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RESEARCH

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Motivational and emotional correlates of physical activity and sedentary behavior after cardiac rehabilitation: an observational study

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Abstract

Background The present study assessed physical activity (PA) and sedentary behavior (SB) levels and their motivational and emotional health-related correlates, in outpatients following a cardiovascular rehabilitation (CR) program, and compared these variables with those of a healthy control group.

Methods The study included 119 participants: 68 CR outpatients (M_{age} 57.76 ± 10.76; 86.76% males) and 51 control participants matched on age (M_{age} 57.35 ± 6.33 years; 45.10% males). PA and SB were assessed using accelerometers during the first week post-discharge for outpatients and during a typical week for controls. Motivational (i.e., perceived capabilities, affective and instrumental attitudes, intention, approach-avoidance tendencies) and emotional health-related variables (i.e., anxiety, depressive symptoms, fatigue, pain intensity) were measured using validated scales. PA and SB data from 17 outpatients and 42 controls were valid for analysis, resulting in a final sample of 59 participants.

Results CR outpatients engaged an average of 60.21 (±34.79) min of moderate-to-vigorous PA (MVPA), and 548.69 (±58.64) min of SB per day, with 18 more minutes of MVPA per day than controls (p = .038). Univariate and multivariate regressions indicated that positive affective attitudes were associated with higher MVPA (b = 10.32, R^2 = 0.07, p = .029), and that males spent more time in SB than females (b = 40.54, R^2 = 0.09, p = .045). Univariate and multivariate logistic regressions showed that meeting the World Health Organization's weekly guidelines for MVPA was associated with higher perceived capabilities toward PA and more positive affective attitudes (OR = 1.17, p = .030; OR = 1.26, p < .001, respectively). Interaction tests showed no significant differences in these results between outpatients and controls.

Conclusion The study highlights an association between higher perceived capabilities and positive affective attitudes toward PA with higher PA levels after outpatient CR. While these findings suggest that enhancing these

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motivational variables may be beneficial for increasing PA levels after CR, longitudinal and experimental studies are needed to further establish their role.

Keywords Exercise, Physical inactivity, Patients, Motivation, Health

Introduction

Physical activity (PA), defined as "any bodily movement produced by skeletal muscles that results in energy expenditure [1]", is a cornerstone of cardiac rehabilitation (CR) programs [2, 3]. Exercise-based CR has demonstrated numerous benefits, including improved exercise capacity, enhanced quality of life, reduced cardiovascular mortality, and a lower risk of hospital readmission [3, 4]. In contrast, sedentary behavior (SB), defined as any waking behavior characterized by an energy expenditure ≤ 1.5 Metabolic Equivalent Tasks, such as sitting and lying down [5], has been associated with various adverse health outcomes. For instance, patients with coronary artery disease who engage in high levels of SB (4–8 h per day) face a 62% higher mortality rate than those with less than 4 h of SB per day [6]. While CR programs aim to increase PA and reduce SB, many patients continue to exhibit low PA and high SB levels after discharge [7–9]. For example, six months after discharge, only 20% of CR patients met the PA guidelines of 150–300 min of moderate-to-vigorous PA (MVPA) per week [7, 10]. Additionally, Bakker et al. [9] found that cardiovascular disease patients exhibited higher SB levels both before and up to 2 months after CR compared to healthy controls. Despite the independent health effects of PA and SB [11–13], few studies have examined these behaviors concurrently. Therefore, assessing PA and SB levels in patients after CR discharge and identifying their correlates is essential.

From a dual-process perspective, two types of psychological processes are thought to influence PA behavior [14–16]. The first, deliberative processes, are intentional, effortful, controllable, or conscious [17, 18]. The second, automatic processes, are typically unconscious, effortless, unintentional, or uncontrollable [18, 19]. Contemporary theoretical frameworks of PA behavior assert that both deliberative variables (e.g., intention, perceived capabilities, attitudes) and automatic variables (e.g., approach-avoidance tendencies), along with emotional variables (e.g., fear, anxiety), play a central role in shaping PA behavior [14–16, 20]. For example, the Affect and Health Behavior Framework (AHBF) [20, 21] posits that conflicts between motivational variables—such as between the intention to be physically active and automatic tendencies toward SB—can generate negative emotional states such as fear or anxiety, which may hinder regular PA engagement. In the context of CR, Bierbauer et al. [8] found that stronger PA intentions were associated with higher levels of PA after discharge. Similarly, Bermudez et al. [2] reported that CR patients with more positive affective attitudes toward PA (i.e., viewing PA as pleasant) had higher PA intention and engaged in more light-intensity PA after discharge. Recent research also suggests that automatic motivational variables may further explain PA engagement. For instance, Chevance et al. [22] showed that a positive automatic affective evaluation of PA was significantly associated with higher PA levels ($\beta = 0.29$) after pulmonary rehabilitation. More recently, Cheval et al. [23] proposed that approach-avoidance tendencies—the automatic preparation of the organism to execute a motor response toward a behavior [24]—may partly account for PA participation following CR programs.

In addition to motivational variables, the presence of depression, anxiety, or pain has also been linked to lower levels of PA following a CR program [7]. For patients with advanced cancer, chronic kidney disease, and chronic obstructive pulmonary disease, perceived fatigue is a significant barrier to PA [25–27]. However, the relationship between fatigue, PA, and SB in patients with cardiovascular disease after CR discharge remains unclear. Overall, these studies suggest that a comprehensive perspective on PA and SB levels after CR should include both deliberative and automatic motivational variables, as well as emotional health-related variables. Despite this, the role of automatic motivational processes in regulating PA and SB among cardiovascular patients has been largely overlooked. Furthermore, while previous research has shown that emotional health-related variables are associated with PA levels [7], the relationship between these variables and SB levels remains poorly understood.

The primary objective of this study was to assess accelerometer-based PA and SB levels during the first week following a 6-week outpatient CR program. In addition, the study aimed to examine psychological factors associated with PA and SB, including motivational variables (i.e., intention, perceived capability, attitudes, and approach-avoidance tendencies) and emotional health-related variables (i.e., depressive symptoms, anxiety, fatigue, and pain intensity). A secondary objective was to compare PA and SB levels, as well as associated motivational and emotional variables, between CR outpatients and a healthy control population to understand potential differences in these factors between the two populations [23, 28].

