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FULL RESEARCH PAPER
Physical activity

A remote booster program to attenuate sedentary behaviour in patients with coronary artery disease: a randomized controlled trial

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Aims Sedentary time (ST) can be reduced in patients with coronary artery disease (CAD) during cardiac rehabilitation (CR), but most patients relapse to sedentarism within months. We examined the effectiveness of a 3-week remote booster intervention on ST changes in CAD patients.

Methods and results Coronary artery disease patients who previously [2.0 (1.9–2.2) years] completed CR were included in this randomized controlled trial (1:1, stratified for gender). All participants received usual care, whereas booster participants additionally received a 3-week remote behavioural change intervention. The primary outcome was the change in accelerometer-derived ST from baseline to post-intervention and secondary outcomes included changes in sedentary behaviour and physical activity (PA) characteristics. A baseline constrained linear mixed model on an intention-to-treat basis was used. Participants (19% female, booster: $n = 21$, control: $n = 21$) were 69 [63–75] years old. Greater decreases in ST {−1.3 [95% confidence interval (CI): −2.0; −0.6] vs. −0.1 (95% CI: −0.8; 0.6) h/day, $p_{\text{-interaction}} = 0.012$} and number of prolonged sedentary bouts [−1.1 (95% CI: −1.6; −0.6) vs. 0.2 (95% CI: −0.3; 0.7) bouts/day, $p_{\text{-interaction}} < 0.001$] in combination with larger increases in light PA [+1.1 (95% CI: + 0.5; + 1.8) vs. +0.2 (95% CI: −0.4; + 0.8) h/day, $p_{\text{-interaction}} = 0.030$] were found for the booster vs. control group. Changes in moderate-to-vigorous PA ($p_{\text{-interaction}} = 0.13$) and step count ($p_{\text{-interaction}} = 0.18$) did not differ between groups.

Conclusion The remote booster program effectively reduced ST and increased light PA in CAD patients. These findings highlight the potential to change physical (in)activity behaviour of patients beyond completion of traditional CR programs.

Trial registration NCT06038188 (ClinicalTrials.gov)

Lay summary This study assessed the effectiveness of a remote 3-week booster program on reductions in daily sitting time in patients with coronary artery disease who previously completed a cardiac rehabilitation program.

- The booster program successfully reduced sitting time (−1.2 h/day) and increased light intensity physical activity (+0.9 h/day).
- A remote booster program is a novel and promising strategy to support patients with coronary artery disease to achieve a physically active lifestyle beyond cardiac rehabilitation.

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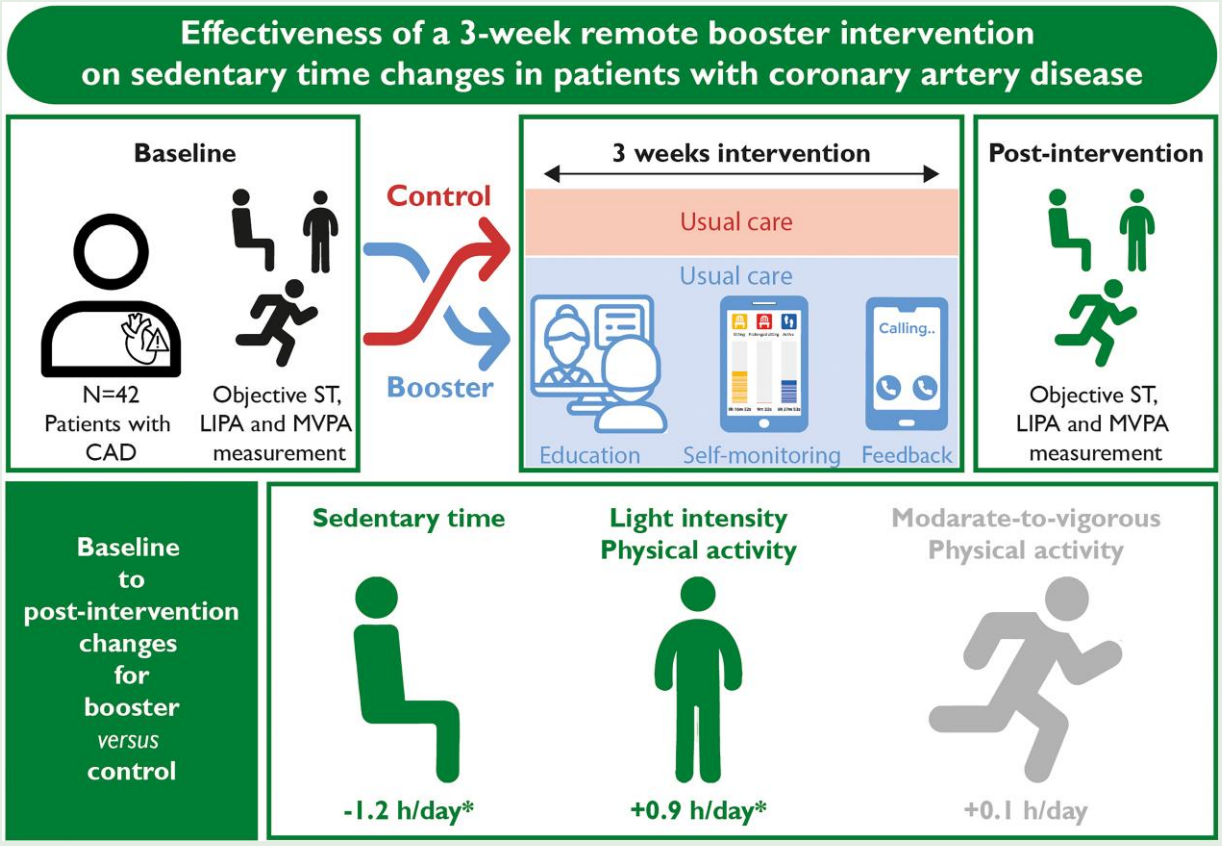
Graphical Abstract



