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Original Research

Physical Activity and Sedentary Behavior in Cardiac Rehabilitation: Does Body Mass Index Matter?

Iris den Uijl, MSc[1,2], Nienke ter Hoeve, PhD[1,2], Madoka Sunamura, MD, PhD[2], Mattie J. Lenzen, PhD[3], Hanneke E.M. Braakhuis, MSc[1], Henk J. Stam, MD, PhD[1], Eric Boersma, PhD, FESC[3], Rita JG van den Berg-Emons, PhD[1]

[1]Department of Rehabilitation Medicine, Erasmus University Medical Center, Rotterdam, the Netherlands
[2]Capri Cardiac Rehabilitation, Rotterdam, the Netherlands
[3]Department of Cardiology, Thoraxcenter, Erasmus University Medical Center, Rotterdam, the Netherlands
*Address all correspondence to Ms den Uijl at: i.denuijl@erasmusmc.nl

Abstract

Objective. The purpose of this study was to investigate the relationship between body mass index (BMI) class and physical activity and sedentary behavior in patients with acute coronary syndrome (ACS) during cardiac rehabilitation (CR).
Methods. This study was a secondary analysis of the OPTICARE trial. Physical activity and sedentary behavior were measured in participants with ACS (n = 359) using actigraphy at baseline, directly after completion of a multidisciplinary 12-week exercise-based CR program and 9 months thereafter. Outcome measures were step count and duration of time (percentage of wear time) spent in light physical activity, moderate-to-vigorous physical activity, and sedentary behavior. Participants were classified as normal weight (BMI = 18.5–24.99 kg/m^2; n = 82), overweight (BMI = 25.0–29.99 kg/m^2; n = 182), or obese (BMI ≥ 30.0 kg/m^2; n = 95). Linear mixed-effects models were applied to study the relationship between BMI class and physical activity and sedentary behavior.
Results. At the start of CR, compared with participants with normal weight, participants with obesity made on average 1.11 steps fewer per minute (952 steps/d), spent 2.9% (25 min/d) less time in light physical activity, and spent 3.31% (28 min/d) more time in sedentary behavior. Participants of all BMI classes improved their physical activity and sedentary behavior levels similarly during CR, and these improvements were maintained after completion of CR.
Conclusion. Participants with ACS who had obesity started CR with a less favorable physical activity and sedentary behavior profile than that of participants with normal weight. Because all BMI classes showed similar improvement during CR, this deficit was preserved.
Impact. This study indicates that reconsideration of the CR program in the Netherlands for patients with ACS and obesity is warranted, and development of more inclusive interventions for specific populations is needed. A new program for people with obesity should include added counseling on increasing physical activity and preventing sedentary behavior to facilitate weight loss and reduce mortality risk.
Lay Summary. People with ACS who have obesity are less active and sit more than individuals with normal weight, both during and after CR. This study suggests that CR needs to be changed to help individuals increase their physical activity to help them lose weight and reduce their risk of death.

Keywords: Acute Coronary Syndrome, Obesity, Rehabilitation

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Introduction

After experiencing an acute coronary syndrome (ACS), it is advised in guidelines that individuals are referred to cardiac rehabilitation (CR).[1,2] CR focuses on physical and psychosocial recovery and the prevention of recurrent cardiac events by targeting cardiovascular risk factors and healthy lifestyle adoption, including achieving optimal physical activity levels. Previous research shows that CR indeed improves physical activity, although the improvements are small and long-term maintenance is suboptimal.[3,4] This is also true for sedentary behavior, which is, in addition to physical activity,[5–8] an independent predictor for health.[9–11] Physical activity is defined as "any bodily movement produced by skeletal muscle that requires energy expenditure"[12] and sedentary behavior as "any waking sitting or lying behavior with low energy expenditure."[11] These 2 concepts should be addressed seperately.[13]

Because the prevalence of obesity is high (38%) among patients with coronary syndromes across Europe,[14] many patients entering CR are obese. Currently all patients are referred to the same CR programs regardless of their body mass index (BMI).[15] It is known that obese individuals often start CR with a more unfavorable cardiovascular risk profile, including a higher prevalence of hypertension, dyslipidemia, and type 2 diabetes mellitus.[16] Furthermore, patients with obesity only reach small changes in fitness level (compared with patients with normal weight) and achieve little to no weight loss during CR.[17,18] An explanation for these small improvements could be that a substantial part of CR consists of weight-bearing exercise sessions, which might be more challenging for individuals with obesity than for individuals with normal weight.[19,20]

