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Physical activity and motivational predictors of changes in health behavior and health among DM2 and CAD patients

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This study tested a physical activity intervention and the self-determination theory (SDT) process model of health-behavior change and health among 108 adult patients with both diabetes mellitus type 2 (DM2) and coronary artery disease (CAD). Patients were randomly assigned to an organized physical activity intervention group (led by instructors) or a non-physical activity control group. At baseline and after 12 months, we measured the following: needs satisfaction, autonomous and controlled motivation for physical activity, perceived competence for physical activity and blood sugar testing, physical activity and blood sugar testing, body weight, glucose control (HbA1c), and self-perceptions of general health and vitality. The intervention produced, as hypothesized, significant changes in all study variables in favor of the experimental group (Cohen's *d* effect sizes: 0.23–0.72), except the non-significant result for controlled motivation and body weight. The data supported the SDT process model, in which the effect of the intervention significantly predicted indirect changes in behavior and health through motivation variables. Considering the moderate to large effects on increases in motivation, behavior, and health, promoting organized physical activity programs that are perceived as need-supportive may have important health implications for patients with DM2 and CAD.

Between 5% and 10% of adults in Norway have diabetes mellitus type 2 (DM2) (Helsedirektoratet, 2010), which has a high frequency of comorbidity with coronary artery disease (CAD) (Østenson et al., 2009). From a population perspective, behavioral patterns have a strong influence on DM2 and CAD (Schroeder, 2007; Ezzati & Riboli, 2013). Favorable behavior patterns for patients with DM2 and CAD involve appropriate regulation of physical activity (PA), diet, and blood sugar testing, and CAD can also be reduced by decreasing tobacco use, obesity, high blood pressure, and heightened lipids (World Health Organization, 2013).

Adequate levels of PA (e.g., equivalent to 45 min of walking 3 days/week) can lower blood sugar, blood pressure, and obesity and help prevent CAD events (Fritz et al., 2006; Amundsen et al., 2009; Helsedirektoratet, 2010). Accordingly, the Norwegian Directorate of Health recommends at least 30 min of moderate daily PA for both DM2 and CAD patients (Helsedirektoratet, 2010). Because there is a dose–response relation between PA and health benefits, additional time and intensity at PA is likely to provide additional positive health benefits, although intensity should be adjusted to the individual's health condition. In sum, effective self--management of DM2 and CAD depend on patients initiating and maintaining significant PA, as well as diet improvement.

In recent years, self-determination theory (SDT; Deci & Ryan, 2000), a general theory of human motivation which focuses on the self-regulation of behavior, has been used to test if motivational processes are involved in the motivation and self-regulation of health behaviors (e.g., Williams et al., 2004; Shigaki et al., 2010; Ng et al., 2012). More specifically, researchers have used this theory to design health-care interventions intended to enhance volitional engagement of healthy behaviors by supporting satisfaction of the patients' basic psychological needs for autonomy, competence, and relatedness.

SDT: needs and motivation

The need for autonomy refers to the necessity of experiencing volition and choice in order to be well. Autonomy, as defined in SDT, should not be confused with independence. Autonomy is the feeling of willingness and concurrence, and it can accompany either dependent or independent actions (Ryan & Deci, 2000). An autonomously dependent person feels that it is important to consider the opinion of others and behave according to them. Conversely, a person who feels free to follow own interests is said to be autonomously independent. No matter how little the culture or person values independence, the person must still experience autonomy for healthy development, and if the need is not satisfied, there will be negative motivation and well-being consequences.

The need for competence refers to the need to interact effectively with the environment (White, 1959) and is a manifestation of people's inherent proactivity. People are more likely to internalize more self-determined motivation for target behaviors and feel competent if the environment is stimulating their interest and engagement, by giving positive competence feedback and providing challenges optimally adapted to the person's abilities. A challenge that is too hard or too easy may lead to alienation and disengagement (Deci & Ryan, 2000).

The need for relatedness refers to the need of all people to build close relationships and feel acceptance from others. Ryan and Deci (2000) argued that the primary reason people initiate extrinsically motivated behaviors is that the behaviors are valued by significant others, so that is an important prerequisite for promoting internalization of health-related behaviors.

The concept of people having three basic psychological needs forms a strong foundation for understanding the effects of social contexts on people's motivation, behavior, and wellness. According to SDT, these needs represent "part of the common architecture of human nature" (Deci & Ryan, 2000, p. 252)—that is, they are essential elements for health and well-being. Thus, all people, regardless of age, gender, economic status, or culture, possess these needs, and a large number of studies (e.g., Williams et al., 2006a) have shown that need-supportive conditions facilitate autonomous motivation, perceived competence, effective behaviors, and both psychological and physical health and well-being. These needs give goals their psychological potency, whereas regulatory processes direct people's goal pursuits (Deci & Ryan, 2000).

Overall, SDT theorists propose that satisfaction of the three needs promotes autonomous motivation, internalization of behavioral regulations, perceived competence (PC), and well-being (Deci & Ryan, 2000). Autonomous motivation encompasses both identified and integrated regulation, which means that patients will have a clear understanding of their basic values and behave in congruent ways. Identified regulation means that a behavioral regulation has been personally accepted as instrumentally important, as when the person accepts the value of exercise for promoting long-term health (Deci & Ryan, 2000). Integrated regulation, the most autonomous internalized motivation, means that the identification has been integrated with other aspects of one's self. Conversely, controlled motivation is formed by introjected and external regulation. Introjected regulation means that the person engages in the health behavior in order to avoid feeling guilt or shame (e.g., being physically active in order to avoid guilt and shame). With external regulation, behavior is controlled by external contingent consequences administered by other people (e.g., being physically active in order to avoid criticism and nagging from others or to get a reward).

SDT theorists further suggest that effective behavior change not only requires people to feel autonomous as opposed to controlled, they need also to perceive themselves as competent to enact the requisite behavior in order to yield desired outcomes (Deci & Ryan, 2000). According to SDT (Deci & Ryan, 2000), perceived competence is an individual motivational outcome of competence need satisfaction (e.g., positive competence feedback from the environment). Perceived competence is a motivational variable measuring whether people can accomplish a specific goal and has been shown to be an excellent mediator of health behavior (Williams et al., 2006b).

The interpersonal context where an individual initiates and regulates behavior can be either *need-supportive* (e.g., promoting choice) or *controlling* (e.g., pressuring one toward specific outcomes). Need-supportive contexts (relative to controlling ones) have been associated with more autonomous motivation and higher PC among diabetes patients (Williams et al., 2009b). As well, the literature indicates that autonomy has been linked to more interest, less pressure, more creativity and cognitive flexibility, better conceptual learning, more positive emotions and self-esteem, greater persistence of behavior change, and better physical and psychological health (Deci & Ryan, 2000). The intervention in this study was designed to be autonomy supportive, so the measure of autonomy support was used as a manipulation check.

We know of no clinical trials that have tested the SDT Model for Health Behavior Change with respect to physical activity with patients who all had both DM2 and CAD. Patients with both DM2 and CAD are different from patients with only one of these diseases. Seen from a diabetes perspective, all patients in this study have macrovascular complications, i.e., their diabetes disease is advanced. In relation to CAD patients without diabetes, this group has also complications, such as insulin resistance, endothelial dysfunction, diabetes dyslipidemia, and is at greater risk for complications from interactions of increased number of medications. Obviously, these complications may be of clinical significance. In addition, patients with the two chronic diseases

(CAD and diabetes) have a greater illness/disease burden, and are more disabled as they experience greater barriers to overcome to be physically active, compared with populations with one diagnosis. Compared with patients with one diagnosis, patients with more/multiple chronic diseases experience greater barriers to be physically active because they are more depressed and likely have less vitality, probably because of the burdens of multiple treatment regimens, concerns about complications, poorer perceptions of health, having to take more medications, and, thus, may perceive lower levels of autonomy and perceived competence in dealing with it all. Of course, they are all human beings and all have psychological needs that need support, and we are not saying that they are different in the needs but that they have greater illness/disease burden, and greater barriers to overcome to be physically active (Williams et al., 2004, 2005, 2007, 2009b). Therefore, the population with both CAD and DM2 patients is unique. In general, few studies have been conducted with this group of patients, and we cannot know their responses to physical activity when compared with patients with one diagnosis.

