

Design Requirements for Cardiac Telerehabilitation Technologies Supporting Athlete Values: A Qualitative Study

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Abstract

Background: Cardiac telerehabilitation (CTR) interventions can provide accessible and affordable remote rehabilitation services. However, as cardiac rehabilitation (CR) primarily targets inactive patients, little is known about the experiences of highly active patients (i.e., recreational athletes or, simply, athletes) with established coronary artery disease (CAD) in CR. Consequently, existing CTR interventions do not address the specific needs of the athletic sub-population. Understanding the needs and values of athletes is crucial for designing meaningful CTR interventions that enhance user acceptance and engagement, thereby facilitating effective rehabilitation for this patient subgroup.

Objective: This study aims to inform the design of technologies that facilitate CTR for athletes. We intend to identify athletes' values related to CR, including health and sports tracking, as well as high-level requirements for technologies that can facilitate the CTR of athletes according to the identified values.

Methods: We employed Value-Sensitive Design (VSD), a human-centric design approach, to elicit design requirements for CTR that can serve athletes with established coronary artery disease (CAD). To identify athletes' values, we conducted 25 value-oriented, semi-structured interviews with 15 athletic patients and 10 healthcare professionals (HCPs) involved in CR programs. In a second phase, we conducted six card-sorting focus group sessions with 13 patients and 7 HCPs to identify desired CTR features. Lastly, we derive high-level CTR technology requirements connected to the athlete's needs and values.

Results: We define 12 athlete values divided into three categories: body-centric, care-centric and data and technology-centric. We cluster findings from the card-sorting activity into CTR technology requirements, such as remotely monitored sport-specific training and training data representations next to clinical limitations, and pair them with corresponding values.

Conclusions: This study provides recommendations for designing value-oriented, tailored CTR technologies that can offer athletes opportunities for optimal recovery and safe resumption of sports practice in the home environment. To our knowledge, this is the first study to explore CTR technology individualization using VSD methods. Design recommendations are related to remote performance monitoring and balancing the need for performance resumption and safe exercise by incorporating clinical limitations within performance metrics.

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Original Manuscript

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Abstract

Background: Cardiac telerehabilitation (CTR) interventions can provide accessible and affordable remote rehabilitation services. However, as cardiac rehabilitation (CR) primarily targets inactive patients, little is known about the experiences of highly active patients (i.e., recreational athletes or, simply, athletes) with established coronary artery disease (CAD) in CR. Consequently, existing CTR interventions do not address the specific needs of the athletic subpopulation. Understanding the needs and values of athletes is crucial for designing meaningful CTR interventions that enhance user acceptance and engagement, thereby facilitating effective rehabilitation for this patient subgroup.

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Conclusions: Athletes have distinct values and health goals in CR compared to general populations

targeted by CTR interventions. Designing patient-centric CTR interventions that address these needs is crucial to support optimal recovery, safe return to sports, and adherence to CTR technologies in the home environment.

Keywords: athletes with established CAD; cardiac telerehabilitation; value-sensitive design; sports monitoring; card-sorting; qualitative research

Introduction

Study Background - CR, CTR and the Athletic Cardiac Subpopulation

Cardiovascular disease (CVD) remains one of Europe's leading causes of mortality[CITATION Wilkins2017CVDStatistics \l 1033]. Interventions focused on promoting a healthy lifestyle, such as exercise-based cardiac rehabilitation (CR), can have a significant impact on the outlook of individuals with CVDs, reducing morbidity and mortality and increasing their quality of life[CITATION Pelliccia2021CRGuidelines \l 1033][CITATION Anderson2016CRReview \l 1033]. In recent years, especially after the COVID-19 pandemic, the acceptance of cardiac telerehabilitation (CTR) - or virtual CR (VCR) – has been on the rise in many jurisdictions[CITATION Kondratova2022VCRHCI \l 1033], [CITATION Peretti2017TelerehabReview \l 1033]. CTR mostly relies on digital and wearable technologies that facilitate delivering CR services to patients in their own homes, encompassing elements such as video-streamed exercise and therapy sessions, remote monitoring of health and behavior, as well as applications enabling patient-healthcare professional (HCP) communication and information provision[CITATION Nilsson2023PerceptionsCTR \l 1033],[CITATION Davis2014RemoteMonitoringPmCare \l 1033], [CITATION Morimoto2022WebPortalsTelerehab \l 1033]. For positive rehabilitation outcomes to be achieved, users (i.e., patients) need to accept, engage with, and adopt CTR interventions – this requires the technology to be usable and offer perceptible value for the patients[CITATION Munteanu2019DesigningOlderAdults \l 1033][CITATION Tsai2020TechAnxietyResistance \l 1033] .

