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Using self-determination theory to promote physical activity and weight control: a randomized controlled trial in women

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Abstract Behavior change interventions are effective to the extent that they affect appropriately-measured outcomes, especially in experimental controlled trials. The primary goal of this study was to analyze the impact of a 1-year weight management intervention based on self-determination theory (SDT) on theory-based psychosocial mediators, physical activity/exercise, and body weight and composition. Participants were 239 women (37.6 ± 7.1 years; 31.5 ± 4.1 kg/m^2) who received either an intervention focused on promoting autonomous forms of exercise regulation and intrinsic motivation, or a general health education program (controls). At 12 months, the intervention group showed increased weight loss (−7.29%,) and higher levels of physical activity/exercise (+138 ± 26 min/day of moderate plus vigorous exercise; +2,049 ± 571 steps/day), compared to controls ($P < 0.001$). Main intervention targets such as more autonomous self-regulation (for treatment and for exercise) and a more autonomous perceived treatment climate revealed large effect sizes (between 0.80 and .96), favoring intervention ($P < 0.001$). Results suggest that interventions grounded in SDT can be successfully implemented in the context of weight management, enhancing the internalization of more autonomous forms of behavioral regulation, and facilitating exercise adherence, while producing clinically-significant weight reduction, when compared to a control condition. Findings are fully consistent with previous studies conducted within this theoretical framework in other areas of health behavior change.

Keywords Theory-based intervention · Randomized controlled trial · Weight management · Autonomy promotion · Self-regulation · Intrinsic motivation

Introduction

Physical activity and exercise have been positively associated with successful long-term weight control in cross-sectional, longitudinal, and retrospective studies (Catenacci and Wyatt 2007), and several major organizations have recommended the addition of 60–90 min per day of moderate intensity PA to a dietary intervention to substantially increase the odds of successful long-term weight loss (Saris et al. 2003; Donnelly et al. 2009). Unfortunately, evidence suggests that more than 70% of US adults fail to meet current PA recommendations (Spiegel and Alving 2005). In Europe, the Eurobarometer (Rutten and Abu-Omar 2004) indicates that although the amount of PA is low, a wide disparity exists (e.g., Northern European countries showing higher levels of physical activity than southern countries) with Portugal reporting the highest percentage (87.8%) of sedentary lifestyles (Varo et al. 2003) and the lowest prevalence (40.7%) of any PA during leisure time (Martinez-Gonzalez et al. 2001). In the context of long-term weight management, it remains unclear why only about 20% of individuals seeking weight loss are able to successfully integrate PA behaviors into their lifestyles and achieve

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long-lasting weight control (Wing and Hill 2001). These numbers raise the central, but largely unanswered, issue of how to optimally facilitate the adoption of a physically active lifestyle among those overweight and obese, and particularly how to assist them in *maintaining* PA levels over the long-term.

Although there are other determinants, a special focus should be given to understanding the motivational dynamics of exercise initiation and persistence. As many studies have shown (e.g., Wilson and Rodgers 2003; Rose et al. 2005; Thogersen-Ntoumani and Ntoumanis 2006) enjoyment, competence, intrinsic motivation, and autonomous regulation are reliably associated with exercise participation. This may also hold true for the role of exercise motivation in weight management. In two studies of psychosocial predictors of weight management, increases in intrinsic motivation for PA were among the strongest predictors of long-term weight change, even after adjusting for initial weight loss (Teixeira et al. 2006, 2009). These and other results (Ryan et al. 1997; Wilson et al. 2004; Mata et al. 2009), support the proposition that an individual's motivational focus needs to shift from extrinsic to intrinsic for long-lasting positive behavioral outcomes (Markland and Hardy 1997).

One theoretical perspective that appears useful for understanding motivation and adherence to exercise, as well as to other health behaviors, is self-determination theory (SDT; Deci and Ryan 1985, 2008; Ryan and Deci 2000). Basic tenets of this theory are that human motivation varies in the extent to which it is autonomous (self-determined) or controlled, and that promoting long-term behavior change implies an understanding of the internalization process, which refers to the inherent tendency, possessed by all humans, to integrate the regulation of extrinsically motivated activities. Thus, SDT accounts for the quality of motivation regulating behavior which lies on a continuum from the lower to the higher autonomously self-determination forms: the least autonomous form of motivation is labeled external regulation, and occurs when a person performs activities either to obtain rewards, or to avoid punishment or sanctions; introjected regulation involves internalizing the behavior's regulation, but not fully accepting it as one's own (behaviors are performed to avoid negative emotions as anxiety and guilt, supporting conditional self-worth); identified regulation reflects participation in an activity because one holds outcomes of the behavior to be personally significant and important (although one may not enjoy the activity itself) and intrinsic, a highly autonomous form of motivation, is present when an activity is engaged because of its inherent satisfaction such as for the fun, interest, or the challenge it offers.

In addition to accounting for the quality of motivation, SDT also addresses the processes that facilitate the motivational development by specifying that more controlled regulations can be internalized and transformed into autonomous motivation, if supportive conditions are in place, i.e., a context that fosters the satisfaction of basic needs for autonomy, relatedness, and competence (Ryan and Deci 2000). When these needs are met, more self-determined forms of motivational regulation guiding behavior and adaptive behavioral (e.g., exercise engagement), cognitive (e.g., commitment) and well-being (e.g., joy) outcomes are postulated to ensue.

Research utilizing SDT has shown that the degree of autonomous motivation is associated with improved attendance, greater reductions in BMI, and improved maintenance at the 23-month follow-up within a weight loss program (Williams et al. 1996), and also with several other health outcomes such as long-term medication adherence (Williams et al. 1998), improved glycemic control and dietary self-care in diabetes patients (Williams et al. 1998), and maintained smoking cessation in adults (Williams et al. 2002). These and other studies (Rose et al. 2005) clearly indicate that being autonomous in one's relevant actions, that is, having an internal perceived locus of causality, is a crucial predictor of maintained behavior change. This also holds true in the context of exercise, where research has shown that more autonomous regulatory motives are conducive to higher long-term PA adherence (Fortier et al. 2007).

