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# The acceptability of technology-enabled physical activity feedback in cardiac patients and health care professionals

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## Abstract

**Purpose** Physical activity is a key component of cardiac rehabilitation (CR). Despite the widely reported benefits of CR, uptake in the United Kingdom is still low. Alternative home-based and technology-facilitated delivery models are needed to improve CR uptake and physical activity. This study set out to explore patient and clinician views of personalised, multidimensional physical activity feedback and its potential use within CR.

**Methods** We developed graphics for the presentation of personalised multidimensional physical activity feedback from data collected through wrist-worn monitors. Thirteen cardiac patients and nine healthcare professionals recruited from South West England wore research grade physical activity monitors for seven days. Participants then attended semi-structured interviews during which personalised physical activity feedback was provided. Interviews were audio-recorded, transcribed, and analysed thematically.

**Results** Two main themes were derived from the data which covered: 1) the perceived value of multidimensional physical activity feedback, and 2) support needed to facilitate understanding. Within the first theme, participants acknowledged that multidimensional physical activity feedback was useful for monitoring progress, goal setting, and increasing self-awareness of physical activity behaviour among both patients and clinicians. Within theme two, the need for more guidance and support from clinicians to aid patient understanding and reassurance was highlighted, particularly for those with very low physical activity levels.

**Conclusions** Multidimensional physical activity feedback delivered using a technology-enabled approach was perceived as acceptable among patients and clinicians. This study provides insights into the potential novel use of technology-enabled physical activity feedback to support and expand the delivery of CR.

**Keywords** Physical activity feedback · Technology · Cardiac rehabilitation · Patient experience · Practitioner experience · Remote monitoring

## 1 Introduction

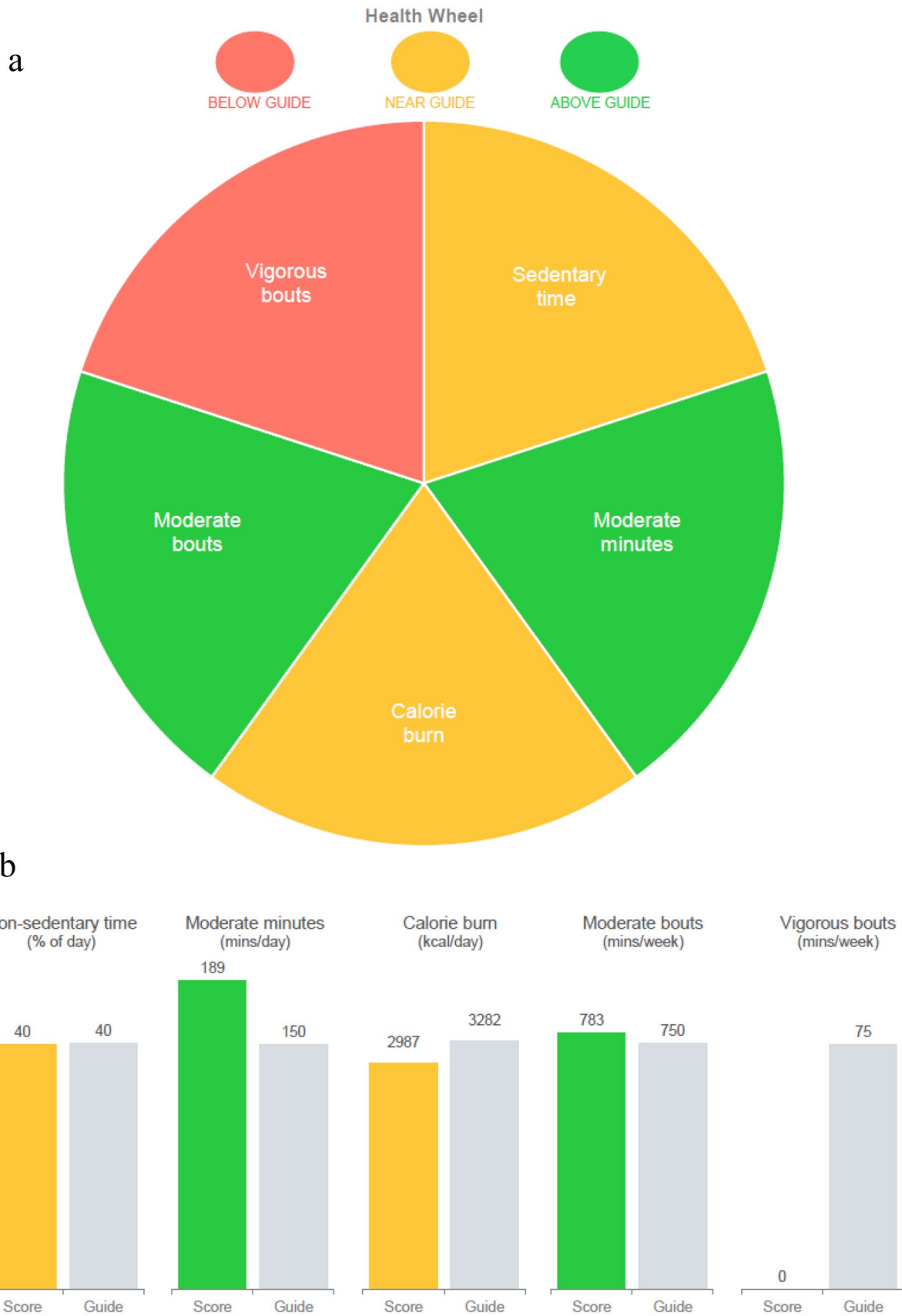
Cardiac rehabilitation (CR) is a comprehensive secondary care programme for patients with heart disease [1]. Despite the well-established benefits of attending, such as reduced

