

Mediators of Weight Loss and Weight Loss Maintenance in Middle-aged Women

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Long-term behavioral self-regulation is the hallmark of successful weight control. We tested mediators of weight loss and weight loss maintenance in middle-aged women who participated in a randomized controlled 12-month weight management intervention. Overweight and obese women ($N = 225$, $BMI = 31.3 \pm 4.1 \text{ kg/m}^2$) were randomly assigned to a control or a 1-year group intervention designed to promote autonomous self-regulation of body weight. Key exercise, eating behavior, and body image variables were assessed before and after the program, and tested as mediators of weight loss (12 months, 86% retention) and weight loss maintenance (24 months, 81% retention). Multiple mediation was employed and an intention-to-treat analysis conducted. Treatment effects were observed for all putative mediators (Effect size: 0.32–0.79, $P < 0.01$ vs. controls). Weight change was $-7.3 \pm 5.9\%$ (12-month) and $-5.5 \pm 5.0\%$ (24-month) in the intervention group and $-1.7 \pm 5.0\%$ and $-2.2 \pm 7.5\%$ in controls. Change in most psychosocial variables was associated with 12-month weight change, but only flexible cognitive restraint ($P < 0.01$), disinhibition ($P < 0.05$), exercise self-efficacy ($P < 0.001$), exercise intrinsic motivation ($P < 0.01$), and body dissatisfaction ($P < 0.05$) predicted 24-month weight change. Lower emotional eating, increased flexible cognitive restraint, and fewer exercise barriers mediated 12-month weight loss ($R^2 = 0.31$, $P < 0.001$; effect ratio: 0.37), but only flexible restraint and exercise self-efficacy mediated 24-month weight loss ($R^2 = 0.17$, $P < 0.001$; effect ratio: 0.89). This is the first study to evaluate self-regulation mediators of weight loss and 2-year weight loss maintenance, in a large sample of overweight women. Results show that lowering emotional eating and adopting a flexible dietary restraint pattern are critical for sustained weight loss. For long-term success, interventions must also be effective in promoting exercise intrinsic motivation and self-efficacy.

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INTRODUCTION

Forty to sixty percent of the adult population in the Western world is actively attempting to reduce their body weight, with higher figures reported in overweight/obese individuals and in women (1–3). Nevertheless, overweight and obesity remain highly prevalent (4,5), suggesting that many attempts to lose weight are unsuccessful. Behavioral or lifestyle obesity treatments are the most frequently adopted programs and are recommended for virtually all overweight/obese persons attempting to lose weight regardless of their level of obesity (6). For individuals who successfully lost weight, maintaining their new weight is often a lifetime challenge. Thus, understanding why and how some people succeed in changing their weight-related behaviors, whereas the majority does not is a key research priority. Identifying predictors of *long-term* successful weight control is especially critical (7).

Most weight management programs emphasize intervention targets such as knowledge, skills, social or environmental factors, viewed as putative mediators of change. Independent of the theoretical framework adopted, positive outcomes include increases in exercise and eating self-efficacy, in flexible cognitive restraint, and in exercise motivation. Conversely, high perceived barriers for exercise or dietary change, high level of external and emotional eating, and poor body image are examples of negative predictors of success across a broad range of programs (8,9). Unfortunately, very few studies have systematically evaluated the extent to which interventions are effective in changing these (and other) variables. Even fewer have reported the predictive power of such changes regarding short- and especially long-term weight control, using randomized controlled designs. Knowing which intervention aspects are more effective and at what point in time during weight control is essential for proactively directing intervention resources to factors most clearly associated with success.

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We have previously analyzed psychosocial variables as predictors of short- and long-term weight loss in middle-aged US women (10–12). Findings highlighted the role of general and exercise-related motivational factors (e.g., self-motivation, self-efficacy, and exercise enjoyment) to achieve weight loss up to 16 months after the start of treatment. Subsequently, we studied the predictive power of a comprehensive set of psychosocial variables when assessed at baseline (13), or expressed as 4-month changes (14), for successful weight loss in Portuguese women. Collectively, results from these studies have shown that variables that are more predictive of short-term weight loss (e.g., eating-related variables such as cognitive restraint and eating self-efficacy) are not necessarily associated with weight loss maintenance (e.g., 12). Overall, the best prediction models accounted for about 30–40% of variance in weight loss. However, the absence of a control group in our previous studies limited interpretation of results and did not allow for mediation analyses to be formally conducted (15).

The purpose of the present study is to identify mediators of 12-month (i.e., intervention-related) weight loss and 24-month weight loss maintenance, in previously overweight/obese women who underwent a behavioral treatment program. Based on previous results (11,13,14,16), we expected eating-related variables to be strongly associated with intervention-related weight loss. Conversely, we predicted that exercise variables would be more predictive of long-term weight control or weight loss maintenance (12,14,17). Changes in body image were expected to predict long-term weight changes over and above other exercise and eating psychosocial variables (18).

METHODS AND PROCEDURES

Study design and intervention

The study was a randomized controlled trial consisting of a 1-year behavior change intervention and a 1-year follow-up period with no intervention. Participants entered the study in three annual cohorts; each cohort was split into two randomly assigned groups, intervention and control. The intervention group attended 30 group sessions for ~1 year. The control group received a general health education curriculum based on several educational courses on various topics (e.g., preventive nutrition, stress management, self-care, and effective communication skills). Details of the study's theoretical rationale, protocol, and intervention curriculum are described elsewhere (ref. 19 and M.N. Silva, P.N. Vieira, S.R. Coutinho *et al.*, unpublished data) and are only briefly summarized here. The Faculty of Human Kinetics Ethics Committee reviewed and approved the study.

