Exercise Autonomous Motivation Predicts 3-yr Weight Loss in Women

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ABSTRACT

SILVA, M. N., D. MARKLAND, E. V. CARRAÇA, P. N. VIEIRA, S. R. COUTINHO, C. S. MINDERICO, M. G. MATOS, L. B. SARDINHA, and P. J. TEIXEIRA. Exercise Autonomous Motivation Predicts 3-yr Weight Loss in Women. *Med. Sci. Sports Exerc.*, Vol. 43, No. 4, pp. 728–737, 2011. **Purpose**: This study evaluated exercise-related predictors of successful long-term weight control in women by analyzing the extent to which sustained exercise participation and self-determination theory (SDT)–based exercise motivation variables mediated the impact of a behavioral weight control intervention on 3-yr weight change. **Methods**: Longitudinal randomized controlled trial consisting of a 1-yr SDT-based intervention and a 2-yr follow-up with 221 female participants (means ± SD: age = 37.6 ± 7 yr, body mass index = 31.6 ± 4.1 kg·m^{-2}). The tested model incorporated experimentally manipulated perceived need support, motivational regulations, and 2-yr exercise adherence as mediators of the intervention's impact on 3-yr weight change. Paths were tested using partial least squares analysis. Where there were significant intervening paths, tests of mediation were conducted. **Results**: Treatment had significant effects on 1- and 2-yr autonomous regulations, 2-yr physical activity, and 3-yr weight change, fully mediated by the tested paths (effect ratio = 0.10–0.61). Moderate and vigorous exercise at 2 yr had a significant effect ($P < 0.001$) on weight loss success at 3 yr and partially mediated the effect of treatment on weight change. The 2-yr autonomous regulation effects on follow-up weight change were only partially mediated by physical activity (effect ratio = 0.42). **Conclusions**: This application of SDT to physical activity and weight management showed that not all types of motivation predict long-term behavioral outcomes and that sustained moderate and vigorous exercise mediated long-term weight change. It provides strong evidence for a link between experimentally increased autonomous motivation and exercise and long-term weight loss maintenance. Results highlight the importance of interventions targeting the internalization of exercise behavioral regulation and making exercise and physical activity positive and meaningful experiences rather than simply focusing on immediate behavior change in overweight/obese women. **Key Words**: RANDOMIZED CONTROLLED TRIAL, OBESITY, MEDIATION, SELF-DETERMINATION THEORY, MODERATE AND VIGOROUS PHYSICAL ACTIVITY

Lifestyle interventions are the most cost-effective means to reduce risk for a variety of important clinical conditions and represent the first step in the treatment of obesity (26). However, poor maintenance of treatment-induced weight loss remains a major challenge in the management of obesity. Although behavioral approaches to the management of obesity are often successful in achieving initial clinically significant weight loss, when the weight reduction programs end, the weight lost is generally regained (18). Unhealthy eating and exercise habits resurface within weeks to months of completing treatment, and empirical evidence highlights the small average long-term weight change (3%–4% of initial weight) (16). This notwithstanding, it should be acknowledged that a large individual variability exists in results from weight loss trials. Thus, focusing on the identification of factors associated with success will enhance the understanding of the most critical mechanisms involved and should be a research priority (33,34).

The National Weight Control Registry has provided continuous insight into the process of weight maintenance (39). In nearly 6000 successful weight loss maintainers, several common themes have emerged, with the expenditure of large amounts of energy in voluntary physical activity as the most consistent. On the basis of empirical evidence, systematic reviews (e.g., 10,36) indicate that individuals who perform greater amounts of physical activity have improved rates of weight loss maintenance. This was also highlighted in the 2009 American College of Sports Medicine Position Stand on physical activity strategies for weight management, which recommended 200–300 min·wk^{-1} of at least moderate physical activity for long-term weight loss (7). However, despite agreement as to the adequate dose of exercise and physical activity, poor behavioral adherence partially explains suboptimal results in exercise-based interventions (17), and it

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remains unclear why only some individuals seeking weight loss are able to adopt and successfully sustain this critical behavior. To date, little attention has been given to the predictors of behavioral maintenance, and even when maintenance is explicitly identified, the promoting mechanisms have not been identified (14,16). To improve our understanding of behavioral maintenance, studies that monitor people through at least 2 yr of follow-up, such as the Project Active trials (9), are needed in overweight and obese people. Furthermore, research on theory-based treatment-induced mediators of behavior change is critical to identify potential causal mechanisms through which interventions operate; randomized controlled trials provide the ideal setting for such work (19).