Little is known about physical activity and sedentary behavior in individuals with obesity who participate in CR. Given the rather disappointing effects on fitness and body weight,[17,18] we expect that CR patients with obesity do not gain the same benefits in physical activity and sedentary behavior as CR patients with normal weight. This might lead to detrimental health outcomes, particularly because we expect that individuals with obesity start CR with a less favorable physical activity and sedentary behavior profile. Promoting an active and non-sedentary lifestyle might be even more important for individuals with obesity to lose weight and improve cardiovascular health.[21,22]

To gain further insight into whether current CR programs should be optimized for individuals with obesity, the aim of this study was to investigate the relation between BMI class and objectively assess physical activity and sedentary behavior in individuals with ACS during CR. It is hypothesized that individuals with obesity start CR with a less favorable physical activity and sedentary behavior profile and that improvements are smaller than in individuals with normal weight.

Methods

Participant Population

This study was a secondary analysis on data collected in the OPTICARE trial conducted at Capri Cardiac Rehabilitation, Rotterdam-The Hague, the Netherlands.[23] The OPTICARE trial was a large randomized-controlled trial in which participants with ACS (aged ≥18 years) were monitored from 2010 to 2016. ACS was defined as "persistent (>20 minutes) chest pain suggestive of myocardial ischemia, which is unresponsive to nitroglycerine and which is accompanied by ST-T changes (electrocardiographic evidence) and/or cardiac troponin elevations (biochemical evidence), regardless of in-hospital treatment."[23] Patients who suffered from severe comorbidities, who had psychological or cognitive impairments that could interfere with participation in CR, or who had a left ventricular ejection fraction <40% were not included in the OPTICARE trial. The primary aim of the OPTICARE trial was to compare the effects of 2 extended CR programs with standard CR. Because our aim was to evaluate standard CR, for the current study, only individuals who were randomized to standard CR for the first 12 weeks and who completed the program were included.

The OPTICARE trial was approved by the Medical Ethics Committee of Erasmus MC, University Medical Centre Rotterdam, the Netherlands (MEC-2010-391). All participating individuals provided written informed consent.

Cardiac Rehabilitation

CR included two 75-minute exercise sessions per week for a 12-week period consisting of gymnastic exercises, running/brisk walking, sports activities, and relaxation exercises. Lifestyle and cardiovascular risk factor education as well as complementary counseling programs such as smoking cessation, nutritional counseling, and stress management were offered on indication. All aspects of the CR program were group-based and met the Dutch guidelines.[1,2] Completion was defined as attending at least 75% of the exercise program (a minimum of 18 exercise sessions).

Data Collection

Person-related and disease-related baseline characteristics on height, weight, sex, age, educational level, work status, marital status, and risk factors and cardiac medication were collected at the start of CR. Height was self-reported. Weight was measured by using a calibrated weight scale. BMI was calculated from height and weight. Participants were categorized as normal weight (BMI 18.5–24.99 kg/m^2), overweight (BMI 25.0–29.99 kg/m^2), or obese (BMI ≥ 30.0 kg/m^2) according to the World Health Organization guidelines.[24] Educational level (low, intermediate, or high), work status (employed or unemployed), and marital status (partnered or unpartnered) were collected by a questionnaire developed for the purpose of the study. Cardiovascular risk factors (dichotomous variables for family history of cardiovascular disease, diabetes, dyslipidemia, hypertension, or smoking before ACS) and cardiac medication (use of acetylsalicylic acids, thienopyridines, statins, or beta blockers and ACE inhibitors) were both collected from medical files.