Primary targets of the intervention included increasing physical activity (PA) and energy expenditure, adopting a diet consistent with a moderate energy deficit, and ultimately establishing exercise and eating patterns that would support weight maintenance. Cognitive and behavioral aspects such as identifying personal resistances, overcoming lapses, establishing adequate goals, and implementing self-monitoring were emphasized. Intervention sessions covered topics such as emotional and external eating, its detection and prevention, as well as improving body acceptance and body image (19). The program's principles and style of intervention were based on Self-Determination Theory (20,21) with a special focus on increasing competence and internal regulation toward exercise and weight control. Guiding principles of the intervention included providing participants with adequate structure and a range of options to choose from, supporting their autonomous decisions during the program, and encouraging participants to

explore their own motivations for treatment and define their personal treatment goals, while limiting external contingencies and controls (e.g., outcomes-based rewards or praise, external monitoring of behaviors and body weight).

Participants

Participants were recruited through newspapers, flyers, and TV advertisements to join a university-based behavioral weight loss program. To be included in the study, participants had to be female, between 25–50 years old, premenopausal, have a BMI between 25 and 40 kg/m², be willing to attend weekly meetings (during 1 year), be free from major illnesses, and not take medications known to interfere with body weight regulation. Of all women who entered the study ($N = 258$), 19 women were subsequently excluded from all analyses because they started taking medication susceptible to affect weight (e.g., antidepressants, anxiolytics, and antiepileptics; $n = 10$), had a serious chronic disease diagnosis or severe illness/injury ($n = 4$), became pregnant ($n = 2$), or entered menopause ($n = 3$). These women were of similar age ($P = 0.575$) and BMI ($P = 0.418$) as the 225 participants considered as the effective initial sample.

Subjects were 37.6 ± 7.0 years old, overweight, or mildly obese (BMI: 31.3 ± 4.1 kg/m²), and 67% had at least some college education. Women in the intervention group did not differ from those in the control group in terms of BMI, age, education, and marital status. There were also no differences between the women who completed the 12- and 24-month assessments and those who quit the program, for any demographics or psychosocial variable at baseline, with the exception of age; women who stayed in the program at 24 months were 2.5 years older at program start ($P = 0.026$).

Measurements

Body habitus. Weight was measured twice, to the nearest 0.1 kg (average was used) using an electronic scale (Seca model 770; Seca, Hamburg, Germany) and height was also measured twice, to the nearest 0.1 cm (average was used). BMI in kilograms per square meter was calculated from weight (kg) and height (m).

Eating psychosocial measures. Cognitive restraint, disinhibition, and perceived hunger were assessed with the 51-item Eating Inventory, also known as the Three-Factor Eating Questionnaire (TFEQ, 22). The cognitive restraint scale (21 items) measures conscious attempts to monitor and regulate food intake, the disinhibition scale (16 items) measures uncontrolled eating in response to cognitive or emotional clues, and the perceived hunger scale (14 items) measures the extent to which respondents experience feelings of hunger in their daily lives. Higher scores indicate higher levels of cognitive restraint, disinhibition, and perceived hunger. Two additional scores, flexible restraint, and rigid restraint were calculated from the TFEQ (23,24). Flexible cognitive restraint (7 items) is associated with low emotional and disinhibited eating, with a higher score indicating a more graduated approach to eating and weight control (e.g., "When I have eaten my quota of calories, I am usually good about not eating any more"). Rigid cognitive restraint (7 items) is associated with a more dichotomous, all-or-nothing eating pattern and with higher disinhibition (e.g., answering yes to "Do your feelings of guilt about overeating help you to control your food intake?"). The Dutch Eating Behavior Questionnaire (25) was applied to assess external and emotional eating. It consists of 31 questions such as "Do you have a desire to eat when you are irritated/smell delicious foods/etc.?" Answers were provided on a 5-point scale, from "never" to "very frequently." Eating self-efficacy, the belief in one's capacity for resisting opportunities to overeat and for self-regulating one's dietary intake, was assessed with the Weight Management Efficacy Questionnaire (26). Statements include "I can resist food when I'm nervous/watching TV/etc.," to be evaluated on a 10-point scale from "not at all confident" to "very confident."

Exercise psychosocial measures. Exercise self-efficacy for exercise was assessed with the Self-Efficacy for Exercise Behaviors scale

(27), measuring beliefs that a person can “stick with” the exercise program under varying circumstances (e.g., when lacking time, when feeling tired). The average of the 10 items was used for the self-efficacy score with higher scores indicating higher self-efficacy. Exercise perceived barriers were assessed with items from the Exercise Perceived Barriers scale (28). Two “obstacles” items from the original instrument were not included in analyses due to very low internal consistency ($\alpha = 0.22$) and low item-scale correlations; the average of the remaining nine items was calculated for the total barriers score. High values indicate more perceived barriers to regularly engage in physical activities. Exercise motivation was assessed with a version of the Intrinsic Motivation Inventory (29) adapted to specifically measure an individual’s level of motivation for exercise and PA in the dimensions of interest/enjoyment (e.g., “I enjoy getting involved in physical activities very much”), perceived competence (e.g., “I think I do pretty well at physical activities, compared to others”), effort/importance (e.g., “It is important for me to do well at physical activities”), and pressure/tension (e.g., “I am usually anxious when I engage in physical activities”), each with four items. The interest/enjoyment scale is considered the effective measure of intrinsic motivation. Perceived competence and pressure/tension are considered precursors of intrinsic motivation, whereas effort/importance is a separate scale also correlated with general motivation for a given task. A total score indicating overall level of exercise motivation was also computed, with higher scores indicating a more internal, self-regulated type of motivation. The pressure/tension scale is negatively correlated with all other scales of the questionnaire; thus, the four items from this scale were reversed before analyses.

Body image measures. Body image is a multidimensional construct and was assessed with the Body Shape Questionnaire (30), the Body Image Assessment questionnaire (31), and with two scales from the Physical Self-Perception Profile questionnaire (32). The Body Shape Questionnaire measures concerns with body shape, in particular the experience of “feeling fat” and consists of 34 items (e.g., “Has being with thin women made you feel self-conscious about your shape?”, “Has being naked, such as when taking a bath, made you feel fat?”) providing a total score for body shape concerns, with higher scores (sum of all items) indicating poorer body image. The Body Image Assessment questionnaire consists of nine silhouettes of increasing size, from which participants are asked to select the figures corresponding to their current (i.e., perceived actual body size) and their ideal body size. Body size dissatisfaction is calculated by subtracting the score for perceived body size from the ideal body size rating. Higher discrepancy indicates higher levels of body size dissatisfaction. The Physical Self-Perception Profile questionnaire measures self-esteem in several dimensions of the physical domain including a global physical self-worth scale (e.g., “Some people feel extremely proud of who they are and what they can do physically”) and a body attractiveness scale (e.g., “Some people feel that compared to most they have an attractive body”), which were used in this study. Each scale has six items and the average was calculated with higher scores indicating higher physical self-worth and higher satisfaction with one’s body.