The conceptual framework provided by self-determination theory (SDT) (6) could be useful in explaining long-term adherence by exploring the dynamics of motivation during behavioral change. Key postulates from SDT are that motivation varies in kind and not just in amount, that internal motivation is energized by having one's psychological needs satisfied, and that there are several forms of regulatory motives varying along a continuum of self-determination, reflecting the extent to which the individual acts with volition rather than feeling pressured to act. Intrinsic regulation, involving a focus on the task itself and yielding energizing emotions such as interest, enjoyment, and challenge as well as identified regulation, reflecting an acceptance of the personal importance and meaningfulness of one's current pursuits, represents autonomous forms of regulation. External regulation, reflecting participation on the basis of contingencies and external demands and introjected regulation, which is based on avoiding feelings of guilt and shame, represents controlled forms of regulation. More autonomous regulation has been shown to predict success in many domains, including exercise (for a review, see Wilson et al. (38)), eating behavior (25), and weight control (32,37), suggesting that lasting behavior change depends not on complying with demands for change but rather on accepting the regulation for change as one's own.

More self-determined forms of behavioral regulation will be promoted to the extent that the basic psychological needs for autonomy (fulfilled when people perceive that they have real choices and are at the origin of their decisions, which they freely endorse), competence (concerning an individual's need to feel a sense of mastery and effectance), and relatedness (concerning having satisfying and supportive social relationships) are met in a dialectic interaction between the individual and the social environment (6). Social contexts that foster autonomous regulation, by supporting basic needs, will facilitate the internalization and integration of regulatory processes and thus promote more adaptive behaviors and better long-term outcomes (6). Thus, both autonomy support and autonomous regulation are important for sustained behavior change. Moreover, a recent study (24) suggests that the quality of motivation may be one mechanism through which successful self-regulation in one area may affect ("spillover") into other behavioral domains, suggesting that autonomously motivated exercise

behavior contributes to improved weight control not only through the effects of physical activity itself but also because of spillover effects on the regulation of other relevant behaviors such as eating.

Despite a growing body of evidence, SDT-based studies have been predominantly cross-sectional (for a review, see Hagger and Chatzisarantis (12)). Consequently, they are restricted in the extent to which they can explain the motivational mechanisms influencing exercise engagement and weight management across time. Longitudinal methodologies are required to examine the internalization process and the role of different regulations over time. Furthermore, despite the relatively well-documented role of need-supportive interventions on promoting more autonomous forms of behavioral regulation (for a review, Wilson et al. (38)), no information exists on the extent to which such regulatory patterns are maintained after termination of the intervention. In other words, evidence for the efficacy of interventions in causing relatively enduring changes in motivation and self-regulation toward exercise is lacking. In this study, in the context of a longitudinal randomized controlled trial, we sought to evaluate predictors of successful long-term weight control by analyzing the extent to which perceived need support, exercise behavioral regulations, and 2-yr exercise participation mediated the impact of the intervention on long-term weight control (29,31). On the basis of theoretical assumptions and on previous research in exercise motivation and adherence (12,38), we hypothesized that i) experimentally manipulated treatment climate would have a positive impact on the development of exercise autonomous regulation up to 1 yr after the intervention's end (2 yr), ii) autonomous regulation at intervention's end (1 yr) would predict autonomous regulation at 2 yr of follow-up, iii) 2-yr autonomous regulation would mediate the effect of treatment on 2-yr exercise, and iv) long-term exercise adherence (2 yr) would be associated with weight change at 3 yr and partially mediate the effects of exercise regulation at 2 yr on weight change. In addition, on the basis of previous studies (1,24), we also hypothesize that autonomous regulation for exercise at 2 yr would be associated with long-term weight loss independently of actual exercise level, that is, direct effects would remain significant after the indirect effects of self-reported exercise minutes were accounted for.

METHODS

Study Design and Intervention

The trial consisted of a 1-yr behavior change intervention and a 2-yr follow-up period with no intervention. The control group received a 29-session general health education curriculum on the basis of several educational courses covering various topics (e.g., preventive nutrition, stress management, self-care, and effective communication skills). The intervention group attended 30 sessions, targeted at increasing PA and energy expenditure, adopting a diet consistent with a

moderate energy deficit, and integrating exercise and eating patterns that would support weight maintenance. The program's principles and style of intervention were based on SDT (6), with a special focus on increasing autonomous regulation toward exercise and weight control. Guiding principles of the intervention included providing participants with an adequate structure and a range of options to choose from, supporting their autonomous decisions during the program, and encouraging them to explore their own motivations for treatment and define their personal treatment goals (within the recommended targets) while limiting external contingencies and controls (e.g., outcomes-based rewards or praise, external monitoring of behaviors and body weight). The study was part of a larger longitudinal randomized controlled trial and set within the context of other publications from the same database, which have detailed the study's theoretical rationale and intervention curriculum and reported 1-yr results (29–31). Approval was obtained from the Faculty Ethics Committee, and all participants gave written informed consent before participating.