Physical activity and sedentary behavior were measured with an Actigraph GT3X+ accelerometer at the start of CR (T0), directly after completion of CR (T1), and 9 months thereafter (T2). Participants were instructed to wear the accelerometer for 8 consecutive days during waking hours on the right hip, except when showering or swimming. Data were sampled at 30 Hz and processed with ActiLife software and MatLab version R2011b. Counts over the 3 axes (vector magnitude) were summed in 15-second epochs. Each 15-second epoch was marked as sedentary behavior (SB, ≤37.5 counts), light physical activity (LPA, >37.5 and <672.5 counts), or moderate-to-vigorous physical activity (MVPA, ≥672.5 counts).[25–27] Additionally, step count (as provided

by the ActiLife software) was extracted. A measurement was marked as successful when the device was worn for at least 4 days and 660 min/d.[27] Non-wear time was defined as a minimum of 60 minutes of consecutive zero counts.

The following outcome measures were included:
Physical activity:

- Step count, expressed as average steps per minute of total wear time (steps per minute);
- Duration of time spent in light physical activity, expressed as a percentage of total wear time (% in LPA); and
- Duration of time spent in moderate-to-vigorous physical activity, expressed as a percentage of total wear time (% in MVPA).

Sedentary behavior:

- Duration of time spent in sedentary behavior, expressed as a percentage of total wear time (% in SB).

Statistical Analyses

Descriptive statistics (mean ± SD or median and interquartile range; or n [%]) were used to present baseline person-related and disease-related characteristics for the 3 BMI classes separately. To test for differences in these baseline characteristics between BMI classes, analysis of variance (with Fisher least significant different as post-hoc test) was used for continuous variables. For categorical variables, linear-by-linear chi-squared tests were used (or Fisher exact test if categories had a frequency ≤5 measurements).

Linear mixed-effect models were used to evaluate the differences between BMI classes in physical activity (step count, % in LPA and % in MVPA) and sedentary behavior (% in SB). For each of these outcomes, 2 separate models were created: first, to investigate differences between BMI classes at the start of CR and during CR (change between T0 and T1), and second, to investigate differences between BMI classes after completion of CR (change between T1 and T2). In each model, the outcome for physical activity or sedentary behavior was the dependent variable. BMI (fixed effect) and time since the start of CR (random intercept) were added to the model as explanatory variables. BMI class (as determined at baseline) was modeled by 2 dummy variables, with BMI 18.5 to 24.99 kg/m^2 being the reference category. Interaction terms between BMI and time were added to the models to evaluate whether changes in the outcome measures differed between BMI classes. All models were corrected for age and sex (fixed effects). We additionally checked the confounding effect of educational level, work status, marital status, cardiovascular risk factors and cardiac medication. These variables appeared not associated with both BMI class and physical activity and sedentary behavior and were therefore not included in the final multivariable model.

All analyses were performed in R Statistical software (Version 1.1.463, RStudio Team, 2016. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA, USA, http://www.rstudio.com/). For overall tests, $P < .05$ was considered statistically significant. Significance was stated at <.0167 for assessing baseline differences between BMI classes and <.025 for the comparison of the 2 higher BMI classes with the reference in the linear mixed-effect models.

Role of the Funding Source

The funders played no role in design, conduct, or reporting of this study.

Results

Participant Selection

For this study, we identified a total of 485 individuals from the OPTICARE database that participated in standard CR in the first 12 weeks and received accelerometer measurements. A total of 86 individuals in this selected group did not complete the CR program and another 40 did not have any successful accelerometer measurement, resulting in 359 individuals included in the analysis (Fig. 1). To investigate the long-term maintenance of physical activity and sedentary behavior, an additional 181 individuals who received an experimental intervention after completion of CR were excluded, resulting in a total of 178 participants available for this part of the analysis.

Baseline Characteristics

Approximately one-half of the participants were categorized as being overweight (n = 182, 50.7%) (Tab. 1). The second largest group consisted of participants with obesity (n = 95, 26.5%), and a total 82 participants were categorized as having normal weight (22.8%). The proportion of participants in each of the 3 BMI classes did not statistically differ between individuals included and excluded for the analyses (results not shown). Individuals with normal weight had a mean age of 60.0 years and were on average 3.7 years older than individuals with obesity ($P = .01$) and 2.5 years older than individuals with overweight ($P = .04$). A family history of heart disease was present in 67.4% of the participants with obesity, whereas in participants with overweight and normal weight, this was 52.2% and 39.0%, respectively ($P < .001$). A total of 20.0% of the participants with obesity suffered from diabetes compared with 6.1% in participants with normal weight and 9.9% in participants with overweight ($P = .01$). One-half of the participants with obesity (49.5%) had dyslipidemia compared with 32.9% in participants with normal weight and 41.2% in participants with overweight ($P = .03$). Statins were less frequently used by participants with obesity than by participants with overweight or normal weight (92.6%, 98.4%, and 100.0%, respectively; $P = .01$).