Keywords Cardiac rehabilitation • eHealth • Prevention • Sitting • Physical activity • Cardiovascular disease

Introduction

Patients with coronary artery disease (CAD) spend substantially more time sedentary per day compared to the general population (10.4 vs. 9.4 h/day).[1,2] A high sedentary time (ST, i.e. ≥9.5 h/day) is associated with an increased risk of cardiovascular disease morbidity and mortality, even after accounting for traditional risk factors.[3] The interruption and replacement of ST with light or moderate-to-vigorous intensity physical activity (LIPA or MVPA) can improve cardiovascular risk factors[4] and attenuates the risk for adverse health outcomes.[1,5] Contemporary exercise-based cardiac rehabilitation (CR) programs aim to enhance habitual physical activity (PA) of CAD patients, but do not specifically target ST.[6] As a result, CR graduates demonstrated no or only slight reductions in ST (−0.4 to −0.2 h/day) and no changes in the number of prolonged sedentary bouts.[2,7,8]

We previously showed that enrichment of CR with a tailored sedentary behaviour intervention (SIT LESS) induces greater reductions in some ST indicators compared to usual care. However, these beneficial behavioural changes were only temporary as attainment of sustainable PA habits after CR remain challenging.[9] eHealth-based programs may offer potential strategies for individual patients to maintain beneficial PA levels following CR.[9] Moreover, remote booster programs may already nudge CR graduates towards a more physically active lifestyle.[10] Such booster programs should ideally include continued support to allow self-monitoring of behaviour, goal-setting, and associated feedback.[9] However, the effect of a remote eHealth-based booster program aiming to reduce ST in patients with CAD who followed a ST reduction program previously is currently unknown.

Our randomized controlled trial examined the effectiveness of a remote 3-week booster behaviour intervention program on changes in objectively measured ST. Secondary outcomes included the participation rate to the study, changes in other characteristics of sedentary behaviour (i.e. prevalence of prolonged sedentary bouts ≥30 min, proportion of patients with ST ≥9.5 h/day), LIPA, MVPA, and step count. We hypothesized that the booster intervention would result in a lower ST and increased PA compared to control.

Methods

Study design and population

A parallel-group randomized controlled trial was conducted to determine the effectiveness of a booster intervention on reducing ST. The booster program consisted of a 3-week, fully remote and personalized behaviour change intervention with a primary focus on reducing and interrupting ST in patients with CAD [i.e. myocardial infarction or (stable) angina pectoris] (ClinicalTrials.gov NCT06038188). The booster is a compressed version of the 'Sedentary Behaviour Intervention as a Personalized Secondary Prevention Strategy' (SIT LESS) intervention, which has previously been

described in detail[11] and the protocol can be found in Supplementary material online, *File S1*. Participants who completed the original SIT LESS intervention ($n = 97$) during their CR program (1.5–2.5 years ago) were screened for this study. First, participants were excluded if they refused to be contacted for follow-up studies or if accelerometer data were repeatedly unavailable (e.g. refused accelerometer measurements or no show) during the original SIT LESS RCT. Thereafter, electronic patient files were screened, and participants were excluded when they were deceased or had medical conditions that made it physically unable to stand or walk. Eligible participants were accordingly approached for participation in this study by email and phone contact including reminders in August 2023 by a researcher of the study team (S.K.). After inclusion, baseline characteristics were collected including baseline assessment of ST and PA characteristics by an accelerometer (see Supplementary material online, *Figure S1*). Following baseline measurements, participants were randomly assigned into the control or booster group. The control group received usual care, which included cardiovascular risk management and regular cardiology consultation. The booster group additionally received the booster intervention. Finally, the accelerometery measurement was repeated in both groups at the end of the booster intervention (post-intervention, ~1 month post-baseline measurement). There were no changes to the study protocol after trial commencement. Our trial was approved by the Medical Ethics Committee of the Radboud university medical centre (NL72604.091.20), and all participants gave written informed consent. The CONSORT checklist is available in Supplementary material online, *Table S1*.[12]

Randomization and masking

Participants were randomly allocated (1:1) to the control or booster group using the validated variable block randomization algorithm of Castor CDMS software (Castor Electronic Data Capture 2021, Ciwit B.V., Amsterdam, The Netherlands). Random block sizes ranging from two to six participants were applied, while stratification by gender was used to ensure balance of the treatment arms. Allocation concealment was ensured as randomization by the centralized method (Castor CDMS) was released after all the baseline measurements were completed. Due to the nature of the intervention, the research team and participants were not blinded to the treatment assignment. However, the primary outcome assessment was performed blinded using an automatized data processing script based on a unique participant identification number, independent from the randomization procedure.