A first publication based on the current data found significant improvements in anaerobic threshold and "time to exhaustion" as a function of the physical activity intervention. The intervention effects on change in glucose control (HbA1c) and maximal aerobic power (VO_{2peak}) were non-significant, although improvements were seen in patients without advanced vascular disease (Byrkjeland et al., 2015). Thus, an aim of this study is to test if the SDT model for health behavior can account for change in glucose control and other health outcomes. Specifically, we will test if the basic psychological needs for autonomy, competence, and relatedness, as well as motivation and behavioral variables (Fig. 2), mediate the effect of the intervention on glucose control and other health outcomes.

It is important to explore that SDT interventions can be effective in motivating very high-risk patients with a high burden of chronic disease because chronic disease can lower their motivation to be physically active and result in decreases in psychological well-being and lower exercise-induced improvements of glucose control and maximal aerobic power (VO_{2peak}). Such studies are also important because of the increasing prevalence and the cost of care of chronic diseases (Schroeder, 2007; Finkelstein et al., 2008; Byrkjeland et al., 2015; Skinner et al., 2015). Most of the SDT health studies are in low-risk patients with little chronic disease burden (Ng et al., 2012). However, studies of patients in cardiac rehabilitation have shown that autonomous motivation is positively related to PA level (Kubitz, 2010; Russell & Bray, 2010; Sweet et al., 2010). For patients with DM2, research supports the importance of need support for increases in autonomous motivation and PC for diabetes self-management and, in turn, improved glycemic control over 12 months (Williams et al., 1998, 2004). Other studies among DM2 patients indicated that need support predicted more autonomous motivation and PC, which, in turn, predicted greater medication adherence and improved glycemic control and lower LDL cholesterol. In another study, Williams et al. (2005) found that need-supportive care positively predicted PC, and PC, in turn, predicted reduced blood sugar levels and less depressive symptoms. Regarding weight loss, a study by Williams and colleagues indicated that both the patient perception of the need-supportiveness of the treatment context at baseline and patient autonomous motivation for physical activity (5–10 weeks into the program) were predictive of a reduction in BMI at the end of the 6-month program. In addition, program attendance and autonomous motivation were both predictive of a reduction in follow-up BMI after 23 months (Williams et al., 1996).

The current trial tested the SDT process model (Ng et al., 2012) in which an intervention based on SDT was hypothesized to increase need satisfaction compared with usual care. Change in perceived need satisfaction was in turn predicted to increase autonomous motivation and PC for PA. Finally, the change in autonomous motivation and perceived competence for PA were predicted to increase PA and indicators of health such as glucose control, weight loss, vitality, and perceived health (a reliable and valid marker of physical health in general Idler & Benyamini, 1997). The intervention was also expected to increase PC for blood sugar testing because patients in the intervention group were educated about the reasons why frequent blood sugar testing is important when they start exercising. In addition, increased PC in the domain of PA was expected to increase PC for blood sugar testing as a spill-over effect on this PA-related behavior—a phenomenon described by Vallerand (2000) as the top-down effect from the contextual level (i.e., the domain of PA) to the situational level (i.e., the particular behavior of blood sugar testing). In turn, an increase in PC for blood sugar testing was expected to predict increases in performance of blood sugar testing, which in turn would lead to decreased HbA1c (Mayo Clinic, 2016).

In sum, based on the theory and reviewed research, the following hypotheses were tested. Participation in an organized weekly PA group designed to be need-supportive, relative to a non-PA control group, would lead to: (a) increases in need satisfaction in PA; (b) increases in autonomous motivation for PA; (c) increases of PC for PA and blood sugar testing; (d) increases in PA and regular blood sugar testing; (e) increases in perceived health and vitality; and (f) decreases in body weight and HbA1c (glucose control). In addition, in line with the SDT process model, the intervention (relative to controls) was hypothesized to influence increases in need satisfaction in PA. The increase in need satisfaction for PA would in turn positively predict changes in autonomous motivation and PC for PA, both of which, in turn, would predict increases in performances of PA. Further, performance of more PA was expected to predict increases in perceived health, vitality, and reduction in body weight. In addition, both the PA intervention and change in perceived competence for physical activity were hypothesized to positively lead to change in PC for blood sugar testing, which, in turn, would be positively linked to performance of regular blood sugar testing. Blood sugar testing would, in turn, decrease HbA1c. Three additional links were added to the basic SDT health-behavior change model just described because previous health research has suggested their importance. That is: *first*, autonomous motivation for PA was expected to predict PC for PA as modeled by recent research among diabetes patients (Williams et al., 2009b), thus predicting the outcome variables indirectly and directly as previously predicted. *Second*, a path from change in autonomous motivation for PA to change in body weight was added because previous research indicated that autonomous motivation significantly predicted the maintained reduction of BMI 23 months later (Williams et al., 1996) and the reduction of body weight 3 years later (Silva et al., 2011). *Third*, finally, a path from change in body weight to change in glucose control was added because increasing body weight is a major cause of insulin resistance, dysglycemia, and type 2 diabetes mellitus (Jensen et al., 2014).

Method

Participants and study design

The study was part of the EXCADI study (EXercise training in patients with Coronary Artery disease and type 2 Diabetes), a clinical trial that took place at Ullevaal University Hospital from August 2010 to March 2013. A total of 463 patients were assessed for eligibility. Of these, 306 were not interested and 20 did not meet the inclusion criteria which included not having other serious diseases, as severe diabetic retinopathy, nephropathy, or neuropathy, unstable angina, decompensated heart failure, severe ventricular arrhythmia, severe valvular heart disease, aortic-aneurysm, deep vein thrombosis, pulmonary embolism, stroke or mitral insufficiency in the last 3 months, cancer, arthritis, COPD, muscular-skeletal disorders, or persistent infections. Regarding PA, only those who were physically active more than 150 min/week (i.e., more than the planned training in the intervention) were excluded. Informed written consent to participate was received from all patients. The study was approved by the Regional Ethics Committee in Norway and is registered at http://www.clinicaltrials.gov (NCT01232608).

The EXCADI patients (*N* = 137) answered the Time 1 motivation, behavior, and health questionnaires and completed the main outcome medical exam measures at baseline (see the study flowchart in Fig. 1). After baseline measures, the 137 participants who had completed the main outcome medical examination measures were randomly assigned[1] to the training group (*n* = 69) and the control group (*n* = 68). Of these 137 participants, 29 had already refused (12 in the training group and 17 in the control group) to complete the baseline questionnaires measuring motivation, behavior, and health, resulting in 108 participants who completed the questionnaires either at baseline (*n* = 89) or after 1 year (*n* = 79) (Fig. 1). Due to this, the number of 108 participants is greater in the training group (*n* = 57) than in the control group (*n* = 51). Dropout was not affected by the experimental conditions (Logistic regression, see below).

Of the 108 participants (79% of the eligible 137), 89 (82.4%) responded to the survey at baseline and 79 (73.2%) responded after 1 year. A missing value analysis showed that the change variables were missing at random (MAR; Little's MCAR test: $\chi^2 = 88.30$, df = 87, $P = 0.44$). Due to this, as one of the recommended missing data methods (e.g., Allison, 2003; Graham & Coffman, 2012), multiple imputation of the original dataset was performed, resulting in five new imputed datasets in which the *N*s = 108 (see the flowchart in Fig. 1). In the following, averaged results from these five datasets are presented for the correlations, the MANOVA, and the ANOVAs (Tables 1, 2, and 3). In the path analyses, because the missing value analysis was non-significant, a Full Information Maximum Likelihood (FIML) was used in the model estimation to account for the missing responses (resulting in *N* = 108) as this estimation method is recommended (Allison, 2003). All participants included had both stable CAD and DM2. They were aged between 41 and 81 years (M = 63.1 years, SD = 7.9) and the majority of participants were males (81%). This sex difference may be explained by a higher proportion of males diagnosed for CAD (Norwegian Institute of Public Health, 2014). The instructions given to participants in the intervention group were the same for all age groups and for both sexes.