Subjects completed psychosocial assessments at baseline and 12 months, following a standard protocol and with a study technician attending every assessment period. Forward and backward translations between English and Portuguese were performed for all questionnaires cited above. Two bilingual Portuguese researchers subsequently reviewed the translated Portuguese versions, and minor adjustments were made to improve grammar and readability. Cronbach’s α ’s for baseline and 12-month measurements are shown in Table 1.

Analytical model and statistical procedures

Two mediation models guided the analytical procedure for this study, represented in Figure 1. The first model (named “weight loss model”) was concerned with predicting intervention-related (12-month) weight change. The predictor was the intervention (vs. control) group status

and mediators were change in exercise- and eating-related psychosocial variables. The second model (“weight loss and maintenance model”) used 24-month weight change as the dependent variable, and change in exercise, eating, and also body image variables as mediators. Body image was not included in the weight loss model because it partially results from weight change (18); to the extent it can also contribute to weight loss, it would likely do so via its effects on exercise and eating-related variables (33,34), some of which were already included in the model. In the weight loss and maintenance model, body image was included to test whether changes during treatment were predictive of long-term weight loss, above and beyond change in other concurrent psychosocial (and weight) changes.

We used a mixed procedure for the analysis, generally following Baron and Kenny’s formal steps for mediation (35), and also using a novel procedure to evaluate total, direct, and indirect intervention effects through selected multiple mediators, as described by Shrout and Bolger (36). This procedure was chosen to provide a detailed description of intervention effects, and of the association between psychosocial and weight changes, before ultimately testing mediation effects. The first criterion for mediation was assuring that the intervention predicted weight change (total effects, path C in Figure 1). Second, intervention effects on the putative mediators (path A) were tested. Effect sizes were calculated to quantify the magnitude of 12-month change differences, including between-group comparisons. The third step assessed whether the mediators were related to outcomes (weight change) after the predictor (group assignment) was controlled, that is, path B. This was done for all mediators separately using partial correlation and also using multiple regression to identify independent predictors within each category of variables (exercise, eating, and body image). Finally, the independent putative mediators selected with multiple regression were included in two multiple mediation models. Preacher and Hayes (37) have recently provided a SPSS macro that calculates total, direct, and indirect effects (total and specific for each mediator), including tests of significance using both normal theory and bootstrap procedures. The latter are considered preferable because they do not assume normality of the distribution of the indirect effects and hence provide stronger protection against type 2 error, compared to normal procedures such as the Sobel test (36). We report results for both normal theory and bootstrap tests, with a resample procedure of 5,000 bootstrap samples (bias corrected and accelerated estimates and 95% CI). Finally, effect ratios were calculated to express the amount of the total effect that is explained by the (total) indirect effects via the mediators. Effect ratios are a preferable (quantitative) way to describe mediated effects, compared to the more common dichotomy of “full” vs. “partial” definitions. For example, an effect ratio of 0.5 would mean that half of the total effects of the independent on the dependent variable is explained by the mediator(s), assuming no suppressing variables are present in the model (36).

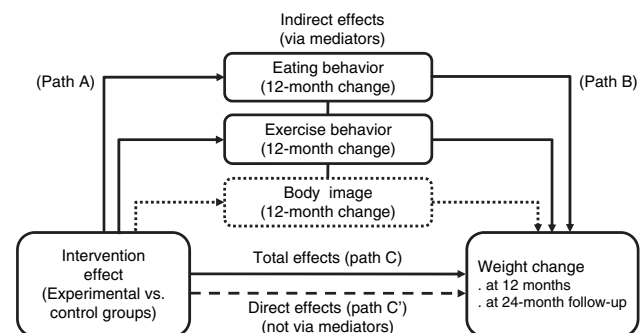


Figure 1 Mediation models. The “weight loss” mediation model excludes body image variables as mediators (dotted lines) and has 12-month weight change as the outcome; the “weight loss and maintenance” model includes body image and predicts 24-month weight change.