Wear Time and Success of Accelerometer Measurements

Participants in all BMI classes wore the accelerometer for a mean time of 14.3 (SD ± 1.1) h/d at the start of CR. On average, 76.0% of the accelerometer measurements was marked as successful. Reasons for not wearing the accelerometer were technical problems, failure of measurement to meet the minimum required duration, or participant inability to visit the rehabilitation center for application of the accelerometer due to lack of time or motivation. The proportion of successful measurements was lower in participants with obesity than in participants with normal weight or overweight (Suppl. Tab. S1). This difference was significantly lower only at T1: participants with obesity had 63.2% of successful measurements, whereas this was 75.3% in participants with

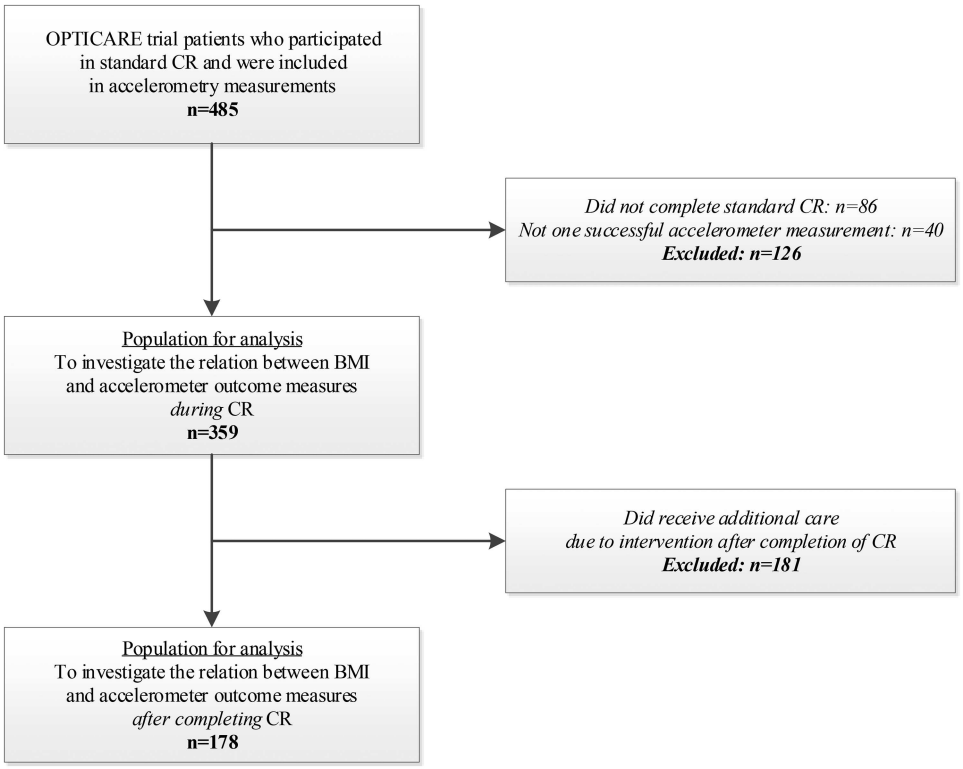

Figure 1. Flow chart of patient inclusion.

Table 1. Baseline Characteristics of the Total Study Population for Participants (n = 359) With Normal Weight (BMI 18.5 to 24.99 kg/m^2), Overweight (BMI 25.0 to 29.99 kg/m^2), and Obese (BMI ≥ 30 kg/m^2)[a]