Methods

Study design and participants

The sample size was initially estimated to ensure adequate power for detecting effects in the Improving

Physical Activity (IMPACT) trial, as detailed in the IMPACT trial protocol [23]. The IMPACT trial, carried out at Geneva University Hospitals (Switzerland), was a phase 3 single-center, placebo, triple-blind randomized controlled trial that enrolled participants from an outpatient CR program. The components of the CR program are described in Supplementary Material 1. The study was approved by the Ethics Committee of Geneva Canton, Switzerland (reference number: CCER2019-02257).

For the present study, a dataset comprising 68 CR outpatients was analyzed. Additionally, 51 community-dwelling control participants were recruited through snowball sampling. Community-dwelling participants were eligible if they were 40 years or older, matched the minimum age of the outpatients, had no contraindications to PA, and were not receiving medical care. PA and SB levels were measured using accelerometers (Actigraph GT3x+; Pensacola, USA) over seven consecutive days following discharge from the CR program for outpatients and during a similar period for control participants. Motivational and emotional health-related variables were assessed prior to measuring PA and SB for all participants.

Measures

Physical activity and sedentary behavior outcomes

Usual levels of PA, defined as the amount of time spent being physically active during a typical week of free time, were assessed using the Saltin-Grimby PA Level Scale [29]. Outpatients reported their PA levels for a typical week before the onset of the health issue that necessitated the CR. Participants were categorized into one of four groups: (a) physically inactive, (b) engaging in some PA, (c) engaging in regular PA, or (d) engaging in regular high-intensity training.

Participants were instructed to wear the accelerometer only during waking hours. Data were included if the device was worn for at least 10 h per day [30]. The Troiano (2007) algorithm, implemented in Actilife software (v. 6.13.3), was used to distinguish between wear and non-wear time. Self-reported diaries documenting the start and end times of wear were used to validate the algorithm's output. Data were included if at least four days met these criteria, including one weekend day [31]. Any participants who did not meet these criteria were excluded from the subsequent analyses. Additionally, daily PA and SB levels were self-reported using the short form of the International Physical Activity Questionnaire [32]. Accelerometer-based daily time spent engaging PA was categorized into light, moderate, vigorous, and moderate-to-vigorous intensity, with the number of steps also recorded. Accelerometer-based daily time spent in SB was used as an indicator of SB levels. The complete R script utilized for data management and analysis is accessible on Zenodo (https://doi.org/10.5281/zenodo.11064184).

Motivational variables

Perceived capabilities to engage in PA were assessed using the following item from the Patients-Reported Outcomes Measurement Information System (PROMIS [33]): "To what extent are you able to perform daily physical activities such as walking, climbing stairs, or moving a chair?". Participants answered on a scale from 1 (*not at all*) to 5 (*completely*).

Intention to be physically active was assessed using the following item: "I intend to do more PA in the near future [23]." Participants answered on a scale from 1 (*totally disagree*) to 10 (*totally agree*).

Instrumental and affective attitudes were assessed using the following two items: "Would you say PA is something …". Participants answered each item on a scale from 1 (*useless*) to 10 (*useful*) for instrumental attitudes, and from 1 (*unpleasant*) to 10 (*pleasant*) for affective attitudes [34, 35].

Automatic approach-avoidance tendencies toward PA and SB were assessed using the Visual-Approach/Avoidance-by-the-Self-Task (VAAST [36]). The VAAST protocol is explained in more detail in Supplementary Material 2.

Emotional health-related variables

Anxiety, depression, fatigue, and pain intensity were assessed using PROMIS items. Anxiety was assessed using the following two items: "In the past 7 days, I felt scared" and "In the last 7 days, I found it hard to focus on anything other than my anxiety." Participants answered each item on a scale from 1 (*never*) to 10 (*always*). Items were averaged (Pearson correlation = 0.61).

Depression was assessed using the following four items: "In the past 7 days, I felt…" "useless," "powerless," "desperate," and "depressed." Participants answered each item on a scale from 1 (*never*) to 10 (*always*). The items were averaged (Cronbach's $\alpha = 0.81$).

Fatigue was assessed using the following three items: "In the past 7 days, I felt tired," "In the last 7 days, I had a hard time starting things because I felt tired," and "In the past 7 days, how tired do you feel on average?". Participants answered each item on a scale from 1 (*not at all*) to 5 (*very much*). The items were averaged (Cronbach's $\alpha = 0.90$).

Pain intensity was assessed using the following item: "How would you rate your average pain level?". Participants answered on a scale from 1 (*no pain*) to 5 (*worst pain imaginable*).

Measures of additional health-related variables such as perceived mobility, limitations in activities of daily living, limitations in instrumental activities of daily living, global physical and mental health, life satisfaction, indication for enrollment in the outpatient CR, left ventricular ejection fraction (LVEF), maximal aerobic power (MAP), abdominal circumference, glycated hemoglobin (HbA1c), triglycerides, low-density lipoprotein (LDL) cholesterol, blood pressure, smoking, and the presence of comorbidity are described in Supplementary Material 3.

Statistical analyses

Descriptive statistical analyses

First, we conducted descriptive analyses of the participants' characteristics and compared them between the outpatient and control participants using independent *t* tests for numerical variables and chi-squared tests for categorical variables. Second, we compared outpatients' motivational and health-related characteristics measured at the beginning and end of the CR program using independent *t* tests. Third, we estimated the levels of PA and SB for seven consecutive days during the week following discharge from the CR program for the outpatients and for seven consecutive days for control participants. Fourth, we compared the levels of PA and SB in outpatients with those in control participants using independent *t* tests.

Univariate and multivariate regression analyses

First, we conducted univariate and multivariate regression analyses to examine the associations of motivational (i.e., perceived capabilities to engage in PA, intention to engage in PA, instrumental and affective attitudes toward PA, and approach-avoidance tendencies) and emotional health-related variables (i.e., depressive symptoms, anxiety, fatigue, and pain intensity) with PA and SB levels. Outpatients' motivational and emotional health-related variables measured at the end of the CR were used in the univariate and multivariate analyses. In the univariate and multivariate regression analyses, interaction terms were tested between participant type (i.e., outpatient vs. control) and the motivational and emotional health-related variables to examine whether the associations of motivational and emotional health-related variables with the levels of PA and SB differed between outpatients and control participants. The independent variables were standardized. Finally, logistic regression analyses were conducted to determine the odds ratio associated with meeting the recommended level of PA (i.e., 150 min of MVPA per week [10]) based on the motivational and emotional health-related variables. Statistical assumptions, including normality of residuals, linearity, multicollinearity, and undue influence, were checked, and met for all models using the Performance R package [37].