Intervention

The intervention group participated in a 12-month PA program developed in collaboration with the Norwegian School of Sport Sciences (NSSS). They were offered group-based instruction by two students with master degrees from the NSSS twice/week, each workout lasting 60 min. The workouts took place at NSSS, both indoors and outdoors. Indoor training consisted of circuit training with different stations focusing on strengthening the major muscle groups in the body, as well as endurance. In addition, there were regular spinning classes. Pure strength training in the weight room was offered for those who preferred it. In summertime, one training session per week was held outdoors, focusing on interval training (walking/jogging uphill). It was recommended that the participants in the intervention group also trained once a week on their own, so that the total training volume reached a minimum of 150 min/week. There were no specific guidelines for the type of self-training that was conducted, and participants could choose an activity they wanted to engage in.

[1]"Randomization was performed by use of consecutively numbered, non-translucent envelopes containing allocation message to either of the randomized groups in a 1:1 ratio according to tables of random numbers, arranged by the Unit of Epidemiology and Biostatistics, Oslo University Hospital – Ullevål" (Byrkjeland et al., 2015, p. 326).

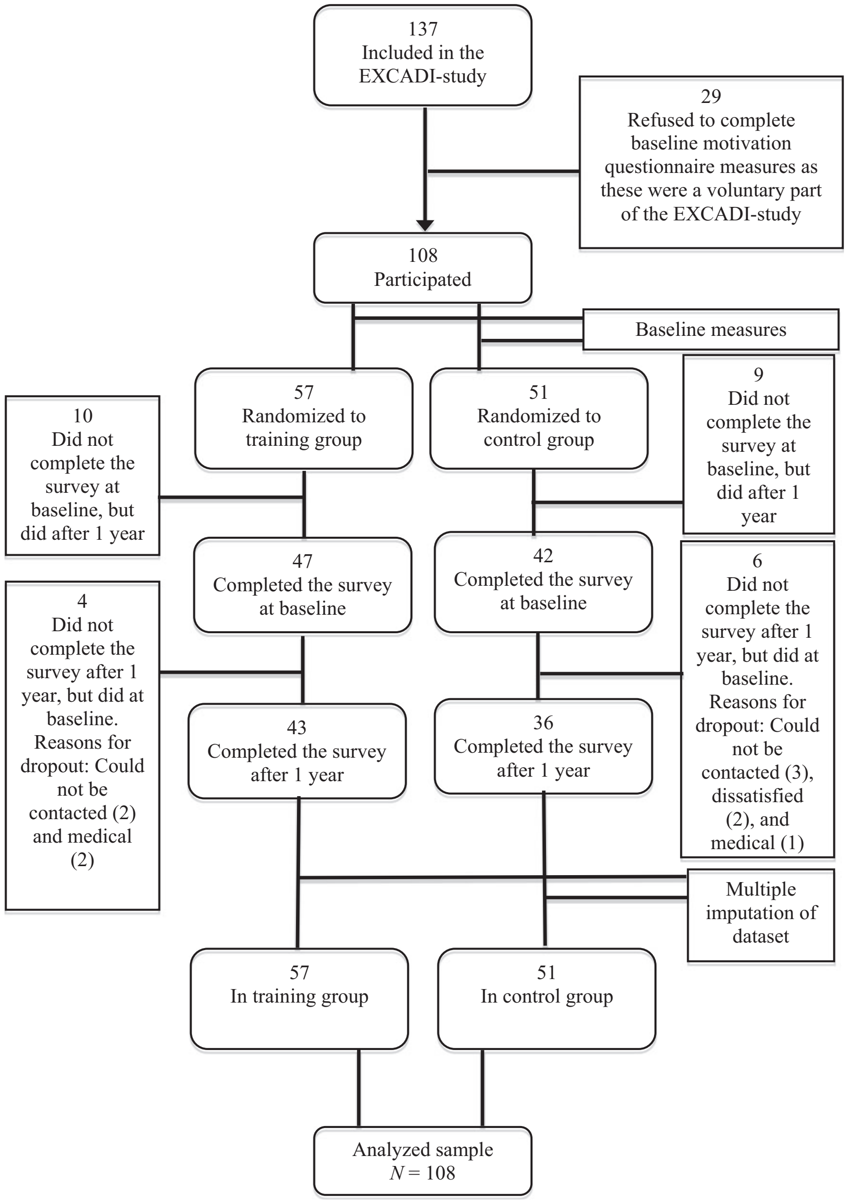

Fig. 1. Study flowchart and time line for measures and procedures.

Participants kept a training diary for their self-training. The self-training diaries indicated activities such as walking, swimming, bicycling, cross-country skiing, and resistance training in health studios. In the supervised exercise sessions, the instructors used Borg's rated perceived exertion (RPE) scale to guide the intensity of the sessions. Each supervised PA session included 5–15 min of high intensity (RPE ≥15) and the rest of the session was of moderate intensity (RPE = 12–14). Heart rate measured (Polar heart rate monitor) during the supervised PA sessions were at average 105 ± 16 beats per minute (bpm), whereas average peak heart rate was 130 ± 19 bpm, corresponding to 75% and 94% of the average peak heart rate reached during the baseline measurement of VO_{2peak} (Byrkjeland et al., 2015).

At the time of inclusion in the study, the health team informed participants in the intervention group about the possible influence of increased physical activity on their blood sugar, in particular concerns related to hypoglycemia under and after training. Participants were, therefore, recommended to test their blood sugar level more often than usual, in particular, in the beginning of the intervention period, in order to better know their own response to physical training. The instructors were also informed and asked to be aware about possible hypoglycemia episodes. In general, hypoglycemia was a small problem over the year as only a few episodes (<5) were observed over the year, and none of these episodes implied contact with the health system. Participants' diabetes care was followed as usual by their medical doctor in both groups.

The intervention involving these elements was designed in a way that would be experienced as need-supportive, with the instructors: (a) offering participants choice of an additional strength training once a week, choice of training times, and choice of activities for their self-training (i.e., intended to support the need for autonomy); (b) focusing on mastery of PA adapted to their skill level and fitness to improve their own skill level (i.e., intended to support the need for competence); (c) encouraging participants to perform high-intensity PA while giving a meaningful rationale for doing it (e.g., high-intensity PA gives an optimal training effect for the cardiovascular system) (i.e., intended to support the needs for

Table 1. Descriptive statistics, effect sizes and reliabilities for SDT-variables, performance of physical activity and blood sugar testing, vitality, health, glucose control, and body weight at baseline (T1) and after 12 months (T2) ($N = 108$)