Characteristics	Normal Weight (n = 82)	Overweight (n = 182)	Obese (n = 95)	*P*
BMI (kg/m^2)[b]	23.7 (22.5–24.4)	27.4 (26.2–28.7)	32.1 (31.0–34.0)	
Sex, males, n (%)	63 (76.8)	153 (84.1)	79 (83.2)	.30
Age (y)[c]	60.0 (9.9)	57.5 (8.6)	56.3 (8.5)	.02[d,e]
Educational level, n (%)				.12
Low	4 (5.5)	8 (5.3)	4 (4.9)	
Intermediate	41 (56.2)	99 (65.1)	62 (75.6)	
High	28 (38.4)	45 (29.6)	16 (19.5)	
Missing	9	30	13	
Work status, n (%)				.83
Employed	39 (56.5)	80 (58.0)	40 (54.8)	
Unemployed	30 (43.5)	58 (42.0)	33 (45.2)	
Missing	13	44	22	
Marital status, n (%)				.71
Partnered	60 (81.1)	134 (87.6)	65 (79.3)	
Unpartnered	14 (18.9)	19 (12.4)	17 (20.7)	
Missing	8	29	13	
Risk factors, n (%)				
Family history of CVD	32 (39.0)	95 (52.2)	64 (67.4)	<.001[e]
Diabetes	5 (6.1)	18 (9.9)	19 (20.0)	.01[e]
Dyslipidemia	27 (32.9)	75 (41.2)	47 (49.5)	.03[e]
Hypertension	27 (32.9)	77 (42.3)	43 (45.3)	.10
Smoking (pre-ACS)	33 (40.2)	61 (33.5)	38 (40.0)	.97
Cardiac medication				
Acetylsalicylic acids	81 (98.8)	177 (97.3)	93 (97.9)	.90
Thienopyridines	68 (82.9)	148 (81.3)	85 (89.5)	.21
Statins	82 (100.0)	179 (98.4)	88 (92.6)	.01[e]
Beta blockers	64 (78.0)	156 (85.7)	81 (85.3)	.21
ACE inhibitors	59 (72.0)	127 (69.8)	70 (73.7)	.78

[a]ACE = angiotensin converting enzyme; ACS = acute coronary syndrome; BMI = body mass index; CVD = cardiovascular diseases. [b]Median and interquartile range depicted (data not normally distributed). [c]Mean (SD) depicted (data normally distributed). [d]Post-hoc tests showed a significant difference between with participants normal weight and obese ($P = .01$) and not between those with normal weight and overweight ($P = .04$). [e]$P < .05$.

Table 2. Mean Physical Activity and Sedentary Behavior Values for the Total Study Population and per BMI Class at the Start of CR and Directly After Completion of CR, and Mean Change (n = 359)[a]

	At Start of CR (T0)		Directly After Completion of CR (T1)	Change During CR (Δ T0-T1)	
	Mean (95% CI)	*P*	Mean (95% CI)	Mean (95% CI)	*P*
Steps/min					
Total population	7.01 (6.72 to 7.30)		7.60 (7.29 to 7.90)	0.59 (0.29 to 0.89)	<001[b]
BMI <25	7.50 (6.89 to 8.11)		7.67 (7.05 to 8.28)	0.17 (−0.45 to 0.78)	
BMI 25–30	7.10 (6.70 to 7.50)	.28	7.86 (7.44 to 8.28)	0.76 (0.34 to 1.18)	.08
BMI ≥30	6.39 (5.82 to 6.97)	.01[b]	7.02 (6.41 to 7.64)	0.63 (0.02 to 1.24)	.23
% in LPA					
Total population	28.63 (27.89 to 29.37)		30.44 (29.66 to 31.22)	1.80 (1.03 to 2.58)	<001[b]
BMI <25	29.41 (27.86 to 30.96)		31.30 (29.73 to 32.87)	1.89 (0.32 to 3.46)	
BMI 25–30	29.32 (28.30 to 30.34)	.92	30.72 (29.64 to 31.80)	1.40 (0.32 to 2.48)	.59
BMI ≥30	26.51 (25.06 to 27.97)	.01[b]	29.07 (27.50 to 30.64)	2.56 (0.99 to 4.13)	.52
% in MVPA					
Total population	6.04 (5.75 to 6.35)		6.61 (6.29 to 6.93)	0.56 (0.25 to 0.88)	<001[b]
BMI <25	6.26 (5.63 to 6.90)		6.40 (5.76 to 7.05)	0.14 (−0.50 to 0.79)	
BMI 25–30	6.05 (5.63 to 6.47)	.58	6.91 (6.46 to 7.35)	0.86 (0.42 to 1.30)	.05
BMI ≥30	5.85 (5.26 to 6.45)	.36	6.21 (5.57 to 6.86)	0.36 (−0.28 to 1.01)	.60
% in SB					
Total population	65.33 (64.45 to 66.21)		62.95 (62.03 to 63.88)	−2.37 (−3.29 to −1.45)	<001[b]
BMI <25	64.33 (62.49 to 66.18)		62.30 (60.43 to 64.17)	−2.03 (−3.90 to −0.16)	
BMI 25–30	64.63 (63.42 to 65.85)	.79	62.38 (61.10 to 63.67)	−2.25 (−3.54 to −0.97)	.83
BMI ≥30	67.64 (65.91 to 69.38)	.01[b]	64.72 (62.86 to 66.58)	−2.92 (−4.78 to −1.06)	.46