Table 1 Changes in psychosocial variables for intervention and control groups

| Psychosocial variables | Cronbach's α | | Intervention group | | ES | Control group | | ES | Between-group difference |
|-----------------------------|---------------------|----------|--------------------|------------------|----------|------------------|------------------|----------|--------------------------|
| | | | Baseline | 12-month | | Baseline | 12 month | | |
| | Baseline | 12-month | Mean \pm s.d. | Mean \pm s.d. | | Mean \pm s.d. | Mean \pm s.d. | | <i>F</i> |
| Eating variables | | | | | | | | | |
| Cognitive restraint | 0.77 | 0.82 | 10.5 \pm 3.86 | 15.0 \pm 2.93 | 1.32*** | 10.5 \pm 4.09 | 13.2 \pm 4.56 | 0.61*** | 24.5*** |
| Flexible restraint | 0.61 | 0.64 | 3.83 \pm 1.7 | 5.88 \pm 1.17 | 1.42*** | 4.00 \pm 1.69 | 5.00 \pm 1.89 | 0.56*** | 17.2*** |
| Rigid restraint | 0.53 | 0.59 | 3.07 \pm 1.6 | 4.95 \pm 1.47 | 1.22*** | 2.89 \pm 1.60 | 3.93 \pm 1.82 | 0.61*** | 11.3** |
| Eating disinhibition | 0.71 | 0.74 | 9.12 \pm 3.35 | 6.20 \pm 3.43 | −0.86*** | 8.91 \pm 3.19 | 7.98 \pm 3.27 | −0.29** | 18.4*** |
| Perceived hunger | 0.77 | 0.78 | 6.58 \pm 3.19 | 3.75 \pm 2.50 | −1.00*** | 6.98 \pm 3.37 | 5.62 \pm 3.65 | −0.39*** | 9.43** |
| Emotional eating | 0.95 | 0.95 | 2.97 \pm 0.86 | 2.65 \pm 0.91 | −0.36*** | 2.93 \pm 0.96 | 2.90 \pm 0.87 | −0.03 | 9.47** |
| External eating | 0.86 | 0.88 | 2.95 \pm 0.57 | 2.52 \pm 0.58 | −0.75*** | 3.03 \pm 0.60 | 2.90 \pm 0.57 | −0.22** | 19.0*** |
| Eating self-efficacy | 0.94 | 0.95 | 121.4 \pm 37.2 | 148.9 \pm 33.5 | 0.78*** | 120.3 \pm 33.5 | 126.4 \pm 37.4 | 0.17 | 21.9*** |
| Exercise variables | | | | | | | | | |
| Exercise self-efficacy | 0.83 | 0.90 | 39.8 \pm 5.11 | 40.5 \pm 5.94 | 0.12 | 39.0 \pm 4.97 | 35.7 \pm 6.52 | −0.57*** | 18.3*** |
| Exercise perceived barriers | 0.75 | 0.85 | 24.9 \pm 6.1 | 22.0 \pm 6.23 | −0.46*** | 25.6 \pm 6.15 | 26.0 \pm 7.55 | 0.07 | 11.8** |
| Exercise motivation (EM) | 0.91 | 0.94 | 3.64 \pm 0.59 | 4.00 \pm 0.62 | 0.59*** | 3.51 \pm 0.56 | 3.54 \pm 0.70 | 0.05 | 22.1*** |
| EM enjoyment/interest | 0.86 | 0.88 | 3.75 \pm 0.79 | 4.15 \pm 0.74 | 0.52*** | 3.69 \pm 0.76 | 3.66 \pm 0.88 | −0.04 | 30.7*** |
| EM perceived competence | 0.69 | 0.80 | 3.40 \pm 0.65 | 3.76 \pm 0.71 | 0.53*** | 3.22 \pm 0.66 | 3.30 \pm 0.73 | 0.12 | 11.7** |
| EM effort/importance | 0.77 | 0.81 | 3.55 \pm 0.75 | 3.95 \pm 0.76 | 0.53*** | 3.38 \pm 0.70 | 3.43 \pm 0.78 | 0.07 | 12.4** |
| EM pressure/tension (rev.) | 0.69 | 0.82 | 3.85 \pm 0.63 | 4.13 \pm 0.72 | 0.42*** | 3.75 \pm 0.62 | 3.79 \pm 0.80 | 0.06 | 5.45* |
| Body image variables | | | | | | | | | |
| Body shape concerns | 0.94 | 0.95 | 100.7 \pm 25.8 | 69.6 \pm 19.5 | −1.38*** | 97.5 \pm 25.0 | 85.3 \pm 25.6 | −0.48*** | 34.1*** |
| Body size dissatisfaction | — | — | 2.52 \pm 0.81 | 1.48 \pm 0.72 | −1.36*** | 2.55 \pm 0.78 | 2.01 \pm 0.78 | −0.69*** | 17.2*** |
| Physical self-worth | 0.80 | 0.88 | 11.7 \pm 3.51 | 15.0 \pm 3.70 | 0.93*** | 10.9 \pm 3.49 | 12.8 \pm 3.51 | 0.55*** | 6.39* |
| Body attractiveness | 0.73 | 0.84 | 11.0 \pm 3.55 | 13.8 \pm 3.38 | 0.81*** | 10.8 \pm 2.99 | 12.1 \pm 3.19 | 0.42*** | 9.35** |

ES, Effect size (within-group differences) and *F* for between-group differences (GLM repeated measures); GLM, general linear model; rev., reversed.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

For correlation, regression, and mediation analyses, psychosocial variables were expressed by the residuals of the 12-month value regressed on the baseline score. For weight, a similar procedure was used, regressing the intervention's end (12-month) and 24-month values on baseline weight. This method is preferable to the use of subtraction scores, which can induce overcorrection of the post by the pre score (38); by design, the residual method creates a variable that adequately represents the change in the measure of choice rendering it orthogonal with (i.e., completely adjusted

for) the pretreatment value. General Linear Model (repeated measures) from SPSS 15.0 for Windows (SPSS, Chicago, IL) used for within- and between-group changes. Significance level was set at $P < 0.05$.

RESULTS

At baseline, there were no differences between intervention and control groups, except for exercise intrinsic motivation

