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ARTICLE

Motivational and self-efficacy reciprocal effects during a 12-month' weight regain prevention program

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Abstract

Objective: Weight regain prevention is a critical public health challenge. Digital behaviour change interventions provide a scalable platform for applying and testing behaviour change theories in this challenging context. This study's goal was to analyse reciprocal effects between psychosocial variables (i.e., needs satisfaction, eating regulation, self-efficacy) and weight over 12 months using data from a large sample of participants engaged in a weight regain prevention trial.

Methods: The NoHoW study is a three-centre, large-scale weight regain prevention trial. Adults who lost >5% of their weight in the past year ($N = 1627$, 68.7% female, 44.10 ± 11.86 years, 84.47 ± 17.03 kg) participated in a 12-month' digital behaviour change-based intervention. Weight and validated measures of basic psychological needs satisfaction, eating regulation and self-efficacy were collected at baseline, six- and 12 months. Correlational, latent growth models and cross-lagged analysis were used to identify potential reciprocal effects.

Results: Baseline higher scores of needs satisfaction and self-efficacy were associated with six- and 12-month' weight loss. Baseline weight was linked to all psychosocial variables at six months, and six-months weight was associated with needs satisfaction and self-efficacy at 12 months. During the

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12 months, increases in eating regulation, needs satisfaction and self-efficacy were associated with weight loss over the same period, and reciprocal effects were observed between the variables, suggesting the existence of Weight Management Cycles.

Conclusions: While further studies are needed, during long-term weight regain prevention, weight decrease, needs satisfaction and self-efficacy may lead to Weight Management Cycles, which, if recurrent, may provide sustained prevention of weight regain.

KEYWORDS
adult, motivation, self-efficacy, weight loss

Statement of Contribution

What is already known on this subject?

- Most people who lose weight regain it.
- Motivation and self-efficacy affect long-term weight regain prevention.
- Different psychosocial processes govern behaviour change initiation and maintenance.

What does this study add?

- Motivation, self-efficacy and weight change are entangled in long-term weight regain prevention efforts.
- Weight management cycles, resulting from positive reciprocal effects among these variables, can explain long-term weight change.

INTRODUCTION

Overweight and obesity increasingly account for the risk of severe health problems (Heymsfield & Wadden, 2017), including an increased risk of COVID-19 (Williamson et al., 2020) and can lead to discrimination and stigma (Spahlholz et al., 2016). Therefore, preventing weight loss regain represents one of today's critical health and societal issues.

Given this scenario, not surprisingly, 40% of adult Europeans engage in weight loss attempts every year (Santos et al., 2017), with some success in the short- but not in the long-term, when the health benefits of weight loss become more salient (Wing & Hill, 2001). Behaviour change interventions are known to be effective at changing the immediate behaviour potential via a specific set of psychosocial mechanisms of action (Teixeira et al., 2015). These interventions use, for example, socio-cognitive or self-regulatory constructs to affect proximal weight outcomes. But when the same constructs are used to explain sustained behaviour change, the evidence becomes very limited (Dombrowski et al., 2014), prompting Kwasnicka and colleagues to recommend further studies supporting the development of behaviour maintenance theories (Kwasnicka et al., 2016). The present research study follows this recommendation, by focusing on psychosocial mechanisms of action, more specifically, on why and how socio-cognitive and motivational processes are associated with changes in weight during a 12-months period (Teixeira et al., 2012, 2015).

According to Kwasnicka et al. (2016) the behaviour potential trajectory over time is affected by five main theoretical themes: (1) Maintenance motives, (2) Self-regulation; (3) Resources; (4) Habit; and (5)

Environmental and social influences. The current study taps into the first theme, looking at how needs satisfaction and eating behaviour regulations, from Self-Determination Theory, and self-efficacy are associated with long-term maintenance of healthy lifestyles.

One of Self-Determination Theory's fundamental premises is that the process of internalizing the motivational regulations for a specific behaviour is fostered when autonomy, competence and relatedness (i.e., the basic psychological needs) are satisfied (Ryan & Deci, 2000). Higher needs satisfaction occurs when the context is perceived as need-supportive, providing autonomy support (i.e., increasing autonomy satisfaction), structure (i.e., increasing competence satisfaction) and involvement (i.e., increasing relatedness satisfaction). When one experiences needs satisfaction, behaviour regulation becomes internalized and integrated, a path leading to increased motivational quality. The theory postulates that autonomous motivations, including intrinsic (doing a task for the inherent pleasure), identified (accepting and recognizing the behaviour) and integrated regulations (accepting the behaviour as part of the self), represent the most sustainable forms of directing and energizing one's behaviour. Conversely, controlled motivations, including external (directed by external contingencies) and introjected regulations (linked with social approval and ego pressures), are expected to be less sustainable, as they only direct and energize behaviour as long as the expected outcome remains important. Hence, behaviour is contingent on extrinsic factors that may be, or become, out of one's control, such as life-events (Ryan & Deci, 2000). Weight regain prevention is a long-term effort, therefore, needs satisfaction and autonomous motivation are expected to provide the best motivational background to sustain weight management-related behaviours. While the theory postulates that needs satisfaction impacts autonomous motivation, we hypothesize that the association between these variables will be reciprocal. In this sense, autonomous motivations provide a more consistent and internalized psychosocial background facilitating the emergence of needs satisfaction. For example, by being intrinsically motivated to exercise, one individual would engage more consistently in types of activities that increase their sense of competence.