[a]Results are based on multivariable linear mixed-effect modelling. BMI <25 is the referent group for all analyses. BMI = body mass index; CI = confidence interval; CR = cardiac rehabilitation; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; SB = sedentary behavior. [b]$P < .025$.

overweight and 82.9% in participants with normal weight ($P = .05$).

Physical Activity

At baseline, participants with obesity made 1.11 steps/min less than participants with normal weight (6.39 vs 7.50 steps/min; $P = .01$) (Tab. 2). This corresponds to a difference of 952 steps/d. They spent 2.90% less time in LPA (26.51% vs 29.41%, which corresponds to 25 min/d, $P = .01$) than participants with normal weight. Furthermore, participants with obesity spent 0.41% less time (6.26 vs 5.85, which corresponds to 3.5 min/d) in MVPA, although this was not statistically significant ($P = .36$). Participants with overweight and participants who were normal weight had similar physical activity levels at the start of CR.

During CR, physical activity improved in the total study population ($P < .001$) (Tab. 2). This improvement was not significantly different between BMI classes, although participants with obesity showed slightly larger increases compared with participants with normal weight. After completion of CR, physical activity did not change (neither improved nor deteriorated) in the total study population, which was again similar between BMI classes (Tab. 3).

Sedentary Behavior

At the start of CR, participants with obesity spent 3.31% more time sedentary than participants with normal weight (67.64% vs 64.33%, $P = .01$) (Tab. 2). This corresponds to a difference of 28 min/d in SB. Participants with overweight and those with normal weight had similar SB levels at the start of CR.

During CR, SB decreased in the total study population ($P < .001$), whereas no change was observed after completion of CR ($P = .81$). The decrease in SB during CR was slightly larger in participants with obesity than in participants with normal weight, although not significantly different between BMI classes (Tab. 2). The stabilization of this decrease was also similar between BMI classes after completion of CR (Tab. 3).

Discussion

To our knowledge, this study is the first to address differences between participants with ACS with normal weight, overweight, and obesity in objectively assessed physical activity and sedentary behavior at the start, during, and after CR. We observed no differences between participants with normal weight and participants with overweight at any time point. At the start of CR, participants with obesity spent less time in LPA, walked less steps, and spent more time in SB than participants with normal weight. During CR, participants of all 3 BMI classes improved their physical activity and SB levels in a comparable manner. After CR, improvements were maintained for all 3 BMI classes, but no further improvements were observed.

Our hypothesis that participants with obesity start CR with less favorable levels of physical activity and SB than participants with normal weight was confirmed. Because this difference was not seen for participants with overweight, this supports our hypothesis that (weight-bearing) exercise might be more challenging for participants with more extreme overweight. Participants with obesity walked a significant amount of 952 steps less per day. A study of Ayabe et al indicates that an average number of 6500 steps/d corresponds to the minimum energy expenditure (1500 kcal/wk) needed to prevent disease progression in participants with ACS.[28] In our study, this threshold was almost met by participants with normal weight. They had on average 6435 steps/d, whereas

Table 3. Mean Physical Activity and Sedentary Behavior Values for the Total Study Population and per BMI Class Directly After Completion and 9 Months After Completion of CR, and Mean Change (n = 178)[a]

