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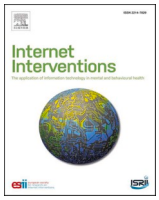

Patient-reported preferences in eHealth-based cardiac rehabilitation: A qualitative investigation of behavior change techniques, barriers and facilitators

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ABSTRACT

Background: Cardiac rehabilitation (CR) reduces recurrent cardiac events and mortality in patients with cardiovascular diseases (CVD). Innovative eHealth methods can facilitate CR uptake and effectiveness by addressing barriers associated with clinic-based rehabilitation. Tailoring eHealth-based CR to patient preferences is needed to further enhance CR.
Purpose: To identify preferred behavior change techniques (BCTs) as well as barriers and facilitators for the different health behaviors targeted in eHealth-based CR among patients who have been referred to CR.
Methods: Thirty-nine patients were interviewed in nine focus groups in The Netherlands, Germany, and Spain. A thematic analysis, using a combined deductive and inductive approach to coding, was conducted to identify BCTs and barriers and facilitators to behavior change. Behaviors under investigation included physical activity, medication adherence, eating a cardiac healthy-diet, stress reduction and smoking cessation.
Results: The perceived helpfulness of BCTs depended on the specific behavior targeted. Common barriers were *negative emotional state* and *physical limitations.* A *desire to feel physically* or *mentally well* and *having experienced a cardiac life event* were the most common facilitators across health behaviors. Specific BCTs, barriers and facilitators were found for each of the health behavior.
Conclusions: Behavior change techniques that patients preferred for each health behavior targeted in eHealth-based CR were identified. A negative emotional state, experiencing a life event, and improving physical functioning are important barriers and facilitators in multiple behaviors targeted in eHealth-based CR programs. Additional tailoring of interventions to patient preferences for BCTs and patient-specific barriers and facilitators per health behavior could lead to further improvement of eHealth-based CR.

1. Introduction

With an estimated 17.9 million lives lost every year, cardiovascular diseases (CVD) are the leading cause of death globally (World Health Organization, n.d.). Secondary prevention through cardiac rehabilitation (CR) reduces the risk of recurrent events and mortality in patients with CVD (Winnige et al., 2021). However, a significant number of patients declines participation or drops out during CR (Chindhy et al., 2020), which may be attributed to several barriers, including lack of time due to work obligations, lack of motivation and a high travel-related burden (Dunlay et al., 2009; Chindhy et al., 2020). Over the past years, eHealth (healthcare practice supported by electronic

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processes, such as mobile phones and the internet (World Health Organization, 2018)) has been increasingly advocated as a delivery mode to facilitate the uptake and accessibility of CR as it circumvents location and time constraint related barriers (Su et al., 2020; Thomas et al., 2019; McIntosh et al., 2017; Sugiharto et al., 2023). Despite its flexible nature, home-based CR is only offered in 34.2 % of countries, with 63.9 % of those programs offering some form of electronic CR (Lima de Melo Ghisi et al., 2018).

Cardiac rehabilitation (both clinic-based and eHealth-based) targets the improvement of several behavioral risk factors for adverse CVD outcomes, including insufficient physical activity, medication non-adherence, dietary habits associated with increased CVD risk, prolonged psychological stress and smoking (World Health Organization, n. d.). To tackle these risk factors, behavior change techniques (BCTs), meaning active components of interventions designed to change behavior to promote health, can be used in a wide range of clinical settings including eHealth-based CR programs (Michie et al., 2014; Duff et al., 2017).

Studies have demonstrated patient acceptance of eHealth-based CR to generally be higher than acceptance of traditional clinic-based CR (Kebapci et al., 2020; Brørs et al., 2019). Research has indicated that patients appreciate the customizable nature of eHealth-based CR interventions and hold a positive attitude towards using mobile devices daily to assist with their rehabilitation (O'Shea et al., 2020). These positive patient perspectives, however, have not resulted in a widespread uptake of eHealth-based CR options in the standard of care for patients with CVD (Lima de Melo Ghisi et al., 2018). To improve patient engagement, compliance and outcomes in eHealth-based CR, more research is necessary (Chong et al., 2021; Su et al., 2020).

Evidence suggests that the development of sustainable eHealth interventions needs to take a user-centered approach that allows for the (sociodemographic- and culture-related) needs and preferences of the target population (van Gemert-Pijnen et al., 2011; Saner and van der Velde, 2016). Several trials and meta-analyses have evaluated the effectiveness of eHealth-based CR interventions using BCTs (Herring et al., 2021; Lindman et al., 2021; Maddison et al., 2021; Su and Yu, 2021; Heimer et al., 2023), but research on patient preferences for specific BCTs and the barriers and facilitators to behavior change that patients experience is limited. Previous patient-centered research has generated important but broad themes (e.g., increase personal contact or involve a patients' social environment) or needs for eHealth usage that should be addressed, but less specific, implementable strategies to facilitate behavior change (Breeman et al., 2021; Rodrigues et al., 2021; Herrera et al., 2022; Akenine et al., 2020). There is a knowledge gap with regard to specific personal preferences for BCTs, the barriers that need to be targeted and the facilitators that may be strengthened in eHealth-based CR.