readmissions and improvements in quality of life [2, 3], less than 50% of eligible UK patients enrol on a CR programme [4, 5]. Among those who do begin CR in the UK, drop-out rates of 12–55% have been reported [6, 7].

The UK National Health Service (NHS) England Long Term Plan aims to increase uptake of CR to 85% by 2028 [8]. One strategy to increase participation is through home-based programmes, which have demonstrated comparable effectiveness to traditional centre-based CR [9, 10]. Following the suspension of face-to-face services due to COVID-19 [11], there have been further calls for alternative delivery models, with an emphasis on home-based and technology-assisted approaches to enable virtual access to information and clinical teams, commonly termed telerehabilitation [12, 13].

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**Fig. 1** Two examples of the physical activity feedback visualisations which were presented to patients. The traffic light system used in the visualisations represent an achieved target (green), within 25% of a target (amber) and below target (> 25%, red). Part a is a simple wheel with segments to represent each physical activity dimension (no magnitude). Part b displays each dimension scaled relative to the target (grey)

Physical activity is a core component of CR [1]. Emerging evidence suggests that the benefits of physical activity can be achieved in many ways, and multiple dimensions (aspects) of physical activity are independently important for health promotion and rehabilitation [14]. Past work has demonstrated that many individuals misjudge their physical activity status due to the lack of access to personalised information [15, 16]. Advances in wearable activity monitoring technology means that it is now possible to capture various physical activity dimensions during free-living conditions [14]. Taking a multidimensional approach provides a more comprehensive and integrated view of physical activity, that offers more behavioural options and personalised advice [17]. However, within a cardiac context, many studies focus on just certain physical activity behaviours such as step counts or sedentary behaviour [18, 19] – which has implications for the depth and quality of the feedback provided to individuals [14].

We have previously developed an innovative digital system for providing multidimensional physical activity feedback in at-risk patient populations in primary care [20]. To date, the acceptability of technology-enabled multidimensional physical activity feedback has not been explored in a cardiac setting, and its potential utility as part of CR is unknown. This is especially important in clinical populations who serve to benefit most from an increase in physical activity (e.g., to manage their risk of chronic disease). Previous research has shown that the following factors are important for the acceptability and efficacy for new technology; how data is presented to patients, whether physical activity feedback can be understood and interpreted accurately [16], and whether patients feel connected to and support by their practitioners [21]. Further, for new technology to be successfully incorporated into routine care, it must be acceptable and usable for healthcare practitioners (HCPs) who will be asked to support its application [22].

The present study aimed to extend past research by exploring the acceptability and perceived utility of providing technology-enabled multidimensional physical activity feedback as part of CR. To achieve this, the study had two main aims:

1. To explore the acceptability of personalised, multidimensional physical activity feedback in cardiac patients and HCPs (mixed roles) using a novel technology-enabled approach.

2. To explore how best to support the incorporation of technology-enabled physical activity feedback into CR provision to address potential barriers to participation.