Results

Descriptive results

Table 1 presents the results of the sample characteristics. A total of 119 participants (68 outpatients enrolled in an CR program [86.76% males; M_{age} = 57.76 ± 10.76 years] and 51 community-dwelling control participants [45.10% males; M_{age} = 57.35 ± 6.33 years]) were included in the study. The mean outpatient LVEF was 52.87% (±10.49), and most outpatients were enrolled in the CR program for acute coronary syndrome (40.30% non-ST elevation and 26.87% ST elevation). Before the cardiovascular event that led to CR, outpatients self-reported significantly lower PA levels than control participants. At the beginning of the CR program, outpatients also reported significantly higher perceived fatigue. Additionally, outpatients self-reported a significantly higher number of IADLs, greater difficulty with mobility, lower global physical and mental health, and lower life satisfaction compared to control participants. Regarding PA-related deliberative motivational variables, outpatients had significantly lower perceived capabilities and less positive affective attitudes toward PA at the start of the CR program compared to controls. However, no statistically significant differences were observed in automatic approach-avoidance tendencies toward PA and SB between outpatients and control participants.

Physical activity and sedentary behavior levels one week after the cardiac rehabilitation

Table 2 presents the PA and SB levels for the outpatients and control participants. Valid PA and SB accelerometer data were available for only 17 out of 68 outpatients and 42 out of 51 control participants (see Fig. 1 for the flow diagram). Consequently, PA and SB levels were analyzed for 59 participants. The results showed that, on average, outpatients spent 548.69 min (±58.64) per day in SB, 211.16 min (±60.83) in light-intensity PA, 57.85 min (±34.68) in moderate-intensity PA, and 2.28 min (±3.67) in vigorous-intensity PA, during the week following CR. Thus, on average, outpatients spent 60.21 (±34.79) min per day in MVPA, with 88.2% of them meeting the recommended weekly level of 150 min of MVPA. Control participants displayed a similar overall pattern, although they spent slightly more time in light-intensity PA (253.77 ± 69.11, $p = .035$) and slightly less time in moderate-intensity PA (37.46 ± 25.03, $p = .014$). On average, control participants spent significantly less time (41.78 ± 2.088, $p = .038$) per day in MVPA compared to outpatients, with 71.4% of them meeting the recommended 150 min per week of MVPA ($p = .310$). Finally, outpatients averaged 10,083 (±4,493) steps per day, while control participants averaged 8,785 (±3,424) steps per day. However, this difference was not statistically significant ($p = .237$).

Table 1 Descriptive characteristics of the outpatients at the beginning of the cardiac rehabilitation program and before the physical activity measures for the community-dwelling participants

Characteristics N = 119	**Outpatients N = 68 (42.2%)**	**Controls N = 51 (31.7%)**	
	M (SD)	M (SD)	*P* value*
Demographics and anthropometrics			
Sex (*n*, %)			
Female	9 (13.24%)	28 (54.90%)	
Male	59 (86.74%)	23 (45.10%)	< 0.001
Age (years, *n*, %)			
< 50	14 (20.90%)	5 (9.80%)	
50–59	25 (37.31%)	31 (60.78%)	
60–69	17 (25.37%)	12 (23.53%)	
70–79	10 (14.93%)	3 (5.88%)	
> 80	1 (1.49%)	0 (0%)	0.074
Body mass index (Kg/m^2; *n*, %)			
Underweight < 18.5	0 (0%)	2 (3.92%)	
Normal 18.5–<25	19 (27.79%)	25 (49.01%)	
Overweight 25–<30	30 (45.45%)	19 (37.25%)	
Obese ≥ 30	17 (25.76%)	5 (9.80%)	0.018
Usual level of PA (*n*, %)			
Physically inactive	18 (26.47%)	3 (6.38%)	
Some PA	28 (41.18%)	18 (38.30%)	
Regular PA	20 (29.41%)	23 (48.94%)	
High training	2 (2.94%)	3 (6.38%)	0.020
Emotional health-related variables			
Anxiety [1–5]	1.79 (0.90)	1.60 (0.87)	0.243
Depressive symptoms [1–5]	1.62 (0.76)	1.58 (0.74)	0.722
Fatigue [1–5]	2.55 (1.06)	2.01 (0.85)	0.003
Pain intensity [1–5]	2.10 (2.29)	1.62 (1.89)	0.226
Additional health-related variables			
Number of ADL (*n*, %)			
No ADL	59 (86.76%)	44 (97.78%)	
> 1 ADL	9 (13.24%)	1 (2.22%)	0.094
Number of IADL (*n*, %)			
No IADL	49 (72.13%)	41 (83.67%)	
> 1 IADL	18 (26.87%)	8 (16.32%)	0.026
Mobility	3.70 (0.54)	3.95 (0.23)	0.002
Global physical health [1–5]	2.88 (0.89)	3.69 (0.82)	< 0.001
Global mental health [1–5]	3.77 (0.98)	4.10 (0.76)	0.046
Life satisfaction [1–7]	5.68 (1.26)	6.24 (0.66)	0.005
LVEF (%)	52.87 (10.49)	Na.	
MAP (Watt)	141.08 (45.08)	Na.	
Abdominal circumference (cm)	99.31 (12.02)	Na.	
HbA1c (%)	5.69 (0.74)	Na.	
Triglycerides (mmol/L)	1.59 (1.08)	Na.	
LDL (mmol/L)	2.94 (1.25)	Na.	
Systolic blood pressure (mmHg)	126.10 (14.64)	Na.	
Diastolic blood pressure (mmHg)	72.49 (8.29)	Na.	
Cigarette (pack/year)	10.82 (14.85)	Na.	
Comorbidity (*N* = 67, *n*, %)		Na.	
0	9 (13.43%)	Na.	
1	18 (26.87%)	Na.	
≥ 2	40 (59.70%)	Na.	
Indication for enrollment in the outpatient CR (*N* = 67, *n*; %)			

Table 1 (continued)

Characteristics N=119	Outpatients N=68 (42.2%)	Controls N=51 (31.7%)	
Acute coronary syndrome NSTEMI	27 (40.30)	Na.	
Acute coronary syndrome STEMI	18 (26.87)	Na.	
Acute coronary syndrome UA	4 (5.97)	Na.	
Coronary artery bypass graft surgery	7 (10.45)	Na.	
Coronary artery disease without ACS or surgery	8 (11.94)	Na.	
Heart failure	2 (2.99)	Na.	
Valvular surgery	1 (1.49)	Na.	
Motivational variables			
Perceived capabilities [1–5]	4.21 (0.97)	4.90 (0.36)	<0.001
Intention [1–10]	5.51 (1.34)	4.99 (1.50)	0.053
Instrumental attitudes [1–10]	9.09 (1.42)	9.36 (1.55)	0.325
Affective attitudes [1–10]	8.16 (2.06)	8.96 (1.60)	0.024
Approach toward PA	-34.22 (109.97)	-20.82 (63.82)	0.461
Approach toward SB	8.98 (102.38)	-20.59 (77.78)	0.111

