

Predicting Long-Term Weight Loss Maintenance in Previously Overweight Women: A Signal Detection Approach

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Objective: Examine psychological and behavioral predictors of 3-year weight loss maintenance in women.

Methods: Participants were 154 women in a 1-year randomized controlled trial on weight management with a 2-year follow-up. Signal detection analyses identified behavioral and psychological variables that best predicted 5% and 10% weight loss at 3 years.

Results: Women with better body image were more likely to have lost $\geq 5\%$ weight at 3 years ($P < 0.001$). Exercise intrinsic motivation had a partial compensatory effect, in that women with poor body image but higher motivation were more likely to maintain weight loss than women with poor body image and lower motivation ($P < 0.001$). Women with high exercise autonomous motivation were three times more likely to have lost $\geq 10\%$ weight than were those with lower autonomous motivation ($P < 0.001$). Among women with lower autonomous motivation, perceiving fewer exercise barriers was somewhat compensatory: these women were more likely to maintain weight loss than women with lower autonomy but more perceived barriers ($P < 0.01$).

Conclusions: In overweight women, improving body image and increasing autonomous and intrinsic motivation for exercise likely promotes clinically significant long-term weight loss maintenance. Decreasing perceived exercise barriers is another promising intervention target.

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Introduction

Long-term weight loss maintenance is a major challenge. Success rates of individuals who are overweight and try to maintain long-term weight loss are 20% at most (1). Typically, one-third of weight lost is regained within 1 year and the other two-thirds within 3–5 years (2). Identifying behavioral and psychological predictors of successful long-term weight loss maintenance is therefore essential to make obesity interventions more effective.

A review of psychosocial pre-treatment predictors of long-term weight control identified few previous weight loss attempts and an autonomous, self-motivated regulatory style as the best prospective predictors (3). Evidence for other variables, such as positive body image, eating self-efficacy, or few perceived barriers to exercise, was mixed or weak. A broader, conceptual review identified a large set of putative predictors of weight loss maintenance (4), including a physically active lifestyle and high social support (i.e., perceived emotional and practical support from significant others), self-efficacy (i.e., the belief in one's ability to

maintain weight loss), and autonomy (be causal agent of one's actions). A recent systematic review of self-regulation mediators of weight control suggested that the most consistent predictors of long-term weight change are exercise autonomous motivation (a concept that includes both intrinsic and meaningful extrinsic motives, such as improving health), exercise self-efficacy, low perceived barriers to exercise, flexible eating restraint (i.e., conscious attempts to monitor and regulate food intake in a flexible way), positive body image, and self-regulation skill use (e.g., self-monitoring, planning, goal-setting) (5).

Although these reviews provide insights critical for understanding the role of behavioral and psychological factors in long-term weight management, the quality and nature of the predictors assessed were very heterogeneous, meaning that any conclusions drawn must be tentative. Moreover, there is a dearth of studies systematically examining a wide range of behavioral and psychological predictors of long-term weight loss beyond 12 months. This study contributes to filling this gap by examining psychological and behavioral predictors of 3-year weight loss maintenance in overweight women involved in a lifestyle

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weight management intervention. We conducted an exploratory data analysis of a large set of behavioral and psychological predictors of weight loss maintenance to create a hierarchy of predictors/profiles of successful weight maintenance. Importantly, the predictors examined were selected on the basis of theoretical considerations and systematic empirical reviews of long-term weight maintenance.

Methods

Study design

The data presented here are from the longitudinal randomized controlled trial “Promotion of Exercise and Health in Obesity” (PESO; see Ref. (6) for a detailed description). Briefly, PESO consisted of a 1-year behavioral weight management intervention and an additional 2-year follow-up period. The aim was to promote long-term weight control by increasing participants’ autonomous motivation toward exercise and eating. The intervention was based on principles from self-determination theory and aimed at encouraging participants to increase their physical activity and energy expenditure and adopt a moderately restricted diet (6). The control group received a general health education curriculum, comparable in duration, and intensity to the treatment of the intervention group. The Institutional Review Board of the Faculty of Human Kinetics, Technical University of Lisbon, approved the study.

Participants

Participants were women recruited from the community at large; they gave written consent for participation. The sample was restricted to women (a) to obtain a more homogeneous sample and (b) because women have a higher risk of weight gain and particularly high rates of obesity (7).

Participants fulfilled the following inclusion criteria: female, between 25 and 50 years old, premenopausal, body mass index (BMI) between 25 and 40 kg/m², willing to attend weekly meetings for 1 year, free from major illnesses, not taking medication known to interfere with body weight. A total of 258 women completed the initial assessments. Of those, 13 started taking medication potentially affecting body weight, 4 were diagnosed with severe illness or injury, 11 became pregnant, and 9 entered menopause. The data from these 37 women were excluded from analyses, leaving 221 eligible baseline participants. A total of 156 women completed the 3-year follow-up assessments (71% overall retention). For the analyses reported here, 2 women without anthropometric data at 3-year follow-up were excluded, leaving a final sample of 154 women. Women who completed the 3-year assessments did not differ from those who quit the program in terms of demographic or baseline psychological variables except for age: women who dropped out were on average 3 years younger (see Ref. (8) for a detailed description of dropouts).