The aim of the current study is therefore to identify which BCTs, from those that are currently used in behavior change apps, are preferred for eHealth-based CR for different health behaviors. In addition, the barriers that need to be targeted and facilitators that may be enhanced to accomplish behavior change in eHealth-based CR will be identified. This information may be used to adapt and implement future eHealth-based CR interventions to the needs of patients.

2. Material and methods

2.1. Design

Focus groups were used to collect the data. Thematic analysis (Clarke and Braun, 2017) was used to investigate important themes for future eHealth-based CR interventions. A combination of deductive and inductive approaches were used to identify themes related to BCTs and to barriers and facilitators to behavior change. The Standards for Reporting Qualitative Research (SRQR) were used to report this study (O'Brien et al., 2014).

2.2. Participant sampling

A purposive sampling strategy (Rapley, 2014) was used to select patients from three hospitals/clinics; Elisabeth-TweeSteden hospital in the Netherlands, clinic Königsfeld in Germany and Hospital Universitario de Santiago de Compostela in Spain, during January and February 2022. Inclusion criteria were (1) being over 18 years of age; (2) referred to CR; (3) speaking the language of the country where the focus groups took place; and (4) being familiar with the use of a smartphone. Special attention was paid to the inclusion of women, as women are often underrepresented in cardiovascular research (Vogel et al., 2021). Exclusion criteria included (1) inability to understand the study and consequences of participating in the study; (2) presence of a physical impairment that would inhibit a patients' ability to use eHealth (e.g., blindness); (3) refusal to informed consent.

In the Netherlands, 90 patients with CVD were invited to participate by the focus group host or their cardiologist either via email, phone or in person during a visit to the cardiology outpatient clinic. In Germany, 14 patients who attended inpatient CR were invited to participate in person by a member of the local research team. In Spain, 20 patients who were currently attending outpatient CR were invited to participate in person by a member of the local research team. As part of the invitation, patients were informed about the purpose of the study and about the time and location of the focus groups. After patients verbally agreed to participate in the focus groups, they were asked to sign and return an informed consent form either via mail or email. In the Netherlands, focus groups were held online via Microsoft Teams. In Germany and Spain, focus groups were held in person at the clinic or hospital. Patients were informed that the discussion would be recorded and transcribed, but that their personal information would be deleted. A total of 85 of the 124 approached patients declined to participate, mainly because of personal circumstances, lack of time or because the interview was held in a group setting. Enrollment was continued until data saturation occurred as part of the data analysis, resulting in 39 patients from nine focus groups (three groups in each country).

2.3. Ethical considerations

The study was approved in the Netherlands by the Medical Ethics Commission Brabant and the institutional Ethics Review Board of Tilburg University (protocol number: NW2021–99), in Germany by Ethik-Kommission der Universität Witten-Herdecke (protocol number: 115/2020) and in Spain by Comité de Ética de la Investigación de Santiago-Lugo (protocol number: 2021/190).

2.4. Data collection

The study was conducted by a research team specialized in patients with CVD. The principal focus group host and lead coder (ERD) was a female researcher who is a PhD candidate in behavioral medicine, with experience in conducting qualitative research. In Spain, the focus group host was a female CR research nurse and in Germany the host was a female PhD candidate in sports sciences who had experience with qualitative research.

The research team conducted the focus groups between February 2022 and May 2022. The focus group discussions lasted between 45 min and two hours and were audio recorded. Two researchers were present at each focus group session; one of the researchers chaired the session and the other researcher took notes. Rapport between the researcher and participants was built by having all patients briefly introduce themselves and discuss their experiences with eHealth solutions for optimizing health behaviors.

The focus group discussions targeted the patient's personal experiences with changing their behavior in the past, and the barriers and facilitators they experienced regarding changing their current health behaviors. Patients were subsequently presented with screenshots and

videos of existing apps and asked whether they would appreciate similar strategies in eHealth-based CR. This method was chosen to facilitate interpretation of BCTs. Only BCTs that were present in the apps were discussed. Relevant apps that were commonly available were first selected in the Netherlands. In Spain and Germany, the same or similar apps in case of unavailability were subsequently selected (for an overview of all apps shown, please refer to Appendix A).

2.5. Data analysis

A combined deductive and inductive approach to coding was used in this study using the Atlas.ti 8 software (Atlas.ti Scientific Software Development, n.d.). To remain as close as possible to the original meaning of the participants, transcripts were coded in the original language by three of the researchers (ERD, SW, and MSF). To standardize the coding process, a codebook outlining themes and sub-themes was established by the principal investigator (ERD) after reviewing one translated transcript from each location. Codes relating to strategies used in the apps were deducted from the Behavior Change Taxonomy (Michie et al., 2013). Codes related to barriers and motivators were inductively created. After coding, quotes were translated, and the related codes were discussed among the researchers until agreement was reached.