	Directly After Completion of CR (T1) Mean (95% CI)	9 Mo After Completion of CR (T2) Mean (95% CI)	Change After Completion of CR (Δ T1-T2) Mean (95% CI)	*P*
Steps/min				
Total population	7.98 (7.54 to 8.42)	7.74 (7.31 to 8.18)	−0.24 (−0.67 to 0.20)	.24
BMI <25	8.42 (7.54 to 9.30)	8.17 (7.26 to 9.08)	−0.25 (−1.16 to 0.66)	
BMI 25–30	8.06 (7.43 to 8.69)	7.79 (7.16 to 8.41)	−0.27 (−0.89 to 0.36)	.984
BMI ≥30	7.44 (6.58 to 8.31)	7.32 (6.49 to 8.15)	−0.12 (−0.95 to 0.71)	.83
% in LPA				
Total population	30.48 (29.37 to 31.61)	30.90 (29.78 to 32.01)	0.41 (−0.70 to 1.53)	.42
BMI <25	31.60 (29.36 to 33.85)	32.40 (30.09 to 34.72)	0.81 (−1.51 to 3.12)	
BMI 25–30	30.84 (29.24 to 32.45)	31.04 (29.45 to 32.63)	0.19 (−1.40 to 1.79)	.63
BMI ≥30	28.84 (26.65 to 31.04)	29.47 (27.36 to 31.57)	0.63 (−1.48 to 2.73)	.90
% in MVPA				
Total population	6.89 (6.42 to 7.36)	6.60 (6.13 to 7.07)	−0.29 (−0.76 to 0.18)	.22
BMI <25	7.11 (6.16 to 8.07)	7.04 (6.06 to 8.02)	−0.07 (−1.06 to 0.91)	
BMI 25–30	7.01 (6.33 to 7.69)	6.56 (5.88 to 7.23)	−0.45 (−1.13 to 0.22)	.51
BMI ≥30	6.46 (5.52 to 7.40)	6.34 (5.44 to 7.23)	−0.12 (−1.01 to 0.78)	.95
% in SB				
Total population	62.64 (61.35 to 63.94)	62.49 (61.20 to 63.78)	−0.15 (−1.44 to 1.14)	.81
BMI <25	61.30 (58.71 to 63.89)	60.52 (57.85 to 63.20)	−0.77 (−3.45 to 1.90)	
BMI 25–30	62.18 (60.33 to 64.03)	62.40 (60.56 to 64.24)	0.22 (−1.62 to 2.06)	.52
BMI ≥30	64.69 (62.15 to 67.24)	64.20 (61.76 to 66.63)	−0.49 (−2.93 to 1.94)	.88

[a]Results are based on multivariable linear mixed-effect modeling. BMI <25 is the referent group for all analyses. BMI = body mass index; CI = confidence interval; CR = cardiac rehabilitation; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; SB = sedentary behavior.

participants with obesity walked on average only 5483 steps/d. Furthermore, participants with obesity spent 25 min/d less in LPA than participants with normal weight, and they also seemed to spend less time in MVPA (3.5 min/d). Even though there are no clear cut-off values for amount of LPA and MVPA for participants with obesity, it has been shown that less time in LPA and MVPA is related to a higher risk of all-cause mortality.[29] Thus, participants with obesity had lower physical activity levels than participants with normal weight at the start of CR, in which lower levels of LPA were not compensated by more time in MVPA.

The current study also showed that participants with obesity spent 28 min/d more in SB at the start of CR. A more sedentary lifestyle is shown to be associated with negative health outcomes, such as hospitalization and mortality.[9,29,30] Although further studies are needed to define clear cut-off values for amount of sedentary time, a large meta-analysis suggested that every hour increase in SB (>7 hours) is related to a 5% increase in all-cause mortality.[9] Another meta-analysis suggested that sedentary time >9 hours and 30 minutes is related to a higher mortality risk.[29] In our study, participants with obesity spent 9 hours and 40 minutes sedentary at the start of CR compared with 9 hours and 21 minutes in participants with normal weight. Although participants of all 3 BMI classes need to decrease the amount of sedentary time, participants with obesity spent the most time in SB and therefore may need extra coaching on preventing this behavior.