In the context of this research study, self-efficacy represents the individual belief about the ability to succeed in preventing weight regain (Bandura, 2001). This construct has been consistently associated with better prospective results in weight management studies (Teixeira et al., 2015), even when compared with constructs from other rationales (Palmeira et al., 2007). Although past results are theorized to be an important element in developing self-efficacy (Bandura, 2001), we have not found evidence that better weight outcomes would lead to self-efficacy improvement in the context of weight regain prevention. Hence this study will test the hypothesis that psychosocial variables, such as self-efficacy and motivation, will impact weight changes, but also that weight changes will impact those psychosocial variables.

A representation of the logic model including the variables used in the present study is available in Figure 1 of the results, which partially reflects the interplay predicted by Kwasnicka et al. (2016). More specifically, the motivational processes are expected to mirror the Self-Determination Theory Health Model (Ng et al., 2012; Ryan et al., 2008) in the sense that needs satisfaction is linked with more autonomous eating behavioural regulations. The Kwasnicka et al., study predicts that maintenance motives will impact self-regulatory processes (Kwasnicka et al., 2016), while the present study model predicts that these variables will be entangled, with reciprocal effects affecting the behavioural potential. We suggest that these reciprocal effects are coined *Weight Management Cycles*, representing smaller scale processes occurring during a long-term weight regain prevention effort, boosting connections between weight and psychosocial changes. When positive (i.e., positive weight management linked with improvements in psychosocial variables), these cycles represent a "battle won in the weight regain prevention war". For example, during the second month of a weight management program, one individual participated in several group sessions where peers shared their successful weight loss efforts. During this period, self-efficacy increased via vicarious experiences boosting weight management behaviours, which then reciprocated to self-efficacy, leading to a positive weight management cycle. Conversely, when these cycles are negative, they are lost battles and should lead to subsequent weight regain in the long-term. One example of these downturn periods could be an injury that may limit weight management efforts and subsequently worsen psychosocial outcomes. On a larger timescale, the Weight Management Cycles we are theorizing may result in Brownell's weight cycling (i.e., "yo-yo diet") situations (Brownell, 1989).

A recent meta-analysis focusing on mediators of behaviour change interventions, showed that socio-cognitive and motivational-related variables have similar small effects on physical activity (Rhodes et al., 2020). More specifically, motivational processes, such as autonomous or controlled behavioural regulations and beliefs about capability, such as self-efficacy, are directly associated with engaging in active healthy lifestyles. However, the studies they reviewed did not present a prediction about reciprocal effects between these variables. In another review, focusing on obesity-related studies, Teixeira and colleagues suggested that both maintenance motives, such as autonomous motivation, and socio-cognitive processes, such as self-efficacy and perceived competence, are mediators of the interventions' effects on weight control (Teixeira et al., 2015). Recently, Sheeran and colleagues found that perceived competence and autonomous motivation covary as mediators in behaviour change interventions (Sheeran et al., 2020). Rodgers et al. (2014) also say that perceived competence and self-efficacy are different constructs, both at a conceptual and statistical level; perceived competence is one's perception of their basic capability of doing a behaviour, while self-efficacy is the confidence a person has about their capability of doing that behaviour under challenging circumstances. There is scarce evidence whether these two constructs may be affecting each other during a difficult challenge such as weight regain prevention.

The studies above present evidence that needs satisfaction, behaviour regulations and self-efficacy are important predictors of weight change. The methodological procedure applied in previous studies included path analysis and mediation analytical models, predicting a specific order of events, for example that changes during an active phase of the intervention in putative psychological processes would affect a follow-up measure of an outcome (Nezami et al., 2016; Silva et al., 2011). But the reviewed literature has not sought to unpick longitudinal reciprocal relations of predictors and outcomes. To achieve this purpose, other research areas have used cross-lagged panel analysis (e.g., educational psychology, Talsma et al., 2018). In brief, these models looked at cross-lagged coefficients, a key indicator of the path from variable A, measured at a time point $t-1$, to variable B measured at a time point t. Concurrently, the path from variable B, measured at $t-1$, to variable A measured at time t, is calculated, providing reciprocal effects information (Usami, 2020). This methodological approach will also be used in the present study.