Variable	M ± SD	M ± SD	Effect size (95% CI)* Cohen's d†	Cronbach's Alpha	
	T1	T2	T1–T2	T1	T2
Total needs satisfaction in physical activity				0.93	0.96
Intervention group	4.80 ± 1.33	5.69 ± 0.99	0.90 (0.73 to 1.07)		
Control group	4.71 ± 1.27	4.66 ± 1.25	−0.05 (−0.22 to 0.12)		
Autonomous motivation for physical activity				0.95	0.97
Intervention group	4.17 ± 1.79	5.00 ± 1.51	0.70 (0.46 to 0.94)		
Control group	4.32 ± 1.53	4.27 ± 1.76	−0.04 (−0.28 to 0.24)		
Controlled motivation for physical activity				0.79	0.80
Intervention group	3.16 ± 1.15	3.64 ± 1.25	0.46 (0.23 to 0.69)		
Control group	2.96 ± 0.99	3.05 ± 1.29	0.08 (−0.15 to 0.31)		
Perceived competence for physical activity				0.92	0.95
Intervention group	5.06 ± 1.41	5.19 ± 1.48	0.09 (−0.17 to 0.35)		
Control group	4.81 ± 1.34	4.30 ± 1.57	−0.35 (−0.61 to −0.09)		
Perceived competence for blood sugar testing				0.90	0.83
Intervention group	5.64 ± 1.36	5.68 ± 1.25	0.03 (−0.25 to 0.31)		
Control group	5.70 ± 1.27	5.43 ± 1.06	−0.23 (−0.51 to 0.05)		
Performance of physical activity				0.96	0.96
Intervention group	3.82 ± 1.50	4.62 ± 1.34	0.74 (0.54 to 0.94)		
Control group	3.86 ± 1.30	3.85 ± 1.49	−0.01 (−0.21 to 0.19)		
Performance of regular blood sugar testing				0.95	0.94
Intervention group	4.17 ± 1.53	4.36 ± 1.37	0.17 (−0.03 to 0.37)		
Control group	4.51 ± 1.47	4.00 ± 1.21	−0.48 (−0.68 to −0.28)		
Vitality				0.93	0.94
Intervention group	4.56 ± 1.34	4.88 ± 1.16	0.37 (0.15 to 0.59)		
Control group	4.34 ± 1.46	4.31 ± 1.39	−0.03 (−0.25 to 0.22)		
Perceived health				0.78	0.87
Intervention group	2.88 ± 0.72	3.28 ± 0.85	0.61 (0.49 to 0.73)		
Control group	2.85 ± 0.73	2.93 ± 1.06	0.11 (−0.01 to 0.23)		
Glucose control (HbA1c)				–	–
Intervention group	7.83 ± 1.58	7.57 ± 1.41	−0.22 (−0.40 to −0.04)		
Control group	7.44 ± 0.97	7.56 ± 1.23	0.13 (−0.05 to 0.31)		
Body weight (kg)				–	–
Intervention group	90.83 ± 15.03	89.46 ± 15.17	−0.45 (−3.19 to 2.29)		
Control group	86.99 ± 19.44	87.30 ± 20.13	0.08 (−2.66 to 2.82)		

*95% CI = effect size ± (SE × 1.96). SE = standard error of the mean of measurement used in calculating of Cohen's d.

†Difference or change given in SD; 0.20 = small, 0.50 = moderate, 0.80 = large (Cohen, 1992).

Averaged means from five multiple imputated datasets. Number of participants are 51 in the control group and 57 in the intervention group. Effect sizes are calculated by using equation 4 in Morris (2008).

competence and autonomy); and (d) encouraging participants to keep a training diary for their self-training. The diaries of participants' self-training were used as a basis for giving positive and constructive feedback in an informative way by acknowledging their training efforts, suggesting ideas for self-training if needed, and proposing alternative activities that were better adapted to their individual interests if existing ones did not seem desirable (i.e., intended to mainly support the needs for competence and autonomy); and (e) focusing on learning the names of participants, and seeing and including all participants in the organized activities (i.e., intended to support the need for relatedness).

The control group was encouraged to continue their PA as before, but did not receive the organized PA intervention. Control group participants did not meet with the PA instructors. Participants in both groups had access to their medical doctors as they had before.

Completers vs dropouts

Before the original dataset was imputed, we analyzed completers vs dropouts of the study. Of the 89 participants who responded to the survey at baseline, 12 dropped out of the experimental group and 14 dropped out of the control group from T1 to T2. Thus, 63 participants completed the survey at both times. We used logistic regression to predict study continuation (0 = completers and 1 = dropouts) from experimental conditions and the 11 study variables measured at T1, and analysis of variance (ANOVA) to analyze whether dropouts differed from completers on demographics. Results indicated that randomization to the intervention or the control group did not predict dropout, $B = 0.44$ (Wald = 0.86), $P = 0.35$. Three of the 11 baseline variables did predict dropout, including lower perceived autonomy support, $B = -0.52$ (Wald = 7.18), $P = 0.007$, lower need satisfaction, $B = -0.53$ (Wald = 5.70), $P = 0.017$, and lower autonomous motivation, $B = -0.42$ (Wald = 4.60), $P = 0.032$. Among completers, the experimental and control groups were not significantly different in baseline measures (logistic regression). There were, however, significant gender differences in the make-up of the two groups, $\chi^2 = 6.86$, df = 1, $P = 0.009$, with relatively more males in the experimental group ($n = 32$) than in the control group ($n = 18$) and relatively more females in the control group ($n = 10$) than in the experimental group ($n = 3$).

Table 2. Correlations* among variables of change† T1→T2 ($N = 108$)

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
1. Intervention*	–																
2. Autonomy support for PA	**0.44**	–															
3. Competence need in PA	**0.62**	**0.64**	–														
4. Autonomy need in PA	**0.34**	**0.45**	**0.62**	–													
5. Social-relatedness need in PA	**0.54**	**0.42**	**0.51**	**0.36**	–												
6. Total needs satisfaction in PA	**0.58**	**0.58**	**0.88**	**0.81**	**0.75**	–											
7. Autonomous motivation for PA	**0.37**	**0.32**	**0.50**	**0.54**	**0.38**	**0.58**	–										
8. PC for physical activity	**0.29**	**0.62**	**0.61**	**0.55**	**0.33**	**0.61**	**0.57**	–									
9. PC for blood sugar testing	**0.35**	**0.34**	**0.44**	**0.16**	**0.36**	**0.33**	**0.33**	**0.40**	–								
10. Performance of physical activity	**0.42**	**0.37**	**0.63**	**0.50**	**0.39**	**0.61**	**0.57**	**0.57**	**0.25**	–							
11. Performance of blood sugar testing	**0.29**	**0.17**	**0.36**	0.05	**0.16**	**0.21**	**0.32**	**0.29**	**0.72**	**0.21**	–						
12. Vitality	**0.37**	0.03	**0.29**	0.09	**0.33**	**0.19**	**0.17**	**0.20**	**0.20**	**0.31**	**0.20**	–					
13. Perceived health	**0.31**	0.04	**0.39**	**0.29**	**0.17**	**0.27**	**0.24**	**0.35**	**0.20**	**0.28**	**0.30**	**0.54**	–				
14. Glucose control (HbA1c)	−0.12	**−0.26**	**−0.31**	**−0.31**	**−0.23**	**−0.38**	**−0.17**	−0.13	**−0.25**	**−0.25**	**−0.32**	0.04	−0.11	–			
15. Body weight	−0.12	−0.01	**−0.27**	**−0.16**	−0.05	**−0.22**	**−0.21**	−0.05	−0.03	**−0.16**	−0.04	0.14	**−0.18**	**0.35**	–		
16. Gender*	**−0.20**	−0.14	**−0.20**	0.00	−0.09	−0.09	−0.09	−0.11	−0.04	**−0.16**	−0.14	−0.02	−0.02	0.02	0.10	–	
17. Age	0.01	**0.16**	**0.27**	**0.22**	**0.17**	0.11	0.03	0.12	−0.01	−0.09	0.06	−0.04	0.06	−0.11	−0.06	−0.02	–

*Pearson correlations, except Spearman's point-biserial correlations are used between the intervention and gender, respectively, and all other variables.

†Change scores (standardized residuals) were created by regression of T2 measures onto T1 measures.

Correlations in bold are significant at least at $P < 0.05$. For gender: 1 = males; 2 = females.

Table 3. ANOVA of study variables

Effects	F	Effect size Cohen's d
Total need satisfaction in PA		
Intervention	7.80**	0.72
Time (T1 and T2)	10.02**	
Intervention × time	20.68***	
Autonomous motivation for PA		
Intervention	1.44	0.52
Time (T1 and T2)	5.39*	
Intervention × time	10.60***	
Controlled motivation for PA		
Intervention	5.61*	0.36
Time (T1 and T2)	10.18**	
Intervention × time	2.22	
Perceived competence for physical activity		
Intervention	5.28*	0.46
Time (T1 and T2)	2.85	
Intervention × time	6.80**	
Perceived competence for blood sugar testing		
Intervention	0.28	0.23
Time (T1 and T2)	2.49	
Intervention × time	3.30*	
Performance of physical activity		
Intervention	3.39	0.57
Time (T1 and T2)	12.58***	
Intervention × time	15.15***	
Performance of blood sugar testing		
Intervention	0.04	0.46
Time (T1 and T2)	2.93	
Intervention × time	4.86*	
Vitality		
Intervention	4.04*	0.25
Time (T1 and T2)	0.92	
Intervention × time	4.80*	
Perceived health		
Intervention	4.70*	0.41
Time (T1 and T2)	4.35*	
Intervention × time	4.80*	
Glucose control (HbA1c)		
Intervention	0.73	−0.28
Time (T1 and T2)	1.14	
Intervention × time	3.71*	
Body weight		
Intervention	1.01	−0.10
Time (T1 and T2)	2.34	
Intervention × time	1.99	

$^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

Averaged F-values from five imputated datasets. $N = 108$. For predicted intervention × time effects one-tailed tests of significance are used. Effect sizes are calculated by using equation 8 in Morris & DeShon (2008).

