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RESEARCH ARTICLE

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Device-based 24-hour movement behaviours in adult phase III cardiac rehabilitation service-users during the COVID-19 pandemic: a mixed-methods prospective observational study

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ABSTRACT

Purpose: To examine changes in device-based 24-hour movement behaviours (MB), and facilitators and barriers to physical activity (PA) and exercise, during remotely-delivered cardiac rehabilitation (RDCR).

Materials and methods: This prospective observational study used wrist-worn GENEActiv accelerometers to assess MB of 10 service-users (63 ± 10 years) at the start, middle, and end of three-months of RDCR. Barriers and facilitators to PA and exercise were explored through self-report diaries and analysed using content analysis.

Results: At start, service-users were sedentary for 12.6 ± 0.7 h day^{-1} and accumulated most PA at a light-intensity (133.52 ± 28.57 min day^{-1}) – neither changed significantly during RDCR. Sleep efficiency significantly reduced from start (88.80 ± 4.2%) to the end (86.1 ± 4.76%) of CR, with values meeting health-based recommendations (≥85%). Barriers to RDCR exercise included exertional discomfort and cardiac symptoms, and reduced confidence when exercising alone. Setting meaningful PA goals, self-monitoring health targets, and having social support, facilitated PA and exercise during RDCR.

Conclusions: Our RDCR programme failed to elicit significant changes in MB or sleep. To increase the likelihood of successful RDCR, it is important to promote a variety of exercise and PA options, target sedentary time, and apply theory to RDCR design, delivery, and support strategies.

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Exercise; sedentary behaviour; physical inactivity; movement behaviours; remote-delivery; cardiac rehabilitation

IMPLICATIONS FOR REHABILITATION

- Practitioners should work with service-users to understand how best to support them to maximise the benefit(s) of remotely/hybrid delivered services.
- Facilitating easy (and regular) access to health professionals during remotely/hybrid delivered cardiac rehabilitation (CR) will support the development of service-users' physical activity (PA) and exercise self-efficacy (i.e., confidence).
- Remotely/hybrid delivered CR should be informed by theory and/or behaviour change techniques to support increased PA, reduced sedentary time and improved sleep during and after CR.
- It is important to include strategies to reduce sedentary time in addition to targeting PA and exercise in remotely-delivered CR.

Introduction

Cardiac rehabilitation (CR) has a robust evidence base for reducing cardiovascular mortality and morbidity, lowering acute hospitalisation, and enhancing health-related quality of life (HRQoL) post-cardiac event [1–3]. Service-users typically attend an 8-12-week programme focused on exercise as well as other lifestyle risk factors, such as habitual physical activity (PA), sedentary behaviour (i.e., an energy expenditure of <1.5 metabolic equivalents [METs] while sitting, lying down, or in a reclined position) and sleep [4]. As these three movement behaviours (i.e., physical activity, sedentary behaviour and sleep) do not occur in isolation, they are best considered from within a 24-h cycle, recognising that an increase or reduction in one would affect another [5].

To maximise its benefit, service-users need to remain physically active post-CR to sustain improvements in exercise capacity and HRQoL [6,7]. International guidelines [8] recommend 150–300 min of moderate-intensity physical activity (MPA), and 75–150 min of vigorous-intensity physical activity (VPA) per week to maintain

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health and wellbeing; aiming specifically to undertake 2–3 structured aerobic endurance exercise sessions per week at 40–60% heart rate reserve (HRR) for 20–30 min [9]. In addition, obtaining a recommended 7–9 h of good quality sleep per night [10] and reducing sedentary behaviour, has been shown to improve cardiovascular (CV) outcomes [11–13].

PA and the structured sub-component, exercise, are key to the success of CR delivery in the management of cardiovascular disease, given the associated benefits, such as improved myocardial perfusion, endothelial function, and regression of cardiac atherosclerosis [14–17]. A systematic review and meta-analysis of 40 randomised controlled trials (6,480 adults with cardiac disease) emphasised how challenging this can be, with only 26% of CR programmes significantly improving PA levels compared to controls, whereby CR increased the proportion of service-users who met PA recommendations in only 9/40 studies in the short-term (≤12 months) [18]. Given that most studies included self-reported measures of PA, this may even be an overestimate due to self-reporting bias [19]. UK-based CR services are susceptible to the same issue as PA levels at baseline and at discharge are typically assessed *via* self-report measures [4]. Furthermore, despite their importance, sleep and sedentary behaviour are not routinely assessed within CR [4], and hence, there are calls for more robust assessments of 24-h movement behaviours (i.e., PA, sedentary time, and sleep) in CR. One proposed solution to this issue is the use of "gold standard" device-based assessment as it offers superior validity and reliability [20,21] and enables measurement of sleep, sedentary time, and rest-activity patterns in addition to PA [22,23].

Recently, a meta-analysis of 15 studies involving people with CVD ($n = 1,434$) using device-based assessments found moderate improvements in PA and sedentary time immediately following CR compared to controls and favourable maintenance of long-term (6–12-month follow-up) activity behaviours [24]. Nevertheless, closer analysis showed that while eight studies indicated significant change in activity behaviours, seven did not. One explanation for this difference is the high heterogeneity across studies due to differences in exercise-based CR protocols (e.g., frequency, duration, and intensity of exercise, home vs. centre-based, concurrent training vs. aerobic only) [24]. Therefore, an ongoing challenge for CR is understanding how to best support service-users' activity behaviours, including optimal delivery modes both during their rehabilitation programme and after discharge. In this regard, qualitative data can provide meaningful insight and has been shown to illuminate issues not easily brought to light *via* "gold standard" quantitative approaches – helping to provide a fuller, context-sensitive picture of service-user experiences of CR [25,26].

Amidst the Coronavirus 2019 pandemic (COVID-19), issues pertaining to the support of service-users were exacerbated whereby CR services were challenged to "do more with less," [27–29] within the context of reduced population-level PA [30,31]. The sudden transfer to remote working associated with COVID-19 – in the United Kingdom staff were redeployed and assessments were delivered remotely [27–29] – encouraged innovation in some services to provide home-based support, including the use of digital technologies [32], such as technology-based wearables and obtaining personalised feedback remotely [33]. Pre-pandemic, there was some evidence to support the effectiveness of non centre-based CR programmes [34,35]. However, the large-scale shift to remote CR by under-resourced and under-staffed services raised questions regarding the quality of pandemic-adapted CR, service-user experiences of this adapted delivery and the ability of services to meet the British Association for Cardiovascular Prevention and Rehabilitation (BACPR) standard core components, including improvement in lifestyle risk factors, such as PA and sleep [4].

In response to these challenges, our study adopted mixed methods to address two main aims. Firstly, to examine changes in service user 24-h movement behaviours during remotely delivered CR as a result of COVID-19. Given the unprecedented circumstances service-users found themselves in, our second aim was to explore service-user's perceived barriers to and facilitators of structured CR exercise and habitual PA during strict COVID-19 protocols and restrictions.

Materials and methods

Study design

The study employed a mixed-methods design and provided a longitudinal analysis of 24-h movement behaviours at the start of CR (within one month of a baseline phase III assessment), two months after beginning CR, and at the end of the three-month programme. The programme was a phase III CR service remotely delivered during the COVID-19 pandemic. A favourable ethics opinion was granted by National Health Service (NHS) Research Ethics Committee and Health and Care Research Authority Wales (21/EE/0032) and the study was pre-registered on Clinical Trials.gov (ID No. NCT04740489). The STROBE (strengthening the reporting of observational studies in epidemiology) checklist was used when preparing this manuscript (supplementary material 1).

Participants

Inclusion criteria were phase III CR service-users ≥18 years participating in a remotely delivered three-month CR programme and who were within four weeks of an initial CR baseline assessment and had capacity to provide consent.

Setting

Data were obtained March 2021 – March 2022 in a UK-based, pandemic-adapted, core NHS (Southern England) CR programme. Core CR is a comprehensive outpatient programme within the CR care pathway, categorised as phase III CR in the UK [36]. Over the course of this study, 50% of CR staff were redeployed to COVID-related roles elsewhere in the NHS and CR standard care transformed from centre-based to remotely delivered support. Service-users received telephone support alongside access to instructional exercise videos and booklets (Supplementary material 2). The amount of contact each service-user received from staff (including cardiac nurses, physiotherapists, and exercise instructors) depended upon personal need, with most receiving telephone support twice per month for three months following recommended minimal provision [37].

Individualised, remotely delivered CR was guidelines-based, providing 2-3, 20–30-min structured aerobic endurance exercise sessions per week at an intensity of 40-60% heart rate reserve (HRR) and subjective ratings of perceived exertion (RPE) of 4–6 on the modified Borg- [38] RPE scale [9]. The aim was to safely progress service-users towards this optimum PA level suggested in CR guidelines through completion of structured exercise (i.e., aerobic interval training using a circuit in the home) and/or PA (i.e., a walking programme), depending on service-user preference. Exercise was tailored to individual needs, considering baseline PA, presence of cardiac symptoms, and individuals' previous experience, familiarity and confidence with engaging in PA and structured exercise training. Habitual PA was also encouraged in line with UK guidelines [39].