Booster intervention

Participants in the booster group received a completely remote version of the SIT LESS intervention.[11] SIT LESS was developed in close collaboration with patients and nurse specialists following the intervention mapping adaptation framework[13] as described elsewhere.[11,14] The booster intervention consisted of a 3-week, personalized behaviour change intervention. At the start of the booster program (Week 1), participants received one remote consultation (30 min by video or telephone, Supplementary material online, *Figure S1*) consisting of an educational refresher, personal goal-setting, and motivational interviewing with coping planning to reduce ST. Participants also received a pocket-worn activity tracker by mail, which was connected to a smartphone application (RISE, Appbakkers B.V., Zwolle, The Netherlands). The activity tracker provided vibrotactile feedback after a predefined limit for sedentary bouts was exceeded (i.e. 30 min) and the smartphone application enabled participants and researchers to register and adjust personal goals and review daily ST.[15] Participants were contacted twice by telephone (±10 min per contact) in Weeks 2 and 3, with the aim to resolve practical issues (e.g. activity tracker, smartphone application), evaluate the personal ST goal and define an action plan to (further) reduce ST the upcoming week using motivational interviewing techniques to stimulate the participant. The intervention was delivered by a researcher of the study team (S.K.), who followed a comprehensive training course in delivering the intervention consultations and applying motivational interviewing, under the guidance of a behavioural psychologist. The SIT LESS manual was followed for the consultation and a standard operating procedure was used for the telephone coaching, both are described elsewhere.[11]

Outcomes

The pre-specified primary outcome was the change in objectively measured ST, expressed in h/day, from baseline to directly post-intervention (see Supplementary material online, *File S1*).[11] Secondary outcomes included participation rate, changes in the number of prolonged sedentary bouts (≥30 min), prevalence of ST ≥9.5 h/day, time spent in LIPA and MVPA, and daily step count.

Measurements

Sedentary time and PA were objectively assessed using a validated accelerometer (ActivPAL3^{TM}micro, PAL Technologies Ltd., Glasgow, UK).[16] The ActivPAL is a small device (25 × 45 × 5 mm), waterproof attached to the participant's thigh using hypoallergenic tape. The ActivPAL combines a triaxial accelerometer with an inclinometer which accurately distinguishes between sitting, standing, and walking.[16] Participants were instructed to wear the ActivPAL 24 h/day for 8 consecutive days and to fill in a diary with sleep times and moment of attachment and detachment. Raw data were analysed by a modified version of the script of Winkler *et al.*[17] Total ST [Metabolic Equivalent of Task score (METs) ≤ 1.5 while awake in a sitting, lying, or reclining posture][18] was expressed in h/day and accumulation of ST was examined by calculating the number of prolonged (≥30 min) sedentary bouts. The daily ST was dichotomized using 9.5 h/day as cut-off as it was previously shown that exceeding this upper limit of normal was associated with an increased risk of morbidity and mortality.[3] Physical activity was categorized as LIPA (METs <3) or MVPA (METs ≥3) and expressed in h/day, whereas step count was expressed as the number of steps/day. Accelerometery data were gathered at baseline and post-intervention.

Baseline characteristics were derived from the hospital electronic patient files and a telephone interview. Subsequently, the Charlson Comorbidity index was calculated.[19] For participants randomized to the booster-arm, the adherence was assessed by counting the number of valid wear days of the activity tracker (≥10 h/day), and by dividing the number of valid days by the total number of days of the intervention period × 100%. The number of completed remote consultations and telephone consultations was noted.

Sample size

As our study has an explorative character, no formal sample size calculation was performed *a priori* to trial initialization.[11] In the original SIT LESS study, the Cohen's D effect size for the primary outcome sedentary time was 0.3[20] with an alpha of 0.05 and beta of 0.2 (power 0.8). According to G*power (version 3.1.),[21] the (*a posteriori*) estimated sample size needed for this study was 24 participants (12 in each study arm) based on previously mentioned parameters, see also Supplementary material online, *File S1*. Given the secondary outcome to assess the participation rate to the booster study, all eligible participants were approached.

Statistical analyses

All statistical tests were performed using R version 4.2.1 with packages 'lme4', 'Lmmstar', 'emmeans', 'compositions', and 'Hotelling'. All tests were two-sided, confidence intervals (CI) were at the 95% level and *P*-values <0.05 were considered statistically significant. Continuous normally distributed data were presented as mean ± standard deviation (SD), continuous not-normally distributed data as median [interquartile range] and categorial variables as frequency (%). All data were visually inspected for normality and the Bartlett test was used to assess homoscedasticity.

Primary and secondary outcome analysis were performed on an intention-to-treat basis using a constrained (i.e. baseline adjusted) linear mixed-model analysis to handle missing data and to avoid baseline

imbalances between treatment arms.[22] Time (categorical) and time*group were included in the model. In addition, we evaluated the difference between the control and booster group in the proportion of participants with ST ≥9.5 h/day post-intervention by constrained logistic mixed-model analysis. Assumptions of normality of residuals, and homoscedasticity were checked for all models. Additionally, we performed a compositional data analysis (CoDA) to explore the change in the daily distribution of the movement behaviours induced by the booster program. Time spent in sleep, ST, LIPA, and MVPA was first normalized to 24 h/day. Compositional means were computed for the proportion of time spent in the different settings at baseline and post-intervention. The change in composition as a proportional change from the baseline overall composition was determined and compared between groups using the Hotelling T^2 test for multivariate pairwise comparisons.[23,24]

To assess the presence of potential selection bias among study participants, historical sedentary behaviour and PA characteristics were compared between our analytical cohort (participants of the Booster trial) and non-participants (participants of the SIT LESS trial not participating in the Booster trial) using an independent samples *t*-test (continuous normally distributed data with homogeneity of variance), Wilcoxon-signed rank test (continuous not-normally distributed data or no homogeneity of variance) or χ^2 test (categorial data). Mixed-model analysis with baseline measurement as reference was used to assess the effect of time in the analytical cohort.