In the NoHoW weight regain prevention study, the authors observed considerable variability in weight outcomes during the 12-month trial (Turicchi et al., 2020) while measuring psychosocial variables at baseline, six and 12 months. This wealth of data provided a suitable setting to study reciprocal effects. Specifically, in our model, we included needs satisfaction, eating regulation, self-efficacy and weight measured at the above-mentioned three-time points and designed a cross-lagged analysis presented in Figure 1 (see results). To our knowledge, this is the first study looking into reciprocal effects of these variables in such a large sample in the context of weight regain prevention.

To test our research hypotheses, we implemented both cross-lagged panels and Latent Growth Model (LGM). In recent decades, cross-lagged models have been widely used to explore bidirectional longitudinal effects with the aim of examining their mutual causality. By analysing the follow-up data collected at two or more time points, it allowed us to examine the potential influence of one construct (e.g., behaviour regulations) on another (e.g., weight change) at a later time point (cross-lagged effects), controlling for the regression of both constructs on themselves assessed at the previous time points (auto-regressive effects). On the other hand, LGM focuses on the features of growth trajectories and allows to estimate the causal effect of the initial level on the rate of change. In LGM, the changes are represented by two main parameters: the intercept, the initial value of the outcome measure, and the slope, which tells us how much the curve grows or the rate of outcome changes over time (Little, 2013).

Therefore, the goal of the present study was to analyse reciprocal effects between psychosocial variables (i.e., needs satisfaction, eating regulation, self-efficacy) and weight over 12 months using data from a large sample of participants engaged in a weight regain prevention trial. We predict that the psychosocial measures will prospectively affect other psychosocial variables and weight results. In addition, we hypothesize that weight and psychosocial variables will affect each other during the course of the 12 months study (i.e., representing Weight Management Cycles).

METHODS

Study design

The NoHoW trial was a three-centre ((University of Leeds (UK), Bispebjerg and Frederiksberg Hospital (Denmark) and University of Lisbon (Portugal)) 2 × 2 factorial, randomized, single- blind, controlled trial testing the proof-of-concept of a digital toolkit for weight regain prevention (European Union's Horizon 2020 research and innovation program under grant agreement No. 643309). The intervention was developed (Marques et al., 2021) according to the Medical Research Council Framework for the Development and Evaluation of RCTs for Complex Interventions to Improve Health (Craig et al., 2013). More details of the trial have been published elsewhere (Scott et al., 2019) and the trial was registered with the ISRCTN registry (ISRCTN88405328). The study was conducted in accordance with the Helsinki Declaration. Ethical approval was granted by local institutional ethics committees at the University of Leeds (17–0082; February 27, 2017), the University of Lisbon (17/2016; February 20, 2017) and the Capital Region of Denmark (H-16030495; March 8, 2017). For the purpose of the present study, data from the four arms of the intervention were pooled into one single group.

Participants

Individuals were eligible if they were aged 18 years or older, had verification of >5% weight loss in the 12 months prior to recruitment (excluding surgical weight loss) and had a BMI of >25 kg/m^2 prior to weight loss. In total, 1627 participants were enrolled in the study. Due to missing data in the variables of interest, this study included 1553 participants at baseline, 1291 at 6 months and 1156 at 12 months. No differences were observed in dropouts between the study centres.

Participants were recruited from national health services, registered clinical nutritionists, leisure centres and commercial weight loss programs. During the trial, participants were asked to maintain their previous weight loss efforts in addition to being randomized to four different weight regain prevention digital interventions lasting 6 months (see Scott et al., 2019 for more information).

Measures

All measures were English, Danish and Portuguese versions of the questionnaires below.

Basic psychological needs satisfaction

The satisfaction of the basic psychological needs was measured by the Basic Psychological Needs Satisfaction Scale - BPNSS (Ng et al., 2013; Richer & Vallerand, 1998) adapted to the weight management context, by adding "weight management" to the stem and some specific items. The scale comprises 16 items distributed in three dimensions, one for each basic psychological need (Autonomy; Competence; Relatedness). To the intend of this study a global score was computed by averaging all items responses to express overall basic psychological needs satisfaction. Scoring ranged from one to seven points Likert scale (1-strongly disagree; 7-strongly agree) and greater scores represents higher needs satisfaction. The BPNSS for Weight Management demonstrated good reliability for all time points (Table 1).