Data collection

Device-based assessment of PA and sleep

Due to COVID restrictions and limited staff capacity we were unable to obtain pre-CR measures of PA. Therefore, the first data point ("start") occurred within four weeks of service-users completing their initial standard CR assessment (supplementary material 3), and 2–4 weeks after commencing their exercise programme. Each service-user was sent a wrist-worn accelerometer (GENEActiv, Activinsights, Kimbolton, Cambridge, UK), sampling at 100 Hz, and measuring acceleration across three axes in gravity (*g*) units (1 *g* = 9.81 m.s$^{2-1}$). The magnitude of signals from the triaxial movement minus 1 *g* (with negative numbers rounded zero) was used to quantify acceleration due to movement in mg (1 m*g* = 0.00981 m.s$^{2-1}$) [40]. Service-users were instructed to wear the accelerometer on the non-dominant wrist for seven consecutive days. GENEActiv accelerometers have been used across clinical population [41,42], and have been validated for the assessment of sedentary time, sleep and PA in healthy adults [43]. These data collection methods were subsequently repeated at the two-month and three-month (end of CR) points.

Self-reported PA and barriers and facilitators

Service-users completed a seven-day self-report PA diary to capture the type of PA engaged in over the course of remotely delivered CR, including the frequency, duration, and intensity (Borg category-ratio 10 scale [38] and HR [finger pulse oximeter, ATMOKO LED: CMS50DL1, Hebei Province, Republic of China]) of structured CR and habitual PA. Participants received the pulse oximeter and Borg scale *via* post from a research team member and were encouraged to measure their intensity during each planned PA and exercise sessions as convenient. Service-users were also asked several open-ended questions in the diary to elaborate on their perceived barriers and facilitators to structured CR exercise and habitual PA (supplementary material 4).

Data analysis. Accelerometer data were processed in R (R Core Team, Vienna, Austria) using the open-source GGIR software package (http://cran.r-project.org). Total PA (minutes.day^{-1}, TPA), light-intensity PA (LPA), MPA, VPA, moderate to vigorous intensity PA (MVPA), 10-min bouts of MVPA, and sedentary time were quantified using validated acceleration threshold values for older adults (sedentary to LPA = 255 g min^{-1}; LPA to MVPA 588 g min^{-1}, for 60 s epochs) [44].

An open-source sleep detection algorithm using GGIR software determined device-based sleep variables. Periods of sleep were defined as nocturnal periods characterised by minimal movement frequency and magnitude of changes to the angle of the arm (i.e., the angle of orientation relative to the horizontal plane) [45]. Sleep efficiency was calculated from sleep duration as a proportion of time in bed, where sleep duration was defined as the sum of all recorded sleep, and time in bed was defined as periods of sustained inactivity measured by changes of less than five degrees in a rolling five-minute window. Periods of accelerometer non-wear time were identified on the basis of the standard deviation and the value range of each accelerometer axis, described in detail elsewhere [40]. Days where accelerometer wear-time was < 16 h were excluded from analyses.

Statistical analyses were conducted using IBM Statistical Package for the Social Sciences software (Version 28, UK) and are presented as means and standard deviations for PA and sleep, unless otherwise stated. Change scores from data point one ("start") to two (2-months), and data point one ("start") to three ("3-months") were calculated for 24-h movement behaviours. Means and standard deviations for frequency (sessions·week^{-1}) of home-based CR circuits and walking were calculated from self-reported diary data at data points one, two and three. Linear mixed models were used to assess changes in outcomes over time using a compound symmetry covariance structure, and Least Significant Difference (LSD) for pairwise comparisons, in *post hoc* analysis. Statistical significance was set as $p < 0.05$.

Content analysis of qualitative diary data

Qualitative diary data were analysed by the first author (SJM) using content analysis, a systematic technique for organising data into codes and content categories and interpreting meaningful patterns related to a phenomenon of interest [46,47]. Initially, PA diaries were read and re-read to immerse and get a sense of the data relating to PA barriers and facilitators during CR. The next step involved analysing patterns and separating the data into meaning units then condensing these, shortening the text while still preserving the core meaning of the data. Condensed meaning units were then labelled by formulating codes in a deductive format with influence from previous knowledge (e.g., research and theory on PA barriers and facilitators). Codes were grouped into categories through author interpretations in relation to the research question and previous knowledge [46,48]. This was an iterative process of coding and categorising then returning to the raw data to reflect on initial analyses [48]. To ensure rigour, a second investigator (CW) acted as a critical friend during the analysis process, including discussing coding and theme generation [49]. CW analysed 30% of diaries separately, in which no significant discrepancies in codes and categories were found. Recognising the ongoing debate in the qualitative research literature regarding rigour/trustworthiness [50] our approach represented one recommended by leading qualitative scholars in exercise [49].

Results

Participants

Ten service users in phase III CR provided fully-informed written consent to participate in the study (Figure 1). Participant characteristics, including the range of cardiac events experienced in this cohort, are presented in Table 1. Pseudonyms have been used to protect service user's identity.

Physical activity and exercise

Device-based measurement

Eighty seven percent of accelerometer data met >16 h·day^{-1} compliance. Device-based data of movement behaviours over the course of CR are presented in Table 2. Twenty percent of the sample ($n = 2$) achieved ≥ 150 min of MVPA in 10-min bouts at all three data points. There were no significant changes ($p > 0.05$) in TPA, sedentary time, LPA, MPA, VPA, MVPA, or 10-min sustained bouts of MVPA between time points over the course of the three-month CR programme (Figure 2).

Self-reported measurement

At data point 1 ("start"), 60% of the sample completed structured CR exercise in the form of home-based circuits and 80% completed weekly walks - frequency of exercise was 1.9 ± 1.8 circuits·week^{-1} and 5.1 ± 2.6 walks·week^{-1}. There were no significant changes in circuit, or walking frequency over time (i.e., between data points 1, 2 and 3; $F_{(2, 44.27)} = 0.06$ $p = 0.95$), but service-users

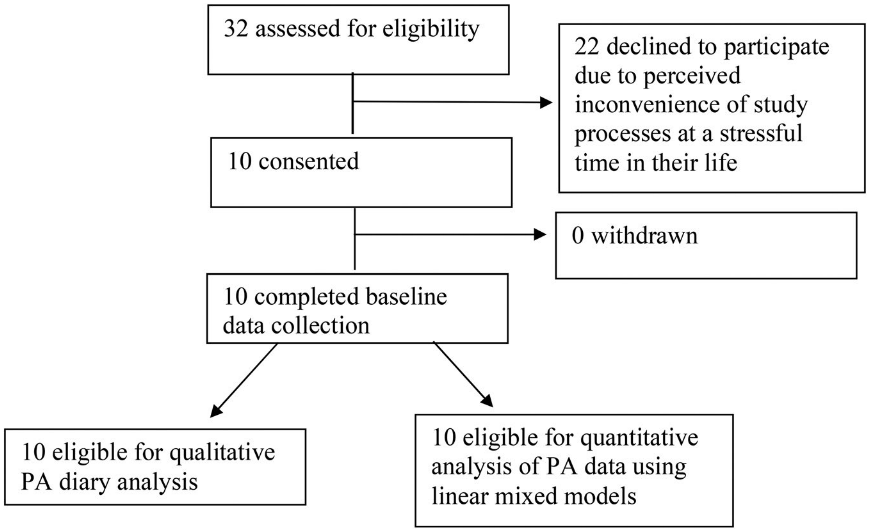

Figure 1. Flow diagram of study.
Analyses examining change in %HRR, RPE, and exercise duration over time were not conducted due to considerable missing data for these variables (41.7% data missing for %HRR, 45% data missing for RPE, and 36.7% data missing for exercise duration).

Table 1. Participant characteristics ($n = 10$).

Pseudonym	Age (years)	Ethnicity	Gender	Initiating Event	Treatment	Risk
Jenny	70	White British	Female	Unstable angina	Elective PCI to RCA	Low
Sophie	68	White British	Female	Mild to moderate LVSD secondary to hypertension	Optimisation of secondary prevention medication	High
Andrew	76	White British	Male	Atrial, tricuspid, and mitral valve regurgitation & severe LVSD	AVR, Mitral & Tricuspid annuloplasty	High
Ted	71	White British	Male	Aortic Dissection - Type B and NSTEMI	PCI to LAD & RCA x 5 stents	High
Derek	65	White British	Male	NSTEMI	PCI to CX & LAD	Low
Ben	44	White British	Male	MI	PCI	Low
Nicholas	59	White British	Male	Severe 3 vessel disease	CABG x3	Medium
Roland	60	White British	Male	Severe 3 vessel disease	CABG x3	Medium
Martin	49	Black African	Male	NSTEMI	PCI to RCA x 1 stent	Low
Jack	63	White British	Male	Aortic stenosis and quadruple vessel disease	AVR and CABG	Low
Mean ± SD or *n* (%)	63 ± 10	9 (90) White British	8 (80) Male			5 (50) low 2 (20) Medium 3 (30) High

AVR, aortic valve replacement; MVR, mitral valve replacement; MI, myocardial infarction; PCI, percutaneous coronary intervention; NSTEMI, non-ST segment elevation myocardial infarction; CABG, coronary artery bypass graft; LVSD, left ventricular systolic dysfunction; AD, aortic dissection; RCA, right coronary artery; LAD, left anterior descending artery.

completed significantly more weekly walks than circuits during CR ($F_{(1, 42.97)} = 27.7$; $p < 0.001$).