Measurements

Translation of measures and their reliability

All questionnaire measures described below were translated into Norwegian, and back-translated into English, and adapted following the procedures suggested by Beaton et al. (2000). Baseline and 12-month reliabilities of these scales are presented in Table 1.

Adherence to the PA program was registered every training session. Thus, the adherence percent is estimated in relation to all 156 PA sessions over the year. Of the 57 participants in the intervention group, 10 (9.3%) attended less than 40% (about 1 PA session/week; value 1), 27 (25.0%) attended from 40% to 70% (about 2 PA sessions/week; value 2), and 20 (18.5%) attended more than 70% (about 3 PA sessions/week; value 3) of the PA sessions. In the intervention group, this adherence variable was used as a covariate in relation to the 11 outcome variables separately in different ANOVAs but did not have any significant effect on any of the motivation, performance, or health outcomes. Thus, we included all participants in the analyses.

Perceived autonomy support for physical activity (T1 and T2)

Perceived autonomy support was measured as an indicator that the intervention was experienced as more need-supportive by those in the intervention group (i.e., as a manipulation check), and it was measured with the six-item version of the Health-Care Climate Questionnaire (Williams et al., 1996). The following stem preceded the six items: The following questions concern your experience of important physical activity and health professionals for your CAD and DM2. It could be persons who recommend physical activities or manage physical activities you take part in, as for instance medical doctors, supervisors, physical activity instructors, or others who recommend physical activities and you may discuss it with. Based on whom you have been related to, your answers can be related to one of these persons, a few, or all of them. Different persons may do this in different ways. In the questions below, we define these persons as "YOUR HEALTH TEAM." By using this procedure to measure autonomy support, the main difference in the health team between conditions was expected to be the PA instructors for participants in the intervention group. A sample item is: "I feel that my health team has provided me choices and options in relation to my physical activity." Responded to on a 1 (*strongly disagree*) to 7 (*strongly agree*) scale, this measure indexed whether the intervention increased participants' perceptions of autonomy support.

Basic psychological need satisfaction in physical activity (*T1* and *T2*) was measured with the Basic Psychological Need Satisfaction in Exercise Scale (Vlachopoulos & Michalidiou, 2006). It consists of 12 items intended to measure satisfaction of the three basic needs for competence, autonomy, and social relatedness with four items each. Participants responded to the items following this stem: "When you are physically active, how untrue or true are the following statements?" Sample items are as follows: "I feel that I associate with the other physical activity participants in a very pleasant way" (relatedness need), "I feel that I can manage the requirements of the training program I am involved in" (competence need), and "I feel that the way I'm physically active is definitely an expression of myself" (autonomy need). Responses were rated from 1 (*not at all true*) to 7 (*very true*). The sum of the three needs was termed total need satisfaction in PA.

Autonomous and controlled motivation for physical activity (*T1* and *T2*) was measured with the 18-item Treatment Self-Regulation Scale (TSRQ) for PA (Levesque et al., 2007) somewhat modified to fit the context of this study. Participants responded to the items following this stem: "I am physically active: …." A total of six integrated motivation items were asked. A sample item is: "Because it feels natural for me to do it." A total of six identified motivation items were asked. A sample item is "Because I want to take responsibility for my own health." A total of three introjection motivation items were asked. A sample item is "Because I'll feel bad about myself if I don't do it." A total of three external motivation items were asked. A sample item is "Because I don't want others to be dissatisfied with me." The items were rated from 1 (*not at all true*) to 7 (*very true*). The averaged sum of integrated and identified regulation items formed the autonomous motivation variable, whereas the averaged sum of introjected and external regulation items formed the controlled motivation variable.

Perceived competence for physical activity and perceived competence for blood sugar testing (*T1* and *T2*) was measured with eight items including two 4-item Perceived Competence Scales previously used in diabetes self-care studies (Williams et al., 1998), and in this study adapted to PA and regular blood sugar testing, respectively. A sample item is "I feel confident in my ability to [be regularly physically active/regularly test my blood sugar]." Participants responded using a scale from 1 (*strongly disagree*) to 7 (*strongly agree*).

Performance of physical activity and blood sugar testing (*T1* and *T2*) was measured with two 10-item scales adapted from Kuvaas (2006). Sample items are "I'll often put in extra time and effort to [be regularly physically active/to regularly test my blood sugar]," and "Compared with what can be expected of persons with DM2 and CAD [my physical activity is performed well according to medical recommendations/my blood sugar testing is performed well according to medical recommendations]." It is the joint effect of effort (5 items) and quality (5 items) that is intended to constitute the performance measures of physical activity and blood sugar testing. Participants responded using a scale from 1 (*does not suit me at all*) to 7 (*suits me very well*). Validity indications for the performance of PA measure in the present study is related to a treadmill direct measure of VO_{2peak} (at baseline and after 12 months) in the first publication based on the present data (Byrkjeland et al., 2015), in which gas exchange and ventilator variables were continuously measured by breathing into a Hans Rudolph two-way breathing mask (2700 Series; Hans Rudolph, Inc., Kansas City, Missouri, USA), connected to a metabolic cart (Vmax SensorMedics, Yorba Linda, California, USA). Performance of PA at baseline was significantly associated with VO_{2peak} (mL/kg/min) at baseline ($r = 0.25$, $P < 0.01$) and predicted VO_{2peak} after 12 months ($r = 0.38$, $P < 0.001$). More important, the measure of performance of PA predicted change in VO_{2peak} over 12 months ($r = 0.32$, $P < 0.002$). In addition, the Cronbach's alpha coefficient was 0.96 at both baseline and at 12 months for this performance of PA measure. Thus, the data indicate that this measure is both reliable and valid.

Perceived Health (*T1* and *T2*) was measured with four questions. The first two questions are from SF-36 (Ware & Sherbourne, 1992). Sample item: "How would you say your health is now?" The third and fourth questions are from a Swedish study (Femia et al., 2001). Sample item: "How would you evaluate your health in relation to others of your own age?" Participants responded using a scale from 1 (*bad*) to 5 (*excellent*).

Vitality (*T1* and *T2*) was assessed with the 6-item Subjective Vitality Scale (SVS; Ryan & Frederick, 1997). A sample item is: "I feel alive and vital." This scale was administrated with the instruction: "Please respond to the following statements by indicating the extent to which the statement is true for you in general in your life." Participants responded using a scale from 1 (*Not at all true*) to 7 (*Very true*).

Glucose control (HbA1c)

Blood samples were drawn by standard venipuncture between 08:00 h and 10:00 h after overnight fast and without medication taken since the preceding evening. HbA1c was measured by turbidimetric inhibition immunoassay (Roche, Basel, Switzerland), and the lower the score the better is the glucose control.

Body weight was measured without shoes and with light clothing, using the same weight for all participants both at baseline and 12 months.

Results

Preliminary analyses

Table 1 shows the means, standard deviations, effect sizes, and reliability for all variables at T1 and T2. High levels of internal consistency (Cronbach's alpha) emerged (0.78–0.97). In addition, the alpha coefficients for autonomy support was 0.93 (T1) and 0.94 (T2).