The BCTs were evaluated based on their perceived helpfulness by patients. A scoring system was used where BCTs were rated on a scale from −2 to +2. A score of −2 indicated that the BCT was perceived as distinctly more negative than positive, while a score of +2 indicated the opposite. Similarly, a score of −1 meant that the BCT was perceived as slightly more negative than positive, and + 1 indicated the opposite. If patients did not indicate a preference or dislike for the BCT, the BCT was given a score of 0. Themes regarding barriers and facilitators were not scored but were determined to either be (most) common (present in most to all patients), relatively common (present in at least half of the patients), common for some (present in three or four patients), common to few (present in two patients) or only common for one patient.

Data collection and analysis overlapped, to ensure saturation of the data. Saturation was identified when all three members of the coding team (ERD, SW and MSF) agreed that the focus groups yielded no new information relevant to the research question (Tong et al., 2007).

2.6. Rigor and trustworthiness

To ensure the trustworthiness of the data analysis, three techniques were applied. First, investigator triangulation was used to confirm findings and highlight potential different perspectives (Carter et al., 2014). Biweekly meetings were held between all coders, to discuss coding differences and similarities to enhance inter-coder reliability. Additionally, recruitment continued until saturation in the data analysis was reached (Tong et al., 2007). The interview guide was pilot tested prior to the focus groups to avoid ambiguity in questions and adjust questions that made the pilot test participants feel inclined to answer in a socially desirable manner.

Because the summarizing and analysis of the focus group data was conducted in English, a language most of the participants lacked sufficient proficiency in, member checking was not performed.

3. Results

Thirty-nine patients, 13 of whom were women, with an average age of 58.6 (SD = 10.7) years, participated in nine focus groups (The Netherlands, $n = 13$; Germany, $n = 12$; Spain, $n = 14$). A detailed outline of the sample characteristics is displayed in Table 1. Most participants had some experience with changing their health behaviors and most participants wanted to improve one or more of their current health behaviors, predominantly exercising more and/or improving their diet. Half of all patients had experience with eHealth, mainly with using wearables or apps to change health behavior.

Table 1
Demographic characteristics of participants.

	Netherlands (n = 13)	Germany (n = 12)	Spain (n = 14)
Age	63.6 ± 10.4	55 ± 7	57 ± 12
Sex (women)	5 (38.5 %)	3 (25 %)	5 (35.7 %)
BMI (kg/m^2)	28.9 ± 4.5*	29.2 ± 5.5	26.6 ± 4.8
Diagnosis (main)			
STEMI	4 (30.8 %)	5 (41.7 %)	6 (42.9 %)
NSTEMI	4 (30.8 %)	4 (33.3 %)	6 (42.9 %)
Unstable Angina	0 (0 %)	2 (16.7 %)	1 (7.1 %)
Stable angina	2 (15.4 %)	1 (8.3 %)	1 (7.1 %)
Heart failure	1 (7.7 %)	0 (0 %)	0 (0 %)
Atrial fibrillation	1 (7.7 %)	0 (0 %)	0 (0 %)
Microvascular disease	1 (7.7 %)	0 (0 %)	0 (0 %)
Smoking status			
Never	12 (92.3 %)	3 (25.0 %)	6 (42.8 %)
Current smoker	0 (0 %)	3 (25.0 %)	7 (50.0 %)
Former smoker	1 (7.7 %)	6 (50.0 %)	1 (7.1 %)
Hypertension	5 (38.5 %)	6 (50 %)	3 (21.4 %)
Diabetes mellitus	3 (23.1 %)	3 (25 %)	4 (28.6 %)
Dyslipidemia	4 (30.8 %)	6 (50 %)	11 (78.6 %)

Data are presented as N (%) or mean (M) ± standard deviation (SD).
* BMI was unknown for one patient in the Netherlands, STEMI: ST-elevation myocardial infarction, NSTEMI: non-ST-elevation myocardial infarction.

3.1. Preferred behavior change techniques and general app use

Table 2 presents the results of the focus group discussions regarding the preferred BCTs for each behavior. Of the 91 behavior change techniques in the taxonomy (Michie et al., 2013), 12 were discussed in the nine focus group discussions.

We identified the most BCTs for physical activity, where patients most positively responded to self-monitoring of behavior, prompts/cues, and instructions on how to perform the behavior. For medication adherence, only four BCTs were identified to which patients responded relatively positively. Five BCTs were identified for obtaining a cardiac-healthy diet, with self-monitoring of behavior, instructions on how to perform the behavior, and conserving mental resources receiving the most positive response. Only two BCTs were identified for stress reduction, one of which patients responded positively to (self-monitoring of behavior) and one of which patients responded negatively to (prompts/cues). For smoking, five BCTs were identified, with only prompts/cues receiving a negative response.

In general, participants frequently brought up *barriers* to using the proposed apps. Several patients reported they found the concept of apps or eHealth unappealing and too taxing, and they would rather receive in-person help with their lifestyle. A few patients reported to lack the knowledge to use the apps or found the apps were often in English, which they had difficulty understanding.

3.2. General barriers and facilitators to behavior change

An overview of all identified barriers and facilitators can be found in Figs. 1 and 2.

