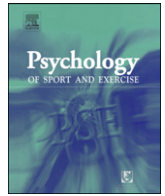




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Helping overweight women become more active: Need support and motivational regulations for different forms of physical activity[☆]

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ABSTRACT

Objectives: This study analyzed mechanisms by which a one-year obesity treatment intervention based on self-determination theory (SDT) influenced physical activity level and whether motivational predictors differed for structured vs. lifestyle forms of physical activity.

Design: Randomized controlled trial lasting 1-year.

Method: Pre-menopausal overweight and obese women ($n = 239$; 37.6 ± 7.1 y; 31.5 ± 4.1 kg/m²) participated in a group intervention designed to increase physical activity and motivation, following SDT. Partial least squares (PLS) latent variable modeling was used to test a cross-sectional multiple-level mediation model comprising experimentally-manipulated contextual need support, perceived need satisfaction, and motivational regulations for two distinct forms of physical activity.

Results: The structural model explained a large amount of variance (62%) for intrinsic motivation, and moderate amounts of variance (16–25%) for the remaining regulations and exercise behaviors. Moderate and vigorous exercise was positively influenced by intrinsic motivation ($p < .001$) whereas lifestyle physical activity was not significantly predicted by motivational regulations. Behavioral regulations were influenced by perceived autonomy and perceived competence and both needs were affected by contextual support from treatment climate ($p < .001$).

Conclusions: Results provide support for using the SDT framework to understand physical activity motivational processes in the context of weight management. Results also highlight structured and lifestyle physical activity as being promoted by different processes as a result of the intervention: more direct effects on lifestyle physical activity and indirect effects on structured exercise, mediated by intrinsic motivation.

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Given the high rates of sedentarism (Abu-Omar, Rutten, & Robine, 2004; Varo et al., 2003) and the well-established positive role of physical activity for successful long-term weight control (Donnelly et al., 2009), a thorough understanding of the determinants and mechanisms of physical activity adoption and maintenance is highly relevant in the context of obesity. Motivation is a critical variable in exercise adherence, and a clear understanding of motivational processes underlying the decision to be physically active and persist in this behavior should provide useful insights for

the promotion of long-term physical activity adoption. To meet this goal, theoretically-grounded longitudinal empirical studies are an important requisite. A growing body of research has provided evidence supporting self-determination theory (SDT) as a comprehensive motivational framework for understanding physical activity and other health behaviors (Deci & Ryan, 1985, 2008; Wilson, Mack, & Grattan, 2008). The present study expands on previous work by providing a multiple-level mediation test of causal mechanisms of behavior (exercise/physical activity) as put forth by SDT, in the context of obesity lifestyle treatment, following current research recommendations for identifying effective strategies for exercise sustained participation (USDHHS, 2008).

The conceptual basis of SDT is organized into several micro-theories. One of these, organismic integration theory (OIT) (Deci & Ryan, 1985) specifies that people can be motivated for different reasons, which can be conceptualized as lying along a continuum of

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relative autonomy or the extent to which the regulation of a behavior has been internalized into the person's sense of self. External regulation occurs when a person performs activities either to obtain rewards or to avoid punishment or sanctions administered by others. Introjected regulation concerns performance motivated by self-esteem-related contingencies (prideful when performing well, guilty when doing poorly) and is a partially internalized form of regulation. Identified regulation is a more autonomous form of motivation and occurs when the person experiences an activity as personally valuable or important to the self, such as exercising to maintain one's health. Integrated regulation emerges when the person engages in a behavior because it is consistent with their core values and beliefs. Intrinsic motivation, the fully autonomous form of motivation, is present when an activity is engaged in because of its inherent satisfactions such as for the fun, interest, or the challenge it offers. Research clearly shows that more autonomous regulatory motives (identified, integrated, and intrinsic) are conducive to greater long-term behavioral adherence in the domains of exercise (Edmunds, Ntoumanis, & Duda, 2006, 2007; Fortier, Sweet, O'Sullivan, & Williams, 2007; Ingledew & Markland, 2008; Ingledew, Markland, & Ferguson, 2009) and weight management (Powers, Koestner, & Gorin, 2008; Teixeira et al., 2006, 2009; Williams, Grow, Freedman, Ryan, & Deci, 1996).

A fundamental premise of SDT is that the internalization of more external behavioral regulations is fostered by the satisfaction of three basic psychological needs. Basic needs theory (BNT) (Ryan & Deci, 2000) specifies this notion, proposing that human beings have innate psychological needs for autonomy (fulfilled when people perceive that they are the origin of their choices and decisions, and that they are acting in accordance with their integrated sense of self and personal values), competence (concerning an individual's need to feel a sense of mastery through effective interaction within their environment), and relatedness (concerning having satisfying and supportive social relationships). OIT and BNT are closely linked. Indeed, to the extent that the social environment (e.g., intervention climate) provides support for the three needs, more self-determined forms of behavioral regulation will be promoted. Based on previous research (Deci & Ryan, 2000; Koestner & Losier, 2002) a recent study examined specific differential mediating effects of psychological need satisfaction in the relation between support for psychological needs and the internalization of behavioral regulation for exercise (Markland & Tobin, 2010). The results supported the central role afforded to autonomy in SDT, and indicated that autonomy was essential for the internalization of behavioral regulation. Koestner and Losier (2002) indicated that relatedness is less salient for intrinsic regulation because people can be intrinsically motivated when engaging in solitary activities (Deci & Ryan, 2000). Instead, competence and autonomy need satisfaction promote intrinsic motivation because this form of regulation involves being drawn to engage in activities that provide the individual with opportunities for experiencing enjoyment, optimal challenges, and the exercise of their skills. Thus, it is reasonable to assume that the need for supportive social interactions would be less salient to their intrinsic motivation.