Participants

Participants were recruited from the community at large through media advertisements. By design, participants had to be female, between 25 and 50 yr old, premenopausal, have a body mass index (BMI) between 25 and 40 kg·m^{-2}, willing to attend weekly meetings (during 1 yr), free from major illnesses, and not taking medications known to interfere with body weight regulation. A total of 258 women completed initial assessments and were randomized to intervention and comparison groups. Thirty-seven women were subsequently excluded from all analyses because they started taking medication (antidepressant, anxiolytic, and antiepileptic) susceptible to affect weight ($n = 13$) or because of serious chronic disease diagnosis or severe illness/injury ($n = 4$). Others were excluded because of pregnancy ($n = 11$) or because they entered menopause ($n = 9$). These 37 women were of similar age ($P = 0.737$) and BMI ($P = 0.852$) as the 221 participants who were considered as the valid initial sample for this study. The effective sample was between 23 and 50 yr old (means ± SD = 37.6 ± 7 yr) and overweight or mildly obese, with an initial BMI of 31.6 ± 4.1 kg·m^{-2}. There were no differences between this initial sample and women who quit the program for any demographics or psychosocial variables at baseline, with the exception of age; women who stayed in the trial until the 3-yr assessments were, on average, 3 yr older ($P = 0.05$) at the start of the program. There were also no differences for the same variables between women who completed the 1-yr intervention and those who were lost to follow-up at years 2 and 3 (all P values > 0.05). Reasons for attrition included financial/time limitations ($n = 15$), moving to another city ($n = 4$), and dissatisfaction with group assignment ($n = 1$); all other women lost to follow-up did not provide a reason ($n = 45$). Thus, 156 women were available for assessments at 3 yr: 71% overall retention, 79% in the intervention

group. Given the differential attrition rate between the two randomly assigned conditions, we explored if the baseline scores for those who later dropped out were different between conditions and if no differences were found (all P values > 0.05). Furthermore, we also analyzed if, within each condition, baseline scores were different between completers and later dropouts; again, no differences were found within either group of women (all P values > 0.05).

Measurements

Perceived need support. This variable, which concerns the quality of the social/treatment environment, was assessed by the Health Care Climate Questionnaire (HCCQ) (38). SDT posits three aspects of a motivationally facilitative social environment—autonomy support, structure, and involvement—which correspond to supporting the satisfaction of the psychological needs for autonomy, competence, and relatedness (Deci and Ryan, 2000). As noted by Markland and Tobin (22), although the HCCQ was designed to assess autonomy support, it includes items reflecting all three dimensions of the facilitative environment: autonomy support (e.g., "I feel that the staff has provided me choices and options"), structure (e.g., "the staff has made sure I really understand my condition and what I need to do"), and involvement (e.g., "the staff handle peoples' emotions very well"). The three support dimensions are, however, highly interrelated, so their items are typically collapsed into a single score. Responses to the 15 items were rated on a 7-point Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree).

Behavioral regulations of exercise. The types of regulations for exercising were measured with the Exercise Self-Regulation Questionnaire (SRQ-E) (28). The SRQ-E comprises four subscales assessing four different types of behavioral regulations, defined in terms of the degree to which the regulation of an activity has been internalized and integrated. Participants have to indicate, for each of the 16 items (4 items for each subscale), their reasons for exercising on a 7-point Likert-type scale, ranging from 1 (not at all true) to 7 (very true). Examples of items included in different regulations subscales are as follows (in order from the least to the most fully internalized): external regulation ("because I feel like I have no choice about exercising; others make me do it"), introjected regulation ("because I would feel bad about myself if I did not"), identified regulation ("because it feels important to me personally to accomplish this goal"), and intrinsic regulation ("because it is a challenge to accomplish my goal," "because it is fun"). Given this study's focus on examining the role of treatment support for exercise autonomous regulation and sustained exercise participation as mediators of the impact of an intervention on a 3-yr weight change, autonomous self-regulation was specified as a higher-order reflective latent variable with identified and intrinsic self-regulations as its lower-order latent indicators. Controlled regulations (external and introjection) were still

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treated separately because they represent dissimilar constructs with potentially differential consequences for behavioral adherence and well-being (20).

Exercise behavior. The 7-d physical activity recall (3) was used to determine the duration and intensity of physical activities. Trained interviewers asked participants to recall time spent doing physical activity for the past 7 d (or a typical week of last month, if the previous week was atypical), guiding the participants through the recall process, day by day. Previous studies have supported the reliability and the validity of the 7-d physical activity recall as a measure of physical activity (13). For the current study, activity reports were collapsed into total minutes of moderate- and vigorous-intensity physical activity in a week (all activities greater than 3 METs were considered).

Body Weight

Weight-related measurements were performed in the morning, after fasting for 3 h. Body weight was measured twice, using an electronic scale calibrated on site and accurate to 0.1 kg (SECA, Hamburg, Germany). Vertex height was measured with a balance-mounted stadiometer to the nearest 0.1 cm. BMI in kilograms per square meter was calculated from weight (kg) and height (m). Weight outcomes were expressed as percent weight change from baseline (16).