Results

Participant characteristics

The participation rate to the Booster trial was 55% (48 included participants out of 87 eligible participants) (*Figure 1*). The baseline measurement was performed in 42 participants between 30 August 2023 and 11 November 2023, which was 2.0 [1.9–2.2] years after CR enrolment. Participants were 69 [63–75] years old and 8 (19%) were female (*Table 1*). Our analytical cohort did not differ in historical sedentary behaviour and PA characteristics from the non-participants (see Supplementary material online, *Table S2*, *Figures S2* and *S3*).

Participants were randomly assigned to the booster group ($n = 21$) and control group ($n = 21$) (*Table 1*). Post-intervention measurements were performed at 35 [35–36] days after baseline measurements between 11 October 2023 and 13 December 2023. Two participants (5%) dropped out in the booster group during the intervention period (*Figure 1*). The adherence to the daily use of the activity tracker was 79 [67–91]% (see Supplementary material online, *Table S3*). No study-related adverse events occurred.

Sedentary behaviour

Greater baseline to post-intervention decreases in ST were found in the booster vs. control group [−1.3 (95% CI −2.0; −0.6) vs. −0.1 (95% CI −0.8; 0.6) h/day, $p_{\text{-interaction}} = 0.012$, *Figure 2A*, Supplementary material online, *Table S4*, *File S2*]. Furthermore, greater reductions in the daily number of prolonged sedentary bouts were observed in the booster vs. control group [−1.1 (95% CI −1.6; −0.6) vs. 0.2 (95% CI −0.3; 0.7) bouts/day, $p_{\text{-interaction}} < 0.001$, *Figure 2B*, Supplementary material online, *File S2*]. The post-intervention prevalence of ST ≥9.5 h/day was, however, not significantly different between the booster and control group (26% vs. 52%, $P = 0.11$) (see Supplementary material online, *Table S4*, *File S2*).

Physical activity

Larger baseline to post-intervention increases in LIPA were found for the booster vs. control group [+1.1 (95% CI: +0.5; +1.8) vs. +0.2 (95% CI: −0.4; +0.8) h/day, $p_{\text{-interaction}} = 0.030$, *Figure 3A*, Supplementary material online, *File S2*]. Changes in MVPA [−0.0 (95% CI: −0.1; +0.1) vs. −0.2 (95% CI: −0.3; −0.0) h/day, $p_{\text{-interaction}} = 0.13$, *Figure 3B*, Supplementary material online, *File S2*] and step count did not differ between groups [−121 (95% CI: −1137; +894) vs. −1053 (95% CI: −2039; −68) steps/day, $p_{\text{-interaction}} = 0.18$, *Figure 3C*, Supplementary material online, *File S2*].

Compositional data analysis

The CoDA showed that the booster group reduced ST by 18% and increased LIPA by 17% compared to baseline, while MVPA (−1% from baseline) and sleep (−1%) did not change (*Figure 4*). In the control group, both the proportion of time spent in ST (3%) and LIPA (9%) increased from baseline, while the proportion of time spent in MVPA (−10%) and sleep (−2%) reduced from baseline. The group × time interaction did not reach significance ($P = 0.16$) (*Figure 4*).

Discussion

This randomized controlled trial examined the effects a remote 3-week booster intervention in patients with CAD who completed CR combined with a ST reduction program 1.5–2.5 years ago. We found that the booster induced a greater reduction in ST and in the number of prolonged sedentary bouts, and a larger increase in LIPA compared to the control group in the short-term. These collective findings show that a short and remote booster program can effectively reduce sedentary behaviour while increasing LIPA. Therefore, this booster program offers a novel possibility to support patients with CAD to achieve sustainable lifestyle changes beyond CR-completion, which is hallmark of tertiary prevention.

Sedentary behaviour and physical activity

In line with our hypothesis, this remote eHealth-based booster program led to a reduction of ST and increase of LIPA by more than 1 h and lowered the number of prolonged sedentary bouts. The changes are larger than observed in the original hybrid, 12-week SIT LESS study (ST: −0.5 h/day, LIPA: + 0.4 h/day) in patients with CAD.[20] A meta-analysis in the general population showed that objectively measured ST reduced by 35 min/day following eHealth interventions targeting ST,[25] where a Cochrane review in community dwelling older adults showed no effects of sedentary behaviour reduction programs.[23] Our outcomes are likely to be clinically relevant as the replacement of 1 h of ST with standing and/or LIPA improves cardiorespiratory risk factors[26] and reduces the risk of all-cause mortality.[5] Moreover, fewer prolonged sedentary bouts (i.e. ≥30 min) may provide additional health benefits, as mortality risk is higher among individuals with prolonged sitting characteristics compared to peers with ST accumulated from less prolonged sedentary bouts.[27] Moderate-to-vigorous physical activity did not change after the ST reduction booster, which is in accordance with earlier research and highlights that ST and MVPA are distinct behaviours that require specific targeting strategies.[20,28] Nevertheless, a sedentary behaviour change program can be seen as the first step to improve cardiovascular health and increase physical activity and cardiorespiratory fitness in CAD patients,[4] which can be followed by a program to gradually increase the volume and intensity of physical activity levels.