Besides proposing that the effects of social-contextual factors on self-determined motivation are mediated by psychological need satisfaction (Guay, Boggiano, & Vallerand, 2001; Markland & Tobin, 2010), the theory further specifies three socio-contextual factors which are held to correspond to the development of a need supportive environment (Markland, Ryan, Tobin, & Rollnick, 2005; Reeve, 2002; Ryan & Deci, 2002). The first is autonomy support, which involves the minimization of controls, offering choice, encouraging individuals to initiate actions for their own reasons and in line with their personal goals and values without pressuring

compliance, and listening with empathy and acknowledging that behavioral change is demanding and challenging from the participants perspective. The second is structure, which involves helping individuals to develop clear expectations, explaining behavior-outcome contingencies, encouraging competence and giving positive feedback. The final factor is involvement, which concerns understanding other people's perspectives, providing unconditional, non-contingent and non-judgmental positive regard and demonstrating genuine concern for their well-being. Using an experimental design (by varying instructional style in group-based educational classes), a recent study showed that these SDT-based social-contextual characteristics, and psychological needs, predicted autonomous regulations and adaptive outcomes in terms of exercise adherence and affect (Edmunds, Ntoumanis, & Duda, 2008). Williams and colleagues have also found that greater perceptions of a more need supportive environment from one's health care provider facilitates the development of more autonomous regulations for smoking cessation (Williams, Gagne, Ryan, & Deci, 2002; Williams et al., 2006).

In exercise settings, a growing body of empirical findings has linked contextually promoted satisfaction of autonomy and competence with autonomous regulations (identified and intrinsic) and physical activity (Edmunds et al., 2007; Wilson & Rodgers, 2003; Wilson, Rodgers, Fraser, & Murray, 2004). However, it is presently unclear which type(s) of autonomous regulations is/are more closely associated with particular behavior outcomes and how this association may vary as a function of the targeted behavior (Burton, Lydon, D'Alessandro, & Koestner, 2006). Future studies on motivational predictors need to be more specific about the type of exercise behavior under examination, as different types of physical activity may be guided by different mechanisms, as demonstrated in a recent study, where introjected regulation, identified regulation, and intrinsic motivation were associated positively with strenuous and total exercise behaviors but failed to be significantly correlated with moderate and mild forms of exercise behavior (Edmunds et al., 2006).

Physical activity behavior is a broad construct that can be separated into several different components. A major distinction is that between formal/planned activities and informal/unplanned (lifestyle physical activity), in which individuals deliberately increase activity as a part of their daily routines (Donnelly et al., 2009). In the context of obesity treatment, physical activity, especially structured exercise, has been positively associated with successful long-term weight control in cross-sectional, retrospective and longitudinal studies (see USDHHS, 2008 for a review). In addition to the well-established benefits of moderate/vigorous structured exercise, some studies (Andersen et al., 1999; Dunn et al., 1999) suggest that lifestyle activity can also help participants improve health and fitness, and maintain their weight loss.

Whilst both structured and lifestyle physical activities may be important for weight management, they typically involve different intensities and may involve different potential for enjoyment and different levels of cognitive processing. Lifestyle and unstructured daily opportunities for being active (e.g., taking the stairs instead of elevators, parking away from destination, walking as a transportation) may represent habitual and automatically enacted behaviors. This notwithstanding, these behaviors can be experienced as self-determined by the individual, because self-determination does not mean controlled by the person, it means endorsed by the self (see Levesque, Copeland, Sutcliffe, 2008 for a review). A recent study (Legault, Green-Demers, & Eadie, 2009) tested the notion that self-determined motivation may be internalized to the point that regulation becomes automatic. According to this internalization–automatization hypothesis, it is theorized that entrenched, rehearsed, and personally-important self-determined goals will be made chronically accessible to the point of

automaticity. For example, the goal to be physically active can become habitually and automatically linked to the ways or means by which it is achieved on a daily basis. On the basis of their results, [Burton et al. \(2006\)](#) speculated that internalizing the importance of a goal, as in identified self-regulation, might lead individuals to build mental scripts for pursuing their goals that subsequently they are able to follow in relatively automatic fashion. This and other studies, although not addressing the issue of automaticity, have shown identified regulation as the strongest predictor for behaviors considered important but not inherently interesting (where the pursuit of the behavior itself fails to invoke uniformly high levels of intrinsic interest) (e.g., [Edmunds et al., 2006](#)). This may be the case for routine informal and unstructured daily opportunities for being active, where identified regulation may be a more salient predictor of task involvement than intrinsic motivation.

For structured physical activity (e.g., leisure-time brisk walks in nature, recreational sports, swimming or biking), typically of moderate or vigorous intensity, people may find the pursuit of the behavior itself sufficiently interesting to regulate participation for no separable consequence besides enjoyment, fun, novelty, challenge, or to re-discover new sensations and feelings ([Deci & Ryan, 2008](#)). Indeed, from the viewpoint of SDT, structured physical activity can be an inherently rewarding activity that satisfies psychological needs and contributes to both happiness and subjective vitality ([Deci & Ryan, 2000](#); [Ryan, Frederick, Lepes, Rubio, & Sheldon, 1997](#)). Thus, this type of physical activity could be regulated more by intrinsic motivation, which in turn is hypothesized to be predicted by the experienced satisfaction of the needs for both competence and autonomy.

Grounded in the previous theoretical and empirical propositions and fueled by the need to identify and test the processes or mechanisms by which theoretical predictors influence exercise behavior ([Hagger & Chatzisarantis, 2008](#)), we aimed to confirm the causal processes and mechanisms by which treatment promoted different form of physical activity, during a one-year obesity treatment intervention based on SDT ([Silva et al., 2008, 2010](#)). Indeed, research on treatment-induced mediators of behavior change may be of help in identifying potential causal mechanisms through which interventions operate and outcome-focused randomized controlled trials provide the ideal setting for such work ([Kraemer, Wilson, Fairburn, & Agras, 2002](#)). We hypothesized that the intervention would enhance physical activity participation through promoting a climate in which psychological needs would be satisfied which in turn would facilitate the internalization of regulations for exercise. It was also expected that different mechanisms would predict different types of physical activity. The following specific hypotheses were tested:

- 1) The intervention program will enhance the perceived need support experienced by intervention participants, leading in turn to the experience of autonomy and competence need satisfaction.
- 2) Perceived autonomy and competence will mediate the relationship between need support and behavioral regulations, and be positive predictors of autonomous regulations (intrinsic and identified) and negative predictors of controlled regulations (external and introjected).
- 3) More autonomous regulations (intrinsic and identified) will positively predict exercise participation, whereas more controlled regulations (external and introjected) will not affect or will be detrimental to exercise participation, as they may predict only short-term participation ([Pelletier, Fortier, Vallerand, & Briere, 2001](#)).
- 4) The influence of the intervention program on different types of physical activity through need support and need satisfaction

will be mediated by different regulatory processes; intrinsic motivation will primarily mediate the relationship with structured moderate/vigorous physical activity, while identified regulation will be the key mediator for lifestyle physical activity.