Sleep duration and efficiency

At data point one ("start"), service-users spent $7.25 \pm 0.94\,h{\cdot}night^{-1}$ asleep, with a sleep efficiency of $88.80 \pm 4.23\%$, and 60% of the sample achieved sleep recommendations ($7–9\,h{\cdot}night^{-1}$ [10]). There were no significant changes in sleep duration between data points one, two, and three (Table 2). Main effects for change in sleep efficiency over time approached significance ($F_{(2, 14.75)} = 3.55$, $p = 0.05$). Post hoc analysis indicated sleep efficiency was significantly lower at the end of CR compared to the start ($p = 0.04$) and middle ($p = 0.04$), although values remained within a range considered healthy (≥ 85%) [10].

Perceived barriers and facilitators to PA and exercise

Four hierarchical categories were constructed from content analysis of free-text, qualitative diary data: *(1)* perceived capability (n [no. of codes] = 92), *(2)* social influences, ($n = 56$), *(3)* motivation ($n = 33$), and *(4)* environmental influences ($n = 22$, Figure 3).

Perceived capability

Perceived capability was categorised into *(1)* physical and *(2)* psychological capability. Participants' perceived physical capabilities were challenged by medication side effects and cardiac symptoms, such as chest pain, aching leg muscles, wound discomfort, breathlessness, and feelings of fatigue:

> For example, Jenny (70 years of age) was still experiencing debilitating symptoms after her elective PCI (percutaneous coronary intervention), indicating she, *'felt stabbing pain on the left-hand side of my chest. I used my spray once. I also had slight palpitations during the week.'*

Similarly, Sophie (68 years), who was undergoing changes to her medication to improve management of heart failure, remarked, "I'm tired and feeling a bit 'under par' this week. Everything felt like an effort, and I had to push myself to go out. Just wish I had more energy and stamina."

Service-users felt frustrated that they struggled to perform their normal ADLs:

Table 2. Physical activity, sedentary behaviour, and sleep of service-users ($n = 10$) at start, change at 2-months, and change at 3-months (end).

	Start	Change at 2-months	Change at 3-months (End)	F – statistic and *p*-value
Sleep Duration (hours·night^{-1})	7.25 ± 0.94	−0.11 ± 0.94	−0.30 ± 0.67	$F_{(2, 14.8)} = 0.25$ $p = 0.43$
Sleep Efficiency (%)	88.80 ± 4.23	−0.49 ± 3.73	−2.70 ± 4.76	$F_{(2, 14.74)} = 3.55$ $p = 0.05$
TPA (minutes·day^{-1})	182.71 ± 47.01	11.61 ± 44.75	1.51 ± 57.14	$F_{(2, 14.49)} = 0.02$ $p = 0.98$
LPA (minutes·day^{-1})	133.52 ± 28.57	8.39 ± 27.47	−1.92 ± 32.8	$F_{(2, 14.3)} = 0.25$ $p = 0.79$
MPA (minutes·day^{-1})	48.42 ± 29.63	3.32 ± 28.99	2.04 ± 35.79	$F_{(2, 14.75)} = 0.01$ $p = 0.99$
VPA (minutes·day^{-1})	0.77 ± 1.16	−0.1 ± 0.67	1.39 ± 3.67	$F_{(2, 16.1)} = 1.7$ $p = 0.21$
MVPA (minutes·day^{-1})	49.19 ± 30.53	3.22 ± 29.31	3.43 ± 38.87	$F_{(2, 14.8)} = 0.05$ $p = 0.95$
MVPA 10 min bouts·day^{-1}	11.77 ± 18.21	5.35 ± 15.76	1.96 ± 18.91	$F_{(2, 14.92)} = 0.4$ $p = 0.68$
Sedentary Time (hours·day^{-1})	12.57 ± 0.59	−0.24 ± 0.95	0.04 ± 0.82	$F_{(2, 15.24)} = 0.32$ $p = 0.73$

TPA, total physical activity; LPA, light physical activity; MPA, moderate physical activity; VPA, vigorous physical activity; MVPA, moderate-to-vigorous physical activity.

For example, Andrew (76 years), who was recovering from open heart surgery indicated he was, '*feeling frustrated at not being able to do jobs, such as lifting things that I could do previously.*'

Nevertheless, throughout CR, Andrew's perceptions of enhanced physical function, including improved fitness and reduced symptoms facilitated PA, and a gradual return to ADLs:

'Everything felt *a bit easier this morning – I had no symptoms…. 'I am now able to help with chores in the house and garden again.*'

Other participants noticed gradual improvements in function, such as Ted (71 years) who reported, "my *walking pace was quicker this week";* a big achievement after suffering a severe aortic dissection.

Perceived psychological capability was impacted by confidence and safety concerns when exercising at home without supervision. For example, Derek (65 years) described experiencing anxiety when exercising alone, even with the availability of tailored CR resources:

'It will be good to go somewhere to exercise, as I'm not motivated to do it at home and unsure of how to safely go about exercising at home even with the CR booklets.'

Confidence influenced service-users' PA dose, with low confidence associated with reduced exercise intensity and duration.

For example, Ben (44 years) questioned the safety of movement after the shock of suffering a heart attack, resulting in a cautious return to PA: *"I cut my walk short due to not being confident with walking a longer duration."*

Social support and influences

Various social aspects influenced PA engagement, including: *(1)* availability of support from a health professional, *(2)* prioritisation of social commitments over exercise, and *(3)* availability of social support from family and friends. Social support was a key factor in coping after a cardiac event, including receiving support from a spouse, friends, and the CR team.

For example, Jenny, who continued to struggle with cardiac symptoms indicated, *"My emotions are a little up and down. I am coping as I have the support of my husband and knowing I have the support of the CR team."*

Similarly, Andrew had essential social support from his wife, who made changes to her own lifestyle to help motivate Andrew, *"My wife has much improved her acceptance of our situation. We have agreed to have professional help with the gardening and decorating. We have also agreed to maintain our physical exercise."*

Nevertheless, family could sometimes be perceived as hindering PA progress, as expressed by Ted whose wife was having difficulty coming to terms with his diagnosis:

"My *wife is still being overprotective*."

Social events and responsibilities were also prioritised over exercise by some individuals, such as visiting friends and family, or attending to care responsibilities. For example, two male service-users indicated:

'My time in the evening is taken up by family, and my weekends are busy.' (Derek)

'*No exercise for me this week as I have been looking after my ill wife.*' (Ben)

Generally, service-users received regular health professional support from the outpatient rehabilitation team and their General Practitioner (GP). However, some experienced frustration and anxiety regarding poor communication and follow up from NHS services. For example, after experiencing major heart surgery to treat severe cardiac disease (CABG x3), Nicholas (59 years) expected more comprehensive personalised support and was disappointed, indicating he, "*felt deflated at the follow-up by the cardiac department at (name) hospital, it felt like a paperwork exercise.*"

Motivation

Motivation was classified into: *(1)* reflective personal drive and *(2)* the influence of emotions. Setting meaningful PA goals, possessing no desire to exercise, and self-monitoring shaped reflective personal drive. For example, at the start of CR Derek described a lack of motivation and ambivalence to exercise, such as feeling there was no need to exercise when he already felt healthy after treatment:

'I feel fine as if nothing has happened. So why would I start exercising? I don't know how I'm meant to be feeling; I don't have a reference point. I'm not exercising. I get up from my desk during work to walk around the garden. I'm not motivated to exercise. Why would I when I feel well?'

However, goals to resume "normal" activities enjoyed pre-cardiac event, such as pleasurable hobbies, and a desire to improve health, motivated service-users to engage in structured exercise. For example, after engaging with the CR programme, including education and goal setting with the CR team, Derek indicated:

'[Exercise] may help prevent a reoccurrence of a heart attack and improve my general health….Exercise helps me to feel better, both emotionally and physically.'

Self-monitoring of treatment targets appeared to improve service-users' motivation when they perceived they were on track, noted by Ben who was meeting his weight loss goals:

'I am happy that clothes are starting to fit me.'