To better recognize what drives the use and perceived value of technology-centric CTR, recent Human-Computer Interaction (HCI) literature has underlined the importance of employing human-centric design in CTR development by acknowledging the collective perspectives of the *prospective users*, including their experiences and needs[CITATION Kondratova2022VCRHCI \l 1033] [CITATION Tadas2023PatientData \l 1033]. In this study, we look into the experiences and needs of an under-researched prospective CTR user group – *athletic patients with established coronary artery disease (CAD)*, the most prevalent cardiovascular condition[CITATION Churchill2020CVCareMA \l 1033]. Although physical activity is associated with a significantly lower risk of CVDs, highly active individuals are not immune to the development of CAD, and vigorous exercise can be the trigger for life-threatening cardiac events[CITATION Aengevaeren2017ExerciseAndCAD \l 1033], [CITATION Mittleman1993InfractionAthlete \l 1033] – approximately 10.6 percent of all acute myocardial infarctions may be attributed to physical exertion[CITATION Culic2023InfractionPhysicalExer \l 1033]. Middle-aged and older athletes are at the highest risk of adverse cardiovascular events during exercise, as the prevalence of CAD increases with age [CITATION Culic2023InfractionPhysicalExer \l 1033]. Although the prevalence of athlete patients in CR programs is not well defined, there has been growing attention towards middle-aged and older athletic cardiac patients in the past ten years – more and more studies show that athletes can develop CAD and its consequences [CITATION Claessen25Athletes \l 1033], investigating the significant impact of adverse events on sports practice and discussing the exercise recommendations and restrictions that apply based on the type and severity of the underlying problem [CITATION

Pelliccia2021CRGuidelines \ 1033]. To foreground this type of CTR user, we adopt the term *athlete* from clinical literature as it is the most accurate description of our target group - highly active patients who engage in at least 4 hours per week of exercise and potentially participate in competitive athletics (e.g., cycling, triathlon, marathon) recreationally [CITATION McKinney2019Athletes \ 1033].

Research Gap and Opportunity – Designing CTR for Athletes

There is a notable scarcity of research on athletes in CR, especially on technological interventions for athletes in CR, with recent work on this subgroup focusing mainly on clinical evidence - e.g., aetiology and prevention strategies [CITATION Claessen25Athletes \ 1033]. This lack of knowledge can be attributed to the fact that, in a largely sedentary population, the central objective of rehabilitation is *improving and increasing* physical activity [CITATION Pelliccia2021CRGuidelines \ 1033]. Consequently, the primary focus of most existing health technology including CTR interventions has been providing support to predominantly inactive and frail populations in their effort to combat sedentary lifestyles and instill healthy lifestyle habits[CITATION Kinast2021TelemonitoringCardio \ 1033],[CITATION Kakria2015HealthMonitoring \ 1033], [CITATION Worringham2011CRExercisemonit \ 1033], [CITATION Canniere2020ECGWearableCR \ 1033], [CITATION Thijs2019PAInCRAfterSurgery \ 1033]. We, therefore, highlight the lack of adequate consideration for the perspectives of athletic patient populations who are already physically active and require guidance on safely and gradually resuming sports, rather than being educated on the importance of physical activity, in the design and development of technologies that support CTR.