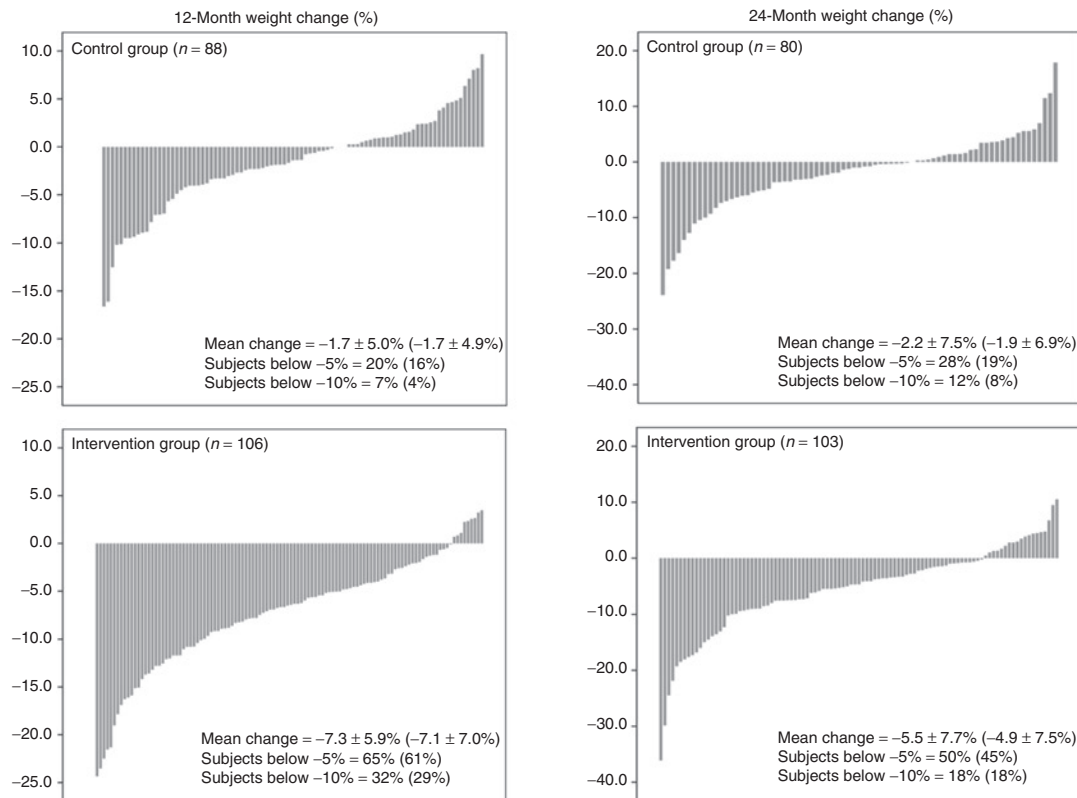


Figure 2 Intervention-related 12-month (left side) and 24-month follow-up (right side) weight outcomes for all participants in control and intervention groups. Values in parentheses are relative to intention-to-treat (baseline carried forward) analysis. Graphs represent subjects who completed assessments at each time point. The percentage of subjects below -5% weight loss includes those below -10% .

showing slightly higher scores in the intervention group for the total scale and perceived competence scales ($P = 0.043$ for both). Retention rates were 93 and 79% at 12 months, and 90 and 72% at 24 months for intervention and control groups, respectively. Reasons for dropping out were self-reported time or financial limitations to attend sessions ($n = 15$), participants moving to a different city ($n = 3$), and dissatisfaction with group assignment ($n = 1$); all other women lost to follow-up did not provide a reason ($n = 23$).

Treatment effects

Changes in psychosocial variables during the intervention are described in [Table 1](#) (path A in [Figure 1](#)). Except for exercise self-efficacy, all variables changed in the expected direction in the intervention group, with corresponding significant differences when compared to controls, favoring the intervention group. The largest effect sizes in women undergoing the intervention were observed for body image and for eating self-regulation, especially rigid and flexible cognitive restraint. Significant between-group differences were observed, despite positive changes in eating-related and body image variables in the control group. No such changes in controls were noticeable for PA variables, emotional eating, or eating self-efficacy. Exercise self-efficacy was significantly reduced in controls, contrasting with no change for this variable in the intervention group.

Changes in weight (in percentage from baseline) are represented in [Figure 2](#), for intervention and control groups, and

for 12 and 24 months (path C in [Figure 1](#)). Data are shown for completers and considering all participants, for an intention-to-treat analysis, using the baseline carried forward method. This method is among the most conservative and has been recommended as a viable solution for obesity treatment trials with missing weight data (39). Despite considerable individual variability, average weight loss and the percentage of participants losing more than the accepted success criteria of 5 and 10% of initial weight was higher in the intervention group ($P < 0.001$ for all comparisons). At the 12-month assessments, about two in three women who completed the main intervention succeeded in reaching the less stringent 5% goal, whereas about one-third surpassed the 10% weight loss goal. Success rates for controls who completed assessments were 20 and 7%. At the 24-month follow-up measurement, about half of all intervention groups, women (45% in intention-to-treat analysis) had lost and maintained at least 5% of their initial body weight.

Associations between predictors and weight changes

Pearson correlations (path B in [Figure 1](#)) are shown in [Table 2](#). Note that because weight loss represents a negative change in weight, negative correlations in [Table 2](#) represent (positive) relationships between increases in the predictor and decreases in weight. At the end of the intervention, the strongest correlates of weight loss were increases in flexible cognitive restraint, eating self-efficacy, and body attractiveness, as well as reductions in emotional eating, concerns with body shape, and body

Table 2 Correlation between psychosocial and weight changes

| Psychosocial variables | All samples | | | | |
|-----------------------------|--|-------------------------------|--|-------------------------------|-------------------------------|
| | 12-Month weight change <i>n</i> = 173,198 | | 24-Month weight change <i>n</i> = 157,178 | | |
| | <i>r</i> | Partial <i>r</i> ^a | <i>r</i> | Partial <i>r</i> ^a | Partial <i>r</i> ^b |
| Cognitive restraint | -0.41*** | -0.29*** | -0.24** | -0.17* | -0.02 |
| Flexible restraint | -0.40*** | -0.30*** | -0.24** | -0.19* | -0.04 |
| Rigid restraint | -0.29*** | -0.19** | -0.12 | -0.06 | 0.06 |
| Eating disinhibition | 0.31*** | 0.20** | 0.18* | 0.12 | 0.02 |
| Perceived hunger | 0.22** | 0.11 | 0.06 | -0.01 | -0.08 |
| Emotional eating | 0.35*** | 0.29*** | 0.08 | 0.03 | -0.13 |
| External eating | 0.26*** | 0.13 | 0.07 | -0.00 | -0.08 |
| Eating self-efficacy | -0.36*** | -0.25** | -0.15 | -0.08 | 0.05 |
| Exercise self-efficacy | -0.32*** | -0.19** | -0.32*** | -0.27*** | -0.21* |
| Exercise perceived barriers | 0.31*** | 0.21** | 0.18* | 0.13 | 0.02 |
| Exercise motivation (EM) | -0.28*** | -0.15* | -0.20** | -0.14 | -0.08 |
| EM enjoyment/interest | -0.25*** | -0.10 | -0.17* | -0.10 | -0.08 |
| EM perceived competence | -0.26*** | -0.15* | -0.16* | -0.10 | -0.02 |
| EM effort/importance | -0.26*** | -0.14* | -0.19* | -0.13 | -0.07 |
| EM pressure/tension (rev.) | -0.16* | -0.08 | -0.16* | -0.12 | -0.11 |
| Body shape concerns | 0.49*** | 0.38*** | 0.12 | 0.04 | -0.15* |
| Body size dissatisfaction | 0.59*** | 0.51*** | 0.31*** | 0.26** | 0.01 |
| Physical self-worth | -0.33*** | -0.25** | -0.22** | -0.17* | -0.08 |
| Body attractiveness | -0.40*** | -0.33*** | -0.20* | -0.15 | -0.01 |

rev., reversed.