3.2.1. Barriers

When disclosing *barriers* to behavior change in general, patients relatively often cited negative feedback from their doctor as demotivating. One patient for example said: *"You should not underestimate, you are of course mentally, after your heart attack … quite down and then [the doctor tells you] that it is because you weigh 20 kg too much…"* Some patients also mentioned their negative emotional state (e.g., experiencing stress and anxiety) made it difficult to change their behavior. A third general barrier that some patients mentioned was pressures from their

Table 2
Preferences for BCTs per behavior.

BCT/Behavior	Physical activity	Medication adherence	Cardiac-healthy diet	Stress reduction	Smoking cessation
Self-monitoring of behavior	+2	+1	+2	+1	–
Prompts/cues	+2	+1		-1	-2
Instructions on how to perform the behavior	+2	–	+2	–	–
Goal setting	+1	–	–	–	+1
Social support	+1	+1	+1	–	
Self-monitoring of outcomes of behavior	+1	–	–	–	+1
Social reward	+1	–	–	–	+1
Social comparison	0	–	–	–	–
Conserving mental resources	_ + 1	+1	+2	–	–
Credible source	+1	–	–	–	–
Information about consequences of the behavior	–	–	+1	–	–
Behavior substitution	–	–	–	–	+1

Note: −2: people responded distinctly more negative than positive, −1: people responded slightly more negative than positive, 0: About as many people responded negatively as positively, 1: people respond slightly more positive than negative, 2: people responded distinctly more positive than negative, −: BCT not mentioned for this health behavior.

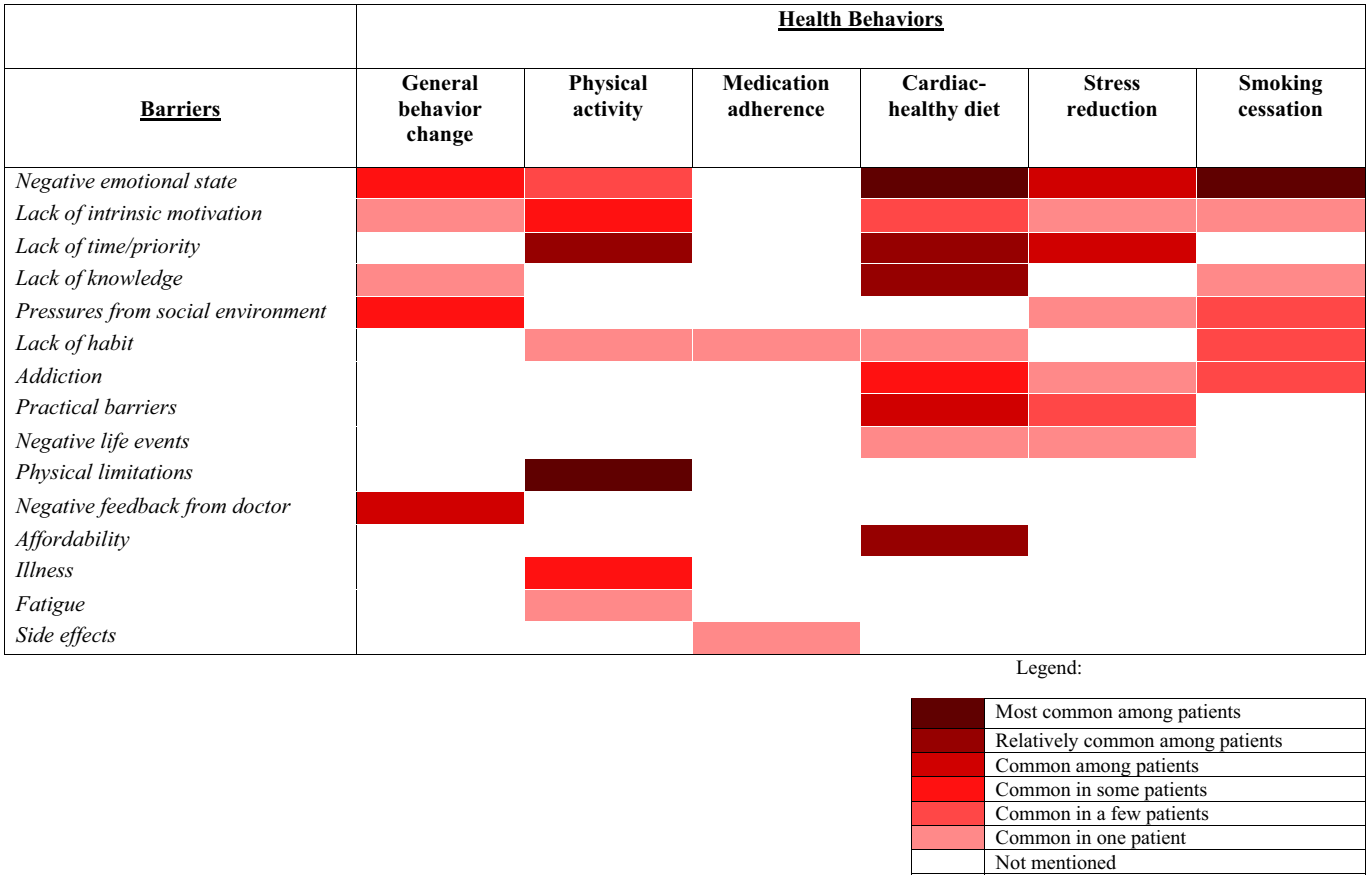

Fig. 1. Barriers to health behavior change for patients with CVD.

social environment (e.g., being a parent), that prevented them from focusing on health behaviors. Other patients mentioned they lacked the knowledge to change, or they did not feel intrinsically motivated to change: *"[It's difficult for people] to steer [me] in the right direction."*

3.2.2. Facilitators

General facilitators to behavior change did not arise during the focus groups. Specific facilitators per health behavior are presented below.