Despite the incomplete evidence on athletes' rehabilitation needs and challenges , indications suggest that athletes with established CAD may perceive traditional CR programs as ill-fitting due to disparities in exercise pace and objectives[CITATION Pavy2016CRActivePatients \ 1033]. They require personalized guidance to ensure optimal recovery, mitigate the risk of exercise-induced events, and safely resume their preferred sports practice [CITATION Borjesson2019RecommendationsMA \ 1033]. Current CTR technologies designed using behavior change and persuasive techniques to motivate homogeneous patient populations in adopting an active lifestyle [CITATION Sankaran2019MotivationCTR \ 1033], [CITATION San16 \ 1033], [CITATION San18 \ 1033] *might not serve the objectives of the athletic patient population* [CITATION Pavy2016CRActivePatients \ 1033]. At the intersection of HCI and clinical research, there is an increasing focus on the significance of tailoring cardiac technologies to align with precision medicine principles. This involves *considering individual patient differences*, ultimately aiming to mitigate complications associated with cardiovascular diseases[CITATION Quazi2022HCIPersonalizedEhealth \ 1033]. Recent efforts from the HCI community have looked into tailoring CTR content and mode of delivery to various user groups - e.g., by identifying the right CTR interfaces based on older patients' technology familiarity or by customizing tracking devices based on lifestyle [CITATION Kondratova2022VCRHCI \ 1033], [CITATION Falter2020CRIdealTool \ 1033], [CITATION Beigoli2021CoDesignCTR \ 1033].

Failing to acknowledge the nuanced needs of the athletic user group in the design of CTR interventions can result in poor user experience and low technology engagement and adoption. This, in turn, can affect the effectiveness of the rehabilitation treatment and induce serious psychological side effects such as depression and anxiety [CITATION Kondratova2022VCRHCI \ 1033], [CITATION Martinez2021Values \ 1033], [CITATION Hwang2023CTRFH \ 1033], [CITATION Brouwers2020CTR2 \ 1033].

Study Objectives

Our overall aim is to provide insight into the design of CTR technologies aiming to support athletic patients. Our study employs a human-centric design approach called Value-Sensitive Design (VSD) - a theory-driven approach to technology design that integrates human values throughout the design process [CITATION Friedman2013VSDFW \l 1033], [CITATION Martinez2021Values \l 1033], with values reflecting what individuals consider important in life and care, driving their needs¹ [CITATION Friedma2019VSDBook \l 1033].

To achieve our aim, we have the following objectives:

- *elicit athletes' values in CR including health and behavior tracking*
- *define design requirements for CTR technologies that meet the athletes' values*

We conduct 25 individual, value-oriented, semi-structured interviews with 15 athletes with established CAD and 10 HCPs involved in CR programs to understand athletes' current challenges in CR, behavior tracking, and technology-centric care and derive values. To identify technology-focused CTR design requirements that can cater to these needs and values, we conducted six card-sorting focus group sessions with 13 patients and 7 HCPs.

Our work contributes in three key ways: (i) we inform the design and development of CTR technologies personalized for the under-researched athletic sub-group of cardiac patients, (ii) we uncover cardiac athletes' needs, values, and desired CTR features currently under-represented, and (iii) we use VSD as an investigation method for participatory design, something novel in the current design of CTR [CITATION Martinez2020FrameworksTeleCR \l 1033].

Related work

The research presented in this paper spans across multiple domains encompassing clinical research on athletes with heart conditions, characteristics of recreational athletes, the design of CTR interventions, and human-centered approaches to CTR and health technology (i.e., eHealth) design overall.