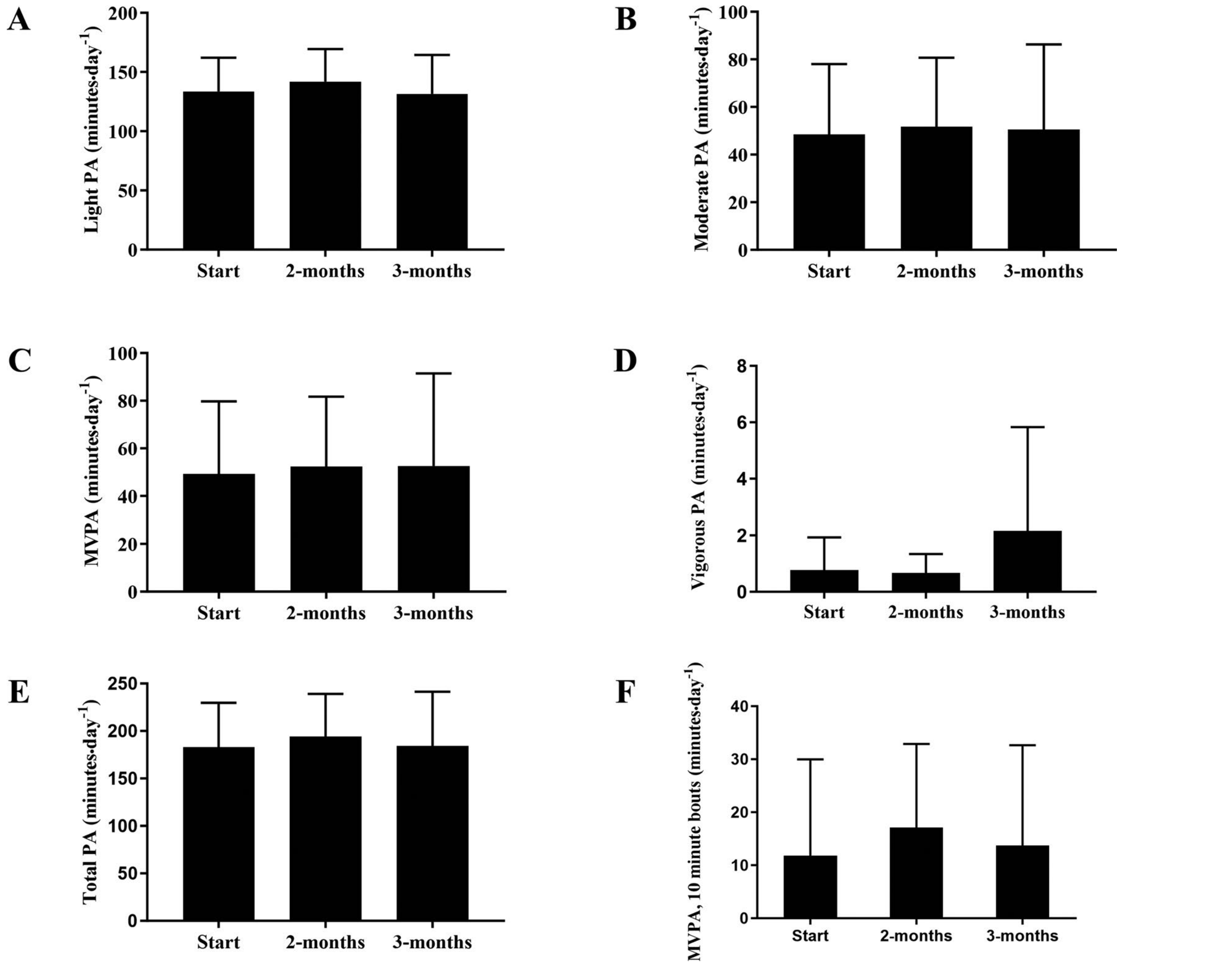

Figure 2. 10-Minute bouts of light-intensity physical activity (PA), moderate-intensity PA, vigorous-intensity PA, total PA and moderate-to-vigorous-intensity at start, 2-months, and end of a three-month cardiac rehabilitation programme.
Data are presented as means and standard deviations unless otherwise stated.

Nevertheless, a lack of clear progress created frustration in others:

> Ted indicated he was, '*Coping well, but I am still a little frustrated at my perceived lack of progress.*'

Service-users described disruptive and positive emotions throughout CR, including feelings of depression, such as:

> being '*tearful*', reported by Sophie and Jenny, and two male service-users expressing:

> feeling '*low*' (Ben); feeling '*happy* (Roland).'

Roland's happiness could be explained by his sense of gratitude and luck that he had treatment before deterioration of his cardiac condition:

> *'Overall, I have positive emotions and I am coping well. I am feeling positive as the bypass surgery has given me a renewed level of energy… I am still grateful my condition was caught before a major heart event. I am coping fine.'*

Environmental influences

Environmental influences on PA and exercise included *(1)* weather, and *(2)* COVID restrictions. Disruptive weather, such as rain and hot conditions, were a barrier to habitual PA, while clement weather conditions encouraged outdoor PA, such as walking and gardening. For example, Ted indicated:

> *'The weather is hot and humid – it is a real struggle today, I'm feeling frustrated'*

> *Similarly, Jenny wrote, 'My walks were motivated by the lovely weather this week.'*

Finally, COVID restrictions were perceived to facilitate PA engagement due to a reduction in social activities:

> Andrew indicated, *'Social activities have reduced due to COVID so I have more time to exercise.'*

Discussion

The aims of this study were to examine service-users' movement behaviours (including sleep), and to explore barriers and facilitators of PA and exercise, during a three-month remotely delivered, hybrid CR programme modified as a result of the COVID-19 pandemic. We found no improvements in PA, sleep efficiency, or sedentary time over the course of a three-month pandemic-adapted CR programme. Cardiac symptoms, exertional discomfort and a lack of confidence engaging in exercise without in-person supervision were key barriers to remote CR exercise, while setting meaningful PA goals, self-monitoring health targets, and having social support, facilitated exercise engagement. Walking was the preferred modality during remote CR compared to structured exercise (i.e., home-based CR circuits).

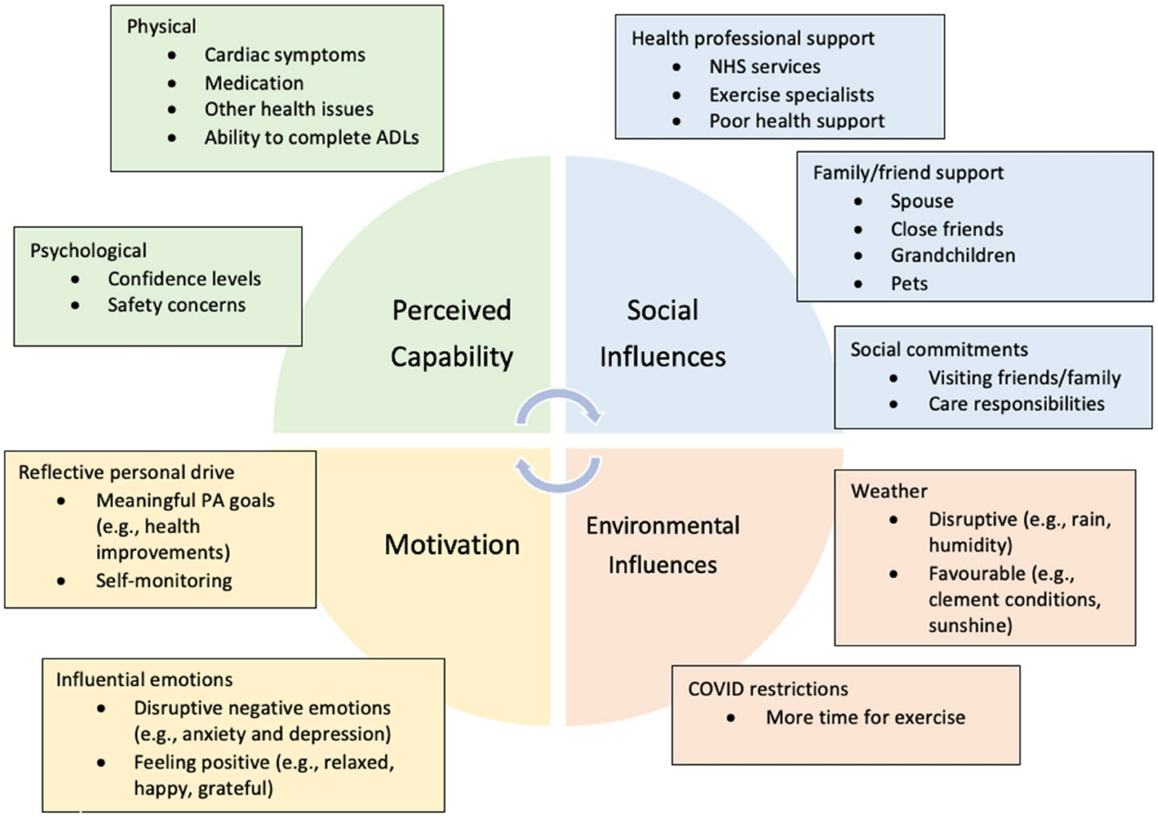

Figure 3. Perceived barriers and facilitators to physical activity during a three-month remotely-delivered cardiac rehabilitation programme.

There were no significant changes in service-users' PA over the course of CR, suggesting CR was not successful in supporting service-users to increase levels of PA. This outcome falls short when compared to similar pre-pandemic studies demonstrating CR significantly improved device-based PA compared to service-users' pre-intervention levels as well as to control groups not receiving structured rehabilitation guidance [51,52].

Qualitative data through service-user diary entries provided important context regarding PA engagement, and based on service-user entries, several issues were identified that could potentially explain low engagement in PA. For example, exercise and PA was not seen as important to a service-user who "already" felt fine. This is consistent with other literature that report participants not experiencing health exacerbations currently may view exercise and/or PA as unimportant or irrelevant [53]. Similar to other studies [54], inclement weather was perceived to deter participation in PA. Finally, service-users noted experiencing a wave of emotions both during and post-CR which result in "good days, and bad days." As a result, engagement can be sporadic as service-users navigate their emotions during a process that can be traumatic [55]. These considerations, as well as others to be discussed later, provide insight into the complexity of supporting increased and maintained PA engagement among CR service-users.