Importantly, not only autonomous motivation has been predictive of change in several health conditions, but it is also modifiable from an intervention standpoint. Recent studies confirmed the effectiveness of manipulating the social–contextual variables proposed by SDT in the context of smoking cessation (Williams et al. 2006) and PA promotion in several contexts, such us sports centres (Edmunds et al. 2008), in school (Wilson et al. 2005; Chatzisarantis and Hagger 2009) and in health care services (Fortier et al. 2007).

Applied intervention research is one of the best ways to evaluate and refine theory and experimental testing of behavior change interventions needs to answer three questions (Michie and Abraham 2004): first, does it work? Demonstrating that an intervention produces measurable improvement relative to an appropriate control group is a prerequisite to investment in subsequent trials or adoption in health care practice. Second, how well does it work? The effect size generated by a successful trial indicates the impact that the intervention is likely to have at an individual or population level. Third, how does it work? It requires an understanding of the causal processes and mechanisms, that is, the underlying psychological changes that account for observed behavior change. Well-designed randomized controlled trials (RCT) can help understand what types of interventions promote change in a particular behavior. Despite evidence regarding the promotion of an autonomy supportive climate, with positive consequences, in several domains, no previous RCT has tested an intervention specifically aimed at increasing patients' perceptions of autonomy support, autonomous self-regulation, and intrinsic motivation for physical activity, in the context of behavioral weight management.

The goal of this study was to analyze the 1-year impact of a SDT-based intervention on several self-regulatory variables (regarding treatment and exercise) and on primary outcomes of this trial, namely PA/exercise, weight, and body composition, in previously overweight/obese premenopausal women. At 12 months, we hypothesized that (1) participants in the experimental condition, compared to controls, would report greater perceived autonomy support, more autonomous self-regulation (for treatment and for exercise), higher exercise intrinsic motivation and perceived competence, more internal locus of causality and more autonomous motives for exercise, as well as higher exercise levels, and increased weight loss (primarily due to fat mass); and (2) the intervention program would produce its effects increasingly with time, i.e., compared to the control group, the intervention program would progressively increase the process of internalization of self-regulation for exercise and promote more weight loss along time, during the first year, considering intermediate (4-month) and intervention's end (12-month) results.

Methods

The study protocol, intervention curriculum, and behavior change strategies are described in more details elsewhere (Silva et al. 2008) and will only be briefly summarized here.

Study design

Randomized controlled trial, consisting of a 1-year behavior change intervention and a 2-year follow-up period with no intervention. Participants entered the study in three annual cohorts and each cohort was split into two randomly-assigned groups, using the random number generator function for Microsoft Excel 2007 for Windows®. Experimental groups received an equivalent amount of face-to-face contact with treatment providers (29 sessions in the control group, 30 sessions in the intervention group). The 29 sessions in the control group were delivered grouped into "thematic courses" such as healthy/preventive nutrition, stress management, self-care, and effective communication skills. The interpersonal climate promoted in this condition was similar to that commonly observed in standard health care settings: choices, rationale, and explanations were limited; specific behavioural goals were not set; minimal feedback was provided (Sheldon et al. 2003).