Recreational athletes in cardiac and HCI research

Existing studies on the requirements and perceptions of CTR technologies have been conducted in heterogeneous populations and in patients with low exercise capacity [CITATION Song2020MobileCTRPerceptions \l 1033], [CITATION And17 \l 1033], a sedentary lifestyle [CITATION Maddison2019CTRPerceptions \l 1033] or specifically in the elderly [CITATION Snoek2021CTRElderly \l 1033]. Nonetheless, the needs of highly active patients (i.e., athletes) in CTR have not yet been addressed. In a wider perspective, apart from a few clinical case reports, there is a clear lack of documented information regarding athletes in CR [CITATION Pavy2016CRActivePatients \l 1033], [CITATION Placeholder1 \l 1033], [CITATION Hathorn2021FirefighterCR \l 1033]. Existing knowledge of this population points to the many benefits CTR interventions could have for their rehabilitation. Firstly, athletes need tailored evaluation and sport-specific guidance before resuming intense activities, preferably in their sports setting, not in traditional hospital-based cardiac rehab [CITATION Borjesson2019RecommendationsMA \l 1033]. Furthermore, there is evidence that athletes are eager to return to sports quickly [CITATION Pavy2016CRActivePatients \l 1033], [CITATION Weber2018CaseStudyCyclist \l 1033], [CITATION Placeholder1 \l 1033], [CITATION Hathorn2021FirefighterCR \l 1033]. CTR helps achieve this by: (i) starting right after

¹ In this work, the terms *needs* and *values* are to be regarded in the context of the VSD framework.

hospitalization, shortening the gap to traditional rehab, and (ii) providing remote supervision to alleviate sport-related anxiety in the post-hospitalization phase [CITATION Andersen2020WearablesForCardiacs \l 1033], [CITATION Pavy2016CRActivePatients \l 1033]. Additionally, in the realm of HCI literature concerning recreational athletes, there is a notable emphasis on their heightened data literacy and the practice of monitoring health and performance via wearable and mobile technologies [CITATION Pandey2019AthletesTracking \l 1033]. Athletes use fitness trackers and mobile applications to measure palpable goals such as speed, duration, and intensity and re-calibrate their subjective, lived sense of performance [CITATION Tholander2015ExperienceSMartW \l 1033]. Digital and data literacy and self-monitoring proficiency are positive indicators for adherence to CTR and more effective self-management [CITATION Andersen2020WearablesForCardiacs \l 1033], [CITATION Tadas2020Barriers \l 1033].

Given our research sits at the crossroads of recreational athletes and cardiac patients, we delve deeper into the established traits of these groups. Regarding recreational athletes, Tholander et al. [CITATION Tholander2015ExperienceSMartW \l 1033] highlight the significance of soft, less measurable goals such as lifestyle and well-being maintenance and identity building as a foundation for sports performance and exercise. Doinigi et al. [CITATION Dionigi2012FamilyInfluencesMAs \l 1033] reinforce the intrinsic motivation and self-reliance that athletes exhibit, with less dependence on social support or external incentives. On the other hand, cardiac patients' values regarding healthcare have been identified in recent work by Bente et al. [CITATION Bente2021CardiacsValues \l 1033]. These values include the need for security, support, not wanting to feel anxious, tailoring of treatment, and personalized, accessible care. Nonetheless, the convergence of values and traits between these two groups remains unexplored. Transitioning from a highly active lifestyle to a sudden halt caused by a CAD diagnosis can alter one's relationship with sports, health, and technology. We aim to investigate this aspect in our research.

Cardiac telerehabilitation: features and current designs

During CR, patients are offered hospital-based support that consists of therapies addressing healthy and sustainable behaviors (e.g., group exercise training 2-3 times/week, education, psycho-educative therapy, smoking cessation therapy), with a focus on increasing physical activity and fitness [CITATION Hartrevalidatie \l 1033], [CITATION EACPR2010SecondPrev \l 1033]. CTR interventions facilitate the delivery of these therapies in the home environment [CITATION Brouwers2020CTR2 \l 1033]. CTR interventions can be remote (with asynchronous communication between clinicians and patients during exercise sessions), virtual (with real-time audio-visual communication between clinicians and patients during exercise sessions), or hybrid (a combination of in-person CR and remote or virtual services) [CITATION Hwang2023CTRFHF \l 1033]. While our paper emphasizes tech-driven rehabilitation design, we do not exclude elements of hybrid interventions (e.g., face-to-face consultations) from our workshop. Prior research indicates that certain patients prefer a blend of remote and in-person services for the social benefits [CITATION Tadas2023PatientData \l 1033]. Thus, we aimed to provide all options to our participants without exclusion.