Regulations for eating behaviour

The regulations for eating behaviour were assessed by the Regulations for Eating Behaviour Scale (Pelletier et al., 2004; Teixeira et al., 2021). The scale comprises 24 items distributed across six dimensions: Intrinsic, Integrated, Identified, Introjected, External and Amotivation. Likert scale scoring ranged from one to seven points (1-not true for me; 7-very true for me), and higher scores represent a higher manifestation of behavioural regulation. To reduce filling time, one item was removed from each subscale totalizing 18 items. The criteria used for removal was the lowest factor loading from the scale's original study. This reduced version used in the NoHoW Trial demonstrated good reliability for all subscales in all measured moments (Table 1). The Relative Autonomy Index (RAI) was computed (−3*Amotivation + −2*external + −1*Introjected +1*Identified +2*Integrated +3*Intrinsic) to provide one single composite measure of motivational autonomy based on the SDT framework (Ryan & Deci, 2017). This composite measure was designated as eating regulation, where higher scores represent more eating autonomous motivation and will be used in the study's analysis.

Self-efficacy

Self-efficacy for weight management was measured with a newly developed 12-item scale adapted from two well-established self-efficacy questionnaires addressing exercise and eating behaviour: the Self-Efficacy for Exercise Behaviours Scale (Sallis et al., 1988) and the Weight Efficacy Lifestyle Questionnaire (Clark et al., 1991). The self-efficacy for weight management scale was designed to tap directly into the confidence that a person holds in their capacity to manage body weight even when something may interfere with his/her goals. The stem of the questionnaire: "I am confident I can manage my body weight even if/when" and the selection/adaptation of the items (e.g. "I am feeling stressed"; "Something interferes with my plans") from the existing scales was discussed by the team's experts on weight loss. An internal validation study was conducted, showing that the scale has sound psychometric characteristics and it is currently being prepared for submission to a peer-reviewed journal. A global score was computed averaging the responses that were provided through a Likert scale scoring ranged from one to seven points (1-not confident at all; 7-extremely confident). Higher scores represent greater confidence in successful weight management. The scale reached a good reliability in all measured moments (Table 1).

Objectively measured weight

Body weight was measured by trained research staff on each clinical investigation day (at baseline, 6 and 12 months), in 10–12 hours overnight fasted participants wearing light clothes using a Seca 704 s instrument (SECA, Germany).

Procedures

Weight was measured at the study centres. The psychosocial variables were measured at baseline, 6 and 12 months, via online versions of the questionnaires. For this purpose, Qualtrics software was used, feeding a data-hub developed and managed by the James Hutton Institute, one of the partners of the NoHoW consortium. All data were collated, anonymized, monitored and securely stored. Quality checks, adherence to protocol and trial management were assured via weekly meetings.

TABLE 1 Descriptive, reliability statistics (McDonald's ω) and correlations among study variables.

	Min	Max	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11
1. Need Satisfaction baseline	1.000	7.000	5.558	.949	.923										
2. Need Satisfaction 6 months	1.000	7.000	5.478	1.076	.474**	.940									
3. Need Satisfaction 12 months	1.000	7.000	5.369	1.171	.441**	.512**	.945								
4. Self-efficacy baseline	1.000	5.000	3.246	.665	.358**	.290**	.266**	.879							
5. Self-efficacy 6 months	1.000	5.000	3.251	.727	.273**	.455**	.339**	.456**	.897						
6. Self-efficacy 12 months	1.000	5.000	3.212	.748	.285**	.330**	.411**	.400**	.514**	.906					
7. Eating Regulation baseline	−32.333	36.000	16.243	9.807	.410**	.276**	.220**	.221**	.174**	.150***	[a]				
8. Eating Regulation 6 months	−32.000	36.000	16.591	10.341	.246**	.498**	.314**	.225**	.323***	.235**	.513**	[b]			
9. Eating Regulation 12 months	−29.333	36.000	16.673	10.269	.318**	.389**	.513**	.230**	.312**	.324**	.529**	.597***	[c]		
10. Weight baseline	50.500	157.700	84.796	17.262	−.084**	−.114**	−.133**	−.022	−.100**	−.021	−.153**	−.151**	−.171**		
11. Weight 6 months	50.000	157.100	84.062	16.942	−.073**	−.186**	−.189**	−.02	−.170**	−.089**	−.142**	−.199**	−.212**	.962**	
12. Weight 12 months	50.400	156.000	84.468	17.032	−.117**	−.210**	−.246**	−.046	−.189**	−.142**	−.147**	−.209**	−.249**	.935**	.976**

[a]Intrinsic Regulation (ω = .901); Integrated Regulation (ω = .844); Identified Regulation (ω = .835); Introjected Regulation (ω = .732); External Regulation (ω = .844); Amotivation (ω = .805).

[b]Intrinsic Regulation (ω = .912); Integrated Regulation (ω = .875); Identified Regulation (ω = .861); Introjected Regulation (ω = .736); External Regulation (ω = .858); Amotivation (ω = .818).