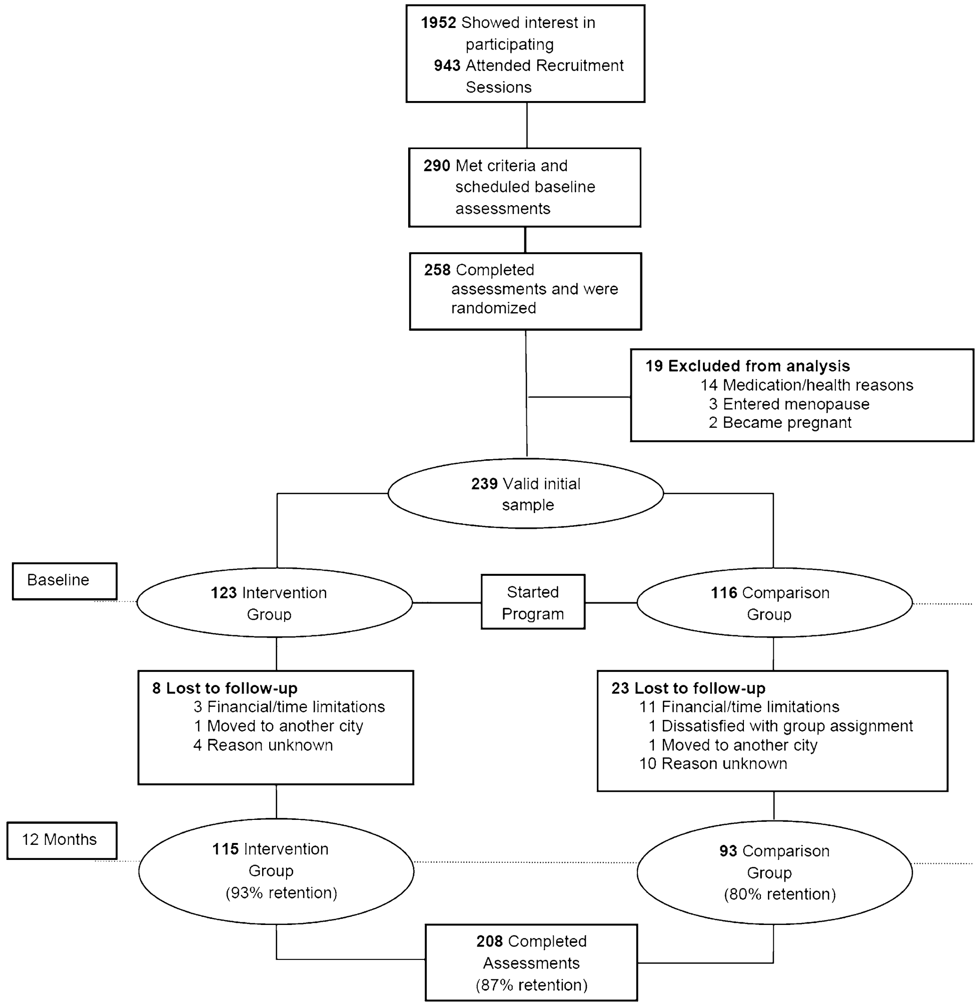
Participants

Participants were recruited through newspaper, flyers, and TV advertisements to enroll in a university-based behavioral weight loss program. To be included in the study they were required to be female, between 25 and 50 years old, premenopausal, not pregnant, have a BMI between 25 and 40 kg/m^2, be willing to attend weekly meetings (during 1 year) and be tested regularly (during 3 years), be free from major illnesses and not taking (or having taken in the previous year) medication known to interfere with body weight regulation, namely anti-depressive medication, and willing to not participate in any other formal or informal weight loss program during the first year of the study (intervention group only). Participants' flow in the study is shown in Fig. 1. Prior to participation, all participants gave written informed consent. The Faculty of Human Kinetics Ethics Committee approved the study.

Intervention

The 30 intervention sessions, designed to follow SDT basic tenets, covering PA, eating/nutrition, body image, and other cognitive and behavioral contents, occurred weekly or bi-monthly and lasted about 120 min each. To create an autonomy-supportive environment, the intervention team attempted to promote in each participant a sense of ownership over their behaviour such that it would stem from an internal perceived locus of causality. This involved (1) building sustainable knowledge that supported informed choices, by using neutral language during interpersonal communication (e.g., "may" and "could", and not "should" or "must"); (2) encouraging choice and self-initiation; the use of prescriptions, pressure, demands, and extrinsic rewards were minimal if not absent; (3) providing participants with a menu of options and a variety of avenues for behavior change; (4) supporting the presentation of tasks and choices with a clear rational to adopt a specific behaviour by presenting clear contingencies between behavior and outcome; (5) encouraging participants to build and explore congruence between their values and goals, and their lifestyles and (6) giving informational positive feedback, acknowledging that the feeling of competence grows from feedback inherent to the task (cues for objective success). Further details on these strategies

Fig. 1 CONSORT diagram



and their theoretical background are available elsewhere (Silva et al. 2008). Regarding structure, the intervention implementation was generally developed in "modules" which were introduced sequentially but with substantial overlap (see Fig. 2). The initial emphasis of the program focused on triggering weight loss, which was achieved primarily by reducing energy intake. Accordingly, Modules I (increasing knowledge) and II (triggering weight loss, improving diet) were focused on understanding energy balance and principles of gaining/losing weight, nutrition

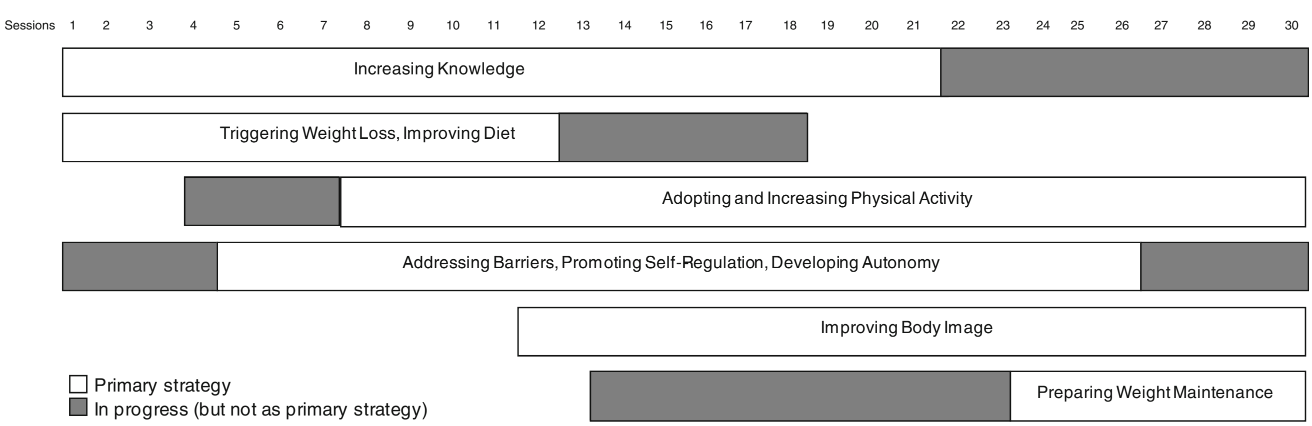


Fig. 2 Intervention modules implementation. *Note*: This representation was inspired by a similar graph by Cooper and Fairburn (2001)

education, and establishing eating patterns more likely to help weight loss. Module III (adopting and increasing physical activity) was introduced by about week 10 and aimed at establishing a more active lifestyle. First we addressed issues related to safety and skills, setting and managing PA goals, monitoring PA, and dealing with barriers to practice, in order to promote feelings of competence. Furthermore, our approach was to provide options and let people make their own decisions, encouraging participants to find the activities they enjoyed the most and were thus most likely to retain for the future. Dance classes and an activity challenge program were also developed to prompt fun, enjoyment, reaching new goals, and experimenting new activities. Module IV (addressing barriers, promoting self-regulation, developing autonomy) focused on identifying and addressing problem areas and difficulties related to the psychological (attitudinal, motivational) and behavioral changes expected to occur during the program. Critical areas addressed were emotional eating, exercise intrinsic motivation, and adequate goals for weight loss. In Module VI (improving body image), participants' concerns about their body shape were systematically addressed, with the goal of promoting greater self-acceptance and establishing more realistic goals for one's weight/body. Finally, aiming at long-lasting behavior change, the main emphasis of Module VI (preparing weight maintenance) was on helping patients acquire the strategies and skills needed for long-term weight control, such as regular monitoring of weight, adoption of flexible guidelines regarding eating instead of rigid dietary rules, and especially establishing a more physically active lifestyle both through formal and informal exercise.

Measurements

Assessments included lab-measured body weight and body composition (assessed at baseline, 4 and 12 months (end of the intervention program)), self-reported physical activity (assessed at baseline, and 12 months), and general (assessed at baseline and 12 months) and exercise (assessed at 4 and 12 months) SDT-relevant psychological variables. Preliminary validations of the selected SDT psychometric battery proved to be valid, internally consistent, and reliable (M. N. Silva, unpublished data). Internal consistency of all scales is shown in Table 2.