Measurements

After the 1-year intervention, participants completed a comprehensive, theoretically motivated battery of psychometric instruments (9). If validated Portuguese versions of the instruments were not available, instruments were translated and back-translated from English to Portuguese; congruence with the factor solutions of the original questionnaires were verified by factor analyses (data not shown). Higher scores always represent higher manifestations of the psycho-

metric variables. Cronbach’s α was calculated to assess internal consistency for each (sub-)scale that was included in the analyses.

General and exercise motivation. General self-determination was assessed using the self-determination scale (10); statements forming two subscales describe individual differences in self-determined functioning (awareness of self subscale, $\alpha = 0.68$; perceived choice subscale, $\alpha = 0.82$). Different types of exercise motivation were measured with the exercise self-regulation questionnaire (11), which comprises two major subscales: controlled ($\alpha = 0.56$) versus autonomous ($\alpha = 0.86$) exercise motivation. Dimensions of intrinsic motivation for exercise (enjoyment, competence, importance, absence of pressure toward exercise) were further explored using the intrinsic motivation inventory (Ref. (12); $\alpha = 0.94$). The exercise motives inventory - 2 (13) assessed intrinsic ($\alpha = 0.79$), and extrinsic exercise goals ($\alpha = 0.51$). Beliefs in being able to adhere to an exercise program for at least 6 months under varying circumstances were evaluated using the self-efficacy for exercise behaviors scale (Ref. (14); $\alpha = 0.90$). Perceived barriers to exercise in terms of time, effort, and obstacles were assessed with the exercise perceived barriers scale (Ref. (15); $\alpha = 0.85$).

Psychological well-being and quality of life. The discrepancy between perceived self and ideal body size, an evaluative component of body image, was measured with the figure rating scale (16), composed of nine silhouettes of increasing body size. The difference between respondents’ perceived current body size and indicated ideal body size represents the discrepancy. Body shape concerns in terms of a dysfunctional investment in appearance were evaluated with the body shape questionnaire (Ref. (17); $\alpha = 0.95$). Self-esteem was assessed with the Rosenberg self-concept/self-esteem scale (Ref. (18); $\alpha = 0.88$). The physical self-perception profile questionnaire (19) assessed self-esteem in several dimensions of the physical domain, including global physical self-worth ($\alpha = 0.88$) and body attractiveness ($\alpha = 0.82$). The social support for exercise survey (20) gauged the level of support that individuals who exercised felt they received from family and friends ($\alpha = 0.90$). Cognitive, affective, and somatic symptoms of depression were measured with the beck depression inventory (Ref. (21); $\alpha = 0.91$). The short-form health survey (22) measured physical ($\alpha = 0.71$) and psychological ($\alpha = 0.75$) health-related quality of life. Weight-related quality of life was assessed using the impact of weight on quality of life-lite (Ref. (23); $\alpha = 0.93$).

Eating behavior and eating habits. The Three-Factor Eating Questionnaire (24,25) assessed flexible cognitive restraint ($\alpha = 0.63$), rigid cognitive restraint ($\alpha = 0.62$), eating disinhibition ($\alpha = 0.74$), and perceived hunger ($\alpha = 0.76$). Energy, fat, and fiber intake were evaluated using a semiquantitative food-frequency questionnaire (26) covering the 12 preceding months. Dietary intake was calculated by multiplying the consumption frequency of each of 86 food items with its standard portion in grams (g) and by a seasonal variation factor for food ingested at specific times. Food information was converted into nutrients with the software Food Processor Plus[®] (ESHA Research, Salem, Oregon).

Physical activity. Duration of moderate plus vigorous physical activity (≥ 3 metabolic equivalents or METs) per week was estimated with the 7-day physical activity recall scale (27). Lifestyle physical activity was assessed using the lifestyle physical activity index (9). This self-administered instrument measures habitual lifestyle physical activities typical of the last month ($\alpha = 0.83$).

Body weight. Body weight was measured twice, with an electronic scale calibrated onsite and accurate to 0.1 kg (SECA, Hamburg, Germany), in the morning, after participants had fasted for 3 h. Weight was expressed as percent weight change from baseline to the end of the study (after 3 years total).

Statistical analyses

Intervention and control groups were collapsed for the analyses: 1-year (post-treatment) data were used to predict 3-year outcomes. This approach was taken because (a) all women in the study intended to lose weight; (b) women in both groups had a comparable amount of contact with health professionals; (c) collapsing the two groups led to a greater variability in behavioral and psychological aspects, and our objective was to identify universal predictors of long-term weight management.

Descriptive analyses were conducted using the IBM Statistical Package for the Social Sciences, version 22. The significance level for analyses was set at $P < 0.05$. Pearson correlations with Bonferroni's corrections were used to examine associations between the predictor variables and weight change at the end of the follow-up period.