3.3. Barriers and facilitators to physical activity

3.3.1. Barriers

The most common barrier to physical activity was the presence of physical limitations, caused by complications due to physical injury or impairments (Fig. 1). For example, one patient mentioned: *"I am not allowed to do any [sports] anymore, because of my [bad] knees and back."* Another common barrier was lack of time or priority: *"As soon as there is any kind of distraction or change, I have found my excuse to not do [physical activity]."* Some patients mentioned they did not have the intrinsic motivation to be physically active. *"Biking just to bike or walking just to walk does not intrigue me at all."* Additionally, some patients mentioned an illness, such as hay fever or asthma, prevented them from being active. A few patients mentioned that their negative emotional state sometimes prevented them from working out. *"I start everyday with good intentions, but during the day I completely fall back. It's either because of stress or because of a busy day, or because I feel upset, or I worked too hard."*

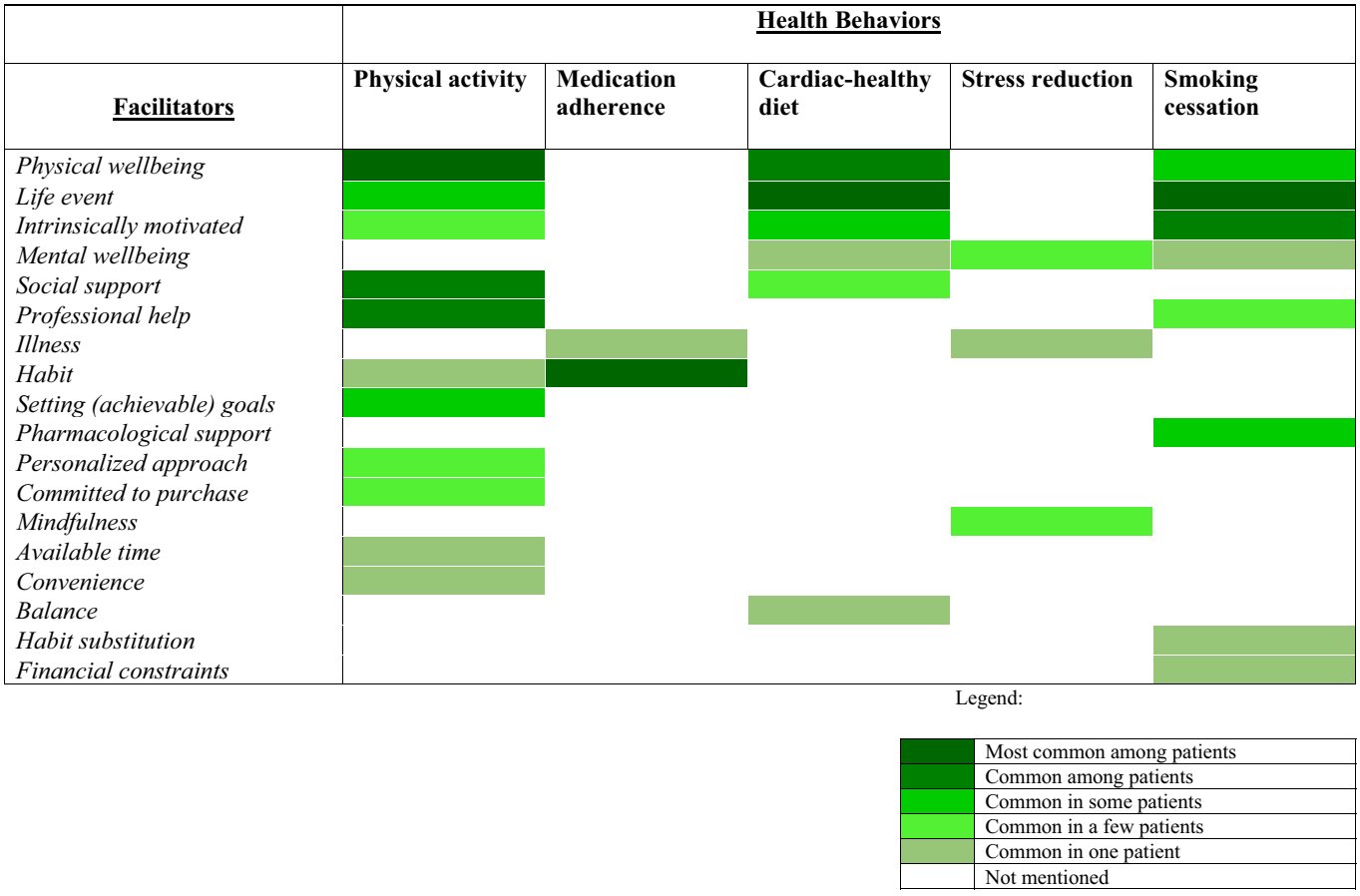

Fig. 2. Facilitators for health behavior change in patients with CVD.