Method

Study design and intervention

The study was part of a randomized controlled trial in a Portuguese sample of overweight and obese women including a 1-year behavior change intervention focused on increasing exercise self-motivation and exercise adherence, aiming at long-term weight control ([Silva et al., 2008](#)).¹ The Ethics Committee of the Faculty of Human Kinetics – Technical University of Lisbon reviewed and approved the study.

Entering in three successive annual cohorts, participants were randomly assigned to intervention and control groups. Group treatment during the first year was delivered following a detailed session-by-session protocol describing the topics to be covered and the manner in which they were to be addressed. Protocol implementation and participant care were facilitated by holding regular meetings to discuss these issues and manipulation checks were conducted by a senior interventionist during randomly assigned sessions to assess fidelity in delivering the protocol (both in person and with taped sessions). Throughout the same year, experimental groups received an approximately equivalent amount of face-to-face contact with treatment providers, but sessions (29 in the control group, 30 in the intervention group, lasting about 120 min each.) differed in terms of contents and interpersonal climate. The control group received a general health education curriculum based on educational courses, covering various topics not directly related to weight control (e.g., 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; goals were not set; minimal feedback was provided ([Sheldon, Williams, & Joiner, 2003](#)). Primary targets of the intervention included increasing physical activity and energy expenditure, adopting a diet consistent with a moderate energy deficit, and ultimately establishing exercise and eating patterns that would support sustained weight loss.

Intervention principles and style of intervention were based on SDT, with a special focus on increasing competence and intrinsic motivation towards exercise and weight control. In order to assure competences regarding the promotion of an autonomous treatment climate, all intervention staff received specific training in the form of workshops and formal and informal training meetings, conducted by in-house as well as external experts in the fields of SDT and Motivational Interviewing. The staff work involved helping participants to develop clear expectations, encouraging them to

¹ This paper is part of a larger study and set within the context of other publications using the same database. Due to the extent, nature, and complexity of the analyses involved, reporting all results from this trial in a single manuscript would be inadequate, severely limiting the amount and depth of what could be reported. Thus, a previous published paper described the intervention in great detail and reported the impact of the intervention on the study's main outcomes (weight, physical activity, and theory-based psychological variables), comparing intermediate (4-month) and final (12-month) results for intervention vs. control groups. Differently, the present paper specifically reports on findings from multiple-level mediation analyses for two different types of physical activity, evaluating by what causal mechanisms behavior might have been affected, in an explicit attempt to test causal pathways proposed by the theory under scrutiny.

believe that they were capable of successfully engaging in weight control activities, encouraging choice, self-initiation and independent problem-solving, providing informational feedback that guided the individual towards a meaningful rationale for change, and making perspective-acknowledging statements. A large range of options was also provided, supporting autonomous decisions during the program, helping individuals to recognize that they could exercise choice and self-direction regarding their behavior, and encouraging participants to explore their own motivations for treatment and define their personal treatment goals, while limiting external contingencies and controls (Edmunds et al., 2008; Markland et al., 2005; Reeve, 2002). Along with more theoretical sessions to build sustainable knowledge that supported informed choices, and training in issues related to safety and skills (e.g., self-monitoring), there was also a dance curriculum to explore fun and awareness of the body in mindful movement. Also, some workshops focused on the development of strategies and skills that would allow participants to intentionally increase their daily energy expenditure. These focused for instance on developing problem-solving skills and allowing a new and more proactive look at daily opportunities to be active (both in formal and informal physical activities), as well as overcoming barriers such as lack of time and opportunities. Accordingly, participants were encouraged to accumulate short bouts of physical activity in their daily routines, such as increasing the amount of walking and using stairs whenever possible, this way accumulating daily physical activity minutes in a way uniquely adapted to each person's lifestyle. A full description of the study's theoretical rationale, protocol, and intervention strategies can be found elsewhere (Silva et al., 2008, 2010).

Participants

Participants were recruited from the community at large through media advertisements. By design, only pre-menopausal women ($n = 258$) were accepted into the study. Of these, 19 women were subsequently excluded from all analyses because they started taking medication likely to affect weight ($n = 10$), had a serious chronic disease diagnosis or severe illness/injury ($n = 4$), became pregnant ($n = 2$) or entered menopause ($n = 3$). There were no significant differences between these 19 women and the 239 participants considered as the valid initial sample by age ($t = .561, p = .575$), education ($t = 4.510, p = 1.01$), marital status ($t = .593, p = .743$), or BMI ($t = -.811, p = .418$). The remaining participants were between 23 and 50 years old (38 ± 6.8 years) and were overweight or mildly obese, with an initial mean BMI of 31.3 ± 4.1 kg/m². Women in the intervention group ($n = 123$) did not differ from those in the control group ($n = 116$) in terms of BMI ($t = -.895, p = .372$), age ($t = -1.254, p = .211$), education ($t = .503, p = .615$), or marital status ($t = -1.451, p = .148$). There were also no differences between the 208 women who completed the 12-month intervention and the 31 who quit the program for any demographic or baseline psychosocial variable, with the exception of age; women who stayed in the program were on average four years older ($t = 3.036, p = .01$). Retention rates were 93% (intervention) and 79% (control).

Measurements

All assessment sessions occurred in the Faculty of Human Kinetics Health and Exercise Laboratory, and were conducted in standardized conditions of comfort and silence, supervised/conducted by trained technicians (Silva et al., 2008). For the present study only the 1-year assessment period was considered, thus all the data reported are cross-sectional (see the Statistical analyses section for a more in-depth explanation).