Considerations for PA and sedentary behaviour

The majority of service users' PA was LPA, which is potentially important as an accumulation of LPA has been shown to positively impact CVD risk factors (e.g., high blood pressure, lipids and blood glucose control) [13,56] and reduce all-cause mortality [57,58]. Furthermore, the MVPA observed (49.19 ± 30.53 min·day^{-1}), is consistent with previous CR studies [51,59–62] and is in line with national PA guidelines for health (150-300 min of MVPA per week) [8]. Only 20% of the sample ($n = 2$) achieved *sustained bouts* of MVPA. Nevertheless, scholars have begun to advocate for an approach within CR that focuses less on individual intensities (e.g., moderate to vigorous) [24] in favour of more holistic approaches that include LPA and reductions in sedentary time [13,58]. Furthermore, it has been suggested that health benefits can be realised at a threshold much lower than 150 min [63].

An analysis of diary data revealed a potential preference for less structured forms of PA such as walking, which has become a common training modality especially in home-based CR programmes. Service-users completed significantly more walks per week than circuit-based structured exercise and despite CR's traditional focus on structured exercise (i.e., circuits) [64], there is evidence to suggest that brisk walking (≥70% HRR) can improve cardiorespiratory fitness in cardiac groups [65,66]. Such evidence, alongside preferences for walking and barriers associated with structured exercise such as service-user unfamiliarity [67], should be considered when elements of CR are designed and discussed with service-users. Consistent with the latter point, diary data also revealed service-user's safety concerns regarding exercising at home without supervision. Particularly among those who are unfamiliar with exercise, or lack prior history engaging in exercise, concerns regarding safety and physical capabilities have been identified as important barriers [68,69]. In contrast, walking is generally highly accessible and poses little risk of injury in populations more likely to have co-morbidities and physical and social barriers to attending CR in-person [70].

Service users were sedentary most of the day (12.57 ± 0.59 h·day^{-1}) and this did not change significantly over the course of CR. This is significant as daily sedentary time exceeding 9.5 h is associated with an increased risk of all-cause mortality and morbidity [56]. Our data suggest CR services as delivered in this study would benefit from interventions specifically targeting reduction of total sedentary time and breaking up sedentary bouts [13,71]. For instance, the SIT LESS intervention utilised behaviour change techniques and a smartphone application as an adjunct to CR standard care [13]. Although there were no significant differences in sedentary time compared to controls, the proportion of service-users with a sedentary time above 9.5 h·day^{-1} was significantly lower post-rehabilitation in SIT LESS (48%) versus controls (72%). Breaking up long periods of sedentary time may also be perceived as more achievable than exercising at vigorous intensities, especially for clinical populations unfamiliar with exercise who possess greater physical restrictions [72–74]. Furthermore, reducing sedentary time by as little as an hour in clinical populations has been shown to significantly improve cardiometabolic risk factors, such as waist circumference, fat percentage, and glycaemic control [75].

Considerations for sleep

With respect to sleep, six out of ten service users achieved sleep recommendations of 7–9 h·night^{-1} and while sleep efficiency significantly reduced from start to end of CR, values remained within recommendations for healthy sleep (≥85%). Typically, existing research has assessed sleep using self-report questionnaires (e.g., Pittsburgh sleep quality index) and polysomnography [76–78]. Therefore, a strength of this study is its insight into sleep, post-cardiac event, *via* wrist-worn accelerometers which are less burdensome than polysomnography and more objective than self-report instruments [45].

In comparison to previous literature, we did not detect sleep disruptions during recovery after a cardiac event [79] which is important as studies investigating self-reported short (< 6 h) and long (> 9 h) sleep duration, as well as poor sleep quality (e.g., difficulty falling asleep), have been associated with an increased risk of CHD and higher risk of mortality in healthy adults [80–82]. However, in this relatively small sample, 40% (4 out of 10), did not meet healthy sleep recommendations [10]. It is difficult to reach a firm conclusion as to why this was the case, but one possible explanation relates to lifestyle changes and disrupted sleep during the COVID-19 pandemic – including decreased sleep quality [83–86]. Additional factors include psychosocial changes associated with living and coping with a new cardiac diagnosis, such as reduced self-efficacy (e.g., confidence to engage with ADL) [87], and kinesiophobia (i.e., fear of movement) [88]. In turn, these psychosocial states can have a profound influence on physical behaviours, such as sleep and PA [87,89,90]. Moreover, sleep disorders, such as insomnia and obstructive sleep apnoea are prevalent in cardiac populations [91–94].

Implications for CR

The challenges identified with respect to service-users' 24-h movement behaviours during remotely delivered CR in the current study provided an opportunity to consider "best practice" approaches. Barriers to CR's effectiveness in terms of PA/exercise adherence during CR included decreased monitoring through staff redeployment, exercise without in-person supervision, and difficulty learning how to exercise virtually – potentially influencing dose-response in this programme. Similar challenges associated with remotely delivered CR have been reported elsewhere [95]. Furthermore, a perceived lack of confidence when exercising alone was likely exacerbated during remote delivery which eliminated the possibility to receive individualised in-person instruction. This was highlighted as a concern in service-user diaries and other studies have pointed out the importance of in-person and/or personalised support and encouragement [96,97]. Going forward, the recent Smartphone Cardiac Rehabilitation Assisted Self-Management (SCRAM) programme which uses a mobile phone app plus a heart rate sensor, may serve as a model to guide future remotely delivered CR [98]. It enables CR practitioners to receive data electronically to monitor exercise performance and provide personalised coaching [98].

To facilitate and sustain improved engagement with behavioural changes, such as increased PA and exercise, but also improved sleep and reduced sedentary time, remotely delivered CR should be underpinned with behaviour change techniques (BCTs) to provide client-centred, empowering interventions [99–101]. For example, a systematic review comprising 11 studies (1,907 adults with CHD) found that effective remotely delivered CR programmes used social support, goal setting, monitoring, and instruction on how to perform behaviours [99]. Our qualitative data reinforced the importance of these factors. For instance, motivation for PA was improved by setting meaningful goals (e.g., return to ADL and improved health), self-monitoring health targets (e.g., weight, changes in symptom severity, progression of walking distance and speed), and receiving social support (e.g., encouragement from family and CR staff). CR should also be theoretically-informed but this did not appear to be the case based on our observations. Given the quick adaptation of services due to pandemic restrictions, this is not surprising. Furthermore, numerous other challenges associated with the application of theory in CR have been identified [102]. Despite these challenges, and the lack of emergence of one "gold standard" theory to guide CR programming, self-determination theory has been recommended as a promising approach in this regard [103]. It appears likely that social-ecological frameworks would also support the maintenance of PA post-CR, but recent research in this area has not yet demonstrated this empirically for service users [104].

While this study identified challenges, such as reduced training intensity and lack of face-to-face support, remotely delivered programmes *can* foster tailored one-to-one communication (something that was acknowledged by participants of our study), offer service-users flexible scheduling, minimise travel barriers, and help integrate behavioural modification with existing home routines, encouraging independence [67]. The necessity of remotely delivered support during COVID-19 has forced expansion and development of remotely delivered services within rehabilitative settings, and with the return of multidisciplinary teams, the addition of remote approaches could offer greater choice and flexibility in how service-users engage with CR [33,98,105] – consistent with the NHS' long-term plan within the UK to increase the range of digital health tools and services [106]. To maximise service-user outcomes, and to ensure the success of remotely-delivered CR, our findings suggest service-user preferences for unstructured PA and regularly accessible support from professional staff must be duly considered and supported alongside an appropriately theoretically-informed delivery approach. Remotely-delivered CR must consider sedentary behaviour reduction as well as encouraging and supporting PA.

Strengths and limitations

There are numerous strengths of the study, including device-based measurement of movement behaviours and sleep, to which compliance was good, as well as incorporating bout analyses to distinguish between sporadic activities of daily living and volitional PA, allowing deeper insight into a clinical population group's rest-activity patterns [23]. Moreover, we used a mixed-methods approach contextualising (dis)engagement in structured exercise and PA through a combination of device-based data with qualitative data from service-user diaries. These data allowed us to "dig deeper" into aspects of PA and exercise engagement. There are, however, limitations that need to be acknowledged. For example, this was a study of convenience with no comparison group, nor pre-rehab measures of PA with a relatively small sample size with no long-term follow-up of outcomes. Consequently, generalisability may be limited – although we would maintain analytic generalisability is a more appropriate metric given our mixed methods approach [107]. Future research should explore CR through different cultural lenses with inclusion of perspectives from a variety of racial, ethnic, gender, sexuality, class, and (dis)ability backgrounds. Moreover, long-term follow-up of outcomes, exploring PA, sedentary behaviour and sleep >12 months post-CR is needed. Finally, in-depth qualitative inquiry based on service-users' experiences of remote delivery would offer important insight to shape the design and implementation of future adapted CR, such as deeper exploration of communication modes, and safety concerns. Although we have captured qualitative data through service-user diaries, further insight is necessary – obtained through more in-depth methods such as interviews and/or focus groups.