Altogether, we showed that participants with obesity start CR with a less favorable physical activity and SB profile than participants with normal weight. An important aim of CR is to improve this profile. In contrast to what we expected, we showed that the improvements during CR (as well as the maintenance during follow-up) were similar between participants with normal weight, overweight, and obesity. As opposed to this result, a previous study suggested that long-term maintenance is less optimal in participants with obesity.[31] Differences in results between studies might be explained by differences in measurement methods. In our study, physical activity and SB were assessed objectively, which is known to be more valid than self-reported measures.[32] Although improvements were observed in our study, the lack of difference in improvements between the BMI classes also means that participants with obesity do not reach the same levels as participants with normal weight at the end of CR. At 1 year follow-up, participants with obesity walked on average 6281 steps/d, which is still below the suggested threshold of 6500,[28] and remained more sedentary (9 hours and 28 min/d) than participants with normal weight (8 hours and 55 min/d). Taking into account the higher risk for cardiovascular disease in participants with obesity, these results are of great concern.[16]

The need for specific intervention programs in CR, combining the standard program with additional counseling on weight loss, physical activity, and SB in participants with obesity, has been suggested by several studies.[21,22,33,34] The current study supports this need from an accelerometry-based physical activity and SB point of view. Participants with obesity may benefit from higher physical activity levels when trying to lose excessive body weight. A moderate weight loss of 5% to 10%, when combined with increased physical activity, can improve cardiovascular risk factors[35] and thereby decrease the risk of mortality.[36] It has been recommended that these additional programs should include self-regulation components (eg, goal-setting and relapse prevention) and should use activity trackers to facilitate goal-setting and provide objective feedback.[37–39] The currently ongoing OPTICARE XL trial (registered on Dutch Trial Register, NT6181) aims at investigating the effect of additional care in participants with obesity attending CR.

Limitations

Some study limitations deserve discussion. First, the cut-off points used in our study to specify physical activity intensity levels were developed for a healthy population. Excessive body weight in participants with obesity adds a larger burden on the body when being physically active; these participants might reach a higher intensity level sooner than participants with normal weight. The intensity levels of physical activity may therefore be underestimated in our participants with obesity. We included a count-based measure (step count) to estimate physical activity, which is not influenced by these cut-off points.[40] Secondly, participants with obesity provided less successful accelerometer measurements than participants with normal weight. Although this was only the case at 1 time point and average wear time between BMI classes was the same, this should be kept in mind when interpreting the results. Lastly, reasons for not completing CR were not provided by all participants. However, reasons most often registered were lack of time or motivation. Proportions of participants in BMI classes who were either included or excluded in our study due to early drop-out were not different, suggesting that reasons for not completing CR were not causally related to BMI.

To conclude, participants with obesity had similar improvements in physical activity and sedentary behavior during CR as patients with normal weight but started with a less favorable profile. We suggest developing CR programs tailored for patients with obesity to correct the deficit in this target population. These programs should include extra counseling on increasing physical activity and preventing sedentary behavior.

Author Contributions

Concept/idea/research design: I. den Uijl, N. ter Hoeve, M. Sunamura, H.J. Stam, E. Boersma, R.J.G. van den Berg-Emons
Writing: I. den Uijl, N. ter Hoeve, H.E.M. Braakhuis, H.J. Stam, E. Boersma, R.J.G. van den Berg-Emons
Data collection: N. ter Hoeve
Data analysis: I. den Uijl, N. ter Hoeve, H.E.M. Braakhuis, R.J.G. van den Berg-Emons
Project management: I. den Uijl, M.J. Lenzen, H.J. Stam, R.J.G. van den Berg-Emons
Providing participants: N. ter Hoeve
Providing facilities/equipment: R.J.G. van den Berg-Emons
Providing institutional liaisons: H.J. Stam
Consultation (including review of manuscript before submitting): I. den Uijl, N. ter Hoeve, M. Sunamura, M.J. Lenzen, H.E.M. Braakhuis, H.J. Stam, E. Boersma, R.J.G. van den Berg-Emons

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Ethics Approval

The OPTICARE trial was approved by the Medical Ethics Committee of Erasmus MC, University Medical Centre Rotterdam, the Netherlands (MEC-2010-391). This study complies with the Declaration of Helsinki.

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Clinical Trial Registration

The trial was registered on ClinicalTrials.gov (NCT01395095).

Disclosures

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

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