Statistics and Data Analysis

Preliminary analyses, group differences, and comparison of individuals with and without missing data were conducted using PASW statistics/SPSS Version 18.0 (SPSS Inc., Chicago, IL). Descriptive results are expressed in terms of group mean $\pm$ SD values, and between-group differences were explored using t-tests for independent samples. Model testing was conducted using partial least squares (PLS) analysis with the SmartPLS Version 2.0 (M3) software (Hamburg, Germany) (27). PLS is a structural equation modeling approach that uses a least squares estimation procedure. It was used in this study for two reasons. First, PLS is a nonparametric method that makes no restrictive assumptions about the distributions of the data, unlike the covariance-based structural equation modeling approach (e.g., LISREL) (4). Second, whereas covariance-based modeling requires a large number of cases relative to the number of parameters in the model to be estimated, PLS is ideally suited for use with smaller sample sizes (5) because of the partial nature of the estimation procedure, with only one part of the model being estimated at each time. Furthermore, by using an iterative estimation method that minimizes residual variance by providing successive approximations for the estimates of loadings and path parameters, PLS allows that the resulting component score for each latent variable is based on the best estimated indicator weights; consequently, it maximizes the variance explained for the dependent variables (i.e., latent, observed, or both).

The model tested in this study, using a prospective three-wave design (Fig. 1), incorporates randomization condition (coded as 0 = control group and 1 = treatment group), perceived need support and forms of exercise self-regulation (autonomous, introjected, and external regulation) at time 1 (1-yr intervention's end), exercise self-regulation and moderate and vigorous exercise at time 2 (2-yr follow-up), and weight change at time 3 (3-yr follow-up). There is a path between each self-regulation variable assessed at time 1 (1 yr) and time 2 (2 yr). In addition, there are also direct paths between 2-yr self-regulations and 3-yr weight change. For the PLS analyses, listwise deletion of missing data was implemented, and only participants with all data points for all variables in the model are included. With models comprising only reflective latent variables, the recommended minimum sample size is 10 times the number of structural paths, leading to the endogenous latent variable with the largest number of such paths (5). For the present model, this amounted to three paths and a minimum sample size of 30, which was far exceeded with the current data.

The PLS model was analyzed in two stages, following the recommendations of Fornell and Larcker (11). In the first stage, the measurement model was tested, including i) estimation of individual item reliabilities by inspecting the loadings of the items on their respective latent variables: for reliability of an indicator, the standardized loading of the indicator on its intended latent variable should be statistically significant and higher than 0.40 (11). ii) Assessment of the latent variables' internal consistency by examining their composite reliabilities (CR): CR is considered superior to Cronbach's alpha reliability coefficient, providing a better estimate of variance shared by a set of indicators because the former does not assume equal weightings of items (a CR of 0.70 or higher represents acceptable internal consistency). iii) Evaluation of discriminant validity of the scales by examining the average variance extracted (AVE) for the scales: AVE is the average amount of variance in a set of indicators explained by their latent variable. Regarding convergent validity, the AVE should be at least 0.50 (i.e., the latent variable explains on average 50% or more of the variance in its indicators). Regarding discriminant validity of the latent variables, the average variance shared between a latent variable and its indicators should be greater than the variance shared between the variable and other latent variables in the model.

In the second stage, the structural model was tested. Autonomous self-regulation was specified as a higher-order reflective latent variable with identified and intrinsic self-regulations (with their respective indicators from the SRQ-E) as its lower-order latent indicators. All other latent variables were also specified as reflective (perceived need support with the items from HCCQ, external, and introjected self-regulations with the respective items from SRQ-E). The standardized path coefficients (β) and the variance explained in the endogenous variables (R^2) were examined. Since SmartPLS does not generate significance tests for

the variance explained in the dependent latent variables, effect sizes of the R^2 values were calculated (5,15): Cohen's $f^2 = R^2 / (1 - R^2)$. Effect sizes of 0.02, 0.15, and 0.35 are considered small, medium, and large, respectively (6). Regarding the standardized path coefficients (β), SmartPLS implements a bootstrapping procedure to estimate mean and SD values for the estimates, which can then be tested for significance by the t-statistic (note: because bootstrap procedures do not assume normality of the distribution, they provide stronger protection against type II error). To assess mediated effects, bootstrapped estimates and SE were obtained for indirect effects where there were significant intervening paths between distal variables. In addition, where there were significant indirect effects, we report the ratio of the indirect effects to the direct effects. The effect ratio indicates the strength of mediation effects and is a preferable (quantitative) way to describe mediated effects, overcoming the full/partial mediation dichotomous distinction (30).

Weight outcomes were expressed as percent weight change from baseline. For putative mediators, absolute scores were used instead of change from baseline. This choice was because perceived need support ("I feel that the staff has…") and exercise self-regulation (e.g., "I exercise because I"…) variables were not assessed at baseline, given that most participants did not engage in regular exercise at the beginning of the intervention. For consistency, we decided to also use physical activity measures at 2 yr instead of change in

physical activity. Because this sample was mostly sedentary at baseline, the outcome measure was considered to represent well the result of the intervention on this variable. Nevertheless, we compared baseline scores between intervention and controls for general self-determination variables and for exercise minutes, and no differences were found ($P > 0.05$).