Patients also mentioned (once) that they lacked the habit of being active or they felt too fatigued.

3.3.2. Facilitators

Regarding facilitators (Fig. 2), optimizing levels of physical well-being was mentioned most often as a motivator to be physically active. For example, one patient mentioned: *"My health is very important to me, I only have one heart."* For many participants, social support from their environment impacted their motivation to work out: *"The social aspect, that someone joins in, maybe for safety reasons, but for me it was more for motivation."* Additionally, professional help, such as enrolment in a CR program, facilitated many patients: *"Because of the cardiac rehabilitation, I was able to trust my body again."* For some patients, setting (achievable) goals helped them to become more active again: *"You also set intermediate goals, I find that very important. You can't say I want 100% in three months, that won't work, but it's very important to set intermediate goals."* Some other patients mentioned that experiencing a significant life event (often related to their cardiac disease) motivated them to change their activity levels. *"After my first stay in the hospital, I had pain in my chest, I started to pay attention [to being physically active]"*. Moreover, a few patients mentioned they were intrinsically motivated to be physically active, they had found a personalized approach (i.e., a lifestyle program) that worked for them, or they felt committed because they had signed up or paid for a program. Other facilitators mentioned (once) were the formation of habits that enabled patients to remain loyal to being physically active, having the time because of retirement, and the perception of physical activity being convenient (i.e., it was part of their commute).

3.4. Barriers and facilitators to medication adherence

3.4.1. Barriers

Only two patients mentioned barriers to medication adherence: experiencing side-effects and lacking the habit to take the medication at the same time every day.

3.4.2. Facilitators

Conversely, the most mentioned facilitator for medication adherence was that it was ingrained in their daily routine: *"I use one of those pill-boxes, and I always take mine during breakfast."* One patient mentioned that their illness motivated them to take their medication, as the consequences of not taking it were not worth it.

3.5. Barriers and facilitators to eating a cardiac-healthy diet

3.5.1. Barriers

A negative emotional state was mentioned most frequently as a barrier to adhering to a cardiac-healthy diet (Fig. 1). For example, one patient mentioned: *"I had a lot of stress at work, and you often compensate for that […] opening a bar of chocolate first, that kind of thing. That was my way of coping with stress."* Lack of knowledge was additionally a common barrier, as well as a lack of time or priority: *"Sometimes because I am feeling too busy. At night, I then just think 'I can start again tomorrow'. So then at night I am eating candy on the couch"*. Affordability of healthy food was also a common barrier: *"If you are looking for a marmalade or something that has no sugar, there are few, and if you want one with high fruit content, even less exist. The ones that exist are expensive"*. Practical barriers, such as difficulty finding healthy foods were also mentioned relatively often. Some patients also mentioned that they felt addicted to overindulging on specific foods: *"Salt is like coffee, the more you [have],*

the more you want." A few patients mentioned that they were simply intrinsically unmotivated to eat healthy or that they felt too fatigued to focus on their diet. Other barriers mentioned (once) were a habit of eating unhealthily or negative life events that disrupted plans to eat healthy.

3.5.2. Facilitators

The most common facilitators to keep a cardiac-healthy diet included optimizing levels of physical wellbeing and experiencing a life event often related to a patient's cardiac health (Fig. 2): *"I have also lost weight: after I had the heart attack, I changed my diet."* Physical wellbeing was often related to a fear of getting sick again: *"It is a feeling and fear of getting sick again. That does quite a bit for me. So, then I also hold back on eating unhealthy food."* Furthermore, some patients mentioned they felt intrinsically motivated to eat healthy: *"I changed my dietary patterns regarding fat and meal sizes, by using willpower."* A few patients mentioned that social support from their environment helped them with their dietary habits: *"We also eat low carb here, my wife does that to lose weight. So [my diet] does not change that easily as long as she keeps it up, then I just go along."* Furthermore, one patient mentioned their mental wellbeing as a motivation, and another pointed out that a balance between healthy and unhealthy helped them to stay motivated: *"Once a week I sin and allow myself to eat fries. I really like to eat things and I do not deny myself that."*

3.6. Barriers and facilitators to stress reduction

3.6.1. Barriers

Patients cited their negative emotional state as a relatively common barrier to reducing their experienced level of stress (Fig. 1): *"When you are stressed or suffering from anxiety your first thought is not 'I'm going to open an app to stop being stressed'."* Additionally, lack of time or priority was a relatively common barrier to stress reduction: *"I wouldn't use any apps or tools to reduce my stress, because with a young daughter it's difficult to find time to do those things."* Practical barriers, such as availability of psychologists or mental health professionals, were also mentioned a few times. One patient mentioned simply missing the intrinsic motivation to reduce stress. Another mentioned they felt addicted to the stress, making it difficult to reduce. One patient mentioned experiencing significant life events (related to their cardiac disease) as a barrier and another mentioned pressure from their social environment (i.e., multiple children and a stressful job) as a barrier to experiencing less stress.

