.85)	17.10, 26.26	3.61
Baseline–month 6	26.01 (2.09)	20.83, 31.19	4.34
Fruits/vegetables (servings/day)			
Baseline–month 6	2.64 (.35)	1.68, 3.61	1.26
Baseline–month 12	2.04 (.32)	1.16, 2.93	.97
Baseline–month 24	2.04 (.32)	1.40, 2.69	.68
Sweets (servings/day)			
Baseline–month 6	-1.31 (.25)	-1.99, -.63	.53
Baseline–month 12	-1.07 (.25)	-1.75, -.39	.69
Baseline–month 24	-1.07 (.24)	-1.56, -.58	.70
Weight (kg)			
Baseline-month 3	-3.23 (.35)	-4.26, -2.20	.28
Baseline–month 6	-6.07 (.52)	-7.60, -4.55	.52
Baseline–month 12	-6.01 (.62)	-7.84, -4.17	.46
Baseline–month 24	-5.42 (1.16)	-3.10, -7.75	.46

[a]All intervals demonstrated significant changes based on Bonferroni-adjusted follow-up *t* tests ($p < .005$).
[b]Cohen's *d*, $M_{\text{change from baseline}}/SD_{\text{baseline}}$.

Changes in the psychosocial variables of self-regulation for controlled eating, self-efficacy for eating, and overall negative mood significantly mediated the prediction of changes in F/V intake from baseline to months 6, 12, and 24 by physical activity changes occurring over months 3, 6, and 12, respectively (Table 3). The mediation was complete in the prediction of changes over 12 and 24 months. In each of those models, changes in self-regulation and self-efficacy were significant independent mediators (after controlling for the other mediators). Change in mood over 12 months was also a significant mediator of the prediction of F/V change over 24 months. When changes in sweets were entered into the above multiple mediation models in place of F/V changes, the overall R^2-values did not reach statistical significance. However, change in mood was a significant independent mediator in each of those 3 equations (Table 3).

In post-hoc multiple regression analyses, the significant weight change found over the 24-month duration of the study (Table 2) was significantly predicted, $R = .50$, $R^2 = .25$, $p = .001$, by changes over the same time frame in intake of F/V and sweets. Change in F/V, $\beta = -.38$, $SE = 1.12$, $p = .008$, but not sweets, $\beta = .21$, $SE = 1.42$, $p = .140$, was a significant independent predictor. An inverse bivariate relationship between changes in the consumption of F/V and sweets over 24 months was significant, $r = -.38$, $p = .003$.

Discussion

For the large subgroup of sedentary women with obesity, the present findings supported the newly proposed role of physical activity positively impacting eating behaviors through treatment-associated improvements in self-regulatory skills usage, overall mood, and self-efficacy to exert control over eating. Results of self-regulation and self-efficacy change being primary mediators of changes in F/V intake, and mood change being the principle mediator of sweets consumption, are consistent with earlier research that had been primarily limited to cross-sectional analyses.[30,64,65] Physical activity-associated improvements in overall mood have been linked to reductions in emotional eating and consumption of unhealthy foods.[66] Possibly, there are practical intervention components (eg, relaxation methods) that can enhance those effects when directed at situation-specific (ie, acute) emotion-prompted eating, especially for persons with binge eating disorder and/or high emotional eating. Direct measurement of emotional eating would be required. In regard to improving F/V intake, a better understanding of interrelations of changes in self-regulation and self-efficacy in the context of behavioral treatments might help to improve effects. For example, directionality of that relationship over different temporal intervals is unclear, but might ultimately prove beneficial for refining treatment.

Although remaining significant, the explanatory power of the multiple regression models predicting F/V change became somewhat weaker as time from baseline lengthened. Possibly, the addition of 1 or more theory-based mediators into the models will be beneficial in extensions of this research. As an example, social support is consistent with social cognitive theory[20] – the theoretical basis of the present intervention – but was not *directly* accounted for in this study. If found to be a salient addition to the present 3 mediators, it might both increase the power of, and stabilize, predictive models over time, as well as adding to the treatment architecture (eg, including instruction/role-playing on recruiting resilient social supports and avoiding those who might undermine productive behaviors).

Although the present findings made substantial theoretical and practical contributions in the role of physical activity/exercise in the weight-loss process, there were notable limitations. For example, replications with men across ethnicities and ages, and with individuals with disorders such as diabetes or a greater degree of obesity (ie, Class 3 [morbid] obesity), are required to evaluate generalizability of findings. Evaluation of whether the treatment can be effectively replicated using Internet-based and/or mobile phone-based technologies to increase cost-effective dissemination is also needed. Additionally, the confounding effects of volunteerism and expectations were unknown. Future trials might include participants who were strongly referred for behavioral treatment by their medical professionals to minimize the impact of characteristics inherent in being a volunteer.

https://newprairiepress.org/hbr/vol1/iss1/9
DOI: 10.4148/2572-1836.1001

Table 3

Results of Multiple Mediation Analyses with Changes in Physical Activity Predicting Eating-behavior Changes (N = 50)