Weight and body composition

All weight-related measurements were performed in the morning, after fasting for 3 h. Body weight was measured twice, using an electronic scale calibrated onsite and accurate to 0.1 kg (SECA, Hamburg, Germany). Vertex height was measured with a balance-mounted/stadiometer to the nearest 0.1 cm. Body mass index (BMI) in kilograms per squared meter was calculated from weight (kg) and height (m). Regional and whole-body composition was evaluated using a Hologic/pencil-beam system (QDR-1500, Waltman, MA, USA). Images were analyzed with Hologic software 5.63 and all scans were conducted and analyzed by the same technician.

Self-determination theory-based instruments

Intervention-related

The *health care climate questionnaire* (Williams et al. 1996) assessed participants' *perceived need support*, measuring perceptions of the degree to which their team of care providers was autonomy supportive versus controlling. This scale includes items reflecting autonomy support (e.g., "I feel that the staff has provided me choices and options"), involvement (e.g., "The staff handles peoples' emotions very well"), and structure (e.g., "the staff has made sure I really understand my condition and what I need to do"), three dimensions considered essential for an optimally supportive health-care context. Answers to the 15 items were rated on a 7-points Likert scale ranging from *1 = strongly disagree to 7 = strongly agree*. A total score was calculated (range 15–105).

The *treatment self-regulation questionnaire* (TSRQ; Ryan and Connell 1989; Williams et al. 2002) assessed autonomous and controlled reasons for participation in the program. The TSRQ has 18 item stems such as: "I am staying in the weight-loss program because…", followed by several reasons that vary in the extent to which they represent autonomous regulation. Examples of more controlled reasons are: "I want others to see that I am really trying to lose weight" and "I'11 feel like a failure if I don't". Examples of more autonomous reasons are: "It's important to me personally to succeed in losing weight" and "I believe it's the best way to help myself." Each reason was rated on a 7-point scale ranging from *not true at all* to *very true*. Typically, the responses on the autonomous items are summed to form the autonomous regulation score (range 5–35) for the target behavior while responses on the controlled items are summed to form the controlled regulation score (range 8–56). These two subscale scores are used separately.

The *self-determination scale* (SDS; Sheldon et al. 1996) assessed individual differences in the extent to which participants tend to function in a self-determined way. It is thus considered a relatively enduring aspect of people's personalities, which reflects (1) being more aware of their feelings and sense of self, and (2) feeling a sense of choice with respect to their behavior. The SDS is a short, 10-item scale, with two 5-item subscales. The first subscale is awareness of oneself and the second is perceived choice in one's actions. Items prompt participants to estimate which of two statements feels more true of them, for example "what I do is often not what I'd choose to do" versus "I am free to do whatever I decide to do". The subscales may be used separately (range 5–25) and combined into an overall SDS score (range 10–50).

Exercise-related

The *locus of causality for exercise scale* (LCE; Markland 1999) assessed the perceived choice (or autonomy) regarding performing PA. It is a 3-item scale and indicates the extent to which respondents feel that they choose to exercise rather than feeling that they have to, addressing the source of the initiation of behavior. An internal locus of causality is evident when an individual engages in a behavior freely and with no sense of coercion. The LCE is designed to sit comfortably with the intrinsic motivation inventory items (IMI, see below). In fact, a central feature of self-determination is the perception of choice, which the IMI does not evaluate (Deci and Ryan 1985). Responses to the LCE are scored on a Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree) combining in a total score (range 3–21) with high scores indicating greater self-determination or a more internal perceived locus of causality.

The *exercise self-regulation questionnaire* (SRQ-E; Ryan and Connell 1989) assessed domain-specific individual differences in types of motivation or regulation (regulatory motives for exercise, referring to the "what" of goal pursuit). The regulatory styles, while considered individual differences, are not "trait" concepts, for they are not general nor particularly stable. There are four different types of behavioral regulation, defined in terms of the degree to which the regulation of an extrinsically motivated activity has been internalized and integrated. The SRQ-E is structured so that it asks one question and provides responses that represent the different forms of regulation. Participants have to choose, for each one of the 16 items (four for each subscale), how they feel in a 7-point Likert scale, ranging from 1 (not at all true) to 7 (very true). Each scale is scored separately by averaging the responses to each of the subscale's items (range 4–28). Examples of items included in different regulations subscales, ordered from the least to the most fully internalized, are: external regulation (e.g., "Because I feel like I have no choice about exercising; others make me do it"), introjected regulation (e.g., "Because I would feel bad about myself if I did not"), identified regulation (e.g., "Because it feels important to me personally to accomplish this goal"). Intrinsic regulation: ("Because it is a challenge to accomplish my goal", "Because it is fun").

The *intrinsic motivation inventory* (IMI; McAuley et al. 1989), measured participants' subjective experience related to exercise 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 pressure/tension scale was reversed as low pressure is associated with higher intrinsic motivation. Analyses were performed for the four subscales and the average of all 16 items was also computed to provide a single score indicating overall level of exercise motivation (range 1–5), with higher scores indicating a more internal, self-regulated type of motivation.

The *exercise motives inventory*-2 (EMI-2; Markland and Ingledew 1997) assessed exercise participation motives (participatory motives, referring to the "why" of goal pursuit). The scale contains a total of 51 items, grouped in scales (in alphabetical order): affiliation, appearance, challenge, competition, enjoyment, health pressures, ill-health avoidance, nimbleness, positive health, revitalization, social recognition, strength and endurance, stress management, and weight management. The stem was "Personally, I exercise (or might exercise)…". The response options ranged from *not at all true for me* (0) to *very true for me* (5). These scales can also be used combined, reflecting five dimensions: psychological motives, interpersonal motives, health-related motives, body-related motives and fitness-related motives (range 0–5).