3.6.2. Facilitators

Regarding facilitators, these were only mentioned once or twice (Fig. 2). Mental wellbeing was cited as a motivation to experience less stress: *"My motivation is to be more relaxed and to slow my brain down."* Additionally, relaxation/mindfulness was mentioned as a facilitator to experience less stress. It was also deemed helpful to have sufficient time available and to seek professional help. For one patient their cardiac disease was a reason to attempt to experience less stress: *"As a result of my cardiac disease, I started to do yoga."*

3.7. Barriers and facilitators to smoking cessation

3.7.1. Barriers

The most common barrier to smoking cessation was a patients' negative emotional state (Fig. 1). For example, one patient mentioned: *"[…] from work stress. Then you come home, and you are alone, so you smoke."* A few patients mentioned they were too addicted to stop, that it was too much of a habit to stop, or that it was still normal in their social environment. One patient mentioned they lacked the intrinsic motivation to stop smoking and one patient mentioned they tried to remain willfully ignorant about the consequences of smoking.

3.7.2. Facilitators

By far the most mentioned facilitator to stop smoking was experiencing a life event related to the patients' cardiac disease (Fig. 2). For example, one patient mentioned: *"The real change [in smoking] came after the heart attack."* Intrinsic motivation was a common facilitator to stop smoking. Some patients employed pharmacological support to stop smoking. Furthermore, some patients cited optimizing their level of physical wellbeing as the reason they stopped smoking: *"That's the biggest motivation. Health, or staying healthy. I think quality of life is also important, and of course it's much better."* A few patients mentioned they had sought professional help to stop smoking. One patient mentioned they had substituted smoking with another habit (biking), another mentioned they stopped for their mental wellbeing, and one person stopped because it became too expensive.

The results related to barriers and facilitators per health behavior are displayed according to how often they arose in Figs. 1 and 2.

4. Discussion

The current study investigated patient preferences regarding BCTs, as well as barriers and facilitators to different health behaviors targeted in eHealth-based CR. The results may be used to inform the development of future eHealth-based CR interventions. Overall, the thematic analysis revealed specific and implementable BCTs, and important themes regarding barriers and facilitators to behavior change. Unique to this study is that it establishes patient preferences for eHealth-based CR.

The findings of the current study demonstrate that the perceived helpfulness of BCTs might depend on the specific behavior targeted, as some BCTs were preferred for one behavior, but not for another (e.g., *prompts/cues* were preferred for physical activity and medication adherence, but not for stress reduction and smoking cessation). In terms of effectiveness, favored BCTs were not consistently in line with prior effectiveness studies. For example, *self-monitoring of outcomes of behavior* was found to be helpful for improving physical activity behavior in the current study, but the literature is inconclusive about its effectiveness (Patterson et al., 2022; Suls et al., 2020). Conversely, some of the BCTs identified for medication adherence (*social support)* and adhering to a cardiac-healthy diet (*self-monitoring of behavior)*, did line up with the BCTs that have previously been found to be effective (Bond et al., 2021; Suls et al., 2020). Overall, in line with previous research (Schmitz et al., 2023), it seems warranted to heed patient preferences and allow for personalization, but verification of the present findings in effectiveness trials will be an important area for future research.

In terms of health behavior change, mental wellbeing was identified as an important theme for patients with CVD. A *negative emotional state* was identified as an important barrier for eating a cardiac-healthy diet, smoking cessation, and stress reduction, whereas *improving mental wellbeing* was identified as an important facilitator for these behaviors. This is in line with previous research that has demonstrated a negative emotional state to be an important barrier to general health behaviors and in particular to stress reduction among the general population (Kelly et al., 2016; Banerjee et al., 2017). Previous research on barriers to dietary behavior among patients with CVD is limited to underserved populations, and reports economic barriers and food insecurity as barriers (McClellan et al., 2019), whereas research into barriers to smoking cessation is limited to patients with peripheral artery disease and has found addiction to be the most important barrier (Hennrikus et al., 2010). Specifically for patients with CVD, it appears important to consider mental wellbeing in the course of behavior change.

Acute CVD-related experiences, such as hospitalization or invasive procedures were additionally found to impact health behavior change both positively and negatively. Improvements in physical activity, dietary habits and smoking cessation were often preceded by *experiencing a life event* that was related to a patient's cardiac disease, which is consistent with prior observations (Epiphaniou and Ogden, 2010; Ogden et al., 2009; US Department of Health and Human Services, 2020; Turner et al., 2012). Conversely, experiencing a stressful life event was found to hamper stress reduction, which is partly inherent to the nature

of these constructs and has been well-established in prior studies (Lee et al., 2022). Addressing patients' behavior change shortly after a life event, for example starting an eHealth-based CR program immediately following hospitalization, may serve as an important tool to improve health behaviors.