## 2 Methods

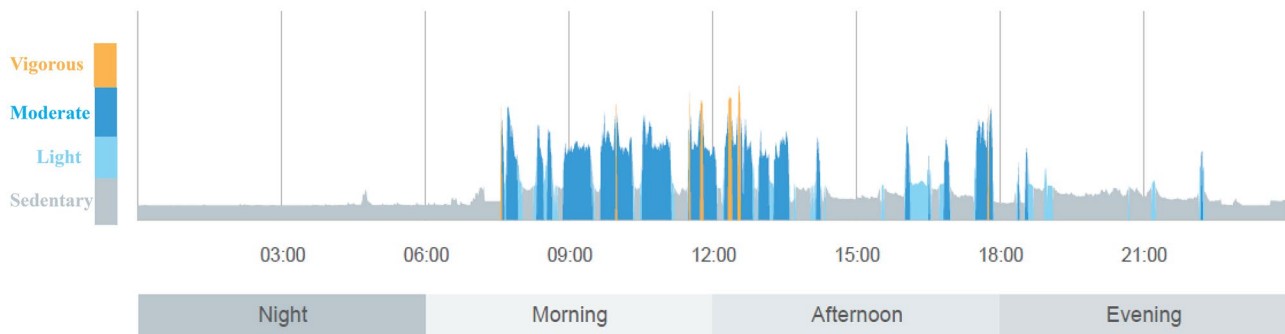
### 2.1 Design

The study was a non-experimental, mixed methodology research study conducted in primary and secondary care with patients receiving cardiology care and HCPs with a background of working with cardiac patients and/or rehabilitation programmes. We developed personalised physical activity graphics and feedback (Figs. 1 and 2), based on a seven-day monitoring period using a research-grade activity monitor. Informational graphics were developed by the project team in prior research on multidimensional physical activity feedback in at-risk patient populations [15], and customised for the current setting. Five individual physical activity dimensions were displayed in the feedback, including: sedentary time, calorie burn (energy expenditure), moderate intensity activity (both individual minutes and accumulated bouts) and vigorous intensity activity bouts. There were three different visualisations of an individual's feedback: a 'health wheel' in pie chart format, displaying the five dimensions of physical activity (Fig. 1a), a series of five bar graphs displaying each physical activity dimension relative to a guide/target (Fig. 1b), and 24-h time-series data for the 7-day monitoring period, displaying time spent and energy expended at different intensity thresholds (Fig. 2). The health wheel and bar graphs were coloured using a traffic light system to represent achieving the guide (green), being within 25% of the guide (amber), and being below the guide (> 25%, red).

Patients and HCPs were presented with the graphics and guided through the feedback, followed by interviews about the usefulness of such technology-enabled feedback for their physical activity behaviours and in supporting CR. HCPs wore the devices in order to gain insight into patients' experience in doing so, but primarily to triangulate patient responses by drawing on their experiences of working with a wider range of patients than could be represented in this qualitative sample. Ethical approval for the study was granted by the National Research Ethics Committee Southwest (reference: 219019). Interviews were conducted between December 2017 and July 2018.

### 2.2 Participants

Adult patients with a clinically documented diagnosis of ischemic heart disease (angina, myocardial infarctions,



**Fig. 2** An example of a single day of physical activity, colour coded by physical activity intensity in calories burnt per minute (kcal)

revascularisation, including angioplasty, stent or coronary artery bypass) or stable heart failure were recruited. Patient identification and recruitment were supported by research nurses at 1) a General Practice surgery (primary care), whereby a database search was conducted by a practice nurse to identify eligible patients, and 2) a General Hospital (secondary care) from the South West of England, whereby a cardiac research nurse identified potentially eligible patients from those that had been admitted to the cardiology ward. Patients who were unable to engage in physical activity were excluded from the study. HCPs were recruited through the Research and Development team of the same General Hospital using a purposive sampling approach, inviting those with experience of working with cardiac patients and/or rehabilitation programmes to participate in the study.

## 2.3 Procedure

All potentially eligible patients and HCPs were invited to attend a baseline assessment clinic, where a researcher or nurse further explained the nature of the study and checked eligibility. Both participant groups then provided written informed consent.

### 2.3.1 Physical activity assessment

All participants who agreed to take part in the study during the baseline assessment clinic were provided with a research-grade physical activity monitor (Bodymedia Core, BodyMedia Inc., Pittsburgh, PA) which has been used in previous research studies and has high levels of accuracy [23, 24]. Participants were instructed to wear the device for seven consecutive days and to only remove it for water-based activities such as showering and swimming. The time spent and energy expended at different physical activity intensities (sedentary, moderate, and vigorous) were calculated for each participant based on metabolic equivalents (METs). To convert energy expenditure to METs, we used age-specific equations to calculate basal metabolic rate [25] and to determine

the amount of time engaged in sedentary behaviour (< 1.8 METs), moderate-intensity activity (3.0 – 5.9 METs) and vigorous-intensity activity (6.0 – 10.1 METs). Physical activity level (PAL), which is the product of total energy expenditure divided by resting metabolic rate [26], was used to categorise participant's activity levels and compare them to the wider population. A valid day required a minimum of 80% data for a given 24-h period, and a minimum of five valid days of data. Missing data was assigned with each individual's basal metabolic rate [25].