[c]Intrinsic Regulation (McDonald's ω = .915); Integrated Regulation (ω = .880); Identified Regulation (ω = .842); Introjected Regulation (ω = .757); External Regulation (ω = .863); Amotivation (ω = .793).

**$p < .01$.

Data analysis

Descriptive statistics (minimum, maximum, mean and standard deviation) and Pearson correlations were calculated for all variables at the three time points using SPSS software version 23.0. Main analyses were calculated using Mplus version 8.4 (Muthén & Muthén, 2017). First, Latent Growth Model (LGM) analyses were conducted to test linear changes by analysing associations between the intercept and slope of the study's variables. Second, cross-lagged analyses were conducted to examine reciprocal longitudinal associations among the study variables. Model fit was assessed with the comparative fit index (CFI), the Tucker-Lewis index (TLI) (TLI and CFI $\geq .90$ or $> .95$ suggest acceptable and excellent fit, respectively), the root mean square error of approximation (RMSEA) and the standardized root-mean-square residual (SRMR) (RMSEA and SRMR $\leq .08$ or $< .06$ suggest acceptable and excellent fit, respectively) and its 90% confidence interval (Byrne, 2013). All the models were estimated using a maximum likelihood estimator and were adjusted for potential confounding variables, including age, gender, study arm and centre. Missing data were handled using full information maximum likelihood estimation (Enders, 2010). The raw data and one example of the code used on Mplus are available in open access at the following link https://osf.io/swzm2/.

RESULTS

A total of 1627 subjects participated in the study, 1117 were female (68.7%, 44.66 ± 12.23 years, 81.08 ± 15.96 kg), and 510 were male (31.3%, 42.59 ± 10.80 years, 92.93 ± 17.23 kg). The number of participants was evenly distributed by centre. Descriptive and correlational analyses at different wave points are displayed in Table 1. Needs satisfaction, self-efficacy and eating regulation were directly associated, but inversely associated with weight.

Table 2 displays the results from the LGM performed with weight, needs satisfaction, eating regulation and self-efficacy in the roles of outcome and/or predictor, whereas fit indices for all models are displayed in the Table S1. In all models, the intercept coefficient refers to the association between the predictor at baseline and changes in outcomes, whereas the slope coefficient refers to the association between changes in predictor and changes in outcomes over time. The weight outcome model (second and third column in the table) showed that participants with higher scores on needs satisfaction and self-efficacy at baseline experienced a decrease in weight over the total 12-months intervention. Furthermore, participants who increased needs satisfaction, eating regulation and self-efficacy experienced a decrease of weight over the same time period.

In addition, we also evaluated reciprocal effects by including weight as a predictor (first lines of results in the table). Smaller values in baseline weight were associated with increases in all psychosocial variables (i.e., needs satisfaction, eating regulation and self-efficacy) over the duration of the trial. In addition, participants who lost weight during the 12 months improved their needs satisfaction, eating regulation and self-efficacy over time.

Finally, the analysis of reciprocal associations between psychosocial variables showed that greater scores in eating regulation and self-efficacy at baseline are associated with an increase in needs satisfaction over time, whereas higher scores on self-efficacy at baseline are also associated with an increase in eating regulation. Furthermore, we found reciprocal effects on psychosocial variables, that is, a significant association between slopes in both ways.

Figure 1 shows results from the cross-lagged path model. This model displayed the following fix indices: χ^2 (*df*) = 136.841(24), CFI = .986, TLI = .948, RMSEA = .054, SRMR = .026. Needs satisfaction at baseline positively predicted self-efficacy 6-months later. Eating regulation at baseline positively predicted needs satisfaction 6-months later. Better self-efficacy at baseline predicted better need satisfaction and eating regulation 6-months later, whereas self-efficacy at 6 months also positively predicted needs satisfaction at 12 months. Furthermore, weight at baseline negatively predicted needs satisfaction, eating regu-

TABLE 2 Regression models growth factors for all variables

Outcome	Weight slope			Needs satisfaction slope			Eating regulation slope			Self-efficacy slope		
Predictors	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*
Weight												
Intercept				−.202	.034	<.001	−.174	.037	<.001	−.080	.035	.023
Slope				−.412	.040	<.001	−.254	.034	<.001	−.389	.042	<.001
Needs satisfaction												
Intercept	−.096	.031	.002				−.034	.043	.432	−.116	.065	.074
Slope	−.417	.038	<.001				.421	.066	<.001	.391	.094	<.001
Eating regulation												
Intercept	−.031	.033	.410	.221	.056	<.001				−.098	.058	.088
Slope	−.249	.035	<.001	.623	.051	<.001				.232	.071	<.001
Self-efficacy												
Intercept	−.088	.029	.003	.364	.049	<.001	.276	.053	<.001			
Slope	−.408	.041	<.001	.230	.077	.003	.320	.043	<.001			

lation and self-efficacy at 6 months, whereas weight at 6 months negatively predicted needs satisfaction and eating regulation at 12 months.