Transient improvements in sedentary behaviour and PA characteristics have been found after CR,[2,8] but most patients relapse to a more physically inactive lifestyle in subsequent months.[29] Additional support

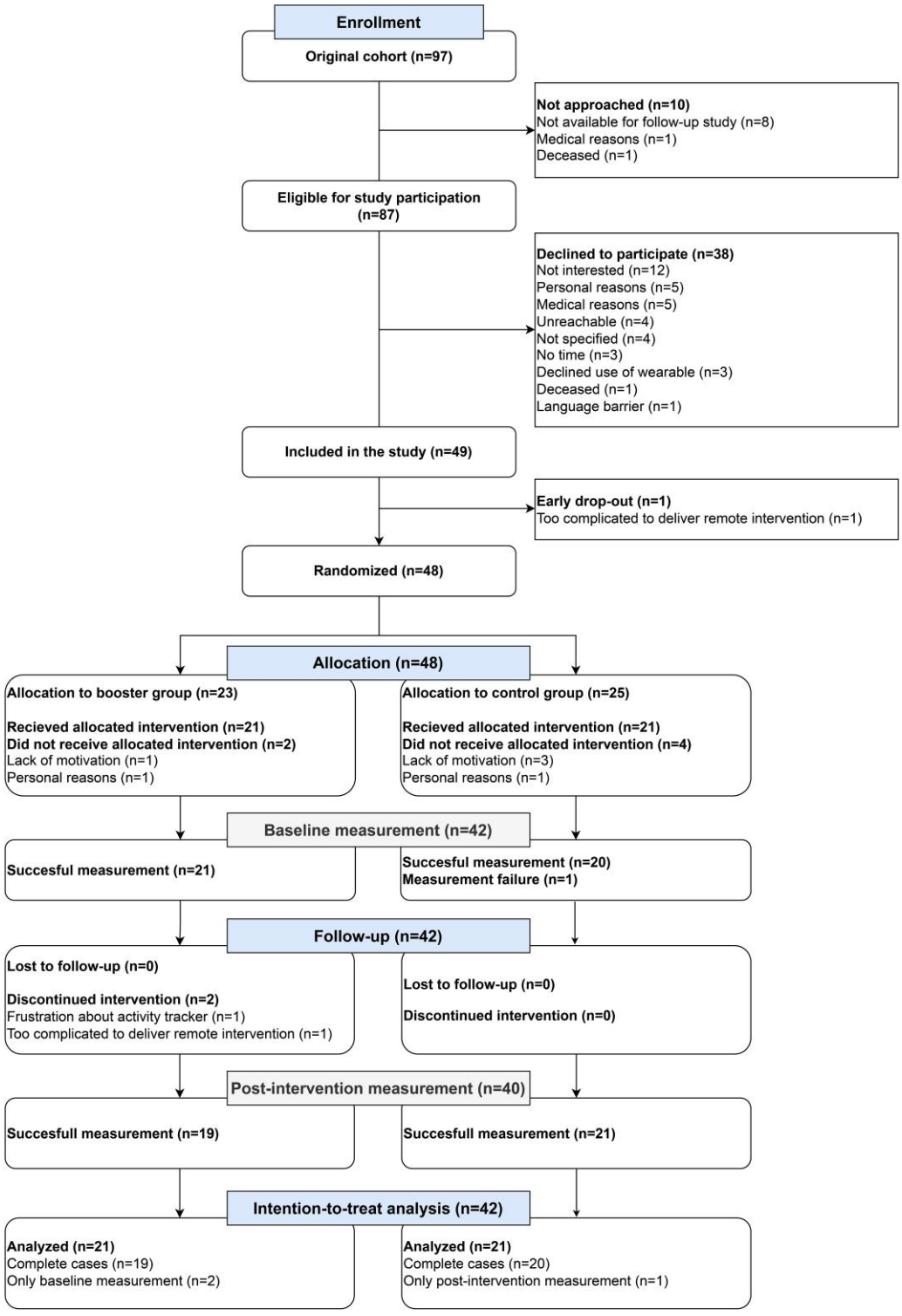


Figure 1 CONSORT flowchart of our randomized controlled trial.[12] Of the original SIT LESS cohort of 97 participants, 87 (100%) were eligible for study participation. Forty-eight (55%) were randomized to either the booster intervention ($n = 23$) or control group ($n = 25$) and the analytical cohort included 42 participants (48%, booster: $n = 21$, control: $n = 21$).

for lifestyle changes is currently not well-structured after CR graduation,[9] which complicates a sustainable transition to a physically active lifestyle. Indeed, no changes in ST or PA were observed during the ~2 years between CR-completion and enrolment in the present study (see Supplementary material online, *Figures* S2 and S3). Moreover, the participation rate to this study was 55%, which was aligned with a study