### 2.3.2 Interview procedure

Participants were invited to attend a one-to-one, semi-structured interview within two to four weeks of their baseline appointment, which took place at the University (patients) or the participant's place of work (HCPs). The interviews lasted approximately 30–60 min and were digitally recorded. The interview topic guide was developed with input from academics, health psychologists, consultant cardiologists and cardiac nurses. Each interview began with overarching questions to capture participants' views on physical activity and CR, and any barriers they may have experienced participating in CR. Personalised physical activity feedback from each participant's wearable device was then presented to the participant, followed by questions regarding experiences wearing the physical activity monitor, their understanding and acceptability of their feedback and practical applications of using technology-enabled feedback in a rehabilitation setting. In addition to their own feedback and preferences, HCPs were further asked about their perceptions of patient understanding and potential uses.

## 2.4 Data analysis

Audio recordings were transcribed verbatim and imported into Nvivo Pro (Version 12.6.970) to code and organise the data. A thematic analysis approach, in line with Braun and Clarke [27–29] was used to analyse the interview data.

Following familiarisation with the interview transcripts, data were coded inductively by DS. Codes were clustered into subthemes, developed into more substantive themes, and refined in regular discussions with the wider research team.

Patient interviews were coded and analysed first, which established the initial framework of themes and subthemes (Table 1). HCP interviews were coded using the same framework, noting areas of overlap and difference.

### 3 Results

Fifteen cardiac patients and nine HCPs were recruited for the present study. However, due to inadequate monitor wear time resulting in incomplete physical activity data, two patients were excluded from analyses, resulting in thirteen patients. Of the HCPs, four were cardiac specialists/nurses, two were GPs and three were consultants (respiratory and diabetes). Average daily wear time among patients and HCPs was very high (99%). Four patients were classified as “sedentary”, one as “low active”, seven as “active”, and one as “very active” based on total energy expenditure (PAL) using guidelines from the Institute of Medicine [30]. HCPs demonstrated higher PALs, with one classified as “low active”, five as “active” and three as “very active”. Patient and HCP characteristics can be found in Tables 2 and 3, respectively. Responses were categorised into two overarching themes focused on 1) the perceived value of multidimensional physical activity feedback, and 2) support needed to facilitate understanding.

#### 3.1 Perceived value of multidimensional physical activity feedback

The first theme is centred around the features, functionality, and benefits of technology enabled multidimensional physical activity feedback, as well as how it could be utilised as part of CR.

##### 3.1.1 Objective evidence to monitor progress

Several patients noted the potential to monitor progress using technology-enabled personalised physical activity feedback, and to compare data at different time points.

*“Yes, I think it’d be much more beneficial, you know mixed with the rehab I think it would give people a chance to see which way they’re going.” (Patient 6, dropped out of CR)*

These views were also reflected among HCPs, who reported the importance of providing patients with feedback to reinforce behaviour:

*“It [multidimensional feedback] would show them absolutely, really, what the changes have been, it’s a more tangible thing, isn’t it?... I think if you can actually give people data and show them physical evidence for improvement, I think that helps them” (HCP 4, Clinical Nurse Specialist for CR)*

##### 3.1.2 Motivation and goal monitoring

In the design of behaviour change interventions, physical activity monitoring is incorporated to enable individuals to set goals and receive objective feedback of their progress [31]. Twelve out of the 13 patients agreed that they found their multidimensional physical activity feedback motivating, with many patients describing the desire to improve their physical activity when seeing their data:

*“It shouldn’t take much to actually improve that... Get more yellow in it. This is the sort of thing I like. If I can see this sort of thing, I’d be saying, ‘Oh, yeah, I’ve got to get some more yellow.’” (Patient 3 – invited to CR, chose not to attend)*

Participants perceived value in the presence of guidelines alongside their own physical activity behaviour, as it enabled comparison to their own physical activity data and highlighted areas that they could improve on:

*“I think all of these things, if you’re interested at all in trying to improve your health, these are quite encouraging because you’ve got something to aim for, haven’t you?” (Patient 3 – invited to CR, chose not to attend)*

The additional value this could have in CR was reinforced by HCPs:

*“I think it’s important that if you are making a suggestion to a patient, and you give them a goal, if there is*

**Table 1** Individual sub-themes clustered together into their overall theme

Theme	Sub-theme
Perceived value of multidimensional physical activity feedback	Objective evidence to monitor progress
	Motivation and goal monitoring
	Improving physical activity knowledge/awareness
	Perceived application to cardiac rehabilitation
Support needed to facilitate understanding	Ensuring safe data interpretation
	Cases when additional support may be required