RESULTS

At 1 yr (intervention's end), the intervention group showed greater weight loss ($-7.3\% \pm 5.9\%$ of initial body weight) and higher levels of moderate plus vigorous exercise (300 ± 179 min·wk^{-1}) than participants in the control group ($-1.7\% \pm 5.0\%$; 162 ± 171 min·wk^{-1}; all P values < 0.001). Furthermore, group differences for the main psychosocial intervention targets were medium to large (d ranged between 0.45 and 1.35), favoring the intervention group (all P values < 0.001), including perceived need support and autonomous regulation (note: for detailed 1-yr results, see Silva et al., 2010). At 2 yr (first year of follow-up), the intervention group showed higher levels of exercise (272 ± 223 vs 179 ± 174 min·wk^{-1} in the control group, $P = 0.009$), higher weight loss ($-5.5\% \pm 7.7\%$ vs $-2.2\% \pm 7.5\%$, $P = 0.004$), and higher scores on the exercise self-regulatory variables: external regulation ($d = 0.40$, $P = 0.020$), introjected regulation ($d = 0.56$, $P < 0.001$), and autonomous regulation ($d = 0.44$, $P < 0.001$). At 3 yr
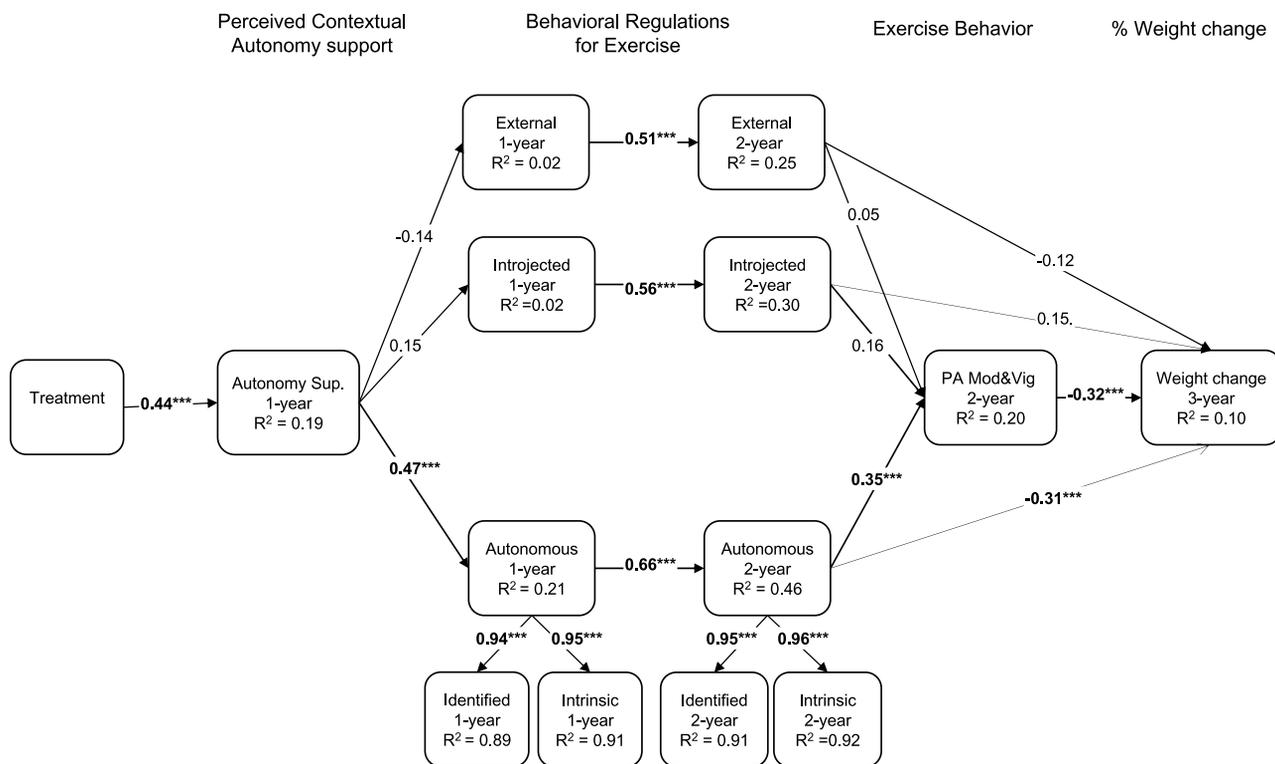

FIGURE 1—Structural model with parameter estimates. Values in the paths represent the standardized bootstrap estimate for direct effects, *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$. To enhance clarity of the figure, the indicators and item uniqueness are not reported.

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TABLE 1. Composite reliability (CR), average variance extracted (AVE), and correlations of factors in the measurement model (N = 135).