Conclusion

We found no improvements in movement behaviours (which included sleep) over the course of a three-month pandemic-adapted CR programme. A lack of confidence engaging in structured exercise without in-person supervision, and restricted exercise coaching through a quick transfer to telephone support during the pandemic were key barriers to remote CR exercise. Notwithstanding the importance of social support and goal setting in facilitating exercise engagement, behaviour change techniques underpinned by a theoretically informed delivery approach is also needed to support service-users in returning to normal and valued activities after experiencing a cardiac event. Walking was the preferred exercise modality during remote CR compared to structured CR circuits, highlighting that future programmes should consider interventions to target wider movement behaviours, including reducing sedentary time and increasing PA in manageable bouts to improve confidence and adherence to long-term behaviour change. While there were many challenges associated with continuing CR services during COVID-19, these difficulties have inspired a new era of hybrid models and a menu-based approach to the delivery of its core components to appropriately support service-users to maintain function, wellbeing and quality of life post-CR [101].

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References

[1] Dalal HM, Doherty P, Taylor RS. *Cardiac rehabilitation*. BMJ. 2015;351:h5000. doi:10.1136/bmj.h5000.

[2] Rauch B, Davos CH, Doherty P, et al. The prognostic effect of cardiac rehabilitation in the era of acute revascularisation and statin therapy: a systematic review and meta-analysis of randomized and non-randomized studies - The Cardiac Rehabilitation Outcome Study (CROS). Eur J Prev Cardiol. 2016;23(18):1914–1939. doi:10.1177/2047487316671181.

[3] Yohannes AM, Doherty P, Bundy C, et al. The long-term benefits of cardiac rehabilitation on depression, anxiety, physical activity and quality of life. J Clin Nurs. 2010;19(19–20):2806–2813. doi:10.1111/j.1365-2702.2010.03313.x.

[4] British Heart Foundation . The national audit of cardiac rehabilitation quality and outcomes report 2021. London: British Heart Foundation; 2021.

[5] McGregor DE, Carson V, Palarea-Albaladejo J, et al. Compositional analysis of the associations between 24-h movement behaviours and health indicators among adults and older adults from the Canadian health measure survey. Int J Environ Res Public Health. 2018;15(8):1779. doi:10.3390/ijerph15081779.

[6] Izawa KP, Yamada S, Oka K, et al. Long-term exercise maintenance, physical activity, and health-related quality of life after cardiac rehabilitation. Am J Phys Med Rehabil. 2004;83(12):884–892. doi:10.1097/01.phm.0000143404.59050.11.

[7] Boesch C, Myers J, Habersaat A, et al. Maintenance of exercise capacity and physical activity patterns 2 years after cardiac rehabilitation. J Cardiopulm Rehabil. 2005;25(1):14–21. doi:10.1097/00008483-200501000-00004.

[8] Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med. 2020;54(24):1451–1462. doi:10.1136/bjsports-2020-102955.

[9] Rehabilitation, B.A.o.C.P.a. Physical activity and exercise in the management of cardiovascular disease. London BACPR; 2014.

[10] Hirshkowitz M, Whiton K, Albert SM, et al. National sleep foundation's sleep time duration recommendations: methodology and results summary. Sleep Health. 2015;1(1):40–43. doi:10.1016/j.sleh.2014.12.010.

[11] Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. Int J Behav Nutr Phys Act. 2017;14(1):75. doi:10.1186/s12966-017-0525-8.

[12] Kim Y, Yeung SLA, Sharp SJ, et al. Genetic susceptibility, screen-based sedentary activities and incidence of coronary heart disease. BMC Med. 2022;20(1):188. doi:10.1186/s12916-022-02380-7.

[13] Bell AC, Richards J, Zakrzewski-Fruer JK, et al. Sedentary behaviour—A target for the prevention and management of cardiovascular disease. Int J Environ Res Public Health. 2023;20(1):532. doi:10.3390/ijerph20010532.

[14] Han M, Qie R, Shi X, et al. Cardiorespiratory fitness and mortality from all causes, cardiovascular disease and can-

cer: dose-response meta-analysis of cohort studies. Br J Sports Med. 2022;56(13):733–739. doi:10.1136/bjsports-2021-104876.
[15] Lanza GA, Golino M, Villano A, et al. Cardiac rehabilitation and endothelial function. J Clin Med. 2020;9(8):2487. doi:10.3390/jcm9082487.
[16] Manresa-Rocamora A, Ribeiro F, Casanova-Lizón A, et al. Cardiac rehabilitation improves endothelial function in coronary artery disease patients. Int J Sports Med. 2022; 43(11):905–920. doi:10.1055/a-1717-1798.
[17] Ornish D, Scherwitz LW, Billings JH, et al. Intensive lifestyle changes for reversal of coronary heart disease. JAMA. 1998;280(23):2001–2007. doi:10.1001/jama.280.23.2001.
[18] Dibben GO, Dalal HM, Taylor RS, et al. Cardiac rehabilitation and physical activity: systematic review and meta-analysis. Heart. 2018;104(17):1394–1402. doi:10.1136/heartjnl-2017-312832.
[19] Haskell WL. Physical activity by self-report: a brief history and future issues. J Phys Act Health. 2012;9(s1):S5–S10. doi:10.1123/jpah.9.s1.s5.
[20] Alharbi M, Bauman A, Neubeck L, et al. Measuring overall physical activity for cardiac rehabilitation participants: a review of the literature. Heart Lung Circ. 2017;26(10):1008–1025. doi:10.1016/j.hlc.2017.01.005.
[21] Le Grande MR, Elliott PC, Worcester MUC, et al. An evaluation of self-report physical activity instruments used in studies involving cardiac patients. J Cardiopulm Rehabil Prev. 2008;28(6):358–369. doi:10.1097/HCR.0b013e31818c3d90.
[22] Kolk MZH, Frodi DM, Andersen TO, et al. Accelerometer-assessed physical behavior and the association with clinical outcomes in implantable cardioverter-defibrillator recipients: a systematic review. Cardiovasc Digit Health J. 2022;3(1):46–55. doi:10.1016/j.cvdhj.2021.11.006.
[23] Bianchim MS, et al. A compositional analysis of physical activity, sedentary time, and sleep and associated health outcomes in children and adults with cystic fibrosis. Int J Environ Res Public Health. 2022;19(9): 5155. doi:10.3390/ijerph19095155.
[24] Meiring RM, Tanimukai K, Bradnam L. The effect of exercise-based cardiac rehabilitation on objectively measured physical activity and sedentary behavior: a systematic review and meta-analysis. J Prim Care Community Health. 2020;11:2150132720935290. doi:10.1177/2150132720935290.
[25] Jennings W, Egert S, Fisher C, et al. Better cardiac care – the patient experience – a qualitative study. Int J Equity Health. 2023;22(1):122. doi:10.1186/s12939-023-01931-5.
[26] Jokar F, Yousefi H, Yousefy A, et al. Begin again and continue with life: a qualitative study on the experiences of cardiac rehabilitation patients. J Nurs Res. 2017;25(5):344–352. doi:10.1097/JNR.0000000000000220.
[27] European Society of Cardiology. Recommendations on how to provide cardiac rehabilitation activities during the COVID 19 pandemic. European Association of Preventative Cardiology (EAPC). 2020. Available from: https://www.escardio.org.
[28] Ogura A, Izawa KP, Tawa H, et al. Impact of the COVID-19 pandemic on phase 2 cardiac rehabilitation patients in Japan. Heart Vessels. 2021;36(8):1184–1189. doi:10.1007/s00380-021-01783-5.
[29] Pinto R, Pires ML, Borges M, et al. Digital home-based multidisciplinary cardiac rehabilitation: how to counteract physical inactivity during the COVID-19 pandemic. Rev Port Cardiol. 2022;41(3):209–218. doi:10.1016/j.repc.2021.05.013.
[30] Woods JA, Hutchinson NT, Powers SK, et al. The COVID-19 pandemic and physical activity. Sports Med Health Sci. 2020;2(2):55–64. doi:10.1016/j.smhs.2020.05.006.
[31] McCarthy H, Potts HWW, Fisher A. Physical activity behavior before, during, and after covid-19 restrictions: longitudinal smartphone-tracking study of adults in the United Kingdom. J Med Internet Res. 2021;23(2):e23701. doi:10.2196/23701.
[32] Golbus JR, Lopez-Jimenez F, Barac A, et al. Digital technologies in cardiac rehabilitation: a science advisory from the American heart association. Circulation. 2023;148(1):95–107. doi:10.1161/CIR.0000000000001150.
[33] Rayner TA, et al. 12 Real-world evaluation of a technology-enabled system for the augmentation of physical activity behaviour change in cardiac rehabilitation. Heart. 2022;108: a 7.
[34] Barnason S, Zimmerman L, Schulz P, et al. Weight management telehealth intervention for overweight and obese rural cardiac rehabilitation participants: a randomised trial. J Clin Nurs. 2019;28(9–10):1808–1818. doi:10.1111/jocn.14784.
[35] Dalal HM, Taylor RS, Jolly K, et al. The effects and costs of home-based rehabilitation for heart failure with reduced ejection fraction: the REACH-HF multicentre randomized controlled trial. Eur J Prev Cardiol. 2019;26(3):262–272. doi:10.1177/2047487318806358.
[36] National Institute for Health and Care Excellence (NICE). Cardiac rehabilitation services: commissioning guide. London: NICE guidelines; 2013.
[37] Dawkes S, et al. *COVID-19 and cardiac rehabilitation: joint BACPR/BCS/BHF statement on cardiac rehabilitation services.* Br J Cardiol. 2020;27(2): 50. doi:10.5837/bjc.2020.019.
[38] Borg G. An introduction to Borg's RPE scale. Ithaca, New York: Movement Publications; 1985.
[39] Care, D.o.H.a.S. *Physical activity guidelines: UK Chief Medical Officers' report*. 2020.
[40] van Hees VT, Gorzelniak L, Dean León EC, et al. Separating movement and gravity components in an acceleration signal and implications for the assessment of human daily physical activity. PLoS One. 2013;8(4):e61691. doi:10.1371/journal.pone.0061691.
[41] Shepherd AI, Pulsford R, Poltawski L, et al. Physical activity, sleep, and fatigue in community dwelling Stroke Survivors. Sci Rep. 2018;8(1):7900. doi:10.1038/s41598-018-26279-7.
[42] Antoun J, Brown DJ, Jones DJW, et al. Understanding the impact of initial COVID-19 restrictions on physical activity, wellbeing and quality of life in shielding adults with end-stage renal disease in the United Kingdom dialysing at home versus in-centre and their experiences with telemedicine. Int J Environ Res Public Health. 2021;18(6):3144. doi:10.3390/ijerph18063144.
[43] Pavey TG, Gomersall SR, Clark BK, et al. The validity of the GENEActiv wrist-worn accelerometer for measuring adult sedentary time in free living. J Sci Med Sport. 2016;19(5):395–399. doi:10.1016/j.jsams.2015.04.007.
[44] Fraysse F, Post D, Eston R, et al. Physical activity intensity cut-points for wrist-worn geneactiv in older adults. Front Sports Act Living. 2021;2:579278. doi:10.3389/fspor.2020.579278.
[45] van Hees VT, Sabia S, Anderson KN, et al. A novel, open access method to assess sleep duration using a wrist-worn accelerometer. PLoS One. 2015;10(11):e0142533. doi:10.1371/journal.pone.0142533.
[46] Elo S, Kyngäs H. The qualitative content analysis process. J Adv Nurs. 2008;62(1):107–115. doi:10.1111/j.1365-2648.2007.04569.x.
[47] Stemler S. *An overview of content analysis.* Pract Assess Res Eval. 2000: 7 (17).