To systematically identify subgroups of individuals who were homogeneous with respect to outcome and predictor variables (28,29), we conducted signal detection analyses using signal detection software for receiver operator characteristics (ROC) (30). This recursive partitioning method is especially useful in exploratory analyses that are likely to involve multicollinearity and interactions between predictors and for generating strong hypotheses to be tested in subsequent validation samples or future tailored interventions (28,29). The signal detection analysis proceeds in a forward iterative fashion and uses χ^2 tests to divide the sample into two mutually exclusive and maximally discriminated subsamples. This empirical process is repeated systematically within each subsample and continues until the number of subjects falls below a specified level or until the most efficient cutoff is no longer significant.

The present signal detection analyses identified characteristics that best predicted 3%, 5%, and 10% weight loss at the end of the follow-up (3-year measurement). Three dichotomous outcome variables (signals) were created: (a) yes/no $\geq 3\%$ weight loss; (b) yes/no $\geq 5\%$ weight loss; (c) yes/no $\geq 10\%$ weight loss, all from baseline to 3-year measurement. A set of 28 predictor variables was examined. All predictors were continuous variables and were simultaneously entered into the analysis. Additionally, belonging to the intervention versus control group was included as nominal predictor variable to test whether the relation between predictors and outcome was confounded by the intervention effect. The significance level for split subsamples was $P < 0.05$; the minimum number of cases within each subgroup was set at 10 and the number of iterations set at 100.

To compare the psychological and behavioral profiles of the most and least successful subgroups emerging from signal detection analysis, we used independent-samples t tests, corrected for multiple testing using the Bonferroni's procedure. The desired significance level, < 0.05 , was divided by the number of tests ($n = 26$ for t tests; $n = 28$ for Pearson's correlations), resulting in an adjusted value of $P < 0.0019$ for difference ($P < 0.0018$ for associations).

Results

Sample characteristics and descriptive results

Women who completed the 3-year assessment had a mean age of 38.7 years (SD = 6.6) and a mean BMI of 29.8 kg/m² (SD = 4.2) at the end of the intervention. The main effects of the intervention and follow-up are described in detail elsewhere (8,31). In brief, at the end of the follow-up (3-year measurement), average weight loss was higher in the intervention group (-3.06 ± 6.1 kg) than in the control group (-1.00 ± 5.8 kg), as was improvement in many of the psychological and behavioral targets (8).

Table 1 shows the descriptive statistics and bivariate correlations of motivational, psychological, eating-related behavior, and physical activity variables with weight change at the end of the follow-up. Numerous predictor variables were highly correlated in the expected direction with weight change at the 3-year measurement.

Signal detection analyses to identify successful subgroups

The tree diagrams in Figures 1 and 2 display the most successful versus least successful subgroups identified by means of signal detection analysis. Results for the 3% weight loss outcome were identical to those for the 5% outcome. Given that achieving a 5% weight loss can be assumed to produce clinically more meaningful health benefits (32), we report only these results.

Figure 1 shows the hierarchy of predictors of at least 5% weight loss at the 3-year measurement. A total of 34% ($n = 52$) of participating women achieved the $\geq 5\%$ weight loss criterion. Self-ideal body size discrepancy emerged as the predictor variable that best differentiated between the high and low success subgroups ($\chi^2 = 14.8$, $P < 0.001$): of those with a low self-ideal body size discrepancy (i.e., a more positive body image), 54% ($n = 29$) met the success criterion. In contrast, only 23% ($n = 23$) of those with a high self-ideal body size discrepancy (≥ 2) achieved $\geq 5\%$ weight loss after 3 years.

No additional predictor further differentiated women in the most successful group. The subgroup of participants with a high self-ideal body size discrepancy was further divided into those with lower versus higher exercise intrinsic motivation ($\chi^2 = 12.5$, $P < 0.001$): Those with high exercise intrinsic motivation (≥ 64) were significantly more likely to achieve $\geq 5\%$ weight loss at 3 years (41%; $n = 17$) than those with low exercise intrinsic motivation (10%; $n = 6$). Thus, high exercise intrinsic motivation proved somewhat compensatory for women with a high self-ideal body size discrepancy in terms of achieving $\geq 5\%$ weight loss after 3 years.

Table 2 summarizes the psychological and behavioral profiles of the most and least successful subgroups identified in Figure 1. The most successful subgroup (i.e., women with low self-ideal body size discrepancy) showed a more positive profile concerning the psychological and behavioral predictor variables than the least successful subgroup.

Figure 2 shows the hierarchy of predictors of at least 10% weight loss at 3 years. Of the full sample of 154 women, 27 (18%) achieved 10% or more weight loss at the 3-year measurement. Exercise autonomous motivation was identified as the most powerful predictor ($\chi^2 = 13.2$, $P < 0.001$): women with high exercise autonomous motivation (≥ 54) more often succeeded in achieving at least 10%

TABLE 1 Descriptive statistics and bivariate correlations between study variables at 1-year assessment and weight change at 3-year follow-up