Abbreviations: PA, physical activity; ADL, limitations in activities of daily living; IADL, limitations in instrumental activities of daily living; CR; cardiac rehabilitation; NSTEMI, non-ST elevation myocardial infarction; STEMI, ST elevation myocardial infarction; UA, unstable angina; ACS, acute coronary syndrome; LVEF, left ventricular ejection fraction; MAP, maximal aerobic power; HbA1c, fasting glycated hemoglobin; LDL, low-density lipoprotein cholesterol; SB, sedentary behaviors. Usual level of PA was assessed with the Saltin-Grimby PA Level Scale. The LVEF is considered to fall within the normal range when it is between 50% and 70% [92]. A waist circumference greater than 95 cm for men and 80 cm for women is associated with an increased risk of all-cause mortality [93]. HbA1c levels are classified as normal, or within the non-diabetic range below 5.7% [94]. Triglycerides levels are considered normal if they are below 1.7 mmol/L [95]. LDL cholesterol levels are desirable if they are below 1.8 mmol/L for individuals with coronary artery disease or other forms of atherosclerosis, and below 2.6 mmol/L for healthy individuals [96]. Systolic blood pressure is considered high if it exceeds 129 mmHg, and diastolic blood pressure is considered high if it exceeds 79 mmHg [97]. Positive score in *Approach toward PA* suggests a tendency to approach PA, while a negative score suggests a tendency to avoid PA. A positive score in *Approach toward SB* suggests a tendency to approach PA, while a negative score suggests a tendency to avoid PA. **P*-value of the difference between the outpatients and control participants

Table 2 Averaged daily physical activity and sedentary behavior levels during the first week after the cardiac rehabilitation program and during a usual week for the community-dwelling participants

Levels (min/day)	Outpatients (N=17*)	Controls (N=42*)	
	M (SD)	M (SD)	*P* value**
Sedentary behavior	548.69 (58.64)	552.26 (78.25)	0.866
Light activity	211.16 (60.83)	253.77 (69.11)	0.035
Moderate activity	57.85 (34.68)	37.46 (25.03)	0.014
Vigorous activity	2.28 (3.67)	3.66 (7.80)	0.490
MVPA	60.21 (34.79)	41.78 (28.08)	0.038
Number of steps	10083.00 (4493.27)	8785.02 (3424.07)	0.237
Meeting the weekly recommended level (150 min MVPA); *n* (%)	15 (88.24%)	30 (71.43%)	0.310

Abbreviations: M, mean; SD, standard deviation; MVPA, moderate-to-vigorous physical activity. *The sample size was reduced because some participants did not complete all the measures. ***P* value of the difference between the different participant types (outpatients vs. controls). Recommendation is of at least 150 min of MVPA per week [10]

Relationships between motivational variables and physical activity and sedentary behavior levels

Accelerometer-based MVPA and sitting time (SB) were used in the primary analyses, while accelerometer-based steps per day, self-reported MVPA, and self-reported time spent sitting were included in the secondary analyses (see Supplementary Materials 4 and 5, Tables S1>, S2, and S3). Table 3 presents the results from both univariate and multivariate regression analyses.

Deliberative motivational variables

The univariate analyses (Table 3) showed that outpatients engaged in more daily MVPA compared to controls (b=18.43, 95% CI [1.10; 35.77], R^2 adjusted=0.06, *p*=.038). Additionally, affective attitudes toward PA were positively associated with daily MVPA (b=10.32, 95% CI [1.09; 19.55], R^2 adjusted=0.07, *p*=.029). No other significant associations with daily MVPA were found. Higher perceived capabilities to engage in PA (OR=1.17, 95% CI [1.02; 1.34], *p*=.030*)*, stronger instrumental (OR=1.11, 95% CI [1.03; 1.19], *p*=.006), and affective attitudes toward PA (OR=1.26, 95% CI [1.12; 1.41], *p*<.001) increased the likelihood of meeting the recommended 150 min of weekly MVPA. No significant interactions were observed between PA or SB correlates and participant type (i.e., outpatient vs. control; *ps*>0.05, see Supplementary Material 6, Table S4).

In the multivariate analyses, affective attitudes remained significantly associated with daily MVPA (b=10.15, 95% CI [1.21; 19.09], *p*=.049) after adjusting for participant type. This model explained 12% of the variance in daily MVPA. Finally, after controlling for instrumental attitudes and participant type, perceived capabilities (OR=1.19, 95% CI [1.05; 1.35], *p*=.007) and affective attitudes toward PA (OR=1.24, 95% CI [1.06;