P* < 0.05; *P* < 0.01; ****P* < 0.001; partial *r*^a adjusted by intervention group; partial *r*^b adjusted by intervention group and 12-month weight change.

size dissatisfaction. After adjusting for control group using partial correlation, cognitive restraint and emotional eating, as well as several body image variables remained the most predictive factors of weight change, regardless of group membership. All PA correlations were considerably reduced after group adjustment.

Predictors of weight loss and maintenance (24-month follow-up measure) were increases in flexible restraint and all exercise-related variables, as well as improvements in body image, except concerns with body shape. After controlling for group membership, exercise self-efficacy, body size dissatisfaction, flexible cognitive restraint, and physical self-worth predicted weight changes in the expected directions. Finally, we ran partial correlations adjusting for group and also for 12-month weight change. This was equivalent to testing whether psychosocial changes during treatment were associated with weight change taking place exclusively during the follow-up period (year 2). Exercise self-efficacy was the only predictor that remained significant after controlling for group and 12-month weight change.

For all subjects, the correlation between 12- and 24-month weight change was 0.58 (*P* < 0.001), whereas the correlation between 12-month weight change and 12- to 24-month change was -0.27 (*P* < 0.001), indicating that larger weight losses during treatment predicted more weight regain during the follow-up period (results not shown). These correlation

coefficients (and *p* values) did not change substantially after adjusting for group membership.

Mediation analysis

Prior to testing for mediation of the intervention effect (vs. controls) on weight loss, and weight loss and maintenance, we ran two multiple regression models with weight change as the dependent variable, group membership as a forced covariate, followed by significant eating-related predictors (first model) and exercise-related predictors (second model) entered in a stepwise fashion (note: the significant predictors entered can be seen in columns 2 and 4 in Table 2). Considering some degree of covariance among all eating (and all exercise) variables that were significantly related to 12-month weight change, this was conducted to identify the strongest independent predictors within each set of variables, which would later be included in multiple mediation models. This procedure was justified to prevent the specification of models with variables sharing a large amount of variance; the inclusion of multiple nonsignificant predictors in multivariate models creates instability in regression coefficients and renders models especially difficult to interpret (38). It should be noted that a stepwise option is not available in the multiple mediation procedure used (37). In the eating-related regression model for 12-month weight change, only eating flexible restraint ($\beta = -0.24$, *P* < 0.001) and emotional eating ($\beta = 0.21$, *P* = 0.001)

Table 3 Multiple mediation models

| | Coefficient | s.e. | Normal theory <i>P</i> | Bootstrap 95% CI |
|--|-------------|-------|------------------------|------------------|
| <i>Weight loss model (12-month weight change)</i> | | | | |
| Total effect (C path) | −0.440 | 0.067 | <0.001 | — |
| Direct effect (C' path) | −0.278 | 0.069 | 0.001 | — |
| Indirect effect (via mediators) | −0.162 | 0.038 | <0.001 | (−0.256; −0.097) |
| Flexible restraint | −0.075 | 0.027 | 0.005 | (−0.133; −0.041) |
| Emotional eating | −0.048 | 0.021 | 0.024 | (−0.103; −0.013) |
| Exercise perceived barriers | −0.039 | 0.023 | 0.087 | (−0.090; 0.004) |
| Model <i>R</i> ² (<i>P</i>) | | | 0.31 (<0.001) | |
| Effect ratio | | | 0.37 | |
| <i>Weight loss and maintenance models (24-month weight change)</i> | | | | |
| Model A | | | | |
| Total effect (C path) | −0.213 | 0.077 | 0.001 | — |
| Direct effect (C' path) | −0.088 | 0.080 | 0.274 | — |
| Indirect effect (via mediators) | −0.125 | 0.039 | 0.001 | (−0.229; −0.065) |
| Flexible restraint | −0.044 | 0.025 | 0.086 | (−0.102; −0.010) |
| Exercise self-efficacy | −0.081 | 0.031 | 0.009 | (−0.161; −0.036) |
| Model <i>R</i> ² (<i>P</i>) | | | 0.13 (<0.001) | |
| Effect ratio | | | 0.59 | |
| Model B | | | | |
| Total effect (C path) | −0.203 | 0.080 | 0.012 | — |
| Direct effect (C' path) | −0.023 | 0.084 | 0.782 | — |
| Indirect effect (via mediators) | −0.180 | 0.048 | <0.001 | (−0.297; −0.090) |
| Flexible restraint | −0.038 | 0.025 | 0.124 | (−0.100; −0.004) |
| Exercise self-efficacy | −0.065 | 0.028 | 0.022 | (−0.141; −0.025) |
| Body size dissatisfaction | −0.077 | 0.034 | 0.024 | (−0.155; −0.003) |
| Model <i>R</i> ² (<i>P</i>) | | | 0.17 (<0.001) | |
| Effect ratio | | | 0.89 | |
| Model C | | | | |
| Total effect (C path) | −0.203 | 0.080 | 0.012 | — |
| Direct effect (C' path) | −0.035 | 0.078 | 0.654 | — |
| Indirect effect (via mediators) | −0.239 | 0.055 | <0.001 | (−0.367; −0.117) |
| 12-Month weight change | −0.184 | 0.049 | <0.001 | (−0.354; −0.054) |
| Flexible restraint | −0.009 | 0.022 | 0.670 | (−0.061; 0.026) |
| Exercise self-efficacy | −0.053 | 0.022 | 0.033 | (−0.124; −0.021) |
| Body size dissatisfaction | 0.009 | 0.032 | 0.789 | (−0.049; 0.085) |
| Model <i>R</i> ² (<i>P</i>) | | | 0.30 (<0.001) | |
| Effect ratio | | | — | |