	M ± SD	[Min; Max]	Weight change at 3 years ^a
General and exercise motivation			
Awareness of self	20.1 ± 3.52	[7; 25]	-0.26
Perceived choice	17.2 ± 4.23	[5; 25]	-0.16
Exercise controlled motivation	18.2 ± 6.40	[8; 40]	0.09
Exercise autonomous motivation	46.4 ± 9.07	[8; 56]	-0.24
Exercise intrinsic motivation	60.7 ± 11.5	[23; 80]	-0.31
Intrinsic exercise goals	11.8 ± 2.44	[4; 17]	-0.29
Extrinsic exercise goals	5.70 ± 3.32	[0; 18]	0.02
Exercise self-efficacy	38.6 ± 6.73	[19; 50]	-0.32
Perceived barriers to exercise	27.7 ± 8.18	[11; 55]	0.33
Psychological well-being and quality of life			
Self-ideal body size discrepancy	1.72 ± 0.78	[0; 4]	0.38
Body shape concerns	76.3 ± 23.4	[36; 146]	0.24
Self-esteem	34.2 ± 4.49	[18; 40]	-0.16
Physical self-worth	13.8 ± 3.63	[6; 24]	-0.28
Body attractiveness	12.8 ± 3.27	[6; 24]	-0.24
Exercise social support	21.6 ± 8.02	[9; 45]	-0.19
Depressive symptoms	5.67 ± 6.62	[0; 41]	0.21
Physical health-related quality of life	84.4 ± 13.6	[27; 100]	-0.26
Mental health-related quality of life	71.4 ± 18.3	[20; 99]	-0.15
Impact of weight on quality of life	48.4 ± 14.5	[31; 109]	0.35
Eating behavior and eating habits			
Flexible restraint	5.49 ± 1.54	[0; 7]	-0.28
Rigid restraint	4.52 ± 1.73	[0; 7]	-0.12
Disinhibition	7.33 ± 3.48	[1; 15]	0.21
Hunger	4.61 ± 3.14	[0; 13]	0.16
Energy intake (kcal/day)	2190 ± 882.4	[681; 6346]	0.05
Fat intake (% kcal/day)	32.3 ± 6.48	[16.8; 55.8]	0.08
Fiber intake (g/day)	32.8 ± 19.1	[5.5; 144.8]	0.00
Physical activity			
Moderate to vigorous physical activity (min/week)	254.9 ± 192.6	[0; 870]	-0.33
Lifestyle physical activity	3.46 ± 0.84	[1; 5]	-0.17

Scales range: Awareness of self and perceived choice [5-25]; exercise controlled and autonomous motivation [8-56]; exercise intrinsic motivation [16-80]; intrinsic exercise goals [0-17]; extrinsic exercise goals [0-18]; exercise self-efficacy [10-50]; perceived barriers to exercise [11-55]; self-ideal body size discrepancy [-8-8]; body shape concerns [34-204]; self-esteem [10-40]; physical self-worth and body attractiveness [6-24]; exercise social support [9-45]; depressive symptoms [0-63]; physical and mental health-related quality of life [0-100]; impact of weight on quality of life [31-155]; flexible and rigid restraint [0-7]; disinhibition [0-16]; hunger [0-14]; lifestyle physical activity [1-5].

^aPearson's correlations. Statistically significant differences are represented in bold type [significance level is Bonferroni's corrected ($P < 0.0018$)].

weight loss (36%; $n = 15$) than did those reporting low exercise autonomous motivation (11%; $n = 12$).

Again, no additional predictor differentiated participants in the most successful group. However, among women with low exercise autonomous motivation, the next best variable to differentiate the sample was perceived barriers to exercise ($\chi^2 = 7.3$, $P < 0.01$). Participants with low perceived barriers to exercise (< 27) were more likely to succeed (22%; $n = 8$) than those with high perceived barriers (5%; $n = 4$).

The psychological and behavioral profiles of the most and least successful subgroups as shown in Figure 2 are described in Table 3. The

most successful subgroup showed a more positive profile concerning psychological and behavioral variables, similar to the most successful group at the 5% criterion. In addition, significant differences in physical activity patterns were observed, in favor of the most successful subgroup. In contrast, the least successful subgroup showed poorer body image and higher impact of weight on quality of life.

Discussion

This study sought to identify effective psychological and behavioral predictors of 3-year weight loss maintenance. Three clinically

TABLE 2 Psychological and behavioral profiles of the most and least successful subgroups emerging from the decision tree for $\geq 5\%$ weight loss