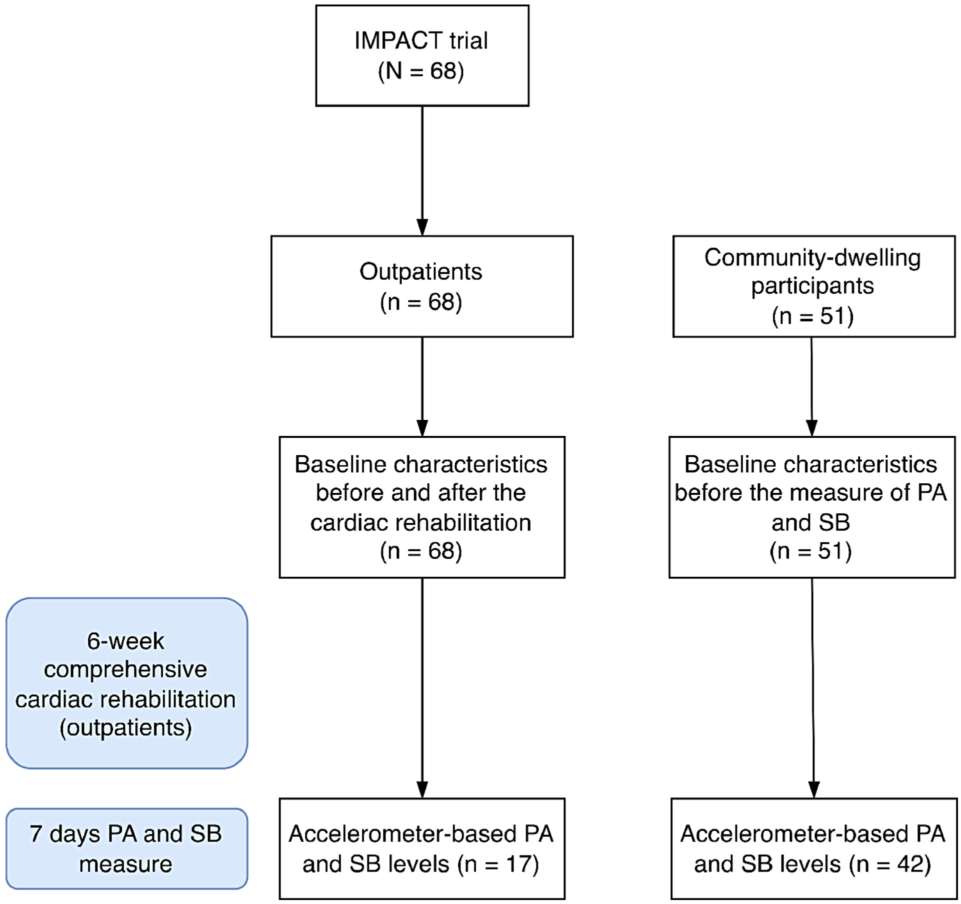

Fig. 1 Flow Diagram of the Study Protocol. Abbreviations: PA, physical activity; SB, sedentary behavior. The data for outpatients comes from the Improving Physical Activity (IMPACT) trial [23]. Outpatients followed a CR program that included exercise sessions every weekday for six weeks (see Supplementary Material 1 for further details). In addition, the program included 12 therapeutic patient education sessions addressing lifestyle modification, dietary advice, smoking cessation, stress management, and psychological support. Baseline characteristics included demographics and anthropometrics information, usual level of PA, number of limitations in activities of daily living, of limitations in instrumental activities of daily living), mobility, motivational and health-related variables, and health-related information

1.45], p=.011) remained significantly associated with an increased likelihood of meeting the recommended 150 min of MVPA per week. However, instrumental attitudes were no longer significant (p=.804). No significant interactions were observed between PA or SB correlates and participant type (i.e., outpatient vs. control; ps>0.05, see Supplementary Material 6, Table S4).

Automatic motivational variables

The univariate analyses (Table 3) showed no significant associations between automatic approach tendencies toward PA (b=2.60, 95% CI [-4.79; 9.99], p=.484) or SB (b=5.50, 95% CI [-1.59; 12.60], p=.0126) and daily MVPA. Similarly, no significant associations were observed between automatic approach tendencies toward PA (b =-4.73, 95% CI [-24.47; 15.02)], p=.633) or SB (b =-16.24, 95% CI [-35.05; 2.57], p=.089), and daily SB.

Emotional health-related variables

The univariate analyses (Table 3) showed that sex (ref. female; b=47.54, 95% CI [11.41; 83.67], R^2 adjusted=0.09, p=.011) and pain intensity (b = -20.44, 95% CI [-38.66; -2.22], R^2 adjusted=0.07, p=.029) were associated with daily SB. In multivariate analyses, sex remained associated with daily SB (ref. female, b=40.47, 95% CI [1.02; 79.92], p=.045) after controlling for pain intensity (b = -14.19, 95% CI [-33.13, 4.74], p=.139) and participant type (b = -17.49, 95% CI [-59.14; 24.17], p=.045). This model explained 10% of the variance in daily SB.

Sensitivity power analyses

Following Lakens' recommendations [38], we plotted a sensitivity curve for a linear univariate regression with an alpha level of 0.05 and a sample size of 59 participants (i.e., those with complete accelerometer-based data). This curve allowed us to assess the effect sizes detectable across a range of desired power levels, from

Table 3 Associations of motivational and emotional health-related variables with physical activity and sedentary behavior levels for one week

Outcome: daily MVPA	Univariate models ($N=59$)		Multivariate model ($N=59$)	
	b (95% CI)	P value	b (95% CI)	P value
Intercept			40.66 (31.55; 49.77)	< 0.001
Participant type (ref. controls)				
Outpatients	18.43 (1.10; 35.77)	0.038	18.81 (1.58; 36.05)	0.047
R^2 adjusted	0.06			
Age	-0.32 (-10.76; 10.12)	0.951		
Sex (ref. Female)				
Male	0.90 (-15.5; 17.2)	0.917		
Body mass index	-4.47 (-14.23; 5.30)	0.364		
Intention toward PA	3.94 (-3.96; 11.83)	0.322		
Perceived capabilities toward PA	8.52 (-1.96; 18.99)	0.109		
Instrumental attitudes	3.74 (-3.82; 11.30)	0.326		
Affective attitudes	10.32 (1.09; 19.55)	0.029	10.15 (1.21; 19.09)	0.049
R^2 adjusted	0.07			
Approach toward PA	2.60 (-4.79; 9.99)	0.484		
Approach toward SB	5.50 (-1.59; 12.60)	0.126		
Depressive symptoms	1.02 (-7.77; 9.81)	0.817		
Anxiety	-0.40 (-8.79; 7.99)	0.9244		
Fatigue	-3.18 (-13.64; 7.29)	0.546		
Pain intensity	-4.02 (-12.10; 4.06)	0.323		
R^2 adjusted for the multivariate model			0.12	
Outcome: daily SB	**Univariate models ($N=59$)**		**Multivariate model ($N=59$)**	
	b (95% CI)	***P* value**	**b (95% CI)**	***P* value**
Intercept			534.90 (506.75; 563.03)	< 0.001
Participant type (ref. control)				
Outpatients	-3.57 (-45.75; 38.61)	0.866	-17.49 (-59.14; 24.17)	0.404
Age	-0.38 (-24.84; 24.07)	0.975		
Sex (ref. Female)				
Male	47.54 (11.41; 83.67)	0.011	40.47 (1.02; 79.92)	0.045
R^2 adjusted	0.09			
Body mass index	0.14 (-22.90; 23.19)	0.999		
Intention toward PA	-8.88 (-27.21; 9.46)	0.336		
Perceived capabilities toward PA	11.17 (-13.68; 36.02)	0.372		
Instrumental attitudes	-3.05 (-20.84; 14.74)	0.732		
Affective attitudes	-15.07 (-37.20; 7.06)	0.178		
Approach toward PA	-4.73 (-24.47; 15.02)	0.633		
Approach toward SB	-16.24 (-35.05; 2.57)	0.089		
Depressive symptoms	-0.56 (-21.08; 19.97)	0.957		
Anxiety	-3.85 (-23.41; 15.70)	0.695		
Fatigue	-11.45 (-35.77; 12.88)	0.350		
Pain intensity	-20.44 (-38.66; -2.22)	0.029	-14.19 (-33.13; 4.74)	0.139
R^2 adjusted	0.07			
R^2 adjusted for the multivariate model			0.10	