According to recent reviews of CTR design features and the definition of CTR, there are four clusters of design features - (i) *education and assistance*, (ii) *consultations, coaching, and guidance*, (iii) *monitoring behaviors for supervision and self-management*, and (iv) *peer support* [CITATION Cramer2015InterventionsStroke \l 1033], [CITATION Kondratova2022VCRHCI \l 1033], [CITATION Ramachandran2022AcceptanceCTR \l 1033]. Nonetheless, in recent work, Andersen et al. [CITATION Andersen2020WearablesForCardiacs \l 1033] point out that existing cardiac

technologies mostly focus only on individual information processing. Within our work, we aim to address the relational aspects of rehabilitation in the home by renaming the fourth category to (iv) *co-experience (social aspect)*, focusing on features related to data in a social context and connecting to peers and family.

CTR features encompass technology and care service features. Technology features facilitate users to achieve a certain goal (e.g., data interpretation, irregularity alerts), while care service features involve patient actions supported by technology (e.g., consultation requests) and services for CTR technology provision (e.g., wearable technology support) [CITATION Kondratova2022VCRHCI \l 1033]. These two categories are strongly intertwined, as the accuracy and engagement of the technology can influence the quality of the care service (e.g., asynchronous text-messaging or video calling facilitating consultations [CITATION BurrIDGE2017Telehealth \l 1033], [CITATION Conroy2020Telerehab \l 1033], wearable sensors enabling remote supervision [CITATION Falter2020SensorsCTR \l 1033], or gamified user experiences providing exercise instructions [CITATION Afyouni2019GamifiedTelerehab \l 1033]), while the delivered care service can dictate the perceived value and engagement with technology (e.g., the type of information provided through digital technologies [CITATION Dinesen2019HeartPortal \l 1033], or allowing family members to participate in remote exercise sessions [CITATION Melholt2018ActiveHeart \l 1033]). HCI practitioners design or optimize interactions between care technologies and patients based on the nature of the intervention (remote, virtual, or hybrid) and its focus (e.g., educational content technologies). For instance, in a recent study, Tadas et al. [CITATION Tadas2023PatientData \l 1033] look into patient-data interaction mechanisms that facilitate the transition from program to self-management. Similarly, Kjærup et al. [CITATION Kjaerup2018DiagnosticAgent \l 1033] investigate user preferences for a data collection application that turns patients into active diagnostic agents. On the other hand, by tackling ways in which care services are provided through technologies, Sankaran et al. [CITATION San18 \l 1033] design more intelligible CTR exercise prescriptions and progress reports to stimulate patient behavior change motivation in mixed sedentary and more active patients. Generally, however, the aim of current CTR interventions revolves around supporting patients in learning about and maintaining healthy behaviors by using various techniques, theories, or methods related to cognition and behavior in their design [CITATION Ramachandran2022AcceptanceCTR \l 1033], [CITATION Martinez2020FrameworksTeleCR \l 1033], [CITATION Clark2023MechanismsCTR \l 1033]. A multitude of CTR interventions are designed using behavior change techniques [CITATION Dinesen2019HeartPortal \l 1033], [CITATION BurrIDGE2017Telehealth \l 1033], [CITATION Duff2018MedFit \l 1033] and motivational techniques [CITATION Athilingam2016HeartMapp \l 1033], [CITATION Melholt2018ActiveHeart \l 1033], [CITATION Brouwers2017SmartCAD \l 1033] to stimulate patients in implementing healthier behaviors and sustaining them in self-management [CITATION Martinez2020FrameworksTeleCR \l 1033], [CITATION Morimoto2022WebPortalsTelerehab \l 1033]. For instance, Dithmer et al. [CITATION Dithmer2016HeartGame \l 1033] re-design remote training sessions into a collaborative game by using collaboration, goals, and rewards in an attempt to increase adherence to the physical activity component of CTR. On the other hand, Ding et al. [CITATION Ding2021MiPace \l 1033] employ individualized goal-setting strategies based on exercise progress to engage myocardial infarction patients in home-based exercise, whereas Hallberg et al. utilize motivational messages and periodic clinical feedback to support patients with hypertension self-management [CITATION Hal18 \l 1033]. Nonetheless, these interventions might not align well with existing indications of operational preferences of the athletic population regarding lifestyle choices, potentially leading to low end-user engagement, satisfaction, and self-management [CITATION Martinez2021Values \l 1033], [CITATION Pavy2016CRActivePatients \l 1033]. In this study, we aim to advance the design of technology-centric, exercise-based CTR interventions by investigating the larger spectrum of CTR