DISCUSSION

The study's goal was to analyse reciprocal effects between needs satisfaction, eating regulation, self-efficacy and weight over 12 months among a large sample of participants engaged in a weight regain prevention trial. The main results showed that needs satisfaction, eating regulation and self-efficacy were inversely associated with weight change during a 12-month' weight regain prevention effort. The slope coefficients showed that increases in these variables were linked to weight loss. Baseline scores of needs satisfaction and self-efficacy were also inversely associated with 12-months weight change (see the significant intercept negative coefficients), meaning that higher levels of these variables at baseline were linked to subsequent weight loss. Conversely, eating regulation at baseline was not associated with a 12-month weight change.

As a whole, these results are in line with the predictions of the Self-Determination Theory Health Model (Ng et al., 2012; Ryan et al., 2008). In fact, in the context of weight regain prevention, we expected that increases in needs satisfaction, autonomous eating regulation and self-efficacy would be linked with better weight regain prevention.

More specifically, this model hypothesize that needs satisfaction would provide the motivational background supporting increases in autonomous eating regulation. This theoretical prediction is partially supported by our data; baseline needs satisfaction predicted long-term weight change, while baseline eating regulation was not associated with long-term results (Table 2). Looking at the other results, we observed mixed evidence about the above prediction. On the one hand, baseline needs satisfaction was positively associated with six- and 12-month' eating regulation (table 1), supporting the prediction. Conversely, eating regulation at baseline affected 6 months' needs satisfaction and that baseline needs satisfaction was not linked with six or 12-months' eating regulation (Figure 1). However, this represents a multivariate analysis, so interactions between all variables in the model may affect the coefficients. Hence, self-efficacy and weight may play a role in the needs satisfaction and eating regulation entanglement, a potential effect that warrants future analysis in other datasets.

The self-efficacy representation in the cross-lagged model predicts that it would be affected by needs satisfaction. The prediction stated that as one is experiencing more autonomy, competence and relatedness, more self-efficacy would emerge, leading to better weight regain prevention behaviours (Kwasnicka

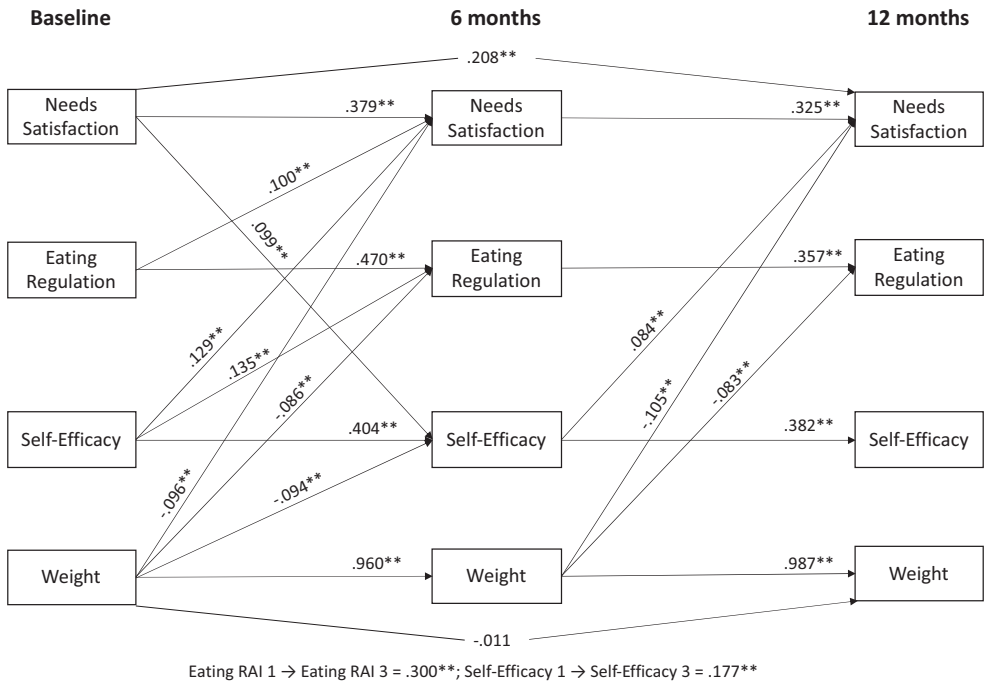

FIGURE 1 Cross-lagged panel analyses on needs satisfaction, eating regulation, self-efficacy and weight among adults in a 12-months' weight regain prevention trial. The model includes data at baseline, 6-months and 12-months, controlling for age, gender, study arm and country. $^{**}p < .01$