Predictor	Mediators	Outcome	Model R^2	Path a β (*SE*)	Path b β (*SE*)	Path c′ β (*SE*)	Total effect/ Path c β (*SE*)	Indirect effect[b] β (*SE*)	Indirect effect[b] [95% CI]
Total for model			.31**			.05 (.03)*	.08 (.02)†	**.03 (.02)**	**[.01, .07]**
Physical activity B-3[a]	Self-regulation B-3	Fruit/vegetable B-6		.24 (.07)†	.08 (.05)			**.02 (.02)**	**[.00, .05]**
Physical activity B-3	Negative mood B-3	Fruit/vegetable B-6		-.51 (.16)†	.00 (.03)			.00 (.01)	[-.02, .02]
Physical activity B-3	Self-efficacy B-3	Fruit/vegetable B-6		.76 (.34)*	.02 (.01)			**.01 (.01)**	**[.00, .04]**
Total for model			.30**			.03 (.03)	.07 (.02)†	**.04 (.01)**	**[.02, .06]**
Physical activity B-6	Self-regulation B-6	Fruit/vegetable B-12		.19 (.05)†	.07 (.06)			**.01 (.01)**	**[.00, .04]**
Physical activity B-6	Negative mood B-6	Fruit/vegetable B-12		-.48 (.15)**	.01 (.02)			-.01 (.01)	[-.03, .01]
Physical activity B-6	Self-efficacy B-6	Fruit/vegetable B-12		1.24 (.29)†	.02 (.01)*			**.03 (.02)**	**[.00, .06]**
Total for model			.25**			.00 (.02)	.04 (.02)*	**.04 (.02)**	**[.02, .07]**
Physical activity B-6	Self-regulation B-12	Fruit/vegetable B-24		.18 (.06)**	.10 (.05)*			**.02 (.01)**	**[.00, .04]**
Physical activity B-6	Negative mood B-12	Fruit/vegetable B-24		-.42 (.16)**	-.03 (.02)			**.01 (.01)**	**[.00, .04]**
Physical activity B-6	Self-efficacy B-12	Fruit/vegetable B-24		1.26 (.31)†	.01 (.01)			**.01 (.01)**	**[.00, .04]**
Total for model			.12			.00 (.02)	-.03 (.02)	**-.02 (.01)**	**[-.04, -.01]**
Physical activity B-3	Self-regulation B-3	Sweets B-6		.24 (.07)†	-.04 (.04)			-.01 (.01)	[-.03, .01]
Physical activity B-3	Negative mood B-3	Sweets B-6		-.51 (.16)†	.03 (.02)			**-.01 (.01)**	**[-.04, .00]**
Physical activity B-3	Self-efficacy B-3	Sweets B-6		.76 (.34)**	.00 (.01)			.00 (.01)	[-.01, .02]

Table 3 (continued)

Results of Multiple Mediation Analyses with Changes in Physical Activity Predicting Eating-behavior Changes (N = 50)

Predictor	Mediators	Outcome	Model R^2	Path a β (*SE*)	Path b β (*SE*)	Path c′ β (*SE*)	Total effect/ Path c β (*SE*)	Indirect effect[b] β (*SE*)	[95% CI]
Total for model			.14			.01 (.02)	-.01 (.02)	**-.02 (.01)**	**[-.05, .00]**
Physical activity B-6	Self-regulation B-6	Sweets B-12		.19 (.05)†				.00 (.01)	[-.02, .02]
Physical activity B-6	Negative mood B-6	Sweets B-12		-.48 (.15)**				**-.02 (.01)**	**[-.04, .00]**
Physical activity B-6	Self-efficacy B-6	Sweets B-12		1.24 (.29)†				-.01 (.01)	[-.03, .02]
Total for model			.17			.02 (.02)	-.01 (.02)	**-.03 (.01)**	**[-.05, -.01]**
Physical activity B-6	Self-regulation B-12	Sweets B-24		.18 (.06)**				-.01 (.01)	[-.03, .01]
Physical activity B-6	Negative mood B-12	Sweets B-24		-.42 (.16)**				**-.01 (.01)**	**[-.04, .00]**
Physical activity B-6	Self-efficacy B-12	Sweets B-24		1.26 (.31)†				-.01 (.01)	[-.03, .02]

*$P \leq .05$. **$P \leq .01$. †$P \leq .001$. [a]Example of abbreviations: Physical activity B-3, change in physical activity from baseline to month 3. [b]Analyses are based on a bootstrapping method for multiple mediation incorporating 20,000 resamples.[61] Bold type indicates statistically significant mediation

DOI: 10.4148/2572-1836.1001

Implications for Health Behavior Research

The present study demonstrates that field research can maintain the benefits of strong external validity and, thus, strong applicability of findings,[27,67] while simultaneously incorporating research methodologies that facilitate an understanding of mechanisms of intervention effects.[22,61-63] Within the present research, both protocol development and theory were advanced by accounting for psychosocial mediators of relationships between physical activity and eating behaviors. Health behavior researchers should consider, in a like manner, regularly overseeing usage of non-invasive but adequately validated measures within applied settings to help foster an improved understanding of dynamic relationships between and among variables related to treatments, psychosocial changes, behavioral changes, and health outcomes. Even when large scale treatment dissemination rather than research is the goal, and cost is a concern, such data streams may be efficiently managed with adequate planning. More objective and cumulative analyses of treatment processes and outcomes, rather than reliance on single-case testimonies or biased accounts, might then become a norm within health-promotion practice settings (and encourage partnerships between researchers and practitioners).

The present research serves as an example of this, and demonstrates how informed health professionals can incorporate a merger of accepted theory, previous research, practical intervention design, and sound investigation of effects for the reduction of the persistent and expensive problem of widespread obesity. As an important step toward this, new interpretations of why exercise has been definitively linked to long-term weight loss (well-beyond its minimal energy expenditures possible in deconditioned individuals[16,35]), were presently identified. It is hoped that research on the present promising treatment and its accompanying theory continue so that obesity might be more effectively controlled through non-invasive behavioral methods.

Acknowledgements

We acknowledge the Thrivent Foundation for their financial support of the project, the volunteers for their participation, and Ms Anna Ly and Ms Chandler Annesi for their roles in the data management. The authors have no conflict of interest to report, financial or otherwise.

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DOI: 10.4148/2572-1836.1001

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