Table 2 shows that the pattern of bivariate correlations is fully in line with the SDT process model (see the FIML/SEM results presented in Fig. 2). For the non-parametric comparisons in Table 2, Spearman's point-biserial correlations were used between the intervention and gender, respectively, and all other variables. Pearson correlations were applied for the relations between all other variables. To be more specific regarding the gender variable, relatively more males had been allocated to the intervention ($n = 52$) than to the control group ($n = 39$), whereas relatively more females had been allocated to the control ($n = 12$) than to the intervention group ($n = 5$) ($r = -0.20$, $P < 0.05$). Compared with females, male participants did also report a higher competence need satisfaction ($r = -0.20$, $P < 0.05$) and PA ($r = -0.16$, $P < 0.05$). Regarding age, older participants reported a somewhat higher autonomy support ($r = 0.16$, $P < 0.05$) and need satisfaction (rs = 0.17–0.27, $P < 0.05$) than younger participants.

Participants in the intervention group experienced a significantly greater increase in autonomy support over 12 months (Pooled $M_{Change} = 0.25$, $n = 57$) compared with the control group ($M_{Change} = -0.25$, $n = 51$); ($t = 2.00$, df = 107, $P < 0.05$; $M_{difference} = 0.50$, SE = 0.24; 95% CI [0.03, 0.97]). These results suggest that the intervention was experienced as autonomy supportive.

Test of the experimental hypothesis

Repeated-measures multivariate analysis of variance (MANOVA) was used to examine the hypothesis for the 11 repeated-measures-dependent variables, followed by 11 repeated-measures analyses of variance (ANOVA). For the MANOVA, the intervention vs control group was the between-group factor crossed with the 11 T1 and T2 assessments as the repeated-measures factor. The analysis yielded two main effects and one interaction. For *condition*, $F(11,108) = 2.09$, $P < 0.05$; for *time*, $F(11,108) = 5.40$, $P < 0.001$; and for the interaction of condition by

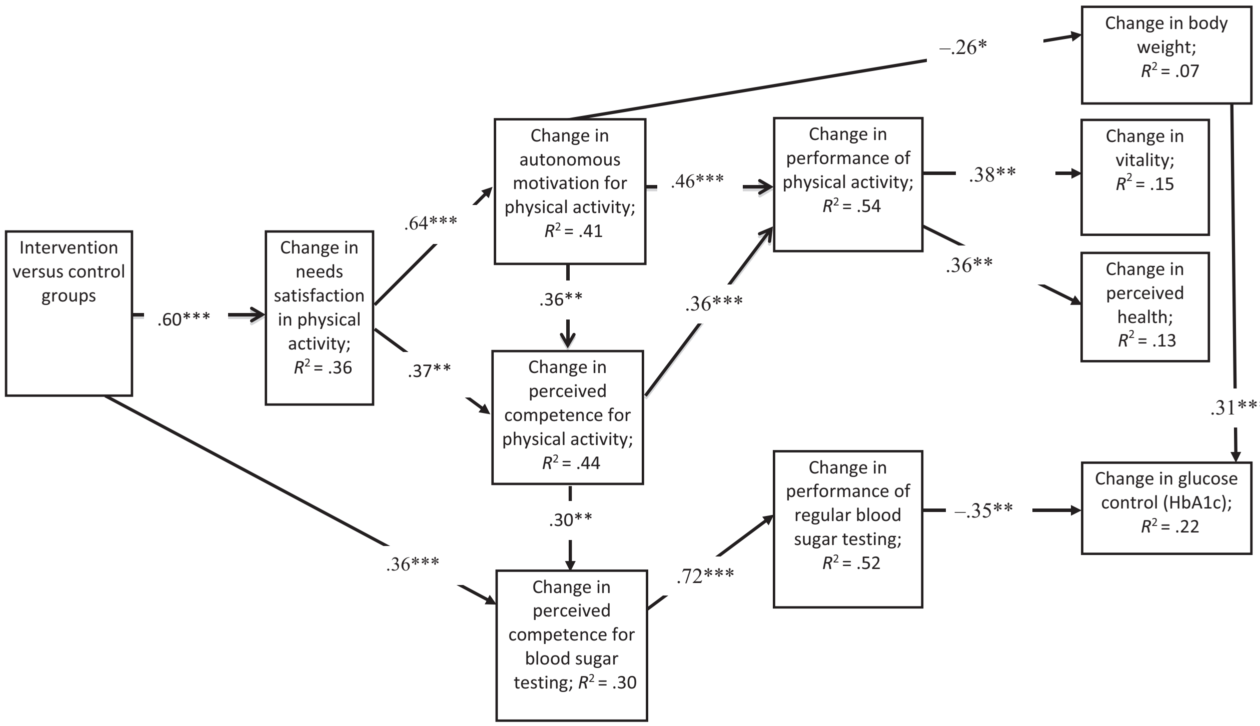

Fig. 2. Self-determination theory (SDT) process path model with standardized parameter estimates based on averaged observed (manifest) variables [χ^2 (df = 41; N = 108) = 55.33, P = 0.067; χ^2/df = 1.35; CFI = 0.96; IFI = 0.96; RMSEA = 0.057]. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

time, $F(11,108) = 3.10$, $P < 0.001$.[2] The significant interaction effect of condition by time indicates that the intervention group changed more positively from T1 to T2 than did the control group, thus, supporting our experimental hypothesis.

Results of repeated-measures ANOVAs (see Table 3) yielded nine significant interactions of the intervention by time. The ANOVA results indicated that the experimental group increased, while the control group remained the same on needs satisfaction, autonomous motivation, PA, vitality, and perceived health, and that the experimental group reduced and the control group remained the same on HbA1c. Further, the experimental group remained the same while the control group reduced their scores on PC for PA, PC for blood sugar testing, and performance of blood sugar testing. These results support the study hypotheses. The interactions of intervention by time for controlled motivation and body weight were not significant. The first hypothesis was significantly supported for all variables except body weight and controlled motivation. Because controlled motivation for PA was not significantly correlated with performance of PA or any of the four outcomes, controlled motivation was not included in the path analysis.

Test of the SDT path model of changes in behavior and health variables

Because the sample size was small, we used path analysis with observed (manifest) averaged variables in AMOS 22 to test the model illustrated in Fig. 2. Age, gender, and adherence were used as auxiliary variables in the FIML estimation. A good fit of the model tested should have a value close to or lower than 0.06 for the Root Mean Square Error of Approximation (RMSEA), and a value close to or higher than 0.95 for the Comparative Fit Index (CFI) and the Incremental Fit Index (IFI). In addition, the chi-square likelihood ratio (χ^2) should have a P-value ≥0.05 and the χ^2/df should be lower than 2 (Bollen, 1989; Hu & Bentler, 1999).

The hypothesized path model yielded acceptable fit for all indices: [χ^2 (df = 41; N = 108) = 55.33, P = 0.067; χ^2/df = 1.35; CFI = 0.96; IFI = 0.96;

[2]Collapsing several variables measured with different scales in repeated-measures MANOVA may interfere with the results. However, running repeated-measures MANOVAs for dependent motivation variables, behavior variables, or health variables as separate outcomes produced exactly the same significant results: For the five motivation outcomes the results were as follows: for *condition*, $F(5,108) = 2.81$, $P < 0.05$; for *time*, $F(5,108) = 3.26$, $P < 0.01$; and for the interaction of condition by time, $F(5,108) = 6.58$, $P < 0.001$. For the two behavior variables, the results were as follows: for *condition*, $F(2,108) = 2.00$, $P > 0.05$; for *time*, $F(2,108) = 10.31$, $P < 0.001$; and for the interaction of condition by time, $F(2,108) = 7.54$, $P < 0.001$. For the four health outcomes, the results were as follows: for *condition*, $F(4,108) = 1.76$, $P > 0.05$; for *time*, $F(2,108) = 2.34$, $P > 0.05$; and for the interaction of condition by time, $F(2,108) = 2.94$, $P < 0.05$.

RMSEA = 0.057]. In this model, all hypothesized links were supported, except the non-significant path from performance of physical activity to body weight, which was not illustrated in Fig. 2. The standardized regression coefficients are illustrated in Fig. 2.