	Low self-ideal body size discrepancy (<2) (n = 54, 53.7% achieved $\geq 5\%$ weight loss)	High self-ideal body size discrepancy (≥ 2) and low exercise intrinsic motivation (<64) (n = 58, 10.3% achieved $\geq 5\%$ weight loss)	P
General and exercise motivation			
Awareness of self	20.4 ± 3.64	19.5 ± 3.25	0.180
Perceived choice	16.7 ± 4.60	16.4 ± 3.72	0.680
Exercise controlled motivation	19.0 ± 7.03	18.1 ± 5.99	0.472
Exercise autonomous motivation	47.7 ± 8.12	41.5 ± 9.96	<0.001
Exercise intrinsic motivation	62.6 ± 11.7	53.1 ± 9.13	-
Intrinsic exercise goals	12.0 ± 2.44	10.7 ± 2.29	0.005
Extrinsic exercise goals	5.83 ± 2.98	6.23 ± 3.08	0.492
Exercise self-efficacy	39.6 ± 6.27	35.4 ± 6.81	0.001
Perceived barriers to exercise	25.5 ± 7.40	32.8 ± 7.33	<0.001
Psychological well-being and quality of life			
Self-ideal body size discrepancy	0.89 ± 0.32	2.29 ± 0.53	-
Body shape concerns	70.3 ± 22.6	85.2 ± 22.7	0.001
Self-esteem	34.5 ± 4.57	33.2 ± 4.69	0.134
Physical self-worth	14.6 ± 3.94	12.2 ± 2.82	<0.001
Body attractiveness	13.7 ± 3.61	11.4 ± 2.60	<0.001
Exercise social support	22.2 ± 7.39	19.9 ± 7.88	0.117
Depressive symptoms	4.56 ± 5.41	6.91 ± 7.35	0.057
Physical health-related quality of life	89.9 ± 8.55	77.7 ± 15.9	<0.001
Mental health-related quality of life	74.2 ± 18.0	65.4 ± 18.7	0.013
Impact of weight on quality of life	41.5 ± 9.81	57.0 ± 15.9	<0.001
Eating behavior and eating habits			
Flexible restraint	6.06 ± 1.01	4.91 ± 1.76	<0.001
Rigid restraint	5.21 ± 1.29	3.84 ± 1.69	<0.001
Disinhibition	6.70 ± 3.23	8.43 ± 3.48	0.008
Hunger	4.40 ± 2.72	5.21 ± 3.53	0.181
Energy intake (kcal/day)	2235 ± 1079	2136 ± 712.0	0.582
Fat intake (%kcal/day)	31.8 ± 6.31	34.1 ± 6.83	0.077
Fiber intake (g/day)	33.7 ± 19.0	29.5 ± 15.1	0.219
Physical activity			
Moderate to vigorous physical activity (min/week)	285.8 ± 169.0	187.8 ± 192.9	0.006
Lifestyle physical activity	3.55 ± 0.86	3.29 ± 0.86	0.138

Values expressed as mean ± SD.

Statistically significant differences resulting from independent-samples *t* test are represented in bold type [significance level is Bonferroni's corrected ($P < 0.0019$)].

meaningful magnitudes of weight loss were examined: 3%, 5%, and 10%. Results for 3% and 5% weight loss after 3 years were identical: Women with a more positive body image after the 1-year intervention were most likely to achieve at least 3% or 5% weight loss. In addition, high intrinsic motivation for exercise buffered the effect of poor body image: Women with poor body image who showed high intrinsic motivation for exercise were the group second most likely to achieve 3% or 5% weight loss over time. Among women who had achieved 10% or more weight loss, high exercise autonomous motivation at the end of the 1-year intervention was the strongest predictor of 3-year weight loss maintenance.

To our knowledge, this is the first study applying signal detection methods to identify behavioral and psychological characteristics associated with long-term weight loss maintenance in women participating in a lifestyle weight management intervention. The signal detection method allowed us to compare the importance of different behavioral and psychological factors for long-term weight loss maintenance, and to explore interacting effects between those factors.

Variables related to both motivational and psychological well-being emerged as the most efficient predictors of 3-year weight loss maintenance. These results are consistent with a recent systematic review

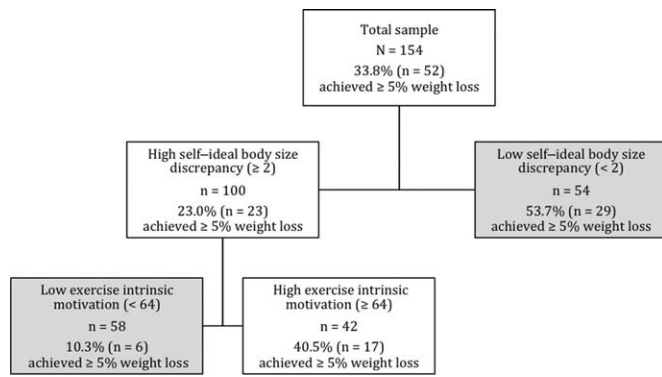


Figure 1 Hierarchy of predictors of $\geq 5\%$ weight loss at the 3-year measurement. The most (women with low self-ideal body size discrepancy) and least successful subgroups (women with high self-ideal body size discrepancy and low exercise intrinsic motivation) are shaded in gray.

on self-regulation mediators of weight control, which identified positive body image and autonomous motivation among the key predictors of successful weight outcomes (5). Among people seeking treatment, poor body image predicted poorer weight outcomes and increased the chance of relapse (33), while positive changes in body image during treatment predicted long-term weight loss maintenance (31).

Increases in exercise intrinsic motivation during treatment (i.e., increases in the experience of enjoyment, genuine interest, and/or feeling positively challenged) partially explain the long-term effects of weight control interventions (34). Experiencing exercise as positive and meaningful rather than solely as a means to control weight increases successful long-term exercise adherence (35). Further, intrinsic exercise motivation may also improve the motivation of other weight-related behaviors: Mata et al. found that exercise intrinsic motivation was associated with improved eating regulation during weight management (36).