Table 3 (continued)

Outcome: meeting the recommended levels of MVPA	Univariate models (*N*=59)		Multivariate model (*N*=59)	
	OR (95% CI)	***P* value**	**OR (95% CI)**	***P* value**
Intercept			1.90 (1.69; 2.13)	< 0.001
Participant type (ref. control)				
Outpatients	1.18 (0.93; 1.50)	0.175	1.23 (0.99; 1.51)	0.066
Age	1.02 (0.88; 1.17)	0.809		
Sex (ref. Female)				
Male	1.10 (0.88; 1.37)	0.415		
Body mass index	0.91 (0.80; 1.03)	0.153		
Intention toward PA	1.10 (0.99; 1.22)	0.090		
Perceived capabilities toward PA	1.17 (1.02; 1.34)	0.030	1.19 (1.05; 1.35)	0.007
Instrumental attitudes	1.11 (1.03; 1.19)	0.006	1.02 (0.90; 1.15)	0.804
Affective attitudes	1.26 (1.12; 1.41)	< 0.001	1.24 (1.06; 1.45)	0.011
Approach toward PA	0.98 (0.87; 1.10)	0.678		
Approach toward SB	1.07 (0.95; 1.19)	0.278		
Depressive symptoms	1.01 (0.90; 1.14)	0.836		
Anxiety	1.01 (0.91; 1.13)	0.817		
Fatigue	1.06 (0.92; 1.22)	0.430		
Pain intensity	1.00 (0.89; 1.11)	0.957		

Abbreviations: PA, physical activity; SB, sedentary behaviors; MVPA, moderate-to-vigorous physical activity; 95% CI, Confidence interval at 95%. The adjusted model includes only the significant correlates of the univariate models, with the exception of the participant type (i.e., outpatients versus control), which was adjusted for. The recommended levels of MVPA have been set at greater than or equal to 150 min of MVPA per week [10]. The R^2 adjusted was calculated only for statistically significant correlates [10]. The R^2 adjusted was calculated only for statistically significant correlates

33% (considered the lower threshold for insufficient power) [38, 39] to 90%. For univariate regression, the sensitivity curve indicated that our study had between 33% and 90% power to detect effect sizes ranging from $f^2=0.04$ (or $R^2=0.04$) to $f^2=0.18$ (or $R^2=0.16$). For a multivariate regression with two predictors (i.e., affective attitudes and participant type), the sensitivity curve showed that our study had between 33% and 90% power to detect effect sizes ranging from $f^2=0.06$ (or $R^2=0.06$) to $f^2=0.25$ (or $R^2=0.20$). For a multivariate regression with three predictors (i.e., sex, pain intensity, and participant type), the sensitivity curve demonstrated that our study had between 33% and 90% power to detect effect sizes ranging from $f^2=0.07$ ($R^2=0.06$) to $f^2=0.29$ ($R^2=0.23$). Additionally, we plotted a sensitivity curve for a logistic regression with an alpha level of 0.05 and a sample size of 59 participants. This curve showed that, for a positive effect of the independent variable on PA and SB levels, our study had between 33% and 90% power to detect effect sizes ranging from OR=1.50 to OR=2.70. Conversely, for a negative effect of the independent variable, the study had between 33% and 90% power to detect effect sizes ranging from OR=0.66 to OR=0.37. Sensitivity curves are available in Supplementary Material 7, Figures S1 and S2, and are further discussed in the Discussion section.

Discussion

The present study showed that during the first week following discharge from CR, outpatients were significantly more physically active compared to control participants in a typical week. Furthermore, motivational variables such as perceived capabilities and affective attitudes toward PA were associated with higher PA levels, while males spent more time in SB than females. Notably, no emotional health-related variables were significantly associated with PA or SB. The finding of higher PA levels in CR outpatients compared to healthy controls suggests that the CR program is effective in promoting PA, at least in the short term. However, this conclusion should be interpreted cautiously, as the groups differ in key demographic and motivational variables.

During the first week post-discharge, 88.2% of outpatients achieved the recommended 150 min of MVPA per week. This aligns with the findings of Bierbauer et al. [8], who reported that around 70% of outpatients met PA recommendations within the first three weeks following a CR program. Additionally, our study found that outpatients engaged in 18 more minutes of MVPA per day than control participants ($p=.038$). Although Barker et al. [40] showed that individuals with cardiovascular disease are typically less active than community-dwelling individuals without chronic disease, Steca et al. [41] reported that the proportion of coronary outpatients achieving the recommended PA levels increased from 35.6% before CR to 60% six months post-discharge. These findings are likely due to the key components of the CR program, which actively encouraged outpatients to increase PA levels and reduce time spent in SB [3]. In the present study, outpatients followed a CR program that included exercise sessions every weekday for six weeks (see Supplementary Material 1 for further details). These sessions were structured following the guidelines of the European Association of Preventive Cardiology, which emphasize the importance of strategies that enhance individual empowerment to improve self-efficacy, self-care, and motivation [42]. Additionally, the program included 12 therapeutic patient education sessions focused on lifestyle modifications, dietary advice, smoking cessation, stress management, and psychological support. These education sessions have been shown to improve patients' biological outcomes (e.g., body mass index [BMI]), adherence to treatment regimens, and psychological well-being [43]. Thus, this comprehensive approach may have created a nurturing environment that increased outpatients' engagement in PA behaviors. Finally, the proportion of outpatients meeting PA guidelines in our study (88.2%) was higher than reported in the literature. This result may be attributed to selection bias, as only 25% of the 68 outpatients wore an accelerometer for the entire week at the end of the six-week rehabilitation period.