For consistency with coefficients (and *P* values) for total and direct effects, coefficients and standard errors shown for indirect effects are relative to normal theory calculations. However, bootstrap 95% confidence intervals (CIs) are preferably interpreted in the text (see Methods and Procedures for more details).

were significant independent predictors of weight change. In the exercise-related model, perceived barriers were the single significant predictor ($\beta = 0.20$, $P = 0.003$), although forcing exercise self-efficacy in the model ($\beta = 0.19$, $P = 0.006$) instead of exercise perceived barriers yielded a similar R^2 ; the intercorrelation between the two constructs was moderately high (-0.51 , $P < 0.001$). For 24-month weight outcomes, this

procedure was deemed necessary only for body image; body dissatisfaction ($\beta = 0.28$, $P = 0.001$) was the only significant predictor, that is, it accounted for the majority of variance explained by physical self-worth, the other significant bivariate predictor. For cognitive restraint, because total restraint and flexible restraint (a specific type of restrained eating) covaried substantially ($r = 0.82$, $P < 0.001$) and because rigid restraint

was not a significant bivariate predictor, only flexible restraint (the stronger predictor) was included in the mediation analysis. For exercise variables, only self-efficacy was significantly related to 24-month weight change (see Table 2) and was used in the mediation.

Table 3 summarizes results for the mediation analyses (path C' and indirect effects in Figure 1). In the "weight loss model," an effect ratio of 0.37 was observed for the significant indirect effects, indicating that about 37% of the total effect of the intervention on weight was explained by the three mediators. However, the direct effect remained significant after the mediators were in the model (suggestive of partial mediation using the more common terminology). Of the three mediators, i.e. flexible restraint, emotional eating, and exercise perceived barriers, the latter showed nonsignificant indirect effects. For weight loss and maintenance, we first built a model (A) including only exercise- and eating related predictors, for a direct comparison with the 12-month model. An effect ratio of 0.59 was observed and direct effects were no longer significant, suggesting a strong (or total) mediation effect. Change in exercise self-efficacy during the 12-month intervention was clearly the strongest mediator of 24-month weight change. Flexible cognitive restraint was also significant according to the bootstrap method, explaining about 35% of the total mediated effect. In model B, body image was also included as a mediator. This increased effect ratio to 0.89 with body dissatisfaction and exercise self-efficacy as the strongest mediators. Because part of the variance in 24-month weight change explained by body image could be due to its covariance with 12-month weight change, we ran an additional "weight loss and maintenance model" (C) adjusting also for 12-month weight change. As expected, this increased the overall predictive power of the model (since 12- and 24-month weight change are intercorrelated) rendering exercise self-efficacy as the only significant predictor. Body image showed a nonsignificant suppression (or negative mediation) effect after 12-month weight change was included, and cognitive restraint was no longer a significant mediator. This model should be interpreted with some caution because it includes two nonsignificant predictors and one suppressor variable (which precludes the calculation of the effect ratio). Nevertheless, it shows that the mediating role of increased exercise self-efficacy toward long-term weight change is independent of intervention-related (or shorter-term) weight changes and of positive changes in flexible cognitive restraint of dietary intake.

DISCUSSION

The main purpose of this study was to evaluate whether intervention-related changes in several psychosocial variables concerning exercise and eating behaviors were mechanisms underlying weight loss (1 year) and weight loss maintenance (2 years) in women participating in a behavioral group obesity treatment program. The majority of variables, especially eating-related factors such as cognitive restraint, emotional eating, and eating self-efficacy predicted weight change immediately after the intervention. Long-term weight outcomes at

the 2-year follow-up were more associated with improvements in well-known correlates of exercise behavior, such as exercise self-efficacy, reduced perceived barriers, and exercise motivation. Our findings highlight the role of increasing flexible cognitive restraint and reducing emotional eating for short-term success, and of (simultaneously) increasing exercise self-efficacy and motivation to achieve longer-term goals. Positive changes in body image mirrored changes in weight loss during the intervention but did not appear to predict long-term weight control additionally.

It is not surprising that eating self-regulation was a good predictor of short-term weight control. The ability to lose a significant amount of weight is dependent on the level of caloric restriction, especially in individuals with difficulties in energy expenditure via PA, such as initially sedentary overweight women. Several previous short-term studies (i.e., 1 year or shorter) showed that variables such as eating self-efficacy, cognitive restraint, or emotional and disinhibited eating closely relate to weight changes (12,16,40–42). Nevertheless, although they may covary during weight control, these variables represent different facets of the dietary self-regulation process. For instance, disinhibition measures the tendency to overeat in response to a variety of stimulus, in the form of "disinhibited" episodes, when the habitual restraint is broken (40). Others have described it as a more general marker for an "opportunistic" pattern of eating (43). Regardless, a high TFEQ disinhibition score represents a risk factor for obesity, as it is consistently associated with total energy intake and unhealthier food choices (see Bryant *et al.* (43) for a review). In the present study, significant decreases in disinhibition scores were observed in both groups, albeit with different magnitudes (strong effect size only for the intervention group), and these reductions were consistently predictive of improved weight loss at 12 and 24 months.

The role of cognitive restraint for successful eating regulation and weight control has been the subject of much debate (44,45). Simply put, if successfully implemented, a high cognitive restraint should effectively restrict calorie intake below some desired level. However, although short-term treatment studies show an overwhelmingly positive impact of increased restraint on weight loss, large-scale cross-sectional and prospective studies present a less clear picture, including reports of no association (46,47) and positive associations between restraint and BMI (48). More common are prospective studies showing baseline restraint scores to predict BMI increases after several years (cf. ref. 49). This suggests that the relationship may change over time (i.e., positive in the short term, but not necessarily in the long run); our results partially support this hypothesis, with one specific qualification: although total restraint predicted shorter-term weight change, only change in *flexible* dietary restraint during the program was associated with 24-month outcomes.