Table 1 Baseline characteristics of the total study sample

	Total study sample (*n* = 42)	Booster intervention (*n* = 21)	Control group (*n* = 21)
Age (years)	69 [63–75]	69 [62–72]	69 [63–75]
Gender (female)	8 (19%)	3 (14%)	5 (24%)
Body mass index (kg/m^2)	26.3 [23.8–27.9]	26.5 [23.3–27.4]	26.3 [24.9–28.1]
Regular step count tracking by smartwatch or smartphone [*n* (%)]	18 (42%)	9 (42%)	9 (42%)
Employed[a]	22 (52%)	11 (52%)	11 (52%)
Alcohol use [*n* (%)]	34 (81%)	15 (71%)	19 (90%)
Current drinker [n (%)]	29 (85%)	13 (87%)	16 (84%)
Units/week (n)	3 [2–6]	4 [2–5]	2 [2–7]
Smoking [*n* (%)]	23 (55%)	10 (48%)	13 (62%)
Current smoker [n (%)]	2 (8%)	2 (20%)	0 (0%)
Packyears (n)	16 [5–24]	21 [12–24]	12 [5–20]
Comorbidities			
Primary CAD diagnosis[a]			
NSTEMI	24 (57%)	10 (48%)	14 (67%)
STEMI	10 (24%)	6 (28%)	4 (19%)
AP	8 (19%)	5 (24%)	3 (14%)
UAP	0 (0%)	0 (0%)	0 (0%)
Charlson Comorbidity Index (% estimated 10-year survival)	53 [21–89]	53 [21–77]	53 [2–90]
Hypertension [*n* (%)]	19 (45%)	9 (43%)	10 (48%)
Dyslipidaemia [*n* (%)]	9 (21%)	4 (19%)	5 (24%)
Diabetes mellitus [*n* (%)]	4 (10%)	2 (10%)	2 (10%)
Prior myocardial infarction [*n* (%)]	35 (83%)	16 (76%)	19 (90%)
Prior PCI [*n* (%)]	26 (62%)	13 (62%)	13 (62%)
Prior CABG [*n* (%)]	15 (36%)	6 (29%)	9 (43%)
Atrial fibrillation [*n* (%)]	7 (17%)	4 (19%)	3 (14%)
Heart failure [*n* (%)]	6 (14%)	1 (5%)	5 (24%)
Peripheral artery disease [*n* (%)]	2 (5%)	0 (0%)	2 (10%)
Heart valve disease [*n* (%)]	8 (19%)	3 (14%)	5 (24%)
Depression [*n* (%)]	3 (7%)	0 (0%)	3 (14%)
Cancer (diagnosed in the past 5 years) [*n* (%)]	5 (12%)	3 (14%)	2 (10%)
Rheumatoid arthritis [*n* (%)]	0 (0%)	0 (0%)	0 (0%)
COPD [*n* (%)]	1 (2%)	1 (5%)	0 (0%)
CVA [*n* (%)]	2 (5%)	1 (5%)	1 (5%)
TIA [*n* (%)]	1 (2%)	0 (0%)	1 (5%)
Chronic renal failure (eGFR < 30 mL/min/1.73 m^2 or dialysis) [*n* (%)]	1 (5%)	0 (0%)	1 (5%)
Cardiovascular medication			
ACE-inhibitor/angiotensin receptor blocker	26 (62%)	14 (67%)	12 (57%)
Anticoagulant	3 (7%)	2 (10%)	1 (5%)
Beta-blocker	20 (48%)	10 (48%)	10 (48%)
PCSK9 inhibitor	0 (0%)	0 (0%)	0 (0%)
Platelet aggregation inhibitor	35 (83%)	19 (91%)	16 (76%)
Statins	37 (88%)	20 (95%)	17 (81%)

Data are presented as *n* (%) for categorical variables and as mean (±standard deviation) or median [interquartile range] for continuous variables. There were no missing data.
ACE, angiotensin-converting enzyme; AP, angina pectoris; CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; eGFR, estimated glomerular filtration rate; NSTEMI, non-ST-elevated myocardial infarction; PCI, percutaneous coronary intervention; PCSK9, proprotein convertase subtilsin-kexin type 9; STEMI, ST-elevated myocardial infarction; TIA, transient ischaemic attack; UAP, unstable angina pectoris.
[a]Data collected during the SIT LESS study.

examining the participation rate to a follow-up questionnaire after 3.5 years (42–62%).[30] Some of the participants mentioned that they were not interested to participate as they considered their rehabilitation as finished. So, an active transition from CR to lifelong maintenance of a healthy lifestyle is essential, while barriers such as the motivation of patients, costs, time, and travel burden should be minimized.[9]

Our booster program shows potential to bridge the gap in preventive cardiology between CR graduation and long-term healthy lifestyle

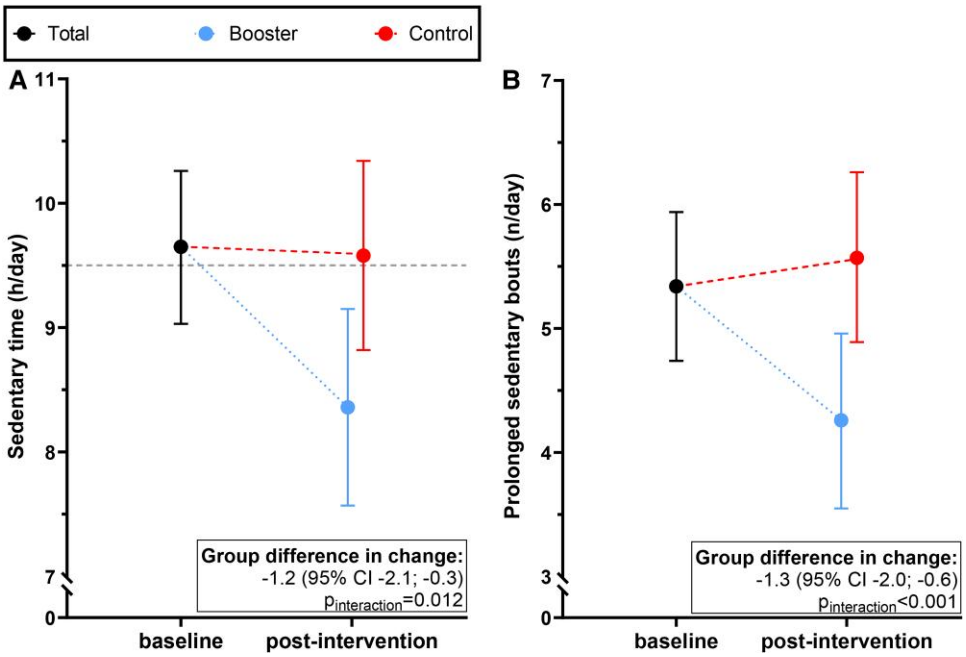


Figure 2 Constrained linear mixed-model sedentary behaviour outcomes. The total study cohort is depicted at baseline ($n = 41$, black) and post-intervention (booster: $n = 19$, blue; control: $n = 21$, red). (*A*) Sedentary time per day. The dashed line represents the level of sedentary time associated with higher mortality (9.5 h/day).[3] (*B*) Number of prolonged sedentary time bouts (≥30 min) per day. Values are provided per day and described with the mean and 95% confidence interval.

adherence. The brief and remote nature of the program enhances its accessibility, feasibility, and scalability during the maintenance phase of patients with CAD. Previous studies showed that follow-up prompts, i.e. brief contacts after a comprehensive intervention, are an effective method of maintaining behaviour change, including physical activity.[10,31] In addition, eHealth is considered as a promising strategy to maintain a healthy lifestyle among CR graduates,[32] as online behavioural interventions appear to outperform other delivery methods because they can be easily tailored to individual preferences and allow for frequent and timely feedback.[33] Our study showed that the eHealth approach was not feasible for all participants.