At the start of CR, outpatients reported significantly lower perceived capabilities and affective attitudes toward PA, along with higher levels of depressive symptoms, fatigue, and pain, compared to control participants. These findings align with existing literature, which highlights the high prevalence of pain, discomfort, and depression among cardiac patients [7, 44]. Although we observed significant differences in certain deliberative motivational variables, such as perceived capabilities and affective attitudes, between outpatients and control participants, no differences were found in automatic approach-avoidance tendencies toward PA and SB between the groups. This result is challenging to compare with the literature as no previous studies, to our knowledge, have directly investigated or compared automatic motivational variables between patients and control participants. However, it has been suggested that automatic motivational variables in patients may be negatively biased due to fear, pain, and discomfort experienced during exercise [23, 45, 46]. For instance, fear of PA, which is particularly pronounced in cardiac patients [47], may trigger automatic avoidance tendencies toward PA [48]. Several factors may explain the lack of observable differences in our study. First, outpatients participating in the IMPACT trial (a 6-week study designed to improve PA behavior [23]) may have been more motivated to engage in regular PA than outpatients who were not involved in the study. Notably, although outpatients and control participants differed in perceived capabilities and affective attitudes, both groups scored highly (>4 out of 5 and >8 out of 10, respectively). Second, previous research has consistently shown that healthy individuals typically exhibit a positive approach bias toward PA stimuli and a negative bias toward SB stimuli [49–53]. However, our findings—along with those of a recent fMRI study using the same approach-avoidance task that the one used in this study [54]—failed to replicate these effects. This discrepancy may be due to the specific nature of the task used in our study. Previous research has typically used an explicit approach-avoidance task in which participants responded to the content of the images, specifically approaching or avoiding depending on whether the stimuli depicted PA or SB. In contrast, our study used an implicit approach-avoidance task in which participants responded to the format of the images (portrait vs. landscape) regardless of content. The literature suggests that implicit evaluations generally yield smaller effect sizes than explicit evaluations [55]. Therefore, the reliance on format-based responses in our task may explain the lack of the expected approach tendencies toward PA and avoidance tendencies toward SB. Moreover, this feature may also explain why we did not observe differences in such tendencies between outpatients with cardiovascular disease and healthy participants.

No significant association was found between emotional health-related variables and accelerometer-based daily MVPA during the first week after discharge from CR or during a typical week for control participants. Our findings of no associations between emotional health-related variables and PA contrast with existing theoretical and empirical evidence, which suggests that such variables including pain, fear, anxiety, depression, and fatigue are typically associated with reduced PA [7, 20, 21, 25–27]. According to the AHBF, fear is hypothesized to lead individuals to avoid activities associated with past negative experiences or perceived threats [20, 21]. For example, negative emotional experiences associated with PA could contribute to fear of engaging in such activities. However, the focus of our study was on general fear and anxiety experienced in the past week, rather than specific fears related to PA, or "anxiety sensitivity", which refers to the fear of experiencing anxiety-related symptoms, such as increased heart rate and breathing difficulties [20, 21, 56]. This lack of specificity may have limited our ability to detect significant associations. In addition, it is worth noting that the interaction of emotional health with PA and SB is complex and may be influenced by several factors not fully captured in our study. The broader literature highlights that these relationships may be mediated by multiple variables, including the intensity and context of emotional experiences, as well as individual differences in coping mechanisms and PA history [20, 57, 58]. Future research should explore these interactions in greater depth, possibly using more nuanced and targeted measures, to better understand the role of emotional health in PA behavior. Empirically, Dagner et al. [7] found that patients with lower levels of anxiety and depression had higher odds of engaging in more than 30 min of PA per week after CR discharge (OR = 0.6). Conversely, patients with high levels of pain had lower odds of engaging in PA (OR = 2.00). Similarly, Andersson et al. [26] reported that individuals with chronic obstructive pulmonary disease and high fatigue had lower odds of engaging in PA (OR = 2.33). However, our sensitivity analyses showed that the present study had approximately 43% power to detect an OR of 0.6 [7], 65% power to detect an OR of 2.0 [7], and 78% power to detect an OR of 2.33 [26] (Supplementary Material 9, Figure S2). These results suggest that the lack of significant associations in our study may be partly due to its limited statistical power, highlighting the need for further research with larger sample sizes to more robustly assess the association between emotional health-related variables and PA behavior and SB. Thus, caution should be exercised when interpreting the present findings.

In contrast to emotional health-related variables, several deliberative motivational variables were associated with daily MVPA. In particular, higher perceived capabilities, along with stronger affective attitudes toward PA were associated with a greater likelihood of meeting the recommended 150 min of MVPA per week. These findings align with Bermudez et al.'s study [2], which showed that patients with more positive affective attitudes toward PA were more likely to engage in higher PA levels after CR discharge. These motivational variables may be particularly important in the post-CR context. For example, perceived capabilities influence patients' confidence in their ability to engage in PA, which can encourage continued PA participation after CR [59, 60]. Moreover, increasing perceived capabilities may enhance the pleasure experienced during PA, which in turn may improve affective attitudes toward PA and promote long-term adherence [2, 20, 61]. Although these data are correlational, existing literature and theoretical models suggest that future interventions targeting both perceived capabilities and affective responses (pleasure-displeasure) during PA could be effective in sustaining PA behaviors. Such interventions might include providing positive feedback during CR exercise sessions (e.g., " *You are doing an excellent work!*" or "*You are performing above average for your age*"), or exercise intensity prescription targeting pleasure (e.g., self-selected intensity) [60, 62–64]. These interventions are particularly important for subpopulations such as those with high BMI, where reduced perceived capabilities may create both physical and psychological barriers to PA [61]. This may lead to a vicious cycle in which increased BMI further impedes PA engagement [61]. In addition, recent research suggests that age and sex may influence perceptions of effort and affective responses during PA, with older adults and females more likely to report higher perceived effort and less positive affective experiences during PA [65]. This highlights the need for tailored interventions that address the specific pressures and barriers faced by these groups. Future research should examine how age, sex, or baseline health status moderates the relationship between motivational variables and PA behaviors to better inform interventions for diverse CR populations.

We found no evidence that automatic approach-avoidance tendencies toward PA and SB were associated with accelerometer-based MVPA or SB in either cardiac outpatients or healthy control participants. These findings contrast with previous research suggesting that automatic processes, including approach-avoidance tendencies, play an important role in regulating PA behavior [14–16]. Specifically, studies investigating automatic processes have shown that PA cues attract attention [66–68], elicit positive affective responses [22, 69], and prompt approach tendencies [49, 53, 70], particularly in highly active individuals. For example, Cheval et al. [70] found a positive correlation between automatic approach tendencies toward PA and accelerometer-based MVPA in healthy adults ($r = .21$). These findings suggest that insufficiently positive automatic responses to PA cues may partially explain reduced engagement in PA. The absence of a significant association in the present study could be explained by at least two factors. As mentioned above, the implicit nature of the task that we used in the current study, coupled with the relatively low sample size ($N = 59$), statistical power may have resulted in insufficient statistical power to detect the true effect size. For example, sensitivity power analyses showed that our study had only 37% power to detect an effect size of $r = .21/f^2 = 0.05$ (Supplementary Material 9, Figure S1), as reported by Cheval et al. [70]. Therefore, before drawing firm conclusions about the lack of association between approach-avoidance tendencies and PA behavior or SB, further well-powered studies using alternative reaction-time tasks are needed.