design features through the lens of cardiac athletes' values.

Applying human-centered design through human values

Although CTR has been proven a safe and effective alternative to center-based CR for patients with CAD [CITATION Ramachandran2022AcceptanceCTR \ 1033], [CITATION And17 \ 1033], engagement with and adherence to the program are highly impacted by the usability, reliability, and engagement of the designed intervention [CITATION Nilsson2023PerceptionsCTR \ 1033], [CITATION Rawstorn2018UserPerceptionCTR \ 1033]. Ensuring ease of use and user satisfaction can be achieved through human-centered design approaches (e.g., user research or participatory design) - increasingly used in eHealth design [CITATION Holeman2020HCDHealth \ 1033]. Recent HCI research on eHealth for chronic conditions stresses the need for human-centric, in-depth investigations into target group challenges. For instance, Min et al. [CITATION Min2023EpilepsyCare \ 1033] investigate epilepsy care challenges and propose design guidelines for information management and care coordination tech. Cha et al. [CITATION Cha2023DiabeticParents \ 1033] study parental risk management for diabetic children's glucose levels and suggest support tech guidelines. Similarly, Sepehri et al. [CITATION Sepehri2023BulgingBinder \ 1033] consult parents of children with health complexity to gather needs for digital management systems. Lastly, Bhat et al. [CITATION Bhat2023CaregiversChronic \ 1033] gather qualitative data on informal caregivers' roles in chronic disease management to inform technologically assisted care options. In the context of CTR interventions, several studies use human-centered methods to elicit needs or desired functionalities. For instance, the Teledialog CTR program is designed through qualitative user need elicitation, cultural probes, and user testing [CITATION Joensson2019ParticipatoryCTR \ 1033]. Similarly, Beleigoli et al. conceptualize a technology-centric CTR program through multi-stakeholder engagement in barrier elicitation and co-design [CITATION Beleigoli2021CoDesignCTR \ 1033]. By innovatively using data-enabled design mixed with human-centric methods, Khanshan et al. iterate on a CTR platform [CITATION Khanshan2023DEDCTR \ 1033]. Having a more traditionally qualitative approach, Dinesen et al. [CITATION Dinesen2019IntegrationofCR \ 1033] investigate the needs of homogeneous populations in CR and, accordingly, design a system of multi-modal CTR technologies. Nonetheless, a recent systematic scoping review points out that less than one-fifth of CTR interventions reported including end users in the design and development of these systems [CITATION Ramachandran2022AcceptanceCTR \ 1033]. HCI practitioners and technology designers are increasingly encouraged to actively involve patients in the design and development of CTR technologies [CITATION Morimoto2022WebPortalsTelerehab \ 1033], [CITATION Nilsson2023PerceptionsCTR \ 1033].