Importantly, among women with low exercise autonomous motivation having low perceived exercise barriers played a somewhat compensatory role. This finding underlines that successful weight loss maintenance depends on a number of factors. If a powerful aspect such as autonomous motivation is absent, it can be partially compensated for by other factors. For example, having low perceived exercise barriers (e.g., easy access to exercise facilities) may help individuals to regulate weight control behaviors, even when the quality of their motivation is less favorable. In sum, the present results support and extend previous findings by identifying body image and autonomous motivation as two promising targets for successful long-term weight management and pointing to additional candidate targets, such as reducing perceived barriers to exercise.

The present findings also highlight differences in the psychological and behavioral profiles of women who successfully lost weight in the long term versus those who did not. The most successful subgroups—women with a more positive body image and women with high exercise autonomous regulation—also showed higher psychological well-being, quality of life, and a more adaptive motivational

profile (e.g., higher perceived choice and self-efficacy). This result is in line with previous findings that a more positive body image facilitates making healthy rather than appearance-based decisions, eventually promoting long-term weight management (31). The present findings also speak to the importance of autonomous motivation in increasing quality of life, psychological well-being (37), physical activity (35), and healthful eating behaviors (38).

In sum, our findings of distinct psychological and behavioral profiles in women who successfully maintain weight loss highlight the importance of targeting body image and motivation quality as potential precursors of physical activity and eating regulation in weight management interventions. Targeting psychological factors underlying behavior, rather than attempting to directly influence behaviors, may be most successful. In fact, a recent study showed that a motivation-focused weight maintenance program offers an effective alternative approach to traditional skill-based programs for long-term weight control (39). Also, the results of this signal detection analysis suggest that achieving more weight loss (10% or more) is—motivationally and cognitively—not simply a linear continuation of less weight loss (at least 5% or more), but may have qualitatively different underlying motivational and cognitive predictors. Importantly, however, exercise motivation was also one of the most important predictors for achieving lower weight loss, underlying its importance in the process.

Important limitations of this study include the homogeneous sample of previously overweight adult women, which may preclude generalization to other populations. Also, smoking habits, known to be related to weight control, should be assessed in future studies. Further, we used self-report measures to assess physical activity. However, the instruments used are valid and reliable measures, and such self-report measures are known to correlate with other behavioral assessments (e.g., based on accelerometry [40]).

The present study used signal detection methods for an exploratory, hypothesis-generating analysis. Alongside with its statistical advantages, this method allowed to determine significant predictors in a hierarchical fashion, creating *profiles of success*. Furthermore, we identified cut-off points for the significant predictors. To our

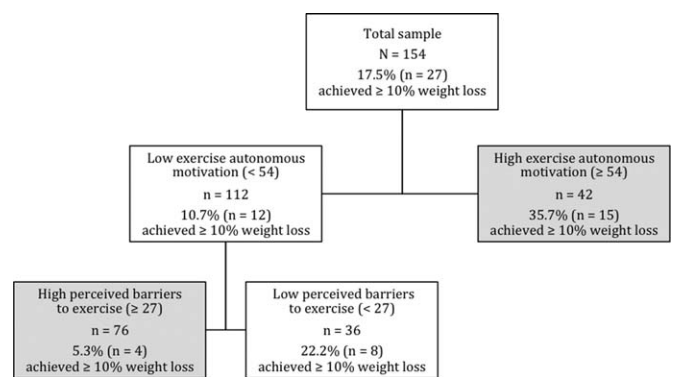


Figure 2 Hierarchy of predictors of $\geq 10\%$ weight loss at the 3-year measurement. The most (women with high exercise autonomous motivation) and least successful subgroups (women with low exercise autonomous motivation and high perceived barriers to exercise) are shaded in gray.

TABLE 3 Psychological and behavioral profiles of the most and least successful subgroups emerging from the decision tree for $\geq 10\%$ weight loss