Additionally, physical wellbeing was another important theme, as a desire to feel *physically well* was an important facilitator for physical activity, eating a cardiac healthy diet, and smoking cessation. This desire was often related to a fear of getting sick again. A previous systematic review that examined barriers and facilitators to the uptake of health behaviors by people at mid-life found this as well (Kelly et al., 2016). Accurately appraising (future) risk has previously been shown to have a beneficial effect on behavior change in patients with CVD (Webster and Heeley, 2010). Given the desire to feel physically well and the physical limitations that patients with CVD experience, it is important for interventions to be adjusted to this population.

An interesting finding is that with regard to medication adherence, patients reportedly experienced little barriers, even though research has demonstrated adherence to cardiovascular medication to be suboptimal (Chowdhury et al., 2013). This discrepancy may indicate a disconnect between perceived and actual medication adherence, possibly because of recall errors and self-serving bias in self-report measures of medication adherence (Williams et al., 2013). Using objective measuring tools, such as electronic monitoring devices in pill containers, could improve the accuracy of medication intake monitoring (Anghel et al., 2019).

An important overall finding of the current study is that patients frequently cited a lack of interest as a barrier to app use, whereas a previous study reported that patients hold a positive attitude towards using apps to help optimize health behaviors during CR (O'Shea et al., 2020). However, previous research was conducted among patients who were already using eHealth-based CR, whereas patients in the current study did not necessarily have experience with eHealth. It is therefore important to generate interest in eHealth-based CR in inexperienced patients, for example by educating patients about the benefits and ease of use.

A limitation of this study is the potential selection bias of the included participants as all patients were referred to CR. In addition, a relatively large number of patients in the Netherlands declined to participate, which might interfere with the generalizability of the study findings. Similarly, the patients who participated in Germany and Spain were recruited face-to-face, which could have resulted in selection bias. Another limitation is related to the slight differences between the apps shown across the three countries, because not every app was available in the necessary language. Although similar apps were shown to minimize the differences, this may have influenced the outcomes. Some of the apps were only available in English and not in the participants' native language, which could have inhibited understanding. Furthermore, the study was homogeneous in terms of ethnicity, as almost everyone was of European descent, meaning the results may not apply to people of other ethnicities. Member checking was not performed due to the language constrictions of the patient sample. Another limitation is that, even though considerable effort was made to include women in the focus groups, women were still underrepresented in this sample.

An important strength of this study is the multi-national nature of the sample, which enabled evaluation of preferences and experiences of patients with CVD across Western European countries. This approach ensures the relevance of future interventions, although it is important to expand the knowledge by researching different countries, specifically those outside the Western European context. Additionally, future studies should aim to evaluate a wider range of BCTs, as the current approach was limited to BCTs that could be observed in the used apps. It is also possible that a dislike of a BCT for a specific behavior may hamper the effects of this BCT. It is recommended future research investigate this potential correlation and compares patient preferences with effectiveness trials.

The current study identified BCTs that patients with CVD consider most likely to experience as helpful in changing their behavior during eHealth-based CR. It demonstrated the need for interventions that determine BCTs according to the behavior to be changed and not based on the overall goal of physical health improvements. Additionally, some overlap could be seen between preferred and effective BCTs, specifically for medication adherence and dietary behavior, giving weight to the notion that patient involvement in developing eHealth-based CR may result in more successful interventions. However, effectiveness trials will be needed to evaluate if these BCTs will result in actual improvements in health behaviors. The study additionally found addressing patients' negative emotional state should be considered during eHealth-based CR programs, as well as the effects of experiencing a life event. Future eHealth-based CR programs are recommended to consider the barriers and facilitators identified in this study, to improve the uptake and reduce the dropout during these interventions and to optimize long-term health behaviors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The detailed focus group protocol used during the current study is available from the corresponding author on reasonable request.

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Appendix A. Overview of apps shown to patients

The following apps were shown to patients:

Physical activity: "Garmin Connect app" (Garmin Connect, n.d.) and "7-Minute Workout" (Johnson and Johnson, n.d.) (NL/DE); "Exercises at home [Spanish: Ejercicios en casa]" (Leap Fitness Group, n.d.) (ES).

Medication adherence: "MedApp" (MedApp Nederland, n.d.) (NL); "MyTherapy" (MyTherapy, n.d.) (DE/ES).

Dietary behavior: "Nutrition calculator [Dutch: Eetmeter]" (Voedingscentrum, n.d.) and "Am I making a healthy choice? [Dutch: Kies ik Gezond?]" (NL); "YAZIO" (Yazio, n.d.) (DE), "Yuka" (Yuka, n.d.) and "VirtuaGym Food" (Virtuagym, n.d.) (ES).

Stress reduction: "VGZ Mindfulness" (Coöperatie VGZ, n.d.) (NL); "Insight Timer" (Insight Network inc., n.d.) (DE/ES).

Smoking cessation: "Nonsmoking heroes app [German: Nichtraucher Helden App]" (Nichtraucher Helden, n.d.) (DE); "It's over [Spanish: S'acabo]" (Sedet, n.d.) (ES); "StopCoach" (Trimbos-Instituut, n.d.) (NL) was selected, but as none of the participants smoked it was not shown.

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