In our pursuit to define design guidelines for CTR interventions that address the needs of the athlete subpopulation, we conduct an empirical study inspired by the VSD tripartite methodology [CITATION Friedman2006ValueSensitiveDesign \ 1033], [CITATION Friedman2017ValueDesignMethods \ 1033]. Holistic approaches to eHealth design, such as the Center for eHealth Research (CeHRes) Roadmap, stress the importance of identifying the diverse and potentially conflicting values of various stakeholders - e.g., *what do patients value in health and life that they ultimately expect technology to cater to?* [CITATION Pijnen2011Cehres \ 1033]. There are recent HCI inquiries that demonstrate the application of VSD methods in the design and development of eHealth interventions - e.g., an AI application targeting individuals with dementia [CITATION Cenci2023AIAppDementiaVSD \ 1033], or a mobile application aimed at weight-loss maintenance [CITATION Asbjørnse2020ValuesObeseTech \ 1033]. An in-depth inquiry into the design of cardiac technologies by Martinez et al. [CITATION Martinez2021Values \ 1033] underlines the importance of addressing patient values in the design of cardiac technologies.

Likewise, Ramachandran et al. [CITATION Ramachandran2022AcceptanceCTR \l 1033] emphasize in their review that considering the needs and preferences of patients during the initial stages of program design can help alleviate issues with poor implementation and adoption of CTR. Although the values of cardiac patients as a foundation for eHealth design have been identified in recent work by Bente et al. [CITATION Bente2021CardiacsValues \l 1033], these values are generic (e.g., “To have or maintain a healthy lifestyle”), do not explore specific behaviors tackled by CR such as exercise behavior or coping mechanisms, and do not address the athlete subpopulations, whose objectives might differ from the heterogeneous population. In the following sections, we uncover our investigation into the value-centric design of CTR technologies for athletes.

Methods

Study Rationale and Design Overview

We conduct a qualitative study guided by the *Human-Centred Design (HCD) paradigm* and the *Participatory Health Research (PHR) paradigm*. The HCD paradigm implies that design activity should prioritize defining the meaning a product, system, or service offers to people, focusing on *motivation, discourse, and learning before addressing implementation* [CITATION Giacomini14HCD \l 1033]. It relies on techniques that *engage, interact with, and empathize with people*, uncovering needs, desires, and experiences beyond their own awareness [CITATION Giacomini14HCD \l 1033]. Similarly, but more focused on the knowledge creation process within a healthcare problem, the PHR paradigm is a collaborative research approach that actively engages stakeholders as co-creators of knowledge throughout the research process, ensuring greater relevance, applicability, and impact of the findings [CITATION ICPHR13PHR \l 1033].

To operationalize this participatory approach, the *Value-Sensitive Design (VSD) framework* was utilized to identify and embed stakeholder's values into the design of CTR interventions. VSD recognizes the interplay between human experiences and technology, where values are both embedded in and influenced by technology [CITATION Friedma2019VSDBook \l 1033]. CTR, deeply reliant on technologies, impacts users' daily lives, from private digital consultations to continuous heart rate monitoring during routine activities [CITATION Kondratova2022VCRHCI \l 1033]. Thus, CTR designers must understand and incorporate what users value in their everyday lives to create interventions that seamlessly align with and support those values. Recent research by Martinez et al. [CITATION Martinez2021Values \l 1033] and Tadas et al. [CITATION Tadas2020Barriers \l 1033] highlights the need for incorporating patients' values into designing cardiac technologies to enhance sustainable self-management, technology adherence, and intervention effectiveness.

We use *participatory qualitative methods* that align with tools used in HCD and PHR (e.g., card-sorting, focus groups) and are rooted in the VSD framework (e.g., value-oriented interviews, stakeholder identification session). We elaborate on these methods in the following subsections.

To achieve our research goals (i.e., (i) *elicit athletes' values in CR including health and behavior tracking*, and (ii) *define design requirements for CTR technologies addressing athlete values*), our study comprises two main phases: (1) *a discovery phase* including key stakeholder identification and recruitment, and data collection through 25 value-oriented semi-structured interviews and 6 card-sorting focus groups, and (2) *a definition phase* in which through data analysis the values (elicited in the interviews) were defined and matched with the identified CTR requirements (derived from the focus group results) (Figure 1).