Tests of indirect links

The indirect associations in Fig. 2 were estimated with RMediation (Tofighi & MacKinnon, 2011). RMediation build confidence intervals (CIs) for mediated or indirect effects (i.e., the product of two regression coefficients). Among other methods, RMediation use the distribution-of-the-product method which has the best statistical performance of existing methods for building CIs for mediated or indirect effects (Tofighi & MacKinnon, 2011). RMediation results indicated that the intervention enhanced both autonomous motivation for PA ($B = 0.81$, SE = 0.18, 95% CI [0.48, 1.20]) and PC for PA ($B = 0.42$, SE = 0.17, 95% CI [0.12, 0.77]) through need satisfaction in PA. Further, indirect links were found between need satisfaction in PA and performance in PA both through autonomous motivation for PA ($B = 0.30$, SE = 0.08, 95% CI [0.16, 0.47]) and PC for PA ($B = 0.13$, SE = 0.06, 95% CI [0.03, 0.27]), between need satisfaction and PC for blood sugar testing ($B = 0.11$, SE = 0.06, 95% CI [0.01, 0.26]) through PC for PA, as well as between the intervention and performance in blood sugar testing ($B = 0.67$, SE = 0.18, 95% CI [0.34, 1.05]), through PC for blood sugar testing. Further, indirect links were found from autonomous motivation for PA to PC for blood sugar testing ($B = 0.11$, SE = 0.06, 95% CI [0.01, 0.26]) through PC for PA, and from PC for PA to performance of blood sugar testing ($B = 0.22$, SE = 0.10, 95% CI [0.02, 0.43]) through PC for blood sugar testing. In addition, the indirect links from autonomous motivation for PA, PC for PA and blood sugar testing to the four outcome variables through the two behavior variables were significantly supported: (a) Autonomous motivation for PA was indirectly related to perceived vitality ($B = 0.18$, SE = 0.07, 95% CI [0.06, 0.33]) and perceived health ($B = 0.18$, SE = 0.07, 95% CI [0.06, 0.34]) through performance in PA, and to glucose control ($B = -0.01$, SE = 0.040, 95% CI [−0.02, −0.01]) through body weight; (b) PC for PA was indirectly related to perceived vitality ($B = 0.14$, SE = 0.06, 95% CI [0.04, 0.28]) and perceived health ($B = 0.14$, SE = 0.07, 95% CI [0.03, 0.28]) through performance in PA; (c) PC for blood sugar testing was indirectly related to glucose control ($B = -0.20$, SE = 0.08, 95% CI [−0.37, −0.05]) through performance of blood sugar testing.

Intention-to-treat analysis

To treat missing data, we evaluated the method of "last observation carried forward." However, this method has been severely criticized as described by Moher et al. (2010) in the CONSORT 2010 guidelines. We, therefore, used the recommended alternative FIML (Full Information Maximum Likelihood) approach to impute missing data (Allison, 2003), using gender, age, and adherence as auxiliary variables. This approach resulted in an imputed dataset with 108 respondents, which is the closest we can come intention-to-treat analysis when combining the motivation and medical/physiological variables in this study—in which the intervention produced significant improvements in all variables, except controlled motivation and body weight. Very few PA interventions have been conducted in participants with both DM and CAD, and these results are novel.

Discussion

This is the first RCT with patients with diabetes and coronary artery disease showing that a PA intervention designed to be supportive of patients' psychological needs for autonomy, competence, and relatedness demonstrated increases in performance of PA, performance of blood sugar testing, vitality, perceived health, and decreases in HbA1c—all at the same time. This is also the first time that satisfaction of the basic psychological needs, motivation, and PC were shown to indirectly account for how patients with diabetes increased their vitality and perceived health, as well as decreased their HbA1c and body weight. Thus, this study identifies satisfaction of basic motivational needs, internalization of autonomous self-regulation, and perceived competence as psychological mechanisms by which physical and mental health can be improved.

The goal of this research was first to examine the effects of the intervention on self-determined motivation, health behaviors, and health among CAD and DM2 patients. The second goal was to examine if the SDT Model for Health Behavior Change could account for the effect of the intervention on changes in vitality, health, body weight, and glucose control. The experimental model was supported for 9 of 11 outcome variables. The intervention led to significant increases in need satisfaction, autonomous motivation, PC for PA and blood sugar testing, as well as performance of PA, regular blood sugar testing, perceived health and vitality, and decreases in HbA1c.

Using path analysis, the data were found to support the SDT process model, in which the intervention significantly predicted indirect changes in autonomous motivation for PA and PC for PA through need satisfaction in PA. In addition, need satisfaction was indirectly linked to performance of PA through the two motivation variables (autonomous motivation for PA and perceived competence for PA). Further, the indirect links from the two motivation variables to changes in vitality and perceived health through PA were significantly supported. As such, this study adds to the randomized trials that have shown improvements in health-related behaviors for the general population, including decreased tobacco use, and lifestyle to lower cholesterol (Williams et al., 2006a,b), and greater PA and weight loss (Fortier et al., 2007; Silva et al., 2011). The intervention did also influence blood sugar testing through PC for blood sugar testing, and change in performance of blood sugar testing increased glucose control (i.e., decreased HbA1c). Perceived competence for blood sugar testing was itself significantly negatively correlated with HbA1c as predicted and further supports previous work identifying this link (Williams et al., 2005). Further, the change in blood sugar testing mediated this link. Increase in autonomous motivation's relations to increases in perceived health and vitality were indirect effects through the increase in performance of PA. The intervention involved the use of structured physical activities for the patient, but the important aspects of the intervention were those designed to facilitate satisfaction of the basic psychological needs. For example, it provided considerable choice about program elements, schedules, and required levels of exertion, as well as support for mastery of specific training activities and positive and constructive feedback.

These results did provide support for the SDT process model of health-behavior change. Several studies have shown that maintained healthy behaviors result when interventions are experienced as need-supportive and satisfy the basic psychological needs. Need satisfaction and autonomy support correlated strongly ($r = 0.58$), and both constructs have led to enhanced autonomous motivation and perceived competence for healthy behaviors. Autonomous motivation has been found to facilitate perceived competence for the target behaviors, so the links from autonomous motivation to healthy behaviors can be both direct and indirect through perceived competence.

The links from the intervention to increases in motivation variables, behaviors, vitality, perceived health, and decreases in HbA1c may be suggested to be causal pathways because the study was designed as a randomized controlled trial. However, the links between changes in motivation, behavior, and health variables are not proven to be causal because these variables were assessed at the same time. Thus, further study of these pathways is needed.

The hypotheses not supported were the two involving body weight, i.e., that participants in the intervention group would decrease their body weight as compared to control group participants, and that increases in physical activity would be associated with decreases in body weight. However, rethinking the rationale for these hypotheses, we would not necessarily expect body weight to be decreased if the participants were not overweight at baseline measures. Actually, as we had measures of body mass index (BMI), these measures indicated that participants were somewhat overweight (BMI = 29.10, SD = 5.07). However, baseline BMI did not moderate the effect of the intervention on body weight, indicating that those more overweight did not decrease their body weight more than participants with relatively normal BMI. The lack of an effect on body weight in this study could also be due to a lack of sufficient intensity, frequency, or duration of PA in the intervention.

According to SDT (Deci & Ryan, 2000), competence need satisfaction is not the same as the motivational variable perceived competence, just as autonomy need satisfaction is not the same as autonomous motivation. The shared variance between these two needs and the two motivation variables are not too high (rs = 0.50–0.61, see Table 2), indicating explained variances from 25% to 37%. Based on SDT, we hypothesized that environmental nutriments have the potential to satisfy these needs, and if satisfied, they would lead to increased autonomous motivation and perceived competence for the target behavior. The correlations and path analyses supported these hypotheses.

These findings are consistent with findings from a cross-sectional prospective study by Russell and Bray (2009), which demonstrated that following completion of cardiac rehabilitation, satisfaction of the need for competence was associated with self-determined motivation for physical activity, which, in turn, was positively correlated with physical activity frequency and duration. Research by Vlachopoulos and Neikou (2007) also supports the significance of the higher levels of competence need satisfaction—which predicted exercise attendance at a fitness center. In addition, the need for competence significantly positively predicted completion of the program. A systematic literature review (Teixeira et al., 2012) of 66 empirical studies on SDT and PA from 2012 found that satisfaction of the need for competence positively predicts PA. Previous studies of cardiac patients specifically (Kubitz, 2010; Russell & Bray, 2010; Sweet et al., 2010) also found that autonomous regulations for PA positively predicted PA. Sweet et al. (2010) observed that patients with controlled regulation, more frequently than those with more autonomous motivation, decreased their levels of PA over time. In sum, these studies have consistently found that satisfaction of the needs for competence and autonomy leads to enhanced autonomous motivation and increased PA. These previous findings are supported with the results of this study and extend them by demonstrating that they are present in a randomized controlled trial with patients who have DM2 and CAD.