Factor	CR	AVE	Correlations									
			1	2	3	4	5	6	7	8	9	10
1. Treatment (intervention vs control group)	–	–	–									
2. Perceived autonomy support (1 yr)	0.97	0.68	0.44***	–								
3. External self-regulation (1 yr)	0.85	0.58	−0.04	−0.14	–							
4. Introjected self-regulation (1 yr)	0.79	0.56	0.32***	0.15	0.27***	–						
5. Autonomous self-regulation (1 yr)	0.95	0.68	0.44***	0.46***	−0.17*	0.35***	–					
6. External self-regulation (2 yr)	0.86	0.60	0.15	0.05	0.50***	0.17*	0.05	–				
7. Introjected self-regulation (2 yr)	0.84	0.64	0.32***	0.12	0.07	0.55***	0.28***	0.31***	–			
8. Autonomous self-regulation (2 yr)	0.95	0.69	0.23**	0.29***	−0.25**	0.23**	0.68***	0.02	0.39***	–		
9. Moderate and vigorous exercise (2 yr)	–	–	0.22**	0.09	−0.07	0.13	0.27***	0.09	0.30***	0.41***	–	
10. Weight change % (3 yr)	–	–	−0.17*	−0.16*	0.12	0.03	−0.23**	−0.08	0.00	−0.25**	−0.32***	–

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

(second year of follow-up), the percent weight change from baseline remained significantly higher in the intervention group ($-3.9\% \pm 7.6\%$ vs $-1.9\% \pm 7.4\%$) than that in the control group, $P = 0.040$) and also higher levels of exercise (234.1 ± 221 vs 148.1 ± 163 min·wk^{-1} in the control group, $P = 0.009$). Following intention-to-treat principles and including all starting subjects in statistical analysis, we used baseline imputation for all dropouts. Whether or not intention to treat was adopted had no effect on the study inferences (differences between the two groups remained highly statistically significant).

Testing of the measurement model. Initial analysis showed that two observed indicators (one for perceived need support and one for introjected regulation) had very low factor loadings and that the AVE with these indicators included were below the acceptable level. Thus, these items were eliminated and the model reestimated. Subsequent PLS and bootstrapped estimates for all factor loadings were greater than 0.40 and significantly greater than zero always. Table 1 shows the CR, the AVE, and the correlations among the variables in the model. CR were all greater than 0.70, and AVE were greater than 0.50, indicating acceptable convergent validity for the items. AVE for each latent variable were greater than the squared bivariate correlations with all the other latent variables, indicating acceptable discriminant validity. Correlation coefficients matched expected patterns of association. Treatment and perceived need support were significantly correlated with autonomous regula-

tion for exercise at both 1 and 2 yr and also with weight loss at 3 yr. Autonomous regulation at both 1 and 2 yr was correlated with exercise at 2 yr and weight loss at 3 yr. External regulation did not show associations with exercise and weight-related variables (nor with autonomous regulation). Although the 1-yr introjected regulation was not correlated with exercise, at 2 yr a significant association emerged. Taken together, these findings suggest that the measurement model was satisfactory.

Testing of the structural model. Figure 1 shows the PLS and bootstrapped parameter estimates for the structural paths included in the model and the variance accounted for in the dependent variables (R^2). With the exception of the effects of perceived need support on external and introjected regulations and of these regulations on exercise and weight loss, all hypothesized paths were significant. The model explained between 2% and 46% of the variance in the dependent variables.

Table 2 shows the bootstrapped estimates and SE for indirect effects and the effect ratios. Treatment had significant indirect effects on 1- and 2-yr autonomous self-regulations, 2-yr exercise, and 3-yr weight change. The effect of treatment on the 1-yr autonomous regulation was partially mediated by perceived need support (effect ratio = 0.46). For the 2-yr autonomous self-regulation, the effect of treatment was partially mediated by both need support and 1-yr autonomous self-regulation, with 61% of the total effect being explained by these indirect paths. The effect of treatment on

TABLE 2. Structural model indirect effects for mediation tests and effect ratios.

From	To	Estimate	SE	Effect Ratio
Treatment (intervention vs control group)	Autonomous self-regulation (1 yr)	0.21	0.05***	0.46
Treatment (intervention vs control group)	Autonomous self-regulation (2 yr)	0.14	0.04***	0.61
Treatment (intervention vs control group)	Moderate and vigorous exercise (2 yr)	0.05	0.01***	0.24
Treatment (intervention vs control group)	Weight change % (3 yr)	−0.02	0.01*	0.10
Perceived need support (1 yr)	Autonomous self-regulation (2 yr)	0.33	0.06***	1.00
Perceived need support (1 yr)	Moderate and vigorous exercise (2 yr)	0.12	0.03***	1.00
Perceived need support (1 yr)	Weight change % (3 yr)	−0.04	0.01**	0.22
Autonomous self-regulation (1 yr)	Moderate and vigorous exercise (2 yr)	0.24	0.05***	0.86
Autonomous self-regulation (1 yr)	Weight change % (3 yr)	−0.08	0.03***	0.33
Autonomous self-regulation (2 yr)	Weight change % (3 yr)	−0.11	0.04***	0.42

N = 135; Estimates derived form 5000 bootstrap samples.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

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the 2-yr exercise and on the 3-yr weight loss was partially mediated by the same paths (effect ratios = 0.24 and 0.10, respectively).