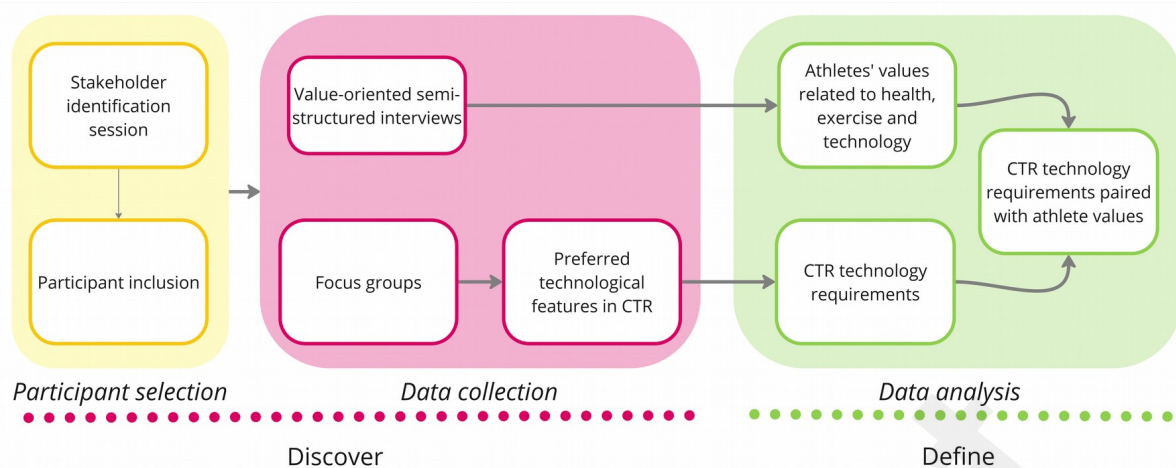


Figure 1 - The structure of our study divided in two phases: (1) discover, including participant selection and data collection, and (2) define, including data analysis

Ethical Approval

The work has been conducted by two Dutch institutions: Eindhoven University of Technology in collaboration with Máxima Medical Centre Veldhoven – a teaching hospital that offers both conventional in-hospital CR and CTR. The study protocol was reviewed by both the University's ethical committee and Máxima Medical Centre's medical ethical committee and received a waiver that ethical approval was not required. The collected data was stored and processed according to the data policies and agreements of the Eindhoven University of Technology.

Stakeholder Identification Session, Participant Selection and Recruitment

VSD posits that technologies - in this case, CTR technologies - have real and sometimes non-obvious impacts on those who are directly or indirectly affected by them [CITATION Hoven2015ValuesInTechDesign \l 1033]. VSD encourages designers to identify a robust set of direct and indirect stakeholders at the beginning of the design process and to legitimate those likely most affected and included in the design process [CITATION Friedman2017ValueDesignMethods \l 1033]. To identify stakeholders next to athletes in the context of CR, we first conducted a stakeholder identification session using the IGOHcaps method [CITATION Mantzana2017IGOHcaps \l 1033]. This method seeks to identify healthcare actors (or stakeholders) in a dynamic environment. As CR is a complex, multi-faceted system of healthcare services that changes its dynamic over a long period of time (i.e., from hospitalization to self-management and further), the IGOHcaps method was considered suitable for identifying the right participants for our study. The stakeholder identification session lasted 60 minutes and involved an eHealth designer and 5 clinicians working in CR: a cardiac nurse practitioner, two cardiologists, a sports physician, and a resident sports physician.

The IGOHcaps method proposes identifying healthcare actors as *humans* or *organizations* that *provide, control, support* or *accept* healthcare services (i.e., (tele)rehabilitation). A set of well-defined guidelines are used in the process, such as “*Actors depend on a specific context and time frame*” [CITATION Mantzana2017IGOHcaps \l 1033]. Based on this method, participants were first asked to identify as many actors as possible, using post-its on big posters in 10-minute