This trial resulted in a significant increase in vitality (modest effect size) that is partially attributable to increases in need satisfaction and autonomous motivation. This is the first SDT-based intervention in a population with chronic disease that demonstrates an improvement in vitality and HbA1c in addition to indirect improvements in the targeted health behaviors. We recommend future studies include measurement of vitality, other well-being constructs such as pleasure and positive affect, and the targeted health behaviors to fully assess the benefit of SDT-based interventions.

Pleasure and positive affect might be both interesting and important to include because these constructs are influenced by different intensities during physical activity and exercise, and the memory of a pleasant experience may, therefore, affect positive changes in motivation for physical activity and future engagement (Ekkekakis et al., 2011). Pleasure is reduced mainly at high-intensity physical activity (i.e., above lactate threshold) and yield large inter-individual variability close to this threshold. Conversely, subthreshold intensities are related to pleasant changes. When the intensity is self-selected, rather than imposed, pleasure is associated with higher intensities (Ekkekakis et al., 2011). In the present study, 5–15 min of the 60-min PA sessions was of high intensity (RPE ≥15 and 94% of the average peak heart rate) in which blood lactate may accumulate, which may interfere negatively with motivation for physical activity and future PA. Thus, high-intensity PA might have reduced the experienced pleasure from the physical activity, and thereby reduced motivation for physical activity among participants. This might have reduced the potential positive effect of the intervention. Thus, future research should be designed in order to be able to control for the intensity factor of physical activity.

In this study, the majority of participants were men, which correspond to figures indicating that women are underdiagnosed for CAD (Norwegian Institute of Public Health, 2014). In addition, the age range was large (41–81 years), and one may wonder if the older age of the sample may have affected the results? Age was significantly positively associated with need satisfaction, so an older age may have affected the outcomes positively through a higher need satisfaction in physical activity (Table 2). A recent RCT indicated that physical activity among older adults (M = 74.3 years) affected positive changes in autonomous motivation and perceived competence, which both affected change in vitality over 16 weeks (Solberg et al., 2013). Thus, studies on physical activity and SDT constructs may function particularly well among older adults.

A recent publication based on the current dataset found the trial partly effective as it improved anaerobic threshold and "time to exhaustion," but did not improve glucose control and VO_{2peak} (Byrkjeland et al., 2015). However, in this study, focusing on motivation variables in addition to body weight and glucose control, 29 participants refused to complete motivational measures. Thus, compared with the Byrkjeland et al. (2014) sample, the present sample might have been more motivated for participation in the trial and thus affected significant decreases in HbA1c. This is even more plausible because these results indicate that participants who did not answer the questionnaire at T2 (i.e., dropped out of the study) had significantly lower baseline scores on perceived autonomy support, need satisfaction, and autonomous motivation. These results are consistent with results from a recent dental health trial in which motivation for participating in the trial was found to be important for changes in dental behaviors to occur (Halvari et al., 2012).

Limitations include, among others, that the data only tested mechanisms for those who attended the intervention. In addition, we cannot separate the effects of the style in which the intervention was delivered from an "attention" effect because the control group did not get an alternative exercise program. Other limitations include the use of self-reports measuring physical activity and blood sugar testing. The proportion of males in the study may be higher than in the population of those with both diabetes and cardiovascular disease, and thus could limit the generalizability of these results to men only. The high proportion of men could also reflect the under diagnosis of coronary artery disease in women. Obviously, the small sample size is a limitation making it impossible to conduct latent SEM analyses. The sample size also limits generalizability of the findings. Thus, larger studies of adequate numbers of men and women are called for to confirm these findings.

At T1, participants had only experienced initial contact with the health team of the EXCADI study, through physical tests and meetings with a doctor. By this, it is likely that the motivational variables at T1 are predominantly shaped by their earlier experience with health care. The motivational variables revealed that patients who experience greater autonomy support, need satisfaction, and autonomous motivation are more likely to remain in the intervention. These findings are in line with earlier research, which has clearly shown that greater autonomous regulation is conducive to greater long-term maintenance of physical activity behaviors (Edmunds et al., 2007; Ingledew et al., 2009). These results provide further support for core constructs of SDT predicting physical activity for those with chronic diseases that benefit from physical activity.

Practical implications

Examining behavioral interventions on a motivational level give us access to underlying psychological processes through which the interventions work. The motivational constructs, in turn, may be used as targets for more successful future interventions guided by SDT. Given that these research findings suggest that autonomous motivation, need satisfaction, and perceived competence foster positive health-related outcomes, the question becomes how can we create treatment climates that promote these processes. A need-supportive approach is predicted to be effective in increasing the chance for internalization and integration: for example, eliciting and reflecting patient perspectives, providing options and a rationale for change, supporting patient initiatives, minimizing controlling language, and remaining non-judgmental as provided in SDT interventions (Williams et al., 2009b) and in motivational interviewing approach (Patrick & Williams, 2012).

Providing a meaningful rationale for an uninteresting behavior, in a setting with support for autonomy, competence, and relatedness, is expected to facilitate internalization and integration of motivation, perceived competence, and persistence of healthy behavior. If patients have not integrated the value of physical activity with their health, programs might test whether interventions suggesting being active with their families might result in healthier outcomes and improved well-being. Participating in PA may not be experienced as pleasurable.

Our findings suggest programs which stimulate and increase competence may motivate healthy change by itself. However, other research indicates that change in perceived competence predicted relatively short-term (6 and 12 months) abstinence from tobacco, but change in autonomous motivation becomes a stronger predictor over the long-term (24-month follow-up; Williams et al., 2009a). This suggests that interventions would do well in supporting competence actively in order to create early change, when patients' needs are being supported and they are regulating autonomously as found in this trial. To promote internalization and integration of motivation for PA, health-care practitioners may inquire about how patients see physical activity fitting in with their broader life values.

Perspective

Patients with diabetes and coronary artery disease have a large burden of disease that can limit their length and quality of life. The highest goal of medicine is to improve well-being, enhance patient autonomy, and reduce discrimination (European Federation of Internal Medicine ABIM Foundation, 2002). The EXCADIA physical activity intervention demonstrates moderate to strong effects on enhancing autonomy and improvements in their physiologic (HbA1c), behavioral (physical activity and glucose monitoring), and important indicators of well-being (vitality, perceptions of health). Perhaps most interestingly, the behavior, health, vitality, body weight, and glucose control improvements were realized by enhancing subject autonomy and perceived competence in the same pattern found in SDT-based interventions for tobacco dependence, dental health, and cholesterol management (Williams et al., 2006a; Halvari et al., 2012). Thus, the EXCADIA intervention meets all the criteria of an important health intervention for a chronically ill population. These results achieve the necessary groundwork for larger effectiveness studies and implementation studies, more representative for the DM2 and CAD population, to demonstrate safety and cost-effectiveness in clinical settings for patients with these two disorders, and suggest SDT-based interventions may improve other chronic conditions as well.

Conclusion

In conclusion, the physical activity intervention (relative to the non-PA control group) was perceived as need-supportive among DM2 and CAD participants and led to increased motivation, performance, and relevant health-related outcomes. The SDT Model for Health Behavior Change was found to account for these changes in health behavior and health outcomes among patients with DM2 and CAD. This suggests that future PA interventions may benefit by training practitioners to facilitate satisfaction of their patients' needs for autonomy, competence, and relatedness in order to increase PA, well-being, and health.

Key words: Physical activity intervention, coronary artery disease and diabetes, motivation, health behavior, psychological needs, vitality, health, glucose control, body weight.

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