[48] Erlingsson C, Brysiewicz P. A hands-on guide to doing content analysis. Afr J Emerg Med. 2017;7(3):93–99. doi:10.1016/j.afjem.2017.08.001.

[49] Smith B, McGannon KR. Developing rigor in qualitative research: problems and opportunities within sport and exercise psychology. Int Rev Sport Exercise Psychol. 2018;11(1):101–121. doi:10.1080/1750984X.2017.1317357.

[50] Burke S, B.S.a.A.C. Sparkes. Rethinking 'validity' and 'trustworthiness' in qualitative inquiry: how might we judge the quality of qualitative research in sport and exercise sciences? In: Routledge handbook of qualitative research in sport and exercise. London: Routledge; 2016. p. 11.

[51] Ribeiro F, Oliveira NL, Silva G, et al. Exercise-based cardiac rehabilitation increases daily physical activity of patients following myocardial infarction: subanalysis of two randomised controlled trials. Physiotherapy. 2017;103(1):59–65. doi:10.1016/j.physio.2015.12.002.

[52] Ter Hoeve N, Sunamura M, Stam HJ, et al. Effects of two behavioral cardiac rehabilitation interventions on physical activity: a randomized controlled trial. Int J Cardiol. 2018;255:221–228. doi:10.1016/j.ijcard.2017.12.015.

[53] Serves N, Pazart L, Gabriel D, et al. Adherence to rehabilitation and home exercise after myocardial infarction: a qualitative study of expectations, barriers and drivers. BMC Sports Sci Med Rehabil. 2023;15(1):98. doi:10.1186/s13102-023-00714-3.

[54] O'Shea O, et al. A qualitative exploration of cardiovascular disease patients' views and experiences with an eHealth cardiac rehabilitation intervention: the PATHway Project. PLoS One. 2020;15(7):e0235274. doi:10.1371/journal.pone.0235274.

[55] El Hussein MT, Dhaliwal S, Hakkola J. The Lived Experience of Cardiac Arrest Survivors: a Scoping Review. J Cardiovasc Nurs. 2024. doi:10.1097/JCN.0000000000001119.

[56] Ekelund U, Tarp J, Steene-Johannessen J, et al. Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. BMJ. 2019;366:l4570. doi:10.1136/bmj.l4570.

[57] Chastin SFM, De Craemer M, De Cocker K, et al. How does light-intensity physical activity associate with adult cardiometabolic health and mortality? Systematic review with meta-analysis of experimental and observational studies. Br J Sports Med. 2019;53(6):370–376. doi:10.1136/bjsports-2017-097563.

[58] Ku P-W, Hamer M, Liao Y, et al. Device-measured light-intensity physical activity and mortality: a meta-analysis. Scand J Med Sci Sports. 2020;30(1):13–24. doi:10.1111/sms.13557.

[59] Freene N, McManus M, Mair T, et al. High sedentary behaviour and low physical activity levels at 12 months after cardiac rehabilitation: a prospective cohort study. Ann Phys Rehabil Med. 2020;63(1):53–58. doi:10.1016/j.rehab.2019.07.008.

[60] Oliveira NL, Ribeiro F, Teixeira M, et al. Effect of 8-week exercise-based cardiac rehabilitation on cardiac autonomic function: a randomized controlled trial in myocardial infarction patients. Am Heart J. 2014;167(5):753–761 e3. doi:10.1016/j.ahj.2014.02.001.

[61] Stevenson TG, Riggin K, Nagelkirk PR, et al. Physical activity habits of cardiac patients participating in an early outpatient rehabilitation program. J Cardiopulm Rehabil Prev. 2009;29(5):299–303. doi:10.1097/HCR.0b013e3181b4ca61.

[62] Yates BC, Norman J, Meza J, et al. Effects of partners together in health intervention on physical activity and healthy eating behaviors: a pilot study. J Cardiovasc Nurs. 2015;30(2):109–120. doi:10.1097/JCN.0000000000000127.

[63] Warburton DE, Bredin SS. Reflections on physical activity and health: what should we recommend? Can J Cardiol. 2016;32(4):495–504. doi:10.1016/j.cjca.2016.01.024.

[64] Cowie A, Buckley J, Doherty P, et al. Standards and core components for cardiovascular disease prevention and rehabilitation. Heart. 2019;105(7):510–515. doi:10.1136/heartjnl-2018-314206.

[65] Quell KJ, Porcari JP, Franklin BA, et al. Is brisk walking an adequate aerobic training stimulus for cardiac patients? Chest. 2002;122(5):1852–1856. doi:10.1378/chest.122.5.1852.

[66] Bravo-Escobar R, González-Represas A, Gómez-González AM, et al. Effectiveness and safety of a home-based cardiac rehabilitation programme of mixed surveillance in patients with ischemic heart disease at moderate cardiovascular risk: a randomised, controlled clinical trial. BMC Cardiovasc Disord. 2017;17(1):66. doi:10.1186/s12872-017-0499-0.

[67] Thomas RJ, Beatty AL, Beckie TM, et al. Home-based cardiac rehabilitation: a scientific statement from the American association of cardiovascular and pulmonary rehabilitation, the American heart association, and the American college of cardiology. J Am Coll Cardiol. 2019;74(1):133–153. doi:10.1016/j.jacc.2019.03.008.

[68] Platz K, Kools S, Howie-Esquivel J. Benefits, facilitators, and barriers of alternative models of cardiac rehabilitation: a qualitative systematic review. J Cardiopulm Rehabil Prev. 2023;43(2):83–92. doi:10.1097/HCR.0000000000000738.

[69] Spiteri K, Broom D, Bekhet AH, et al. Barriers and motivators of physical activity participation in middle-aged and older adults—a systematic review. J Aging Phys Act. 2019;27(4):929–944. doi:10.1123/japa.2018-0343.

[70] Murtagh EM, Murphy MH, Boone-Heinonen J. Walking: the first steps in cardiovascular disease prevention. Curr Opin Cardiol. 2010;25(5):490–496. doi:10.1097/HCO.0b013e32833ce972.

[71] van Bakel BMA, Kroesen SH, Bakker EA, et al. Effectiveness of an intervention to reduce sedentary behaviour as a personalised secondary prevention strategy for patients with coronary artery disease: main outcomes of the SIT LESS randomised clinical trial. Int J Behav Nutr Phys Act. 2023;20(1):17. doi:10.1186/s12966-023-01419-z.