et al., 2016; Scott et al., 2019; Teixeira et al., 2015). Our results partially supported this prediction; both baseline and the evolution of self-efficacy during the 12 months were linked to the prevention of weight regain results (see Table 2). In addition, baseline needs satisfaction was directly associated with six- and 12-months' self-efficacy (Table 1), while baseline needs satisfaction predicted 6 months' self-efficacy. However, baseline self-efficacy predicted 6 months' needs satisfaction and 6 months' self-efficacy predicted 12 months' needs satisfaction (Figure 1). We suggest that, instead of a linear causality path, these results point to the presence of reciprocal effects.

One of these instances is evident in our data. Reciprocal effects could be observed between needs satisfaction and self-efficacy. Participants would see their confidence reinforced as they experienced a context supportive of their autonomy, competence and relatedness. Reciprocally, the heightened sense of self-efficacy would reinforce needs satisfaction, particularly via changes in perceived competence. Although behaviour change experts such as Rothman have suggested the integration of Self-Determination Theory and Socio-Cognitive Theory-related variables as far back as 2004 (Rothman, 2004), only in a recent meta-analysis structural equation modelling of randomized controlled trials was there some evidence that perceived competence and autonomous motivation covary as mechanisms of action resulting from Self-Determination Theory based interventions towards health behaviours (Sheeran et al., 2020). The present data add support to this prediction, suggesting that reciprocal effects may represent one of the ways these variables covary.

Figure 1 depicts an image where seven cross-lagged paths are present from baseline to 6 months, while only three were significant from six to 12 months (no cross-lagged paths were detected from baseline to 12 months). Note that the NoHoW study tested a digital behaviour change intervention designed to be delivered in 6 months. Hence, we expected more changes to happen during this initial phase of the program. Other studies also showed that interventions' initial phase is usually associated with more changes (Dombrowski et al., 2014). Interestingly, our results suggest that while the psychosocial variables

were related to the attained weight 6 and 12 months later, weight also seemed to drive future scores of these psychosocial variables. Behavioural interventions should, therefore, be designed to piggyback on this effect, making these psychological changes sustainable and allowing for the desired long-term results. For example, anticipated weight results should elicit participants to reflect on the psychosocial context leading to those outcomes, promoting an internalization of the motivational processes, perceived competence and self-efficacy reinforcement. This may be easily achieved in digital behaviour change interventions, where algorithms observing weight (or energy deficit balance behaviours) can elicit participants' reflections and provide cues to the internalization processes.

As in previous studies, autonomous motivation is most important in the prevention of weight regain in the long-term (Teixeira et al., 2012, 2015). The cross-lagged analysis showed that the internalization of eating regulation was affected by antecedent weight trajectories, a different direction than the one suggested in that evidence (note that some studies analysed exercise regulation, for example; Mata et al., 2009). We can hypothesize that eating regulation is more dependent on weight outcomes than exercise motivation, as exercise is, for example, linked with psychological well-being (Biddle et al., 2000), representing a different mechanism of action to attain weight regain prevention at the long term. When weight increases, compensatory eating behaviours are common; by focusing on "eating to a certain number on the scale", participants engaged in a form of controlled motivation (Teixeira et al., 2012). Compensatory exercise behaviours are also possible, but while more intrinsic forms of eating - associated with pleasure or interest - are more commonly linked with obesogenic foods, the intrinsic forms of exercise are usually associated with increases in energy expenditure, a healthy lifestyle with spill-over effects (Mata et al., 2009) and potentially weight loss.

Eating regulation and self-efficacy were included as separate mechanisms of action. While eating regulation is related to an organismic perspective of how we energize our behaviours (Teixeira et al., 2012), self-efficacy is a more procedural and self-regulatory mechanism representing the confidence level towards attaining a specific behaviour or goal, even under challenging contexts (Bandura, 2001). In our model, increases in autonomous eating regulation would be associated with increases in self-efficacy. Teixeira et al. (2010) and Sweet et al. (2009) studies have also suggested that self-efficacy and autonomous motivational variables may play independent roles in the context of weight loss interventions. Our data partially supported these predictions, showing that while all bivariate correlations were significant, only the path from baseline self-efficacy to six months' eating regulation was significant (Figure 1). In addition, the baseline eating regulation Pearson's r with baseline to 12 months' self-efficacy decreased. In comparison, baseline self-efficacy correlation with baseline to 12 months' eating regulation remained stable, signalling that the entanglement between these variables was either stable or may have decreased over time. We can interpret these results as supporting the notion that eating regulation and self-efficacy processes play different roles in our behaviours towards weight regain prevention. Albeit feelings of competence may thrive in an autonomous motivational context, our data and the referenced studies show that self-efficacy may also thrive in the absence of such contexts (Rodgers et al., 2014), resourcing to more cognitive or explicit goals such as engaging in a specific eating pattern that is not necessarily enjoyable or interesting. Another hypothesis is that as internalization processes occur and habits are formed, participants become less conscious of these processes (Rothman et al., 2009). The path from being consciously incompetent to sub-consciously competent may not be captured by the psychometric measures used, which rely on the participants being aware of these processes. To further analyse these variables' dynamics, future studies should increase the measurement frequency, use qualitative methods or N-1 studies (Kwasnicka & Naughton, 2020) and measure habit formation to grasp the immediate feedback loops between weight, motivational and self-efficacy changes.