**Table 2** Patient characteristics

Patient number	Sex	Age group	Cardiac event	Cardiac rehabilitation status	Used a PA monitor before	Daily sedentary time (% waking day)	Daily moderate activity (min/day)	Daily vigorous activity (min/day)	Physical activity level (PAL)
1	Male	70–79	MI, pacemaker, angioplasty	Completed		89	26	1	1.30
2	Male	60–69	Atrial flutter, atrial fibrillation	Eligible, not invited	✓	45	356	27	2.28
3	Male	60–69	Angina, congenital	Declined offer	✓	60	189	6	1.82
4	Male	50–59	MI	Completed		84	100	4	1.54
5	Male	60–69	MI, heart failure	Completed		79	125	21	1.65
6	Male	70–79	MI, transplant	Started but dropped out		77	93	0	1.76
7	Male	60–69	MI, congenital	Completed		69	160	10	1.73
8	Male	60–69	Angina	Invited, planning to attend	✓	79	138	15	1.66
9	Male	50–59	Heart failure	Eligible, not invited		95	11	0	1.23
10	Female	50–59	LV assist	Eligible, not invited		96	11	0	1.16
11	Male	40–49	MI	Invited, attending private CR instead	✓	68	184	3	1.80
12	Male	60–69	MI	Invited but not attending		81	97	7	1.60
13	Male	40–49	MI	Invited, planning to attend	✓	90	39	0	1.39

CR cardiac rehabilitation, MI myocardial infarction, LV left ventricular, PA physical activity

Physical activity dimensions that were presented in the ‘health target’ section of the feedback were as follows:

- Daily sedentary time was the percentage of a 16-h waking day (8 h of sleep was assumed and subtracted from the total sedentary time) spent sedentary (<1.5 METs)
- Daily moderate activity was the average number of single minutes of moderate activity (3 METs, <6 METs)
- Daily vigorous activity was the average number of single minutes of vigorous activity (>6 METs)
- PAL: Physical activity level calculated by total energy expenditure divided by resting metabolic rate. PAL $\geq$ 1.0<1.4 (sedentary), PAL $\geq$ 1.4<1.6 (low active), PAL $\geq$ 1.6<1.9 (active), PAL $\geq$ 1.9<2.5 (very active)

*no evaluation of that, it gets lost and that’s the bit that we don’t do” (HCP 9, Heart Failure Nurse)*

HCPs also supported the idea that patients may feel increased motivation to improve their physical activity behaviours as a result of viewing their feedback, in addition to the cardiac event itself. One HCP, speaking about the use of feedback among patients, recognised the achievement that patients may feel when reaching goals, and how this

may contribute towards maintaining their improved physical activity behaviour.

One patient described feeling like their physical activity feedback was a type of a wake-up call, that was needed to prompt a change in their behaviour:

*“Yes, yes, it’s hopefully gonna be the kick up the jacksy that I need. The push that says do it instead of well do I have to? It’s gonna be do it.” (Patient 7 – completed CR)*

**Table 3** Healthcare practitioner characteristics

HCP	Sex	Age group	Job role	Used a PA monitor before	Daily sedentary time (% waking day)	Daily moderate activity (min/days)	Daily vigorous activity (min/day)	Physical activity level (PAL)
1	Male	40–49	Respiratory - consultant		75	150	28	1.81
2	Male	40–49	General practitioner		74	183	40	1.92
3	Female	40–49	General practitioner		81	74	5	1.58
4	Female	60–69	Cardiology - Clinical nurse specialist for CR		60	198	9	1.89
5	Female	50–59	Cardiology - Catheterisation lab	✓	68	168	19	1.82
6	Female	50–59	Diabetes and Endocrinology - consultant		71	173	34	1.90
7	Male	40–49	Cardiology - Consultant chest physician		82	113	17	1.68
8	Female	50–59	Cardiology - Heart failure specialist nurse	✓	72	168	28	2.00
9	Female	50–59	Cardiology - Heart failure specialist nurse		74	152	10	1.77

Physical activity dimensions that were presented in the ‘health target’ section of the feedback were as follows:

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- Daily moderate activity was the average number of single minutes of moderate activity (3 METs, <6 METs)
- Daily vigorous activity was the average number of single minutes of vigorous activity (>6 METs)
- PAL: Physical activity level calculated by total energy expenditure divided by resting metabolic rate. PAL $\geq$ 1.0<1.4 (sedentary), PAL $\geq$ 1.4<1.6 (low active), PAL $\geq$ 1.6<1.9 (active), PAL $\geq$ 1.9<2.5 (very active)

### 3.1.3 Improving physical activity knowledge/awareness

Some participants identified that the discrepancies between their perceived physical activity, and their actual physical activity measured by a wearable device caused them to reflect and challenge their assumptions. Patient 13 (waiting to start CR) stated: “one person’s opinion of high intensity might not be the same as somebody else’s”, suggesting that viewing physical activity feedback may help them to be more objective in understanding the intensity of the activity they do, which was also reflected in others’ comments.