Physical activity

The 7- *day physical activity recall* (7Day-PAR; Blair et al. 1985; Hayden-Wade et al. 2003) was used to determine the duration and intensity of physical activities. Trained interviewers asked participants to recall time spent doing PA for the past 7 days (or typical week of last month, if last week was atypical), guiding the participants through the recall process, day by day. Previous studies have supported the reliability and validity of the 7-Day PAR as a measure of PA (Washburn et al. 2003). For the current study activity, reports were summarized into total minutes of moderate or vigorous intensity physical activity (METs > 3.0) in a week.

Participants carried a Yamax Digi-Walker SW-200 step counter (New Lifetyles, Lee's Summit, MO, USA) for assessment of daily steps (Welk et al. 2000; Le Masurier and Tudor-Locke 2003). Participants were instructed to place the pedometers on each morning and to reset the device to zero each day. Subjects then wore the pedometers over the course of the entire day (during 1 week, including weekend days). Data from the pedometers were processed on a daily basis and averaged across 7 days to reflect typical daily steps for the week; mean steps per day were computed.

A *lifestyle physical activity index* was specifically developed for this study as a simple self-administered instrument for measuring habitual lifestyle physical activities typical of the last month. This variable is typically not available in existing PA questionnaires. To calculate this index we used a score based on seven questions (using stairs or escalators; walking instead of using transportation; parking away from destination; using work breaks to be physically active; choosing to stand up instead of sited; choosing hand work instead of mechanic/automatic; choosing to be physical active whenever possible). Options ranged from *never* (1) to *always* (5) on a Likert scale.

Statistical analyses

Analyses were carried out using SPSS 17.0 software (SPSS Inc., Chicago, IL, USA). Internal consistency estimates and descriptive statistics were calculated for all dependent variables. Primary analysis included only subjects for whom weight data were available at 12 months (completers, $n = 203$), 86% retention. Additionally, to account for potential selective dropout biases known to limit completers-only analyses, we also performed analyses including all 239 women who started the program and had valid data, carrying forward the baseline value for weight, a conservative estimate procedure (Ware 2003). For further insight into attrition-related bias, statistical comparisons of weight loss and demographic variables at baseline were conducted between the 12-month completers and the women who dropped out during first year.

To quantify the impact of the 1-year intervention on SDT treatment and exercise-related psychosocial variables, lifestyle PA, and weight and body composition changes, effect sizes were calculated. Effect size (or Cohen's *d*) is a standardized measure of the magnitude of the observed effect (e.g., difference between intervention and control groups). Cohen (1988) proposed widely accepted criteria for the magnitude of the effect: <0.30 small effect size; 0.30–0.80 medium effect size; >0.80 large effect size. Independent samples *t*-tests were carried out to analyze differences in self-regulation psychosocial variables, weight loss, body composition, and physical activity between intervention and control groups, at the end of intervention. This option was justified by the absence of several baseline SDT measures; because some questionnaires pertained intervention-related aspects (e.g., perceived autonomy support by the intervention team), they could not be assessed at baseline. Regarding exercise psychosocial measures, the questionnaire used to assess self-regulation (SRQ-E) did not contemplate a scale of amotivation (a completely non-self determined form of regulation reflecting a state of lacking any intention to engage in a exercise behavior); thus, given the fact that our baseline sample was mostly sedentary, responses to self-regulation and locus of causality for exercise questionnaires (e.g., "I try to exercise on a regular basis because…") were deemed as less valid at baseline and not used (also for consistency with the analysis for treatment-related variables). Nevertheless, we compared baseline scores between intervention and controls for general self-determination variables (e.g., SDS). Rank-order correlation (Spearman's rho) was used to estimate the relationship between adherence (displaying a non-normal distribution, thus warranting the use of this non-parametric technique) and main outcomes.

To test within and between-group differences during the course of the intervention (4-month and 12-month), a 2×2 repeated measures multivariate analysis of variance (GLM) was conducted, comparing weight change and psychosocial self-regulation scores between intervention and controls.

Results

The baseline characteristics of the 239 participants who initiated the study are given in Table 1. No differences between intervention and control groups were observed for demographic, physical activity, weight, and body composition variables. We also compared the groups for general self-determination and also found no differences ($P > 0.05$).

According to established exclusion criteria (see "Methods") subjects for whom health issues (non-intervention related), menopause, or pregnancy occurred during the intervention were removed from analyses. At 12 months, 31 subjects (eight in the intervention group) had dropped out from the study. Reasons for attrition are explained in Fig. 1. Thus, 208 women were available for assessments at treatment's end (13% attrition). We compared completers and dropouts for age ($P = 0.127$), BMI ($P = 0.211$), and several demographic characteristics (e.g., marital status, $P = 0.796$; level of education, $P = 0.857$) and found no differences. Additionally, four women were excluded from statistical analysis because they had data which were not considered valid: two women with extreme

Table 1 Baseline characteristics

	Intervention	Control
Demographics		
Age (years)	38.1 ± 7.04	37.1 ± 6.99
Higher education	64%	69%
Single	30%	37%
Married	56%	54%
Divorced, widow	14%	9%
Body habitus		
Height (m)	1.61 ± 0.06	1.61 ± 0.06
Weight (kg)	82.1 ± 11.9	81.5 ± 12.1
Body mass index (kg/m^2)	31.7 ± 4.24	31.3 ± 4.00
Body fat (%)	43.7 ± 4.9	44.1 ± 4.94
Fat mass (kg)	36.0 ± 8.42	36.0 ± 8.04
Lean mass (kg)	45.5 ± 5.12	45.0 ± 6.13
Physical activity		
Moderate + vigorous (min/week)	110.2 ± 150.1	88.6 ± 122.3
Lifestyle activity index	2.79 ± 0.88	2.89 ± 0.83

Data are given as mean ± SD or %. There were no significant differences (independent *t*-test) between intervention and control groups

weight and body composition data values (above four standard deviation units from mean) and two women who reported a very high level of difficulty understanding questionnaire instructions and written questions. In some analyses, due to occasional incomplete questionnaire data, a smaller number of subjects were considered.