	High exercise autonomous motivation (≥ 54) ($n = 42, 35.7\%$ achieved $\geq 10\%$ weight loss)	Low exercise autonomous motivation (< 54) and high perceived barriers to exercise (≥ 27) ($n = 76, 5.3\%$ achieved $\geq 10\%$ weight loss)	<i>P</i>
General and exercise motivation			
Awareness of self	21.9 \pm 2.79	19.1 \pm 3.52	<0.001
Perceived choice	19.6 \pm 3.98	15.9 \pm 4.02	<0.001
Exercise controlled motivation	18.6 \pm 6.50	19.3 \pm 6.10	0.588
Exercise autonomous motivation	55.2 \pm 0.90	41.7 \pm 9.44	-
Exercise intrinsic motivation	69.7 \pm 7.33	54.2 \pm 10.9	<0.001
Intrinsic exercise goals	13.8 \pm 1.83	10.8 \pm 2.41	<0.001
Extrinsic exercise goals	5.75 \pm 3.97	6.18 \pm 3.14	0.558
Exercise self-efficacy	43.2 \pm 4.97	34.9 \pm 6.60	<0.001
Perceived barriers to exercise	22.0 \pm 6.13	33.9 \pm 5.54	-
Psychological well-being and quality of life			
Self-ideal body size discrepancy	1.56 \pm 0.79	1.96 \pm 0.76	0.013
Body shape concerns	68.5 \pm 20.8	84.8 \pm 23.4	<0.001
Self-esteem	35.7 \pm 3.95	33.3 \pm 4.59	0.005
Physical self-worth	16.2 \pm 3.64	12.3 \pm 2.99	<0.001
Body attractiveness	14.4 \pm 3.77	11.5 \pm 2.67	<0.001
Exercise social support	22.8 \pm 8.44	20.8 \pm 7.53	0.200
Depressive symptoms	4.35 \pm 5.88	6.68 \pm 7.26	0.067
Physical health-related quality of life	90.6 \pm 7.80	79.7 \pm 14.9	<0.001
Mental health-related quality of life	78.1 \pm 16.8	66.9 \pm 18.6	0.001
Impact of weight on quality of life	42.8 \pm 12.5	53.9 \pm 15.0	<0.001
Eating behavior and eating habits			
Flexible restraint	6.05 \pm 0.97	5.09 \pm 1.74	0.002
Rigid restraint	5.02 \pm 1.49	4.09 \pm 1.80	0.004
Disinhibition	6.68 \pm 3.86	8.16 \pm 3.30	0.042
Hunger	4.27 \pm 2.67	5.24 \pm 3.58	0.131
Energy intake (kcal/day)	2373 \pm 1087	2179 \pm 834.4	0.331
Fat intake (%kcal/day)	30.8 \pm 6.46	33.4 \pm 6.45	0.045
Fiber intake (g/day)	39.5 \pm 25.1	31.1 \pm 16.7	0.038
Physical activity			
Moderate to vigorous physical activity (min/week)	319.5 \pm 192.5	191.8 \pm 182.4	0.001
Lifestyle physical activity	3.90 \pm 0.81	3.14 \pm 0.77	<0.001

Values expressed as mean \pm SD.

Statistical significance differences resulting from independent-samples *t*-test are represented in bold type [significance level is Bonferroni corrected ($P < 0.0019$)].

knowledge, the current study is the first to provide cut-off values of significant determinants of successful long-term weight loss maintenance (or lack thereof), which are of particular clinical relevance. For example, if exercise autonomous motivation is equal or higher than 54 points, the probability of maintaining 10% or more weight loss is significantly higher. While confirmatory evidence is needed, the present study is a step forward towards identifying groups with the most and the least successful profiles for long-term weight loss maintenance on the basis of their psychological and behavioral characteristics during treatment. **O**