Regarding device-measured SB, male participants spent significantly more time in SB than female participants. Additionally, we observed a significant negative association between pain intensity and SB, indicating that higher pain intensity was linked to lower SB levels. However, this association lost significance after adjusting the model for participant type and sex ($p = .139$). This finding differs with O'Leary et al.'s study [71], which found a positive correlation between pain intensity and SB in rheumatoid arthritis patients ($r = .31$). As in our study, this association became non-significant when other variables, such as age and gender, were included in multivariate models. Overall, these results suggest that motivational and emotional health-related variables related to PA are limited in their ability to explain SB levels. It is important to note, however, that most of the variables measured in this study pertained to PA, not SB (e.g., perceived capabilities related to PA). While other studies have used PA-related motivational measures to predict SB [72, 73], this approach may explain the lack of significant associations in our study. Future research should explore a broader range of variables directly targeting SB to better understand the role of motivational and emotional health-related variables in influencing SB (e.g., "*During the next two weeks, I intend to spend no more than four hours in SB a day during my leisure time.*") [72].

Finally, no significant interactions were observed between motivational and emotional health-related correlates, PA or SB, and participant type (i.e., outpatient vs. control). However, due to the small sample of outpatients ($n=17$), this finding should be interpreted with caution.

Constraints on generality and strengths

This study has several limitations that affect the generalizability of its findings. First, the sample size was relatively small, with 17 CR outpatients and 42 community-dwelling participants, who had significantly different baseline characteristics. As a result, the lack of association with PA for some motivational and emotional health-related variables should be interpreted with caution, as the small sample may have led to underpowered analyses and distorted effect size estimates [74, 75]. A larger sample size is needed to provide more accurate estimates of motivational and emotional health-related PA determinants on patients. Second, all outpatients in the study were enrolled in a CR program at Geneva University Hospitals, Switzerland, limiting the applicability of the results to patients in other CR settings. Third, as with many longitudinal studies, there is a risk of selective attrition bias. More motivated outpatients may have been more likely to continue participating, which could explain the relatively high proportion of CR outpatients who met the weekly recommended 150 min of MVPA. Future studies that retain a larger proportion of patients could yield findings more representative of this population. Fourth, while this study used the Actigraph GT3X to measure SB, it is worth noting that the activPal™ device is considered the most reliable for SB measurement [76, 77]. Fifth, although our statistical analyses examined the associations of motivational and emotional variables with daily MVPA and SB levels, the correlational nature of this study precludes drawing causal conclusions. Therefore, further well-powered randomized controlled trials are necessary to establish causal relationships between these variables. Finally, although this study focused on PA and SB, other important lifestyle factors, such as diet and sleep, play a significant role in the management and outcomes of cardiovascular disease [78–80]. Proper nutrition supports both recovery and long-term health maintenance in clinical populations [81, 82], while adequate sleep is critical for mental and physical recovery [79, 83, 84]. Recent research also suggests that these factors interact with PA and SB to collectively influence health-related outcomes [85–88]. Future studies should consider the combined effects of PA, diet, and sleep to provide a more holistic understanding of disease management and improve patient well-being.

Despite these limitations, the study has several strengths. First, it included both CR outpatients and community-dwelling participants, enabling the observation of PA and SB across different contexts, including leisure time PA after CR. Second, the study focused on both PA and SB, addressing a gap in the literature, as most research considers these behaviors independently, despite their distinct impacts on the health benefits of rehabilitation [11–13]. Third, the use of accelerometer-based measures for PA and SB provided more reliable estimates than self-reported questionnaires [89–91]. Finally, the study examined motivational variables influencing PA and SB at both the deliberative (i.e., intention, perceived capabilities, attitudes) and automatic (i.e., approach-avoidance tendencies) levels. This approach is relatively rare in the literature and offers a more comprehensive view of the variables that regulate these behaviors.

Conclusion

The present study found that outpatients who completed a 6-week CR program engaged in higher levels of daily MVPA during the week post-discharge compared to community-dwelling individuals. Higher perceived capabilities and positive affective attitudes toward PA were significantly associated with higher daily MVPA among all participants. In addition, males spent significantly more time in SB compared to females. These results highlight the role of deliberative motivational factors in influencing PA behaviors in both CR patients and the general community. Although our findings suggest some associations, these results must be interpreted with caution due to several limitations, including potential selection bias and the correlational design, which limit the generalizability and causality of the findings, respectively.

Abbreviations

CR	Cardiac rehabilitation
HbA1c	glycated hemoglobin
IMPACT	Improving Physical Activity trial
LDL	low-density lipoprotein
LVEF	Left ventricular ejection fraction
MAP	Maximal aerobic power
MVPA	Moderate-to-vigorous physical activity
PA	Physical activity
PROMIS	Patients-Reported Outcomes Measurement Information System
SB	Sedentary behavior
VAAST	Visual-Approach/Avoidance-by-the-Self-Task

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13102-024-00997-0.

Supplementary Material 1

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Author contributions

The first draft of the manuscript was written by L.F. and B.C. and all authors commented on the previous versions of the manuscript. All authors read and approved the final manuscript. L.F. contributed to conceptualization, methodology, formal analysis, investigation, writing—original draft; E.T. contributed to writing–review and editing, resources; C.C. contributed to writing–review and editing, investigation; P.S. contributed to supervision, writing–review and editing; P.M. contributed to writing–review and editing, resources; C.L. contributed to writing–review and editing, resources; E.H.D contributed to writing–review and editing, resources; B.C. contributed to conceptualization, methodology, supervision, formal analysis, investigation, writing—original draft.

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Data availability

Deidentified data, data management, analysis codes and research materials have been made publicly available on Zenodo (https://doi.org/10.5281/zenodo.11064184).

Declarations

Ethics approval and consent to participate

The present study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Geneva Canton, Switzerland (reference number: CCER2019-02257). Prior to participation in the study, all participants signed an informed consent form.

Competing interests

The authors declare no competing interests.

Consent for Publication

Not applicable.

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