[72] Lyden K, Boucher R, Wei G, et al. Targeting sedentary behavior in CKD: a pilot and feasibility randomized controlled trial. Clin J Am Soc Nephrol. 2021;16(5):717–726. doi:10.2215/CJN.12300720.

[73] Belcher BR, Kang D-W, Yunker AG, et al. Interventions to reduce sedentary behavior in cancer patients and survivors: a systematic review. Curr Oncol Rep. 2022;24(11):1593–1605. doi:10.1007/s11912-022-01313-0.

[74] Manns PJ, Mehrabani G, Norton S, et al. The sitless with ms program: intervention feasibility and change in sedentary behavior. Arch Rehabil Res Clin Transl. 2020;2(4):100083. doi:10.1016/j.arrct.2020.100083.

[75] Nieste I, Franssen WMA, Spaas J, et al. Lifestyle interventions to reduce sedentary behaviour in clinical populations: a systematic review and meta-analysis of different strategies and effects on cardiometabolic health. Prev Med. 2021;148:106593. doi:10.1016/j.ypmed.2021.106593.

[76] Banack HR, Holly CD, Lowensteyn I, et al. The association between sleep disturbance, depressive symptoms, and health-related quality of life among cardiac rehabilitation par-

ticipants. J Cardiopulm Rehabil Prev. 2014;34(3):188–194. doi:10.1097/HCR.0000000000000054.

[77] Fernandes NM, Nield LE, Popel N, et al. Symptoms of disturbed sleep predict major adverse cardiac events after percutaneous coronary intervention. Can J Cardiol. 2014;30(1):118–124. doi:10.1016/j.cjca.2013.07.009.

[78] Madsen MT, Huang C, Zangger G, et al. Sleep disturbances in patients with coronary heart disease: a systematic review. J Clin Sleep Med. 2019;15(3):489–504. doi:10.5664/jcsm.7684.

[79] Susuthi P. Factors affecting sleep quality in acute coronary syndrome survivors. Chula Med J. 2020;64(3):283–290. doi:10.58837/CHULA.CMJ.64.3.8.

[80] Cappuccio FP, Cooper D, D'Elia L, et al. Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. Eur Heart J. 2011;32(12):1484–1492. doi:10.1093/eurheartj/ehr007.

[81] Lao XQ, Liu X, Deng H-B, et al. Sleep quality, sleep duration, and the risk of coronary heart disease: a prospective cohort study with 60,586 adults. J Clin Sleep Med. 2018;14(1):109–117. doi:10.5664/jcsm.6894.

[82] Strand LB, Tsai MK, Gunnell D, et al. Self-reported sleep duration and coronary heart disease mortality: A large cohort study of 400,000 Taiwanese adults. Int J Cardiol. 2016;207:246–251. doi:10.1016/j.ijcard.2016.01.044.

[83] Jahrami H, BaHammam AS, Bragazzi NL, et al. Sleep problems during the COVID-19 pandemic by population: a systematic review and meta-analysis. J Clin Sleep Med. 2021;17(2):299–313. doi:10.5664/jcsm.8930.

[84] Lin YN, Liu ZR, Li SQ, et al. Burden of sleep disturbance during COVID-19 pandemic: a systematic review. Nat Sci Sleep. 2021;13:933–966. doi:10.2147/NSS.S312037.

[85] Alimoradi Z, Broström A, Tsang HWH, et al. Sleep problems during COVID-19 pandemic and its' association to psychological distress: a systematic review and meta-analysis. EClinicalMedicine. 2021;36:100916. doi:10.1016/j.eclinm.2021.100916.

[86] Morin CM, Carrier J, Bastien C, et al. Sleep and circadian rhythm in response to the COVID-19 pandemic. Can J Public Health. 2020;111(5):654–657. doi:10.17269/s41997-020-00382-7.

[87] Woodgate J, Brawley LR. Self-efficacy for exercise in cardiac rehabilitation: review and recommendations. J Health Psychol. 2008;13(3):366–387. doi:10.1177/1359105307088141.

[88] Dabek J, et al. Fear of movement (kinesiophobia) – an underestimated problem in Polish patients at various stages of coronary artery disease. Ann Agric Environ Med. 2020;27(1):56–60. doi:10.26444/aaem/106143.

[89] Rogerson MC, Murphy BM, Bird S, et al. "I don't have the heart": a qualitative study of barriers to and facilitators of physical activity for people with coronary heart disease and depressive symptoms. Int J Behav Nutr Phys Act. 2012;9(1):140. doi:10.1186/1479-5868-9-140.

[90] Wheatley EE. Bodies at risk: an ethnography of heart disease. Aldershot, UK: Ashgate Publishing Ltd; 2006.

[91] Da Costa D, Allman A-A, Libman E, et al. Prevalence and determinants of insomnia after a myocardial infarction. Psychosomatics. 2017;58(2):132–140. doi:10.1016/j.psym.2016.11.002.

[92] Le Grande MR, Beauchamp A, Driscoll A, et al. Prevalence of obstructive sleep apnoea in acute coronary syndrome patients: systematic review and meta-analysis. BMC Cardiovasc Disord. 2020;20(1):147. doi:10.1186/s12872-020-01430-3.

[93] Loo G, Chua A-P, Tay H-Y, et al. Sleep-disordered breathing in cardiac rehabilitation: prevalence, predictors, and influence on the six-minute walk test. Heart Lung Circ. 2016;25(6):584–591. doi:10.1016/j.hlc.2015.12.005.

[94] Wang X, Fan J-Y, Zhang Y, et al. Association of obstructive sleep apnea with cardiovascular outcomes after percutaneous coronary intervention: A systematic review and meta-analysis. Medicine (Baltimore). 2018;97(17):e0621. doi:10.1097/MD.0000000000010621.

[95] Vanzella LM, et al. Physical activity level and perspectives of participants transitioning from onsite to virtual cardiac rehabilitation during the early COVID-19 pandemic: a mixed-method study. J Clin Med. 2022;11(16): 4838. doi: 10.3390/jcm11164838.

[96] Carter J, Donelan K, Thorndike AN. Patient perspectives on home-based care and remote monitoring in heart failure: a qualitative study. J Prim Care Community Health. 2022;13: 21501319221133672. doi:10.1177/21501319221133672.

[97] Okwose NC, O'Brien N, Charman S, et al. Overcoming barriers to engagement and adherence to a home-based physical activity intervention for patients with heart failure: a qualitative focus group study. BMJ Open. 2020;10(9): e036382. doi:10.1136/bmjopen-2019-036382.

[98] Rawstorn JC, Ball K, Oldenburg B, et al. Smartphone cardiac rehabilitation, assisted self-management versus usual care: protocol for a multicenter randomized controlled trial to compare effects and costs among people with coronary heart disease. JMIR Res Protoc. 2020;9(1):e15022. doi:10.2196/15022.

[99] Heron N, Kee F, Donnelly M, et al. Behaviour change techniques in home-based cardiac rehabilitation: a systematic review. Br J Gen Pract. 2016;66(651):e747-57–e757. doi:10.3399/bjgp16X686617.

[100] Grimmett C, Bates A, West M, et al. SafeFit trial: virtual clinics to deliver a multimodal intervention to improve psychological and physical well-being in people with cancer. Protocol of a COVID-19 targeted non-randomised phase III trial. BMJ Open. 2021;11(8):e048175. doi:10.1136/bmjopen-2020-048175.

[101] British Association for Cardiovascular Prevention and Rehabilitation (BACPR). The BACPR Standards and core components for cardiovascular disease prevention and rehabilitation 2023. BACPR, 2023. Available from: https://www.bacpr.org/__data/assets/pdf_file/0021/64236/BACPR-Standards-and-Core-Components-2023.pdf

[102] Whittaker EM, et al. Using behavior change interventions in cardiac and pulmonary rehabilitation: perspectives from healthcare professionals in the United Kingdom. Int J Environ Res Public Health. 2022;19(4): 1980. doi:10.3390/ijerph19041980.

[103] Rahman RJ, Hudson J, Thøgersen-Ntoumani C, et al. Motivational processes and well-being in cardiac rehabilitation: a self-determination theory perspective. Psychol Health Med. 2015;20(5):518–529. doi:10.1080/13548506.2015.1017509.

[104] Reid RD, Wooding EA, Blanchard CM, et al. A randomized controlled trial of an exercise maintenance intervention in men and women after cardiac rehabilitation (ECO-PCR Trial). Can J Cardiol. 2021;37(5):794–802. doi:10.1016/j.cjca.2020.10.015.

[105] Deighan C, Michalova L, Pagliari C, et al. The digital heart manual: A pilot study of an innovative cardiac rehabilitation programme developed for and with users. Patient Educ Couns. 2017;100(8):1598–1607. doi:10.1016/j.pec.2017.03.014.

[106] Service NH. Online version of the NHS long term plan. Available from: https://www.longtermplan.nhs.uk/online-version/.

[107] Yin RK. 652 Causality, Generalizability, and the Future of Mixed Methods Research. In: Hesse-Biber SN, Johnson R, editors. The oxford handbook of multimethod and mixed methods research inquiry. New York (NY): Oxford University Press; 2015.