One participant dropped out because of a language barrier that was more apparent when delivering the intervention completely remote and two others dropped out because of the complexity of this intervention when delivered at home. However, it should be mentioned that these two participants were the oldest patients of our cohort (82 and 87 years old). As 47% of the participants were 70+ years old, it seemed that only a very high age was a limitation for study participation. Altogether, we show the high potential of a short, remote booster program to assist patients with a healthy lifestyle beyond CR-completion.

Towards implementation

Our booster program was effective, but some elements can be optimized to facilitate large-scale implementation. For example, participants had to return the activity tracker after the intervention period. Exploring (financial) possibilities to give participants an activity tracker that they can keep, could increase self-monitoring after the intervention period, which is an important aspect in preventing relapse to previous behaviours.[34] Secondly, the smartphone application can be used more extensively by incorporating educational videos, offering the possibility of shared goal-setting with a dyad, facilitating a supportive social environment.[35] Machine-learning techniques can be adopted to deliver just-in-time notifications, with the content or timing tailored to the individual participant's data (e.g. no reminders just after a predefined PA session or when they are asleep).[36] The combination of eHealth with personal contact by telephone or emails seems superior to achieve behavioural change,[37] which is supported by recent evidence suggesting that self-monitoring of behaviour with automatic generated feedback alone is not sufficient to improve PA or ST levels in patients with cardiovascular disease.[38,39] Taken together, future research should investigate how (smartphone) applications, connected wearables, and the balance between personal and automated feedback could improve feasibility, usability, and effectiveness of the booster intervention—and particularly in the long-term and outside of the context of a trial.

Strengths and limitations

To the best of our knowledge, we are the first to examine the effectiveness of a booster behaviour intervention aiming to reduce sedentary behaviour in CR graduates. Nevertheless, some limitations should be addressed. First, selection bias could have occurred as included participants may be more inclined to behaviour change compared to participants who declined participation, possibly leading to an overestimation of the effects. However, we compared the historical ST and PA characteristics and found no differences between participants and non-participants (see Supplementary material online, *Table S3*). Secondly, we examined the effectiveness of the booster program in participants who were familiar with the wearable and smartphone application, due

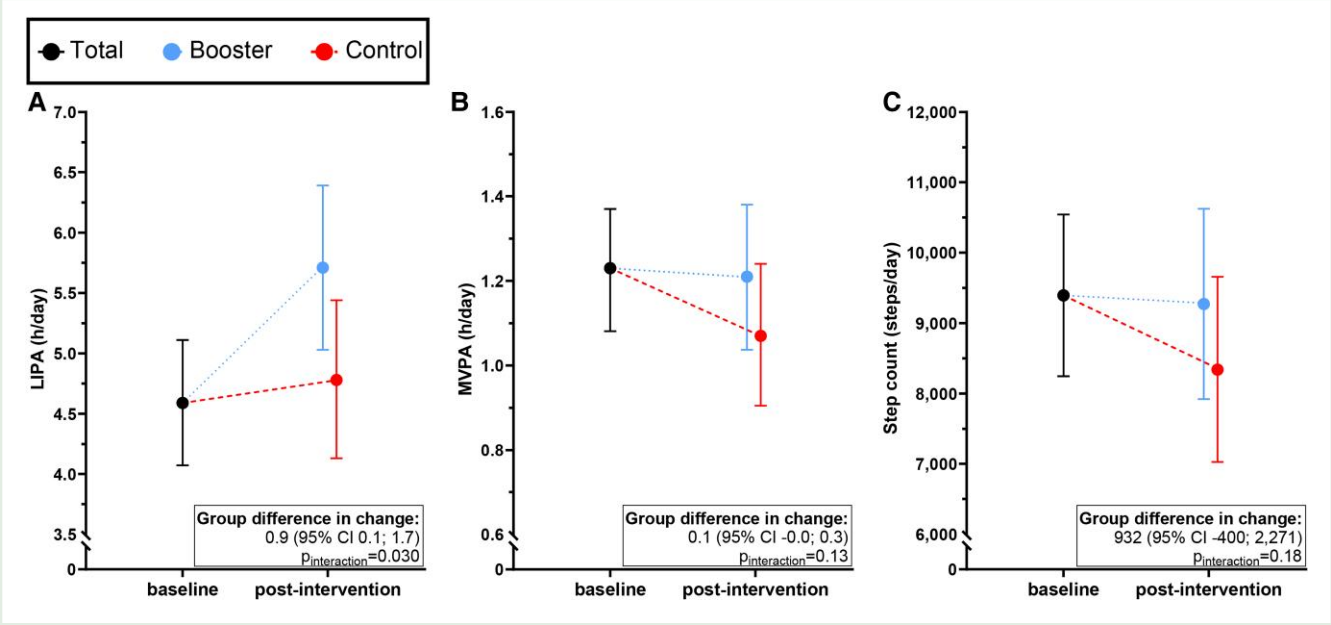


Figure 3 Constrained linear mixed-model physical activity outcomes. The total study cohort is depicted at baseline ($n = 41$, black) and post-intervention (booster: $n = 19$, blue; control: $n = 21$, red). (*A*) Time spent in light intensity physical activity (LIPA). (*B*) Time spent in moderate-to-vigorous intensity physical activity (MVPA). (*C*) Number of steps. Values are provided per day and described with the mean and 95% confidence interval.