Perceived need support effects on the 2-yr autonomous self-regulation were mediated by the 1-yr autonomous self-regulation and on exercise at 2 yr mediated by the 1- and 2-yr autonomous regulations (both effect ratios = 1.0). Perceived need support also had significant effects on the 3-yr weight change, partially mediated by autonomous self-regulations and exercise (effect ratio = 0.22). One-year autonomous self-regulation effects on the 2-yr exercise were largely mediated by the 2-yr autonomous self-regulation (effect ratio = 0.81), and effects on 3-yr weight change were partially mediated by both 2-yr autonomous self-regulation and exercise (effect ratio = 0.33). Finally, the 2-yr autonomous self-regulation effects on the 3-yr weight change were partially mediated by exercise, with 42% of the total effect being explained by this particular indirect path.

DISCUSSION

The primary purpose of this study was to evaluate predictors of successful long-term weight control in overweight and obese women by analyzing the extent to which sustained exercise participation and theory-based psychosocial variables related to exercise motivation mediated the impact of a behavioral intervention on 3-yr weight change. This is a relevant research target considering the well-established need to identify predictors of sustained weight loss and lifestyle change over time in this population. Despite consistent evidence that individuals who exercise regularly tend to maintain their weight loss (10,36), mechanisms regulating behaviors as widely prescribed as exercise and physical activity need to be more thoroughly understood and extensively tested. For its role in energizing the direction and the persistence of human behavior, motivation is clearly among the best candidates for predicting exercise participation, including among overweight and obese people (12). In this study, we show that not all types of motivation predict long-term behavioral outcomes and that autonomous regulations are the critical intermediate mechanisms. Also, we describe the extent to which 2-yr moderate and vigorous exercise mediates 3-yr weight loss and maintenance. To our knowledge, both findings are novel in the area of exercise adherence in overweight and obese people.

As hypothesized, long-term exercise participation had a significant effect on weight loss success at 3 yr and partially mediated the effect of treatment on weight change. These results support and expand previous retrospective, cross-sectional, and prospective observational studies, highlighting the critical role of exercise in weight loss maintenance (15,39). The present results clearly indicate that, in the context of a comprehensive behavioral intervention (also including a nutrition and eating behavior component), overweight and obese women who increase and sustain their physical activity over time will benefit in terms of their long-lasting ability to manage body weight. We are unaware of previous studies that have reported 3-yr weight outcomes as a function of increases in exercise induced by a controlled intervention. Jakicic et al. (15) have also demonstrated that when the 12-month data were analyzed on the basis of the amount of exercise actually performed, greater levels of exercise were associated with a greater magnitude of weight loss after a 12-month treatment.

The most critical pathways by which exercise contributes to safe and effective obesity treatment are still under investigation. The most important physiological mechanisms include direct increases in energy expenditure, promotion of fat oxidation and fat tissue loss, and attenuation of the weight loss–induced decline in resting energy expenditure (10). Increasingly, researchers are also highlighting the role of psychological mechanisms associated with regular exercise participation, specifically in the overweight and obese population (e.g., improved well-being and self-esteem, reduced anxiety and depression, and also enhanced self-regulatory skills). These could also affect long-term weight control, for example, by their effect on compliance with dietary changes (2,23). In this study, we found evidence of similar mechanisms by showing that the effects of autonomous regulation on 3-yr weight change were only partially mediated by physical activity, with 42% of the total effect being explained by this particular indirect path; the remaining effects of exercise motivation presumably affected weight through alternative pathways. For instance, a recent study indicated the possibility of "spillover" effects in self-regulation, showing that increased general self-determination and exercise motivation facilitated improvements in eating self-regulation during weight control in women (24). Certain types of regulations/motivational styles may also be more associated than others with psychological well-being, for instance, at the emotional and self-perception levels (6). These aspects are often ignored in the behavior change literature, specifically in obesity studies, but there are suggestions that, for example, improved self-worth and body image can also benefit weight control (32) and are also associated with more internal exercise motivation (21). There may, in fact, be an intricate interplay between physiology and psychology regarding the effects of exercise on sustained weight loss. However, this interplay only applies if the exercise is actually performed, which has led some researchers (e.g., 10) to conclude that low adherence largely explains the mixed results for the role of exercise in weight control. Our results are supportive of this assertion in a sample of overweight and obese women.

Considerable research has been conducted to identify factors connected with long-term exercise adherence (for a review, see Trost et al. (35)). However, as most of the work in this field relies on cross-sectional studies, longitudinal and intervention research is required if causal relationships are to be inferred (12). Furthermore, effective testing of theoretical models within an intervention trial requires longitudinal assessment of theoretical constructs, followed

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by mediation analyses (19). Accordingly, this study tested experimentally manipulated perceived need support and motivational regulations as mediators of the intervention's impact on long-term exercise adherence and weight loss. We chose SDT because this framework is at the forefront of research examining the psychological antecedents, mechanisms, and basis for intervention in exercise contexts (12,38).