*“I think it would cut out the subjectiveness of it all, relying on the person to subjectively assess themselves, because I think people are probably differing in their ability to describe what they’ve been up to, so I think that would be useful” (Patient 4 – completed CR)*

The opportunity to improve participant’s knowledge of what constitutes different intensities of physical activity and awareness of their own behaviour was a clear benefit of using technology-enabled feedback among clinicians and patients:

*“Yeah, obviously, it just confirms I am doing some sort of activity which is now looked as vigorous, which per-*

*haps I wasn’t fully aware of what vigorous meant.” (Patient 2 – not invited to CR)*

Patients recognised that without objective feedback, their self-reported activity may be exaggerated, for example through the desire to please their clinicians:

*“I think some people say what they want people to hear because they don’t like to disappoint people. I think some people are probably convincing themselves they are doing different to what I’m doing, so I think I’m quite self-aware.” (Patient 4 – completed CR)*

HCPs also took interest in the difference(s) between their perception of their own behaviour in comparison to their measured physical activity. They highlighted the potential for technology-enabled feedback to enlighten patients about the reality of their physical activity, and suggested that it would be revealing for patients who are not as active as they could be:

*“...this is what I was interested in, to see how the reality matches up with the actual activity and what my perception of my lifestyle would be. So, when you see it like that...it really brings it home to you what your own*



*perception is and what the reality actually is” (HCP 4, Clinical Nurse Specialist for CR).*

### 3.1.4 Perceived applications to cardiac rehabilitation

Patients reported receiving limited physical activity and rehabilitation guidance when initially released from the hospital following a cardiac event, which was generally interpreted as implicit advice to ‘take it easy’ for an indefinite period. Some patients felt there was a delay in receiving information and reassurance concerning physical activity, which left them feeling ‘lost’. Patients reported a desire for physical activity guidance and support to regain confidence after their cardiac event:

*“I need the reassurance of someone who knows and understands it properly and say, “Ok, this is the exercise you can do”, and it’s about reassurance and confidence because you’ve, you know, we’ve all had a big event” (Patient 12 - invited to CR, chose not to attend)*

As a cardiac event can be very traumatic, and unexpected in cases where a patient was very active previously, it may lead to increased anxiety around being physically active again [32]. HCPs were largely aware and considerate of patient fears of exercising following a cardiac event. One HCP (6, Diabetes Consultant) suggested that experiencing physiological symptoms (e.g., breathlessness and dizziness) as a result of a cardiac event can be a barrier to CR. As a result, many patients raised the issue of not knowing how much physical activity is safe to do after their cardiac event, fearing doing ‘too much’, thus further damaging their heart. Wearable physical activity monitoring paired with feedback from a practitioner was perceived as a way to improve patient’s awareness of their physical activity and physiological responses:

*“...You’d think, “Oh crikey, I better not push it too much”. This one [physical activity monitor] is telling me I haven’t. If you can relate that to an individual’s requirement, their heart requirement so it’s more specific and it then came out that you’re doing 60% of 100, that would enable somebody to understand, “Oh I can push myself a bit more without being worried”, because it’s a worry isn’t it?” (Patient 12 - invited to CR, chose not to attend)*

Patient 13, who had been invited to CR but had not yet begun, described a personal benefit of using physical activity monitoring:

*“For me, specifically, it will enable me to understand what I will be able to do in the future without hav-*

*ing to actually guess. It will take some of the fear, I suspect, of going back to exercise” (Patient 13)*

By enabling HCPs to provide some guidance and supervision during this period of uncertainty (between hospital discharge and the start of CR), technology-enabled feedback was highlighted as a strategy to support patients in taking the first steps towards a return to physical activity whilst waiting for their CR programme to begin:

*“I think also following myocardial infarction big, scary events like that, they need to have hand holding and confidence building, that they’re able to go back and do certain elements. So, it’s really useful for them.” (HCP 3, General Practitioner)*

## 3.2 Support needed to facilitate understanding

The second theme includes patient and HCP perception of the depth and frequency of support that patients may need to be able to interpret their data and make changes to their behaviour. Most patients felt confident about using a website or a smartphone application to monitor their physical activity and view their feedback, but would value the opportunity to discuss this with a HCP. Several HCPs agreed that patients may need initial support with understanding their data, before they are able to interpret their feedback and implement changes on their own, and that it may be feasible to provide support remotely.

### 3.2.1 Ensuring safe data interpretation

Patients mainly described the role of HCPs alongside technology as somebody to check that they are interpreting their data correctly, to provide reassurance and advise on what to do as a result:

*“... a monthly review would be good, you know, from a professional who looks at the data and says, “Based on what we’re seeing, we would recommend the following”. Yeah. I think it’s always good to have somebody else, another opinion, especially a professional one.” (Patient 13 – waiting to start CR)*

Some patients felt that an initial explanation of the physical activity graphics would be sufficient for future understanding:

*“I think so. Obviously, without an explanation it would be difficult to read, but with an explanation, I suspect this is fine now.” (Patient 11 – private CR route)*