The distinction between flexible and rigid cognitive restraint may be relevant for understanding how cognitive efforts to restrict one's dietary intake could influence weight control. Despite a similar goal (to restrict energy intake), the type or

“quality” of the restraint drive can be different. Flexible control involves less internal pressure to diet and a more gradual and relative understanding of diet’s impact on energy balance. In turn, a “rigid restrained eater” gives higher absolute value to restraining calorie intake; failing to do so could originate a negative emotional response, a higher likelihood of disproportionate compensatory behaviors, including stricter cognitive restraint and compulsive exercise, or even counter-regulatory behaviors, such as a higher tendency to binge (50,51). In fact, the rigid cognitive restraint scale of the TFEQ is associated with high disinhibition, which is not the case for the TFEQ’s flexible restraint scale (23). With this in mind, it is easier to understand why a more flexible pattern of dietary self-regulation could represent an advantage in long-term weight control, as our data and those of others (23,46,47,52–55) suggest.

A mail-based intervention with >7,400 participants in Germany showed that baseline flexible restraint predicted increased weight loss at 1 year, whereas higher rigid restraint predicted less weight loss (in women; (23)). In 352 women from the Quebec Family Study, rigid restraint was cross-sectionally associated with higher BMI and more body fat, whereas flexible restraint scores predicted less fatness (47). In a prospective analysis, 75 men and women were followed for 6 years with changes in both flexible and rigid cognitive restraint negatively related with weight change for men and women (52); however, the association of flexible restraint was stronger than that observed for rigid restraint, which was not significant in women. Quite similar overall results to those from the Quebec Family Study were observed in the Pound of Prevention Study, with stronger cross-sectional and prospective associations with BMI (or 3-year BMI change) for flexible compared to rigid control of eating, although both were significant (46). More recently, a nondieting intervention over 14 weeks showed that flexible but not rigid restraint was associated with weight loss in the intervention groups, whereas the two cognitive restraint types were equally highly correlated with weight loss in controls (53).

Despite the high prevalence of overweight and obesity, there are many people who are successful at maintaining a stable healthy weight. However, little is known about the strategies adopted by those who have, for instance, begun to monitor and control their weight after a small initial increase but were never obese. Additionally, about 20% of individuals who attempt to lose weight are able to achieve and sustain a reduced weight for a number of years (56,57). Perhaps many of these individuals have learned in time to adopt a flexible eating self-regulation pattern, allowing them to enjoy all foods and compensating for more caloric meals that occur naturally in subsequent meals or through PA. For these people, a dichotomous “all or nothing” view of food and diet (e.g., allowed/forbidden foods, “good”/“bad” eating days, etc.) would not be the prevailing stance. The present results suggest similar processes may have occurred for many study participants, as the 24-month association of (total) cognitive restraint with weight loss and maintenance were mostly explained by changes in the flexible form of restraint. Mediation analysis showed that most of this

effect was due to weight changes already taking place during the intervention, which were then successfully maintained.

Exercise self-efficacy was a strong predictor of long-term weight control in this study. Indeed, by merely measuring this construct at the end of the intervention, it would have been possible to predict success level at the 2-year follow-up with acceptable accuracy. Exercise self-efficacy is a consistent predictor of exercise and PA adherence (58). Although we measured the consequence of energy balance–related behaviors—weight change—rather than exercise behavior itself, the present study supports previous findings on the positive role of exercise/PA for long-term weight loss maintenance (59). Increasing self-efficacy for exercise could lead to the development of a more generalizable sense of “weight management confidence” (9). Research on motivational and cognitive processes underlying (multiple) behavior change indicate that “spill-over” or transference processes may occur where positive (or negative) changes in the self-regulation of one particular behavior might affect another (60,61), and the level of self-determination and autonomous self-regulation could be a mechanism through which such transference might occur across general and more specific behavioral domains (62). It is also possible that self-confidence for exercising regularly helps relax an otherwise rigid control of diet. If a person trusts he/she can increase energy expenditure in periods when energy intake is increased (e.g., during a festive period), this is likely to decrease internal pressure to strictly control caloric intake and lessen feelings of guilt after (over)eating; in effect, it should contribute to adopting a more flexible restrained eating pattern. In the context of weight control, Baker and Brownell have hypothesized that constructs such as motivation and self-efficacy could mediate the relationship between exercise behaviors, and continued commitment and compliance to one’s dietary plan (63), a proposition which has since received empirical support (64). Exercise intrinsic motivation is another construct which, based on Self-Determination Theory (20,21) and previous post hoc findings (12,65), we hypothesized to be beneficial for long-term weight control. Results largely supported our hypothesis because all dimensions of the exercise Intrinsic Motivation Inventory predicted 24-month weight change.

The need to find long-term solutions for those seeking to overcome excessive body weight highlights the relevance of finding predictors of both weight loss *and* weight loss maintenance. The 2-year follow-up is a key strength of this study, providing a reasonably distal measure of weight control. However, the absence of 24-month psychosocial measures could be seen as a limitation. In practical terms, although helping individuals initially reduce their weight, it is also a therapeutic imperative to maximize the chances that the processes affected by such interventions, often limited in duration, are also predictive of long-term success. Unfortunately, what is currently known about these predictors is derived mostly from indirect evidence (e.g., 66), short-term, or non-controlled studies (8). The present results indicate that weight loss interventions in women should focus on reducing emotional eating and promoting a flexible,

nondichotomous eating self-regulation approach. To our knowledge, this is the first weight management trial showing the long-term benefits of changing flexible over rigid cognitive restraint. Additionally, this study confirms that failing to increase exercise motivation and confidence in one's ability to remain active after the end of a weight control program is likely to forestall success in the long run. The challenge is thus set upon interventionists to devise programs that most effectively target and change these mediators.

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DISCLOSURE

The authors declared no conflict of interest.

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