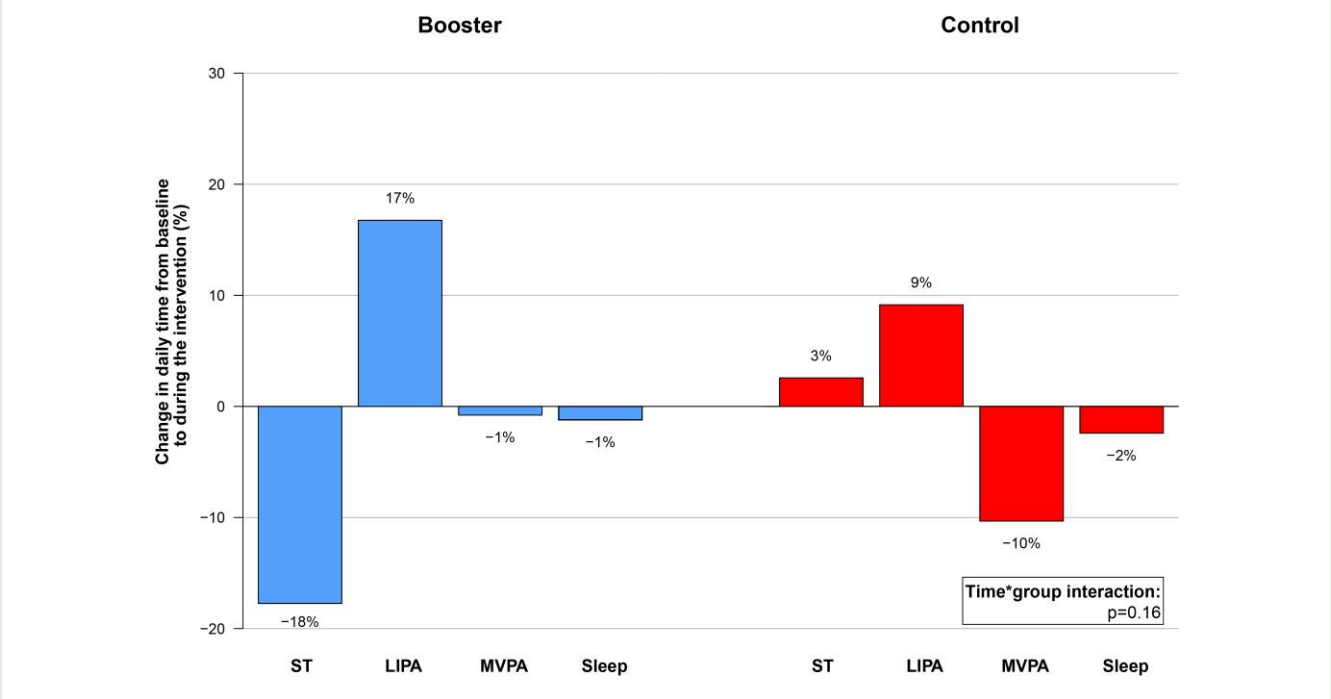


Figure 4 Change in daily activity composition for the booster and control group. The change in daily activity composition was calculated as a percentage difference in compositional mean post-intervention compared to the baseline composition. Difference in composition change between booster ($n = 19$) and control group ($n = 20$) was assessed by the Hotelling's T^2 test.

to previous participation in the SIT LESS RCT (see Supplementary material online, *Figure S1*).[20] This could have increased the feasibility of the remote booster program. Additional manuals or instructions might be needed for naive users to perform this remote program in different settings. Thirdly, the small sample size may limit the generalizability and did not allow us to assess differences in specific subgroups, for

example gender-specific effects or the influence of certain comorbidities. Finally, the current study assessed short-term effects of this remote intervention, hence, long-term behaviour change necessary for beneficial health effects remains to be investigated.

Conclusions

The 3-week remote booster program effectively reduces sedentary behaviour and the number of prolonged sedentary bouts, while increasing LIPA in patients with CAD who followed CR with a ST reduction program. These findings highlight the potential to improve activity behaviour in patients beyond completion of traditional CR programs. The accessible and feasible delivery method offers the opportunity to use a booster program to transition from supervised exercise training sessions as part of CR to lifelong maintenance of physical activity in the patient's living environment, empowering sustainable lifestyle changes.

Supplementary material

Supplementary material is available at *European Journal of Preventive Cardiology*.

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Author contributions

Concept and design: S.K., B.v.B., E.B., D.T., and T.E.; Acquisition, analysis, or interpretation of data: S.K., B.v.B., M.B., M.P., F.B.O., M.H., D.T., E.B., and T.E.; Drafting of the manuscript: S.K.; Critical review of the manuscript: B.v.B., M.B., M.P., F.B.O., M.H., D.T., E.B., and T.E.; Statistical analysis: S.K., F.B.O., E.B., and T.E.; obtained funding: T.E.; Supervision: E.B., M.H., and T.E.; Patient enrolment: S.K.

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Conflict of interest: none declared.

Data availability

Data from the SIT LESS Booster randomized controlled trial are available upon reasonable request via the corresponding author.

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