### 3.2.2 Responding to potential negative impacts of feedback

Several HCPs explained that it may be demotivating for patients to see that they have not met the target levels of physical activity, especially if they think that they are doing well in their recovery. HCPs were concerned that it may feel impossible for some patients to achieve the guidelines, which could be disheartening. They further described the importance of ensuring that patients understand their cardiac condition and its implications on their physical activity. HCP 6 (Diabetes Consultant) explained that it would be important to ensure that “people understand that we know this probably isn’t exactly what you were doing beforehand, but let’s just use it as a starting point”. The importance of this was highlighted by one patient, who described concerns around overexerting themselves to reach the guidelines without appropriate supervision:

*“Again, if I was looking at this every day, there would be a danger I’d be trying to make myself green and actually trying to do that in a short space of time, which might not be very good for somebody” (Patient 4 – completed CR)*

It was highlighted by both patients and HCPs that where patients recorded low values across physical activity dimensions, and had a predominantly ‘red’ health profile because they had not achieved target levels of physical activity, support in how to respond to data to mitigate against negative feelings, such as guilt, may be needed:

*“The feeling part of it, a little bit hard, because from my perspective I would never expect to see red. Not ever. And it just compounds and confirms that I’m in a period in my life that I don’t want to be in, you know” (Patient 13 – waiting to start CR)*

## 4 Discussion

### 4.1 Summary of findings

The present study aimed to explore patient and HCP perceptions of novel technology-enabled, multidimensional physical activity feedback and whether this approach could enhance CR service provision. Both patients and HCPs reported positive experiences of using wearable technology and most found their feedback motivating. Specifically, patients found the personalised feedback provided guidance and reassurance on how much physical activity is safe and appropriate, improved the depth of their physical activity knowledge and awareness, and was useful in monitoring progress. Support may be needed from HCPs initially to

aid the understanding of physical activity data; patients felt that meeting with an HCP on a regular basis would provide reassurance that they are interpreting their data correctly. Some patients and HCPs raised concerns around the risk of the feedback having the potential to demotivate patients who may not be meeting targets.

### 4.2 Technology-enabled, multidimensional physical activity feedback

Despite the growing number of studies using mobile technologies to target physical activity for CR [33], few exploit the multidimensional characteristic of physical activity. Most patients in the present study demonstrated a clear understanding of their personalised multidimensional physical activity feedback and found it motivating. This implies that patients can comprehend potentially complex and in-depth information about their physical activity with support. Understanding that there are many different ways to benefit from physical activity provides patients with more options and choice to change their behaviour and could help them to make more informed decisions [14]. The benefits of this type of rich informational physical activity feedback in individuals at risk of cardiovascular disease, is consistent with findings from Western and colleagues [15], who also found multidimensional physical activity feedback to be motivating, comprehensible and a strategy to facilitate behaviour change. It has also been reported that objective physical activity monitoring has the potential to improve an individual’s awareness of their own physical activity behaviour [34]. Our results align with these findings, with patients in the present study describing the feedback as useful for improving their knowledge of different aspects and intensities of physical activity and removing subjective assumptions about their own behaviour. This was supported by HCPs who highlighted that many individuals may have a distorted perception of their actual physical activity, and that multidimensional feedback may help to reduce this discrepancy.

The multidimensional aspect of the feedback provided in the present study provides a more complete picture of one’s physical activity profile, reducing the likelihood of misclassifying an individual’s physical activity level due to reliance on single dimensions [14]. Breaking down an individual’s physical activity profile into multiple dimensions may appear much less daunting and more manageable, as they can focus on a given aspect that they feel more comfortable with (reducing sedentary behaviour, rather than increasing vigorous intensity activity, for example). This is particularly pertinent for the cardiac population, who may experience anxieties about certain types or intensities of activity following a cardiac event.

### 4.3 The need for support

The present study highlighted patients' desire to have the opportunity to discuss their physical activity data with clinicians, to facilitate accurate and safe data interpretation to improve understanding. It has previously been reported that the sharing of patient data with clinicians via telemonitoring provided patients with a sense of security and assurance [35]. In addition, high acceptability (71–99% of participants) of telerehabilitation in cardiovascular disease patients has been attributed to tailored content and the opportunity for patients to interact with HCPs [36].

Despite the positive experiences of technology-enabled feedback found in the present study, some patients reported feelings of guilt and demotivation associated with not meeting physical activity targets, and for some, receiving feedback displaying 'red' sections (unmet guide or target) reaffirmed that they were at a difficult stage in their life. This may be a common perception among cardiac patients, due to them potentially having experienced traumatic health conditions, various risk factors (e.g., obesity) and limited physical capabilities. As such, it is important that patients are provided with sufficient support and guidance alongside their feedback, to mitigate any possible negative impact that it may have. Focus should be given to the opportunity for positive lifestyle change, building confidence, and encouraging safe and enjoyable physical activity. The importance of understanding the potential negative consequences of feedback is apparent from research by Western and colleagues [16], who reported that 'low active' primary care patients needed greater reassurance when interpreting data, experienced more feelings of disappointment and shame, and more commonly used denial as a coping mechanism compared to 'high active' patients, upon receiving multidimensional physical activity feedback.