Need support from the intervention staff

Participants' *perceived need support*, which concerns the quality of the social environment, was assessed by the Health Care Climate Questionnaire (HCCQ) (Williams et al., 1996). Although HCCQ has traditionally been considered to measure autonomy support, it also addresses support for competence, with items related to the provision of structure (e.g., "practitioners made it clear what I need to do to") and relatedness support, with items measuring involvement (e.g., "practitioners handle peoples' emotions very well"). Responses to the 15 items were rated on a 7-point Likert-type scale ranging from 1 = *strongly disagree* to 7 = *strongly agree*. Although items in the HCCQ tap into different underlying dimensions of support, they are highly inter-related; thus, a total score was calculated. As in previous studies (Markland & Tobin, 2010; Niemiec et al., 2006), the term 'need support' will be used in the current paper to refer to the supportive intervention environment.

Need satisfaction

Perceived autonomy was assessed by the Locus of Causality for Exercise Scale (LCE) (Markland & Hardy, 1997). This 3-item scale indicates the extent to which respondents feel that they choose to exercise rather than feeling that they have to exercise (e.g., "I exercise because I like to rather than because I feel I have to"). The perceived locus of causality construct addresses the source of behavior initiation; an internal locus of causality is evident when an individual engages in a behavior freely and with no sense of coercion. Responses to the LCE are scored on a Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree), with high scores indicating greater self-determination or a more internal perceived locus of causality.

Perceived competence was assessed with the four items from the perceived competence subscale of the Intrinsic Motivation Inventory (McAuley, Duncan, & Tammem, 1989) referring to exercise in general (e.g., "I think I do pretty well at physical activities, compared to others"). Responses were scored on a five-point scale ranging from 0 to 5, with high scores indicating higher perceived competence for physical activity.

Behavioral regulations of exercise

The types of regulation for exercising (source level motives for exercise) were measured with the Exercise Self-Regulation Questionnaire (SRQ-E) (Ryan & Connell, 1989). The SRQ-E assesses four different types of behavioral regulations, 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 indicate, for each of the 16 items (4 for each subscale), how they feel on 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). Examples of items included in different regulations subscales are (in order from the least to the most fully internalized): 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") and Intrinsic motivation: (e.g., "Because it is a challenge to accomplish my goal", "Because it is fun"). In common with other measures of the exercise behavioral regulation continuum (e.g., the Behavioral Regulation in Exercise Questionnaire-2) (Markland & Tobin, 2004), the SRQ-E does not include an integrated regulation subscale, apparently because it

was difficult to empirically distinguish between integration and identified regulation on the one hand and intrinsic regulation on the other hand.

Physical activity

Structured/formal physical activity was expressed by the total minutes of moderate or vigorous intensity physical activity (METs > 3.0) in a week, assessed by the Seven-Day Physical Activity Recall (7-Day PAR) (Blair et al., 1985; Hayden-Wade, Coleman, Sallis, & Armstrong, 2003). Trained interviewers asked the participants to recall time spent doing physical activity for the past 7 days (or a typical week of last month, if last week was atypical). Previous studies have supported the reliability and validity of the 7-Day PAR as a measure of physical activity in adults (Washburn, Jacobsen, Sonko, Hill, & Donnelly, 2003).

Routine daily lifestyle physical activity was assessed by a *Lifestyle Physical Activity Index*, from a questionnaire specifically developed for this study, measuring habitual lifestyle physical activities typical of the last month. This is a variable typically not available in existing physical activity questionnaires. To calculate the Lifestyle Physical Activity Index we used a score based on 7 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 sitting"; "Choosing manual/physical work instead of mechanical/automatic"; "Choosing to be physically active whenever possible"). The response options ranged from *never* (1) to *always* (5) on a Likert scale.

Statistical analyses

Model testing was conducted using partial least squares (PLS) analysis with the SmartPLS Version 2.0 (M3) software (Ringle, Wende, & Will, 2006). PLS was developed (Wold, 1985) as a general method for the estimation of path models involving latent constructs indirectly measured by multiple indicators. Chin (1998) described PLS as comprising two models: (1) a measurement model, also called the outer model, specifying the relationships between latent variables (LVs) and their associated observed or manifest variables (MVs); (2) a structural model, also called the inner model, relating some LVs to other LVs. 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).

While covariance-based modeling (e.g., LISREL) 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 (Chin, 1998) due to the partial nature of the estimation procedure, with only one part of the model being estimated at each time. The model in the present study comprised 8 latent variables with 44 observed indicators. Given the sample size available (146 following deletion of missing data, see below), the covariance-based modeling approach would have been impractical. In PLS analysis, with models comprising only reflective latent variables, the recommended minimum sample size is ten times the number of structural paths leading to the endogenous latent variable with the largest number of such paths (Chin & Newsted, 1999). For the present model, this amounted to four paths, and a minimum sample size of 40, which was far exceeded with the current data. Following the recommendations of Hulland (1999), the PLS model was analyzed in two stages, testing first the adequacy of the measurement model and then assessing the structural model.

Testing of the measurement model included first the estimation of individual item reliability. For reliability of an indicator, the standardized loading of the indicator on its intended latent variable should be statistically significant and higher than .40 (Hulland, 1999). Next, the internal consistency of the latent variables was assessed by examining their composite reliabilities (CRs). According to Fornell and Larcker (1981) a CR of .70 or higher represents acceptable internal consistency. 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. Next, convergent and discriminant validity of the scales was assessed by examining the average variance extracted (AVE) for the scales (Fornell & Larcker, 1981). The 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 .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. Thus, discriminant validity is satisfied when a latent variable's AVE is greater than the squared bivariate correlations between it and the other latent variables in the model.

The testing of the structural model included first the estimation and testing of the significance of the structural path coefficients and the indirect effects of the latent variables through intervening variables. SmartPLS implements a bootstrapping procedure to estimate means and standard errors 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) (MacKinnon, Lockwood, & Williams, 2004). In the present analyses, 5000 bootstrap samples with replacement were requested. Next, the relative amount of 'explained' or 'reproduced' variance of LVs (R^2) was examined. Because SmartPLS does not generate significance tests for the R^2 values for latent variables, effect sizes of the R^2 values (Cohen's f^2) were calculated to show whether the amount of variance explained is negligible, small (<.15), medium (<.35) or large (>.35) (Cohen, 1988).

Tests of mediation were conducted by examining the significance of the indirect paths that emerged from the independent to the dependent variables, using the bootstrapping procedures incorporated in SmartPLS. When examining mediating effects, past work has shown the bootstrapping approach to be superior to the alternative methods of testing indirect effects, such as the Sobel test, with respect to power and Type I and II error rates (MacKinnon et al., 2004). The significance of the indirect effects was analyzed both in the absence of the intervening variable(s) (total effects, denoted C paths) and in their presence (direct effects, denoted C' paths). Baron and Kenny's (1986) formal steps for testing mediation were followed: (a) the independent variable must have an effect on the dependent variable; (b) the independent variable must have an effect on the intervening variable(s); and (c) intervening variable(s) must affect the outcome, after controlling for the independent variable. To establish full mediation, the total effect of the independent variable on the outcome (C path) must become non-significant in the presence of the intervening variable(s) (C' path), while the indirect effect is significant. Partial mediation is established when the C' path remains significant but is substantially reduced and the indirect effect is significant. Finally, effect ratios were calculated to express the amount of the total effect that is explained by the indirect effects via the mediator(s). This is a preferable (quantitative) way to describe mediated effects, overcoming the full/partial mediation dichotomous distinction, provided that no suppression effects are present in the model (Shrout & Bolger,

2002). One reason to include a control group resides in the fact that mediation analyses (to identify the most relevant processes of change associated with the primary outcomes) require a standard control group when conducted in the context of a randomized controlled trial (Kraemer et al., 2002). Analyses are potentially facilitated by maximizing effect sizes between intervention and controls.

Absolute scores (assessed at 12 months) were used for all analyses. This choice was based on the fact that not all psychosocial variables were assessed at baseline. Most participants did not engage in regular exercise at the beginning of the intervention, which would therefore have yielded less valid exercise psychosocial measures (e.g., Self-regulation “I exercise because I”; locus of causality for exercise “I try to exercise on a regular basis because...”). Also, perceived need support from health care climate could only be assessed after the start of the intervention. For consistency, we decided to also use physical activity measures at 12 months, instead of change in physical activity. Nevertheless, we compared baseline scores between intervention and controls for general self-determination variables (e.g., SDS) and for exercise minutes, and no differences were found ($p > .05$).

Results

The central focus of this study was to test a theoretically-based process model by which the intervention produced its effects on different types of physical activity. The *main effects* of the intervention trial on putative mediators and outcomes are reported in detail elsewhere (Silva et al., 2010). Briefly, group differences in key intervention targets were medium to large favoring the intervention group (all $ps < .001$), including perceived need supportive environment, need satisfaction, autonomous self-regulation and exercise. In the current study the effective sample size at 12 months following listwise deletion of missing data was 146. *t*-tests comparing the valid dataset group vs. the missing dataset group were performed and no significant differences were found between the two groups. This suggests analyses should yield unbiased parameter estimates (Schafer & Graham, 2002). The mean age of the effective sample was 36.6 (SD 7.0 years) and the mean body mass index was 30.2 (SD 4.3 kg/m²).

Measurement model

Initial measurement model analysis showed that one observed Introjected Self-Regulation indicator had a negative and very low factor loading (−.031) and that the AVE with this indicator included was below the acceptable level (.35). Thus, this item was eliminated and the model re-estimated. PLS and bootstrapped estimates for all

factor loadings were greater than .40 (only seven loadings were less than .70) and significantly greater than zero in all cases. Need Support had loadings between .59 and .89 ($p < .001$), Perceived Autonomy had loadings between .72 and .90 ($p < .001$), Perceived Competence had loadings between .69 and .84 ($p < .001$), External Self-Regulation had loadings between .59 and .81 ($p < .001$), Introjected Self-Regulation had loadings between .50 and .97 ($p < .01$), Identified Self-Regulation had loadings between .77 and .90 ($p < .001$), Intrinsic Motivation had loadings between .81 and .90 ($p < .001$) and the Lifestyle Physical Activity Index had loadings between .57 and .81 ($p < .001$).

Table 1 shows the CRs, AVEs, and correlations among the variables in the model. CRs were all greater than .70 and AVEs were greater than .50, indicating acceptable convergent validity for the items. AVEs for each latent variable were greater than the squared bivariate correlations with all the other latent variables, indicating acceptable discriminant validity of the scales. Correlation coefficients matched expected patterns of association grounded in SDT and supported a simplex-like pattern among the behavioral regulations (Ryan & Connell, 1989). Treatment and Perceived Need Support by the health care climate were correlated with key self-regulatory variables and Perceived Autonomy and Perceived Competence were positively associated with more autonomous self-regulations and negatively with external ones. All the LVs (with exception of external regulation) were correlated with physical activity variables. Taken together, these analyses suggest acceptability of the measurement model.

Structural model

Fig. 1 shows the PLS and bootstrapped parameter estimates for the structural paths, and the variance accounted for in the dependent variables (R^2). Group randomization (intervention vs. control conditions) positively predicted need support, which in turn positively predicted satisfaction of the basic needs for autonomy and competence. Autonomy negatively predicted external regulation and both autonomy and competence positively predicted introjected, identified and intrinsic motivations. Only one path between behavioral regulations and physical activity behaviors emerged as significant, with intrinsic motivation positively predicting structured moderate-vigorous physical activity. The model explained between 6% and 62% of the variance in the variables. The variances explained in perceived autonomy ($f^2 = .06$), perceived competence ($f^2 = .10$), and external regulation ($f^2 = .11$) were small. Moderate amounts of variance were explained for perceived need support ($f^2 = .20$), introjected regulation ($f^2 = .31$), identified regulation ($f^2 = .34$), and physical activity variables: moderate and vigorous ($f^2 = .21$) and lifestyle physical activity ($f^2 = .19$). For the remaining variable,

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

Factor	CR	AVE	Correlations												
			1	2	3	4	5	6	7	8	9	10			
1. Treatment	–	–	–												
2. Need support	.98	.65	.41***	–											
3. Perceived autonomy	.87	.68	.24**	.24**	–										
4. Perceived competence	.85	.59	.25**	.30***	.55***	–									
5. External self-regulation	.82	.54	−.08	−.15	−.30***	−.23**	–								
6. Introjected self-regulation	.74	.51	.35***	.33***	.42***	.46***	.02	–							
7. Identified self-regulation	.91	.72	.45***	.42***	.48***	.39***	−.10	.44***	–						
8. Intrinsic self-regulation	.92	.73	.43***	.48***	.73***	.65***	−.16*	.50***	.76***	–					
9. Moderate & vigorous exercise	–	–	.35***	.26***	.35***	.33***	−.15	.22**	.35***	.40***	–				
10. Lifestyle physical activity	.88	.51	.41***	.36***	.29***	.18*	.06	.29***	.35***	.34***	.37***	–			

Note: $N = 146$.

* $p < .05$, ** $p < .01$, *** $p < .001$.

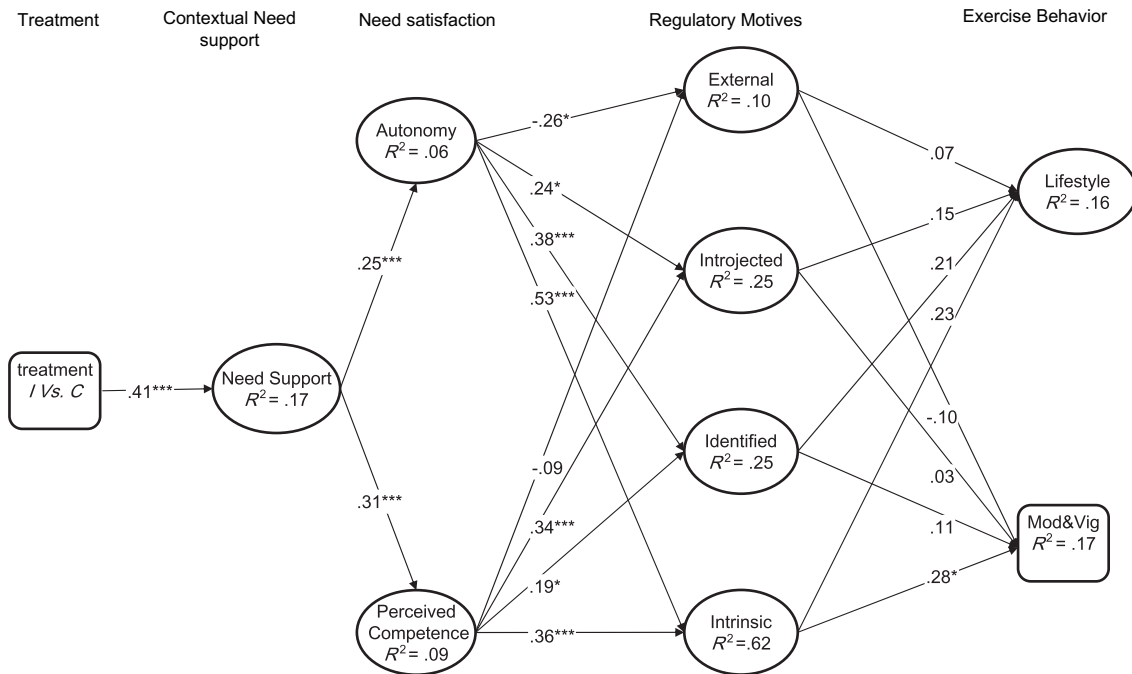


Fig. 1. Partial least squares model. Values in the paths represent the standardized bootstrap estimate, **p* < .05, ***p* < .01, ****p* < .001.

intrinsic motivation, a large amount of variance was explained ($f^2 = 1.62$).

Table 2 shows the indirect effects where there were intervening variables. For all the possible combinations of intervening variables, significant indirect effects were found. Results of the mediation analyses to explore the role of these SDT variables as mediators of the effects of intervention on moderate and vigorous and lifestyle physical activity, are expressed in Table 3.

The effects of treatment on perceived autonomy and on perceived competence were totally mediated by perceived need supportive environment (effect ratios of .42 and .47, respectively). Furthermore, for moderate and vigorous physical activity, the effect of this supportive health care climate was totally mediated by both

need satisfaction and intrinsic motivation, with 61% of the total effect being explained by these particular indirect paths. More specifically, the effects of perceived autonomy and perceived competence on this type of physical activity outcomes were also totally mediated by intrinsic motivation (effect ratios of .64 and .43 respectively). Furthermore, treatment had significant indirect effects on moderate and vigorous physical activity through a partial mediation by perceived need supportive environment, need satisfaction, and intrinsic motivation (effect ratio .17). For lifestyle physical activity, despite the treatment effect being mediated by autonomy and competence (effect ratios of .63 and .64 respectively), treatment also displayed a significant direct role on this outcome.

Table 2
Indirect effects in the structural model.

Relationship	Bootstrap estimate	
From	To	
Treatment	Perceived autonomy	.11**
Treatment	Perceived competence	.13***
Treatment	External regulation	-.04*
Treatment	Introjected regulation	.07**
Treatment	Identified regulation	.07**
Treatment	Intrinsic motivation	.10***
Treatment	Moderate & vigorous exercise	.04**
Treatment	Lifestyle physical activity	.04*
Need support	External regulation	-.10*
Need support	Introjected regulation	.17***
Need support	Identified regulation	.16**
Need support	Intrinsic motivation	.25***
Need support	Moderate & vigorous exercise	.10***
Need support	Lifestyle physical activity	.11*
Perceived autonomy	Moderate & vigorous exercise	.23***
Perceived autonomy	Lifestyle physical activity	.22**
Perceived competence	Moderate & vigorous exercise	.14***
Perceived competence	Lifestyle physical activity	.16**

Note: *N* = 146; Estimates represent 5000 bootstrapping testing. **p* < .05, ***p* < .01, ****p* < .001.

Table 3
Tests of mediation in the structural model.

Relationship	Total effect (C path)	Direct effect (C' path)	Effect ratio	
From	To	Estimate	Estimate	
Treatment	Perceived autonomy	.25***	.18	.42
Treatment	Perceived competence	.27***	.17	.47
Treatment	Intrinsic motivation	.34***	.27***	.30
Treatment	Moderate & vigorous exercise	.24***	.22***	.17
Treatment	Lifestyle physical activity	.36***	.34***	.11
Need support	Intrinsic motivation	.49***	.33***	.50
Need support	Moderate & vigorous exercise	.17***	.10	.61
Need support	Lifestyle physical activity	.31***	.24**	.35
Perceived autonomy	Moderate & vigorous exercise	.35***	.13	.64
Perceived autonomy	Lifestyle physical activity	.35***	.11	.63
Perceived competence	Moderate & vigorous exercise	.33***	.13	.43
Perceived competence	Lifestyle physical activity	.25*	.07	.64

Note: *N* = 146; Estimates represent 5000 bootstrapping testing. **p* < .05, ***p* < .01, ****p* < .001.

Discussion

According to Shroul and Bolger (2002), mediation models of psychological processes allow interesting associations to be decomposed into components that reveal possible causal mechanisms. While a large body of research has established the efficacy and effectiveness of a range of psychological variables in treatments, it would be of great value to understand how they work, as research could then focus on enhancing the effective elements and discarding those found to be redundant (Murphy, Cooper, Hollon, & Fairburn, 2009). Randomized controlled trials provide an often-missed opportunity to investigate the mediators of treatment effects, and guidelines have been proposed for accomplishing this (Kraemer et al., 2002). Although a growing body of literature supports the utility of SDT as a useful framework to understand exercise promotion, no study has tested it in the context of a randomized controlled trial for exercise and weight control. The present work aimed at providing greater understanding of the role of motivational regulations influencing different physical activity behaviors, searching for specific, differential mechanisms by which the intervention produced its effects.

The model testing supported the acceptability of both the measurement and the structural models, and accounted for a substantial portion of the variance in intrinsic ($R^2 = .62$), identified and introjected regulations ($R^2 = .25$). The results were supportive of the proposed pattern of causal sequences and generally consistent with the specific hypotheses encapsulated by the model. Thus, aligned with the theoretical tenets of the SDT, the results revealed that the treatment condition increased participants' perceptions of a need supportive environment. In turn, this had positive effects on the satisfaction of the needs for autonomy and competence (supporting the first hypothesis), leading to more autonomous forms of exercise motivational regulations (as encapsulated in the second hypothesis). Autonomy need satisfaction emerged as a negative predictor of external regulation, but positively predicted the more self-determined motivations (identified and intrinsic). Competence also positively predicted autonomous motivations but had no effect on external regulation.

Contrary to our hypothesis regarding controlled regulations, need satisfaction had a positive effect on introjected regulation. A similar positive effect was also observed in a previous study where athletes' perceptions of coaches' autonomy support were positively associated with intrinsic motivation and identified regulation, as well as, albeit to a lesser extent, with introjected regulation (Pelletier et al., 2001). In the present study, the significant association between introjected and identified and intrinsic motivations (in the absence of a relation with external regulation) suggests that, in this sample, introjected regulation is closer to the autonomous regulations than to external regulation. Culture-specific aspects may help explain this finding. Introjected regulation is a partially internalized form of controlled regulation where a person is motivated by internally imposed controls and contingencies related to self-esteem. In a cultural background where external approval is learned to be contingent on compliance and conformity (e.g., to God or expert opinion), introjection could be a common form of motivational regulation. It might have been the case that, even when presented with a self-determination focused intervention climate, ego involvement of the participants became on average more pronounced. However, to fully understand the impact of autonomy and competence need satisfaction on introjection, research should examine the distinct regulatory styles at different levels of personality and take into account not only domain-specific factors but also situational (e.g., cultural) and dispositional influences. For example, Ingledew and Markland (2008) found that behavioral regulations were directly influenced by personality.

In their study, conscientiousness had direct effects on external and introjected regulation. It could also be that differences in relatedness need satisfaction (not measured in the present study), particularly in relationship with need support and perceived autonomy, might have influenced the development of introjected regulation (Markland & Tobin, 2010). This notwithstanding, the observed positive association between need satisfaction and introjection should not be interpreted as advocacy for instilling feelings of guilt or contingent self-worth in individuals. Indeed, there is evidence demonstrating that introjected regulation typically results in behavior that is less stable, less persistent, and less coordinated with other aspects of the self than autonomous regulations (Pelletier et al., 2001). Accordingly, in the present study, introjected regulation failed to predict physical activity level at treatment end.

Despite the unexpected pattern for introjection, results suggest that in overweight/obese individuals, feelings of choice and volition about what types of activity are engaged in, as well as perceptions of competence that they can effectively perform the chosen activities, are important to the development of self-determined motivation towards exercise. Specific mediation tests also supported SDT assertions that the effects of social-contextual factors on self-determined motivation are mediated by psychological need satisfaction (Guay et al., 2001). The mediation results were also consistent with the model depicted in Fig. 1, stressing that the experimental supportive context explained the adoption of moderate and vigorous physical activity by its effect on the satisfaction of autonomy and competence needs on intrinsic motivation. Indirect effects explained substantial proportions of total effects, consistent with the form of the model. These findings add credence to the theoretical proposition that the concepts of psychological needs and self-determined motivations are important because they can help researchers and practitioners identify the motivational constructs that are necessary for understanding the process of behavioral change (Hagger, Chatzisarantis, & Biddle, 2002; Wilson et al., 2008).

Regarding our third and fourth hypotheses, results generally supported the expected pattern – a positive influence of intrinsic motivation on structured physical activity and a neutral or negative influence of external and introjected regulation on physical activity. Identified regulation was not a significant predictor of physical activity in the presence of the other regulations (despite a strong bivariate correlation with moderate and vigorous PA). Considering the high shared variance between the two autonomous forms of motivation in this sample, we interpret this finding simply as suggesting that intrinsic motivation is the stronger predictor or the two regulations. However, we cannot fully assert that identified regulations were not within the causal path of moderate and vigorous physical activity in this trial (note: when intrinsic motivation was not included the model, identified regulation was the strongest mediator and highly significant; results not shown).

As it was mentioned in the introduction, differently from structured moderate and vigorous physical activity (which is more likely to need deliberate self-regulation), lifestyle physical activity, at least as it was assessed in the present study, is concerned with more habitual and automatically enacted behaviors. Thus, the processes by which the intervention promoted these two types of physical activity were different and more direct in the second case (lifestyle activity) – a behavior which is not as intrinsically motivating and that requires little competence. The absence of mediation effects of autonomous or controlled regulations for lifestyle physical activity in this study is consistent with Edmunds' et al., (2006) research where exercise behavioral regulation was found to be predictive of vigorous and purposeful engagement in exercise but not for lower intensity incidental behaviors, suggesting that

such habitual activities may require less cognitive processing than more structured and vigorous forms of exercise. Indeed, other social cognitive models have also been found to be poorly predictive of habitual or low intensity behaviors such as walking (Sallis & Hovell, 1990).

According to the internalization–automatization hypothesis, self-determined motivation may be internalized to the point that regulation becomes automatic. That is, over time, an explicit, conscious motive can come to operate in an implicit, efficient, and effortless fashion (Legault et al., 2009). Associative environmental cues can unconsciously activate goal pursuit and go on to influence intentions and behavior. In fact, recent research indicated that some types of motivation can be activated merely by associated cues (Ratelle, Baldwin, & Vallerand, 2005). Consequently, one can imagine that the participant's identified motivation may become activated simply by the sight of a stair (opposed to the elevator), and this may occur even when she is tired, distracted, or facing other demands on conscious attention, since little effort is required for such activation. When being physically active is habitual or automatic, people are likely to say that, for them, daily physical activity is part of their life and integrated with their values and life.

Given these internalization–automatization studies, and the suggestion that lifestyle physical activity represents a more habitual, automatic behavior, the present study's results may not preclude the hypothesis that identified regulation plays an important role in this behavior and that the intervention may have worked in the promotion of lifestyle physical activity through the internalization–automatization of identified regulation. In fact, this mechanism may still hold true but was not captured by the explicit nature of our measures (the Burton et al. (2006) study was performed with implicit measures). The intervention curriculum (see Silva et al., 2008) was designed to foster the internalization of regulations for exercise, and, although in the case of moderate and vigorous physical activity the intrinsic appeal was stressed, lifestyle physical activity promotion was based on fostering identification, by exploring issues related to the importance of the target activities for the individuals' systems of values.

Limitations

The absence of implicit measures represents a limitation of the present study. Self-determination researchers traditionally measure motivation regulation on an explicit level. If internalizing the importance of a goal leads individuals to construct mental scripts for how to pursue them, the development of implicit measures of self-regulation may add further explanatory power to research based on SDT focusing on sustained adoption of physical activity. Other limitation pertains to the questionnaires used to assess SDT main constructs. This study was part of a larger trial and the definition of the assessments and their protocol of application were already established and could not be changed by the time of these analyses. This led to three assessments-related shortcomings that should be acknowledged. First, relatedness need satisfaction was not addressed in the model because it was not originally included in the assessments battery. When this trial started there was a relative lack of systematic instrument development to assess Basic Needs Theory's constructs specific to exercise setting; consequently, we focused primarily on autonomy and competence (derived from other scales, as described in the *Methods* section). A second limitation is the absence of a measure of integrated regulation, due to the fact that the SRQ-E does not include such a subscale. One last consideration concerns the lack of baseline assessments for exercise and treatment-related outcomes, an option which is justified in the *Methods* section.

It is also important to acknowledge that the steps taken to ensure that interventionists uniformly delivered treatment following SDT principles were not sufficient to consider that fidelity was assessed in a systematic way. Lastly, it should be considered that all participants who entered the study were seeking to lose weight. In that sense, they were all already motivated (to lose weight, not necessarily to perform exercise or to alter dietary patterns) and may not adequately represent the entire population who desires weight loss. Amotivated individuals should also be investigated, possibly with a separate research design aimed at raising intention to begin addressing body weight problems.

Summary and future directions

Notwithstanding these limitations, a distinctive contribution of the present study was the incorporation of lifestyle physical activity and moderate plus vigorous physical activity as separate outcomes to be predicted in the context of obesity treatment, while testing a mediational model aimed at outlining theory-based mechanisms. Convergent with previous research, but extending it into the context of a randomized controlled trial, our model indicates that both psychological needs (for autonomy and competence) and intrinsic motivation mediate the effects of the experimental treatment climate on exercise behavior, at least on its structured form. Results indicate that providing support for autonomy, structure, and involvement will encourage individuals to develop more autonomous regulations, setting the ground to the discovery of personal meaning and enjoyment of exercise. By enhancing our understanding of the mechanisms by which an intervention works in promoting targeted outcomes, and allowing experimental testing of key relationships in a controlled fashion prior to their application in real settings, results from this and other randomized controlled trials can provide ways to develop and implement intervention programs that enhance autonomous motivation and significantly contribute to the development of more cost-effective interventions. A next step in validating the effectiveness of SDT-based interventions will be to explore these associations in the long-term (i.e., over several years), searching for a more in-depth understanding of the dynamics of motivation while providing further information regarding their interrelationships with more enduring dependent variables (e.g., long-term adherence, well-being). Future research should also consider the inclusion of measures of integrated regulation as a predictor of lifestyle physical activity, particularly given the suggestion in the present results that physical activity which proceeds automatically is likely to be described by individuals as part of their lives and as having been well-integrated with their values. Indeed, integration is the process through which individuals fully transform their identified values and behaviors into the self. The process of bringing new ways of thinking, feeling, and behaving in congruence with the self's pre-existing ways could involve some degree of self-examination. For example, exercisers who incorporate the role of being physically active into their identity would act reflectively in accordance with this role and engage in exercise-related activities to reinforce this aspect of their self-concept. Furthermore, to more accurately examine the possibility of automatic processes in self-regulation, the development of implicit measures of motivation is warranted.

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