Self-regulation for treatment and exercise

Results for self-regulation psychosocial variables can be seen in Table 2. For each scale/sub-scale, internal consistency coefficients were calculated. In most cases, observed Cronbach alpha values were greater than 0.80. Participants in the intervention group reported higher levels of self-determination (awareness of self and perceived choice) and autonomous self-regulation for treatment, and a more autonomy supportive perceived treatment climate. The same pattern of results was observed for exercise-related targets such as exercise intrinsic motivation, autonomous self-regulation, internal locus of causality, and exercise psychological and fitness motives, with participants in the intervention group scoring significantly higher in these variables. Comparing intervention and controls at 12 months, intervention targets such as more autonomous self-regulation (for treatment and for exercise), intrinsic motivation, psychological motives (related to fun, challenge), and a more autonomy perceived treatment climate revealed medium to large effect sizes, favoring intervention. Conversely, motives related to interpersonal and body attractiveness reasons, and external regulation showed small or negative effect sizes.

Physical activity

As depicted in Table 2, participants in the intervention group showed significant higher levels of PA at 12 months, reflected in more steps per day (+2,049 ± 571) and substantially more minutes of moderate and vigorous PA (+138 ± 26) per week, compared to controls. Results for the lifestyle PA index also confirm the intervention group as being significantly more active.

Weight and body composition

Weight outcomes were expressed as percent weight change from baseline (Fig. 3). At 12 months (and already at 4 months) participants in the intervention group achieved more weight loss compared to controls. The mean difference between groups at the end of the intervention was of about 6%. Following intention-to-treat principles (ITT) and including all starting subjects in statistical analysis, we used baseline imputation for the 31 dropouts. Whether or not ITT were adopted, this had no effect on the study inference (differences between the two groups remained highly statistically significant).

Concerning changes in body composition at 12 months, the intervention group lost 5.6 ± 4.1 kg of fat mass (vs. −1.5 ± 4.3 kg in the control group, $P < 0.001$ for between-group difference), and showed −1.1 ± 1.8 kg of change in lean mass (vs. −0.2 ± 1.6 kg, $P < 0.001$). Percent body fat changed by −6.9 ± 7.9% in the intervention group (vs. −2.5 ± 7.5%, $P < 0.001$). BMI change also differed significantly ($P < 0.001$) between the two groups: −2.3 ± 1.9 kg/m^2 for intervention and 0.7 ± 1.9 kg/m^2 for controls.

Adherence to the weekly or bi-weekly scheduled intervention sessions (mean 87.2 ± 12.9%, median 90.5%) was also considered. Changes in BMI, weight loss, percentage of body fat, and number of steps per day were significantly correlated with adherence ($P < 0.003$). An efficacy analysis using only participants who attended 80% or more intervention sessions (79% of intervention group participants) showed the following intervention-control differences: −5.9 ± 0.7% (−5.5 ± 0.8% for all intervention completers) in % body weight change, +156 ± 27 min/week (+138 ± 25 for all intervention completers) in moderate and vigorous PA, +2,298 ± 585 steps/day (+2,049 ± 571 for all intervention completers) in walking, and large effect sizes regarding the lifestyle index (0.95) and more autonomous forms of regulation for exercise

Table 2 Between-group comparison for psychosocial and exercise variables (12 months)

Psychosocial variables	Alpha	Intervention control		t	ES
		Mean ± SD	Mean ± SD		
Treatment-related, general					
Health care climate	.96	93.1 ± 11.2	78.5 ± 16.6	−7.40***	1.06
Treatment self-regulation					
Controlled	.86	23.7 ± 9.03	22.5 ± 8.03	−0.93	0.14
Autonomous	.79	32.9 ± 2.78	26.9 ± 6.14	−9.09***	1.35
Self-determination					
Awareness of self	.67	20.6 ± 3.32	19.5 ± 3.62	−2.15*	0.32
Perceived choice	.84	17.8 ± 3.88	16.2 ± 4.68	−2.44*	0.35
Total score	.81	38.3 ± 5.96	35.8 ± 7.15	−2.74**	0.40
Exercise-related					
Locus of causality for exercise	.80	16.2 ± 4.43	13.1 ± 4.76	−4.76***	0.68
Exercise intrinsic motivation					
Enjoyment/interest	.89	4.14 ± 0.74	3.65 ± 0.89	−4.21***	0.60
Perceived competence	.80	3.27 ± 0.91	2.78 ± 0.94	−3.66***	0.53
Pressure/tension	.82	4.12 ± 0.72	3.78 ± 0.79	−3.08**	0.45
Effort/importance	.82	3.94 ± 0.73	3.46 ± 0.79	−4.34***	0.68
Total score	.94	3.99 ± 0.62	3.54 ± 0.70	−4.77***	0.69
Exercise self-regulation					
External	.72	7.53 ± 3.56	7.89 ± 3.61	0.70	−0.10
Introjection	.67	11.3 ± 4.48	8.84 ± 3.39	−4.42***	0.65
Identification	.85	26.1 ± 1.98	22.7 ± 4.53	−7.12***	1.05
Intrinsic	.87	24.0 ± 3.89	18.9 ± 5.62	−7.59***	1.08
Motives for exercise					
Psychological	.91	3.77 ± 0.77	3.29 ± 0.80	−4.22***	0.61
Interpersonal	.78	1.73 ± 1.02	1.71 ± 0.83	−1.71	0.03
Health	.90	3.64 ± 0.66	3.65 ± 0.75	0.11	0.01
Body	.84	3.94 ± 0.71	3.84 ± 0.79	−0.91	0.13
Fitness	.87	4.06 ± 0.72	3.81 ± 0.78	−2.27*	0.35
Physical activity variables					
Moderate + vigorous (min/week)		300 ± 179	162 ± 171	−5.31***	0.79
Steps/day		9902 ± 3331	7852 ± 3470	−3.59***	0.60
Lifestyle activity index	0.84	3.84 ± 0.69	2.98 ± 0.81	−7.33***	1.14

* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$ for *t*-test comparing intervention and control groups at 12 months; α Cronbach's alpha, *SD* standard deviation, *ES* Cohen's *d* effect size (between-group differences)

(0.99 identified and 1.12 intrinsic), favoring intervention. All differences were significant at $P < 0.001$.