### 4.4 What is the potential for technology to enhance CR delivery?

Face-to-face CR classes can typically only accommodate a small number of patients, meaning that waiting lists are long. It has been previously demonstrated that a failure to start CR in the recommended timeframe in England (33 days) results in a reduction of 15.3% in uptake and 7.4% in completion [37]. Shorter wait times have also been shown to elicit greater improvements in exercise capacity compared to longer wait times [38]. Many of the prominent barriers to participation in CR, which are widely reported in the literature [39, 40], including long wait times, could be addressed using a remote, technology-enabled approach, enabling patients to begin their programme once their practitioner deems it is safe. In the present study HCP 4 (Clinical Nurse Specialist for CR) suggested that patients

may be attracted to a remote method which utilises technology if they do not have to go back into hospital for consultations or exercise classes, and therefore it could be a route to improve uptake for patients who would typically decline face-to-face CR. Also, the use of multidimensional physical activity feedback with HCP support may help to reduce the feelings of uncertainty and fear of being physically active after a cardiac event, which were commonly reported by patients. The reassurance provided by the objective nature of physical activity monitoring, paired with advice from a health professional may help to rebuild patient's confidence and provide valuable education around physical activity that can be implemented in their lifestyle during CR and beyond.

One consideration for clinical adoption is that in the present study, the provision of feedback on a single occasion meant that the inclusion of behaviour change techniques was limited to self-monitoring, feedback on behaviour, and discrepancy between behaviour and goal [31]. Previous studies have suggested that single feedback sessions are not sufficient to facilitate behaviour change [24, 34], and that health interventions are most effective when grounded in behaviour change theory and include elements of social support, problem solving and motivational messages [41]. Patients may therefore need prolonged access to feedback and support, which incorporates a variety of behaviour change techniques, warranting further exploration of multidimensional physical activity feedback in CR patients over a prolonged period.

### 4.5 Strengths and limitations

Patients recruited into the study were either awaiting CR, had dropped out of a programme, or had completed CR. Therefore, a range of experiences and opinions were gathered regarding patients' intentions to participate, their experiences during CR and whether those who had dropped out believed that technology-enabled physical activity feedback would have been helpful. While this has provided us with an overview of the types of feelings and experiences that patients have at different stages of their rehabilitation, a larger sample would enable a more detailed exploration. Similarly, HCPs were from a variety of disciplines, with only four out of nine recruited from a cardiology background. This allowed for a diverse set of perceptions from people working with patients at different stages of recovery, and with different points of interaction with formal CR. Nonetheless, data gathered from HCPs who work with cardiac patients more infrequently may be less relevant to the cardiac population.

Since the collection of data for this study, the covid-19 pandemic has had a large impact on the delivery of CR services, with most trusts forced to provide only home-based

programmes to limit the spread of infection [11]. The rapid changes in response to the pandemic have accelerated the use of technology in CR and the uptake of novel, remote options are increasing [42]. As a result, the perceptions and experiences of technology-enabled feedback found in this study are now even more relevant, and the importance of providing patients with more options to manage their physical activity is more widely recognised. This presents an exciting opportunity to harness the benefits of technology-enabled multidimensional physical activity feedback for future CR delivery.

## 5 Conclusion

Overall, cardiac patients and HCPs found multidimensional physical activity feedback motivating, reassuring, and felt satisfied with the usability and experience of wearing a physical activity monitor. It is evident from the present study that most patients would feel confident using a mobile application or web-based platform to view and access physical activity feedback. If implemented in the future, this type of remote monitoring could allow for many more patients to participate in CR from their homes and would reduce the need for patients to attend face-to-face consultations to monitor progress, as this could be conducted remotely. The study highlighted that CR patients may need support from HCPs for data interpretation in the initial stages, particularly for those with low physical activity levels. Such support could be delivered using online consultations alongside a digital system for providing physical activity feedback. Future research is needed to explore whether regular multidimensional physical activity feedback can improve physical activity, clinical outcomes, uptake, and adherence to CR.

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## Declarations

**Ethics approval** This study was performed in line with the principles of the Declaration of Helsinki. Ethical approval for the study was granted by the National Research Ethics Committee Southwest (reference: 219019).

**Consent to participate** Written informed consent was obtained from all individual participants included in the study.

**Consent to publish** The authors affirm that human research participants provided informed consent for publication of their data.

**Conflict of interest** The authors have no relevant financial or non-financial interests to disclose.

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