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References

1. Wing RR, Phelan S. Long-term weight loss maintenance. *Am J Clin Nutr* 2005;82:222S-225S.

2. Powell LH, Calvin JE. Effective obesity treatments. *Am Psychol* 2007;62:234-246.
3. Teixeira PJ, Going SB, Sardinha LB, Lohman TG. A review of psychosocial pre-treatment predictors of weight control. *Obes Rev* 2005;6:43-65.
4. Elfhag K, Rossner S. Who succeeds in maintaining weight loss? A conceptual review of factors associated with weight loss maintenance and weight regain. *Obes Rev* 2005;6:67-85.
5. Teixeira PJ, Carraça EV, Marques MM, et al. A systematic review of self-regulation mediators of success in obesity interventions: The SPOTLIGHT project. *BMC Medicine* (in press).
6. Silva MN, Markland D, Minderico CS, et al. A randomized controlled trial to evaluate self-determination theory for exercise adherence and weight control: Rationale and intervention description. *BMC Public Health* 2008;8:234-247.
7. Williams L, Germov J, Young A. Preventing weight gain: A population cohort study of the nature and effectiveness of mid-age women's weight control practices. *Int J Obes* 2007;31:978-986.
8. Silva MN, Markland D, Carraça EV, et al. Exercise autonomous motivation predicts 3-yr weight loss in women. *Med Sci Sports Exerc* 2011;43:728-737.
9. Silva MN, Vieira PN, Coutinho SR, et al. Using self-determination theory to promote physical activity and weight control: A randomized controlled trial in women. *J Behav Med* 2010;33:110-122.
10. Sheldon K, Ryan R, Reis H. What makes for a good day? Competence and autonomy in the day and in the person. *Pers Soc Psychol B* 1996;22:1270-1279.
11. Ryan RM, Connell JP. Perceived locus of causality and internalization: Examining reasons for acting in two domains. *J Pers Soc Psychol* 1989;57:749-761.
12. McAuley E, Duncan T, Tammen VV. Psychometric properties of the intrinsic motivation inventory in a competitive sport setting: A confirmatory factor analysis. *Res Q Exerc Sport* 1989;60:48-58.
13. Markland D, Ingledew D. The measurement of exercise motives: Factorial validity and invariance across gender of a revised exercise motivation inventory. *Br J Health Psychol* 1997;2:361-376.
14. Sallis JF, Pinski RB, Grossman RM, Patterson TL, Nader PR. The development of self-efficacy scales for health-related diet and exercise behaviors. *Health Educ Res* 1988;3:283-292.
15. Steinhardt MA, Dishman RK. Reliability and validity of expected outcomes and barriers for habitual physical activity. *J Occup Med* 1989;31:536-546.
16. Stunkard AJ, Sorensen T, Schulsinger F. Use of Danish Adoption Register for the study of obesity and thinness. *Res Publ Assoc Res Nerv Ment Dis* 1983;60:115-120.
17. Rosen JC, Jones A, Ramirez E, Waxman S. Body Shape Questionnaire: Studies of validity and reliability. *Int J Eat Disord* 1996;20:315-319.
18. Rosenberg M. Society and the Adolescent Self-image. Princeton University Press: Princeton, NJ; 1965.
19. Fox KR, Corbin CB. The physical self-perception profile: Development and preliminary validation. *J Sport Exerc Psychol* 1989;11:408-430.
20. Sallis JF, Grossman RM, Pinski RB, Patterson TL, Nader PR. The development of scales to measure social support for diet and exercise behaviors. *Prev Med* 1987;16: 825-836.
21. Beck AT, Steer RA. Manual for the Beck Depression Inventory. Psychological Corporation: New York; 1987.
22. Ferreira PL. [Development of the Portuguese version of MOS SF-36. Part II—Validation tests]. *Acta Med Port* 2000;13:119-127.
23. Engel SG, Kolotkin RL, Teixeira PJ, et al. Psychometric and cross-national evaluation of a Portuguese version of the Impact of Weight on Quality of Life-Lite (IWQOL-Lite) questionnaire. *Eur Eat Disorders Rev* 2005;13:133-143.
24. Stunkard AJ, Messick S. The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *J Psychosom Res* 1985;29:71-83.
25. Westenhoefer J, Stunkard AJ, Pudel V. Validation of the flexible and rigid control dimensions of dietary restraint. *Int J Eat Disord* 1999;26:53-64.
26. Lopes C, Aro A, Azevedo A, Ramos E, Barros H. Intake and adipose tissue composition of fatty acids and risk of myocardial infarction in a male Portuguese community sample. *J Am Diet Assoc* 2007;107:276-286.
27. Blair SN, Haskell WL, Ho P, et al. Assessment of habitual physical activity by a seven-day recall in a community survey and controlled experiments. *Am J Epidemiol* 1985;122:794-804.
28. Kiernan M, Kraemer HC, Winkleby MA, King AC, Taylor CB. Do logistic regression and signal detection identify different subgroups at risk? Implications for the design of tailored interventions. *Psychol Methods* 2001;6:35-48.
29. Kiernan M, Moore SD, Schoffman DE, et al. Social support for healthy behaviors: Scale psychometrics and prediction of weight loss among women in a behavioral program. *Obesity* (Silver Spring) 2012;20:756-764.
30. Signal detection software for receiver operator characteristics [WWW document]. Available at <http://www.stanford.edu/~yesavage/ROC.html>. Accessed on January 2014.
31. Teixeira PJ, Silva MN, Coutinho SR, Palmeira AL, Mata J, Vieira PN, Carraça EV, Santos TC, Sardinha LB. Mediators of weight loss and weight loss maintenance in middle-aged women. *Obesity* 2010;18:725-735.
32. Jensen MD, Ryan DH, Donato KA, et al. Guidelines (2013) for managing overweight and obesity in adults. *Obesity* 2014;22(S2):S1-S410.
33. Teixeira PJ, Going SB, Houtkooper LB, et al. Exercise motivation, eating, and body image variables as predictors of weight control. *Med Sci Sports Exerc* 2006;38: 179-188.
34. Teixeira PJ, Silva MN, Mata J, Palmeira AL, Markland D. Motivation, self-determination, and long-term weight control. *Int J Behav Nutr Phys Acta* 2012;9: 22-35.
35. Teixeira PJ, Carraça EV, Markland D, Silva MN, Ryan RM. Exercise, physical activity, and self-determination theory: A systematic review. *Int J Behav Nutr Phys Acta* 2012;9:78-108.
36. Mata J, Silva MN, Vieira PN, et al. Motivational "spill-over" during weight control: Increased self-determination and exercise intrinsic motivation predict eating self-regulation. *Health Psychol* 2009;28:709-716.
37. Vieira PN, Mata J, Silva MN, et al. Predictors of psychological well-being during behavioral obesity treatment in women. *J Obes* 2011;936153.
38. Verstuyf J, Patrick H, Vansteenkiste M, Teixeira PJ. Motivational dynamics of eating regulation: A self-determination theory perspective. *Int J Behav Nutr Phys Act* 2012;9:21-37.
39. West DS, Gorin AA, Subak LL, et al. A motivation-focused weight loss maintenance program is an effective alternative to a skill-based approach. *Int J Obes* 2011;35:259-269.
40. Jacobs DR, Ainsworth BE, Hartman TJ, Leon AS. A simultaneous evaluation of 10 commonly used physical activity questionnaires. *Med Sci Sports Exerc* 1993;25: 81-91.