The degree to which participants experienced the staff as need supportive was a significant mediator of autonomous reasons for engaging in exercise 1 yr after the intervention ended, something which has not been reported before. This is of great practical significance because it suggests that the interpersonal climate created by the health-care staff in a weight loss program can influence participants' long-term perceived autonomy and their motivation for being physically active. In addition, the finding that 1-yr autonomous regulation effects on 2-yr exercise were fully mediated by 2-yr autonomous regulation (effect ratio = 0.81) supports the *a priori* mechanistic explanation for long-term exercise adherence; self-motivation can become more critical over time because continued behavioral changes require overcoming new obstacles, persisting through difficult times, and sustaining action when the initial impetus and reinforcers associated with the intervention are no longer available (as in the case of a follow-up period). From an SDT perspective, the internalization process (integration within the self of the behavioral regulation) can explain these findings (6). Autonomous motivation implies proactivity, whereby individuals act on the environment to exert some control over it. Thus, even in the absence of the intervention's autonomy-supportive context, more autonomously motivated participants may have managed to stay on course by actively transforming their exercise environment (because they internalized the means to do it). Furthermore, only autonomous motivation was a mediator of the effect of treatment on 2-yr exercise outcomes and on 3-yr weight loss. As hypothesized, the mediation paths through introjected and especially external regulations were small and failed to attain statistical significance. According to SDT, even when controlled regulations act as catalysts of short-term changes, only more autonomous motivation is associated with enhanced maintenance of behavior change. In previous studies, increases in intrinsic exercise motivation during treatment explained some of the long-term effects of a behavioral intervention on weight control (34), in one case above and beyond short-term changes in weight- and eating-related variables (32).

This study is not without limitations. It only included overweight and obese women, and therefore it is unclear whether similar results would be observed in men. Exercise was measured using a self-report questionnaire that has been shown to provide a valid and reliable assessment of physical activity. However, future studies may consider incorporating objective measures of physical activity, such as accelerometry and HR monitors. Furthermore, this study only considered moderate and vigorous exercise. Other forms of physical activity could also be considered to explain the intervention effects on weight control. Another limitation concerns the lack of assessments of exercise behavioral regulations at baseline (an option justified in the Methods section). Although there were no differences regarding demographic and more general SDT variables, the possibility that groups differed at baseline cannot be entirely ruled out.

Practical implications. Considering the importance of exercise in successful long-term obesity treatment, understanding the mechanisms behind the development of autonomous regulation, widely viewed as a predictor of continued behavioral adherence, is an important topic for conceptual and practical reasons, namely, to develop more effective exercise promotion interventions and practices. Although in many studies exercise has been an element of treatment, the main focus was weight loss or body composition change, and only the physiological elements of the exercise program were described (e.g., Donnelly et al. (8)). Conversely, description of the finer details of program delivery (as they are likely to have a major influence on successful adoption and long-term adherence), and especially of the psychological mechanisms underlying successful behavior change, is scarce in literature. Although some studies have examined *post hoc* associations between exercise and weight loss maintenance (e.g., 15) and others have focused on the effect of motivational constructs on exercise behavior and/or weight change (32,34,37), this study examined both these elements in an integrated longitudinal model, within the context of a randomized controlled trial. The results of this study with overweight and obese women may have implications for future interventions by highlighting the importance of an increased focus on making exercise a positive and meaningful experience rather than simply attempting to change behavior. External (or introjected) contingencies can produce results, but they are a short-term solution for a long-term problem. In the general population, research has now consistently shown that maintenance of exercise is especially related to the process and the quality of the exercise participation experience, which emphasizes intrinsic or well-integrated motives (12,38). We have now shown that the same applies to overweight and obese women. Thus, health professionals are encouraged to help participants make the transition from "should" to "want to" motivation. Partially, this means going beyond teaching/training particular behavior change skills (e.g., goal setting, self-monitoring) to encompass strategies like participants' verbalization of their own behavioral goals and exploration of how these goals can be accomplished in the context of their lifestyle, identifying factors that encourage more identified and intrinsic reasons for change (while downplaying external reasons to exercise), promoting competence and confidence (e.g., through modeling). Also, and most importantly, the support of autonomy and self-initiation are recommended by assuring choice (e.g., promoting active experimentation, supporting subjects' initiatives, minimizing

external sources of control/pressure), exploring individual values, meanings, and goals and how they can be linked to the targeted behavioral changes, and interpreting and deconstructing social pressures/expectations. In sum, it is important to help overweight and obese women focus on their own valued goals (e.g., health and fitness, improved well-being) as well as behavioral targets (i.e., adopting certain exercises or attending a certain number of sessions per week) and also encourage the creation of enjoyable exercise environments. Fortunately, a wide variety of sports and physical activities are available, and these provide multiple opportunities for optimal challenges and different experiences that can help all people develop the sense of ownership and mastery that underpins autonomous regulation. The challenge is thus on the side of health professionals to effectively target and change the most important mediating mechanisms, while discarding the least effective, for the (long-term) benefit of those who seek their expert guidance.

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