Group specific time-course of changes in self-regulation

We also wanted to examine and compare group-specific time-course of changes in autonomous self-regulation for exercise during the program. This was assessed using GLM repeated-measures to determine whether there were significant main effects of time, group, and group x time. Results can be seen in Fig. 4. There was a significant main effect of group on autonomous forms of self-regulation, i.e., intrinsic ($F = 47.7$, $P < 0.001$) and identification ($F = 47.8$, $P < 0.001$), and on introjection ($F = 20.5$, $P < 0.001$) with higher scores for the intervention group, and also a time effect for introjection ($F = 50.95$, $P < 0.001$) with a decrease in both groups. There were a significant time x group effects for intrinsic ($F = 8.90$, $P = 0.003$), identification ($F = 9.05$, $P = 0.003$), and external regulation ($F = 4.05$, $P = 0.045$), indicating that between-group differences at 4 months were accentuated at 12 months.

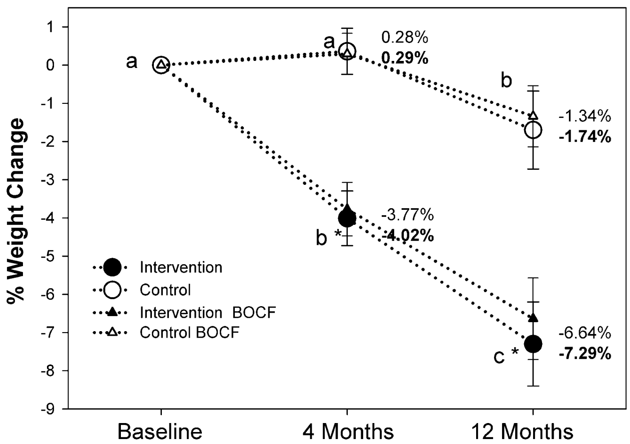


Fig. 3 Weight change during the first year for intervention and control groups. *Errors bars* show 95% confidence interval. To evaluate the pattern of change in weight, GLM repeated measures were used. There was a significant time x group interaction at 4 and 12 months, compared to baseline ($P < 0.001$). Mean values with the same *superscript letter* are not different ($P > 0.05$) within intervention and control groups. * $P < 0.001$ between groups at each time point for completers-only and baseline observation carried forward (BOCF) analysis

Discussion

The use of theory-based intervention studies helps discern which components work to produce expected outcomes, and to what extent. Furthermore, research and application have recursive effects, each enhancing the quality and relevance of the other. A recent review on existing behavioral interventions for preventing and treating obesity in adults (Sharma 2007) found that the majority were not based on any explicit behavioral theory, and that approximately half of the interventions were less than 6 months in duration. Moreover, the most common outcome for measuring the impact of the interventions was weight or BMI, with energy balance-related behaviors being infrequently measured. Even interventions which used behavior theories did not, typically, measure changes in constructs that could predict behavior. Such measurements are critical for identifying the most salient constructs and for increasing their predictive potential, as well as for improving theory itself. In comparison to other aspects of SDT framework, research focusing on manipulating socio-environmental context has been limited. Considering previous reports (Williams et al. 2002; Edmunds et al. 2008), more studies, using more sophisticated experimental designs, are needed. We developed a RCT with a novel intervention grounded on SDT, where group differences in general self-determination, and in perceived autonomy support, intrinsic motivation, perceived competence, and autonomous regulation for treatment and PA were evaluated after a 12-month group-based behavioral program in premenopausal women.

The large intervention effect size observed for perceived autonomy-promoting treatment climate adds evidence to

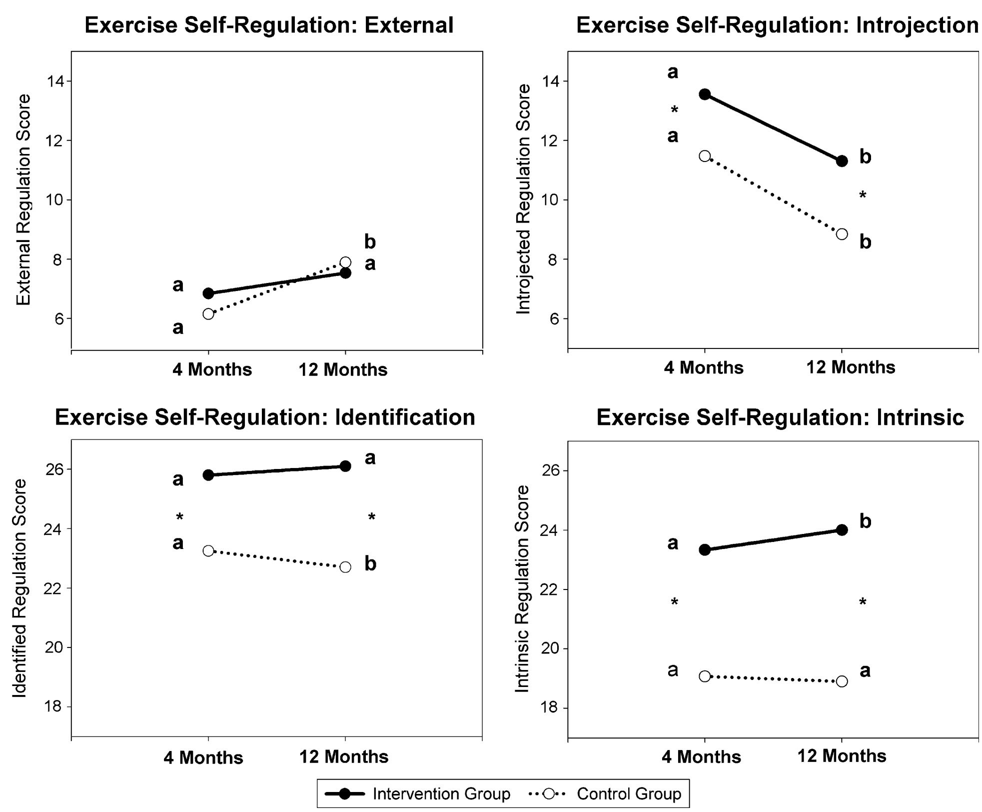


Fig. 4 Changes in self-regulation for exercise at 4 and 12 months. GLM repeated measures were used. Same *superscript letter* indicates no differences ($P > 0.05$), within intervention and control groups. * Indicates differences ($P < 0.05$) between groups at each time point

previous research demonstrating that, when treatment staff are characterized by minimizing pressure and control, understanding participant's perspectives, and regular provision of choices rather than fixed prescriptions (Williams et al. 1998, 2004, 2006) they are perceived by participants as being more autonomy-supportive, ensuring self-determined motivational regulations. At intervention's end, participants in the experimental condition, compared to controls, also reported more autonomous self-regulation (for treatment and for exercise), higher exercise intrinsic motivation and perceived competence, a more internal locus of causality, and more autonomous motives for exercise. Furthermore, other differences between control and intervention groups support that the intervention also tapped into more general aspects of self-determination (e.g., awareness of self). Taken collectively, results show significant intervention effects on SDT-related variables.

To analyze the intervention effects along the time course of the program, namely the internalization of a more autonomous exercise regulations process, we compared psychosocial scores between intervention and controls at 4 and 12 months. This assessment scheme was useful because, as noted in the "Methods" section, the intervention was implemented in sequential modules; for instance, the physical activity main self-regulation components were implemented progressively, starting approximately at week 10. In agreement, intrinsic and identified self-regulation increased with time in the intervention group with significant time × group effects, confirming that the intervention program increased the process of internalization of autonomous self-regulation for exercise along time, during the first year. These findings add credence to SDT's arguments that social-contextual characteristics of health interventions are amenable to manipulation and play an important role in facilitating the internalization process (Ryan and Deci 2000). When an autonomy-supportive climate is present, it is postulated that the regulation of behavior will be perceived by the participant as his/her own, and the most autonomous forms of regulation will arise (Deci et al. 1994; Edmunds et al. 2008).

A critical outcome of this intervention was exercise/PA at intervention's end. Regarding moderate plus vigorous PA, the average of about 300 min per week is consistent with current physical activity recommendations to achieve meaningful health benefits and also to help sustain weight loss (Saris et al. 2003; Donnelly et al. 2009). A previous study with overweight sedentary women enrolled in a 12-month behavioral intervention showed that weight loss was significantly greater in the group reporting more than 200 min per week of exercise, especially compared with the group with less than 150 min/week (Jakicic et al. 2003). For daily walking, although mean steps per day for the intervention group did not reach the 10,000 steps a day recommendation (Tudor-Locke and Bassett 2004), these women reported about 2,000 steps/day more than controls, a reasonable intervention effect. This variable reflects all walking, some of which is strongly influenced by the physical/built environmental and other contextual influences (e.g., job-, and family-related) less likely to be changed, compared to other types of physical activity. Perhaps more sensitive to intervention influences was the variable we named lifestyle PA, including parking further away from one's destination, takings the stairs more often, standing instead of sitting, etc., for which a large effect size favoring intervention was observed. This outcome is frequently omitted in PA studies. However, because the 7-day PAR includes moderate plus vigorous PA in bouts of activity longer than 10 min, it is possible for an individual to accumulate a substantial amount of lower-intensity daily PA but still report little or no moderate/vigorous exercise. Also, because steps per day include planned and unplanned walking, pedometry could not specifically capture these daily lifestyle changes. In fact, the lifestyle index and steps/day were only moderately correlated (results not shown).

Regarding weight loss and changes in body composition, results are in line with the other outcomes already discussed. It is important to notice that at 12 months (as well as at 4 months), comparing to controls, participants in the intervention group not only achieved significantly more weight loss, but the relative amount of weight loss from baseline (7.3 ± 5.9%) is consistent with recommendations regarding the magnitude of weight loss necessary to reduce health risk (Donnelly et al. 2004). The average of 7% is also consistent with outcomes achieved in some of the most intensive and comprehensive lifestyle change programs (Tuomilehto et al. 2001; McBride et al. 2008). For changes in body composition, results showed that the weight lost in the intervention group was largely due to fat mass (percent body fat was reduced by 6.9 ± 7.9%). A recent review confirmed the selective effect of exercise on body composition in people who are overweight or obese (Shaw et al. 2006).

This study has some limitations that need to be acknowledged. First, the nature of the control group precluded a direct comparison of this intervention with other types of weight loss programs. The decision for a standard care control group, which is common in this type of research (e.g., Williams et al. 2006), was related to other goals of this RCT, namely testing the motivational sequence embedded in SDT, which might facilitate our understanding of the mechanisms that foster self-determined motivation for exercise in weight loss settings. A second limitation concerns the lack of baseline assessments for exercise and treatment-related outcomes (an option justified in the "Methods" section). Despite the fact that there were no differences regarding demographic and more general SDT variables (such as causality orientations and general self-determination), the possibility that groups differed at baseline cannot entirely be ruled out. The lack of an economic evaluation of the intervention can also be considered as a study limitation, to be addressed in future research. Translational studies involving cost-effectiveness analyses represent an important research need in the behavioral sciences to optimize associated economic and clinical benefits for both society and participants involved. Since the present trial was primarily concerned with studying mechanisms of behaviour change and identifying individual-level predictors of success, cost analyses were unfortunately not planned and could not be calculated post-hoc.

In summary, this SDT-based intervention for weight control appears to have been well-implemented, resulting in meaningful changes in exercise/PA behavior, and changes in weight and body composition of clinical relevance. Results at 1 year provide a positive answer to Michie and Abraham's (2004) two questions regarding RCTs, namely (1) "does it work?": we demonstrated that the intervention produced measurable improvements in main outcomes and psychological theory-grounded variables, relative to an appropriate control group; and (2) "how well does it work?": moderate to strong effect sizes were observed, favoring the intervention. All participants are now being followed for two additional years to evaluate weight maintenance and other relevant long-term processes and outcomes.

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