While discussing these results, we acknowledged that several prospective, linear effects take place during an effort to prevent weight regain. Increases in needs satisfaction, autonomous eating regulation and self-efficacy were linked with weight loss. But we also entertained the idea of Weight Management Cycles, representing the entanglement between changes in weight, behavioural and psychosocial variables. As one experiences a change in one of these variables, others will also change, which in turn affects the initial variable - a dynamic and reciprocal effect. The cross-lagged panel analysis partially suggested one of such cycles, where needs satisfaction and self-efficacy were positively affecting each other in different

points in time. This finding provides practical information to develop interventions and treatments. By increasing support of the basic psychological needs one can expect an increase in self-efficacy; but also, by increasing self-efficacy, one can expect an increase in needs satisfaction. Importantly, and not surprisingly, weight plays a role in the Weight Management Cycle; weight seems to be driving psychosocial changes, meaning that interventions should consider ways to spark a Weight Management Cycle by focusing on attaining weight reductions at regular periods. If contextualized in a larger scenario of sustained weight regain prevention, boosting a period of weight loss may provide motivational and self-efficacy spikes to energize the long-term processes. Albeit with less strength, our data suggests that boosting needs satisfaction or self-efficacy may also jump-start new Weight Management Cycles, leading to the desired long-term weight regain prevention. These are, of course, hypotheses that demand further testing.

The present study was limited by the number of variables we tested in the cross-lagged panel analysis. The analytical procedure used rendered results that were very difficult to interpret when we added more than four variables to the model. Hence, we decided to use variables representing the overarching rationales of motivation and self-regulation (and weight as outcome). Self-regulatory skills such as action planning or motivational variables associated with goal contents and exercise behaviour were left off in the current analysis. Future studies should consider adding these variables or studying them in alternative models. In addition, gender in-balance in our sample should be considered when reading the article, and the lack of a published validation of the self-efficacy scale represents other limitations of the present article.

Conversely, this article's strengths rely on the large sample, gathering 12 months' of data from a controlled trial in three European countries, with validated and standardized methods used in all centres. Albeit replication is warranted, the results may be generalized to several European regions, considering the large samples collected in the three countries representing Scandinavian, UK and Southern Europe regions. In addition, we used a cross-lagged analytical procedure, common in other research areas but used scarcely in weight management settings.

In conclusion, we propose that behaviour maintenance theories need to consider the existence of longitudinal and reciprocal cycles among its variables (i.e., Weight Maintenance Cycles) to better represent the long-term experience of weight regain prevention. This article adds the idea of smaller-scale behavioural cycles may be in place, more consistent with the "human scale" of behaviour. When weight outcomes and mechanisms of action, such as motivational and self-efficacy variables, become positively entangled, they can provide the nutrients for forming habits and automaticity processes supporting the desired longer-term effects of healthy behaviours.

AUTHOR CONTRIBUTIONS

David Sánchez-Oliva: Formal analysis; software; writing – original draft; writing – review and editing. **Jorge Encantado:** Investigation; writing – review and editing. **Marta M. Marques:** Conceptualization; methodology; writing – review and editing. **Inês Santos:** Investigation; supervision; writing – review and editing. **Cristiana Duarte:** Investigation; project administration; supervision; writing – review and editing. **Marcela Matos:** Conceptualization; writing – review and editing. **Sofus C. Larsen:** Investigation; project administration; supervision; writing – review and editing. **Graham Horgan:** Data curation; software; writing – review and editing. **Pedro J. Teixeira:** Conceptualization; funding acquisition; project administration; writing – review and editing. **Berit L. Heitmann:** Conceptualization; funding acquisition; project administration; supervision; writing – review and editing. **R. James Stubbs:** Conceptualization; funding acquisition; project administration; supervision; writing – review and editing.

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CONFLICT OF INTEREST

All authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available at https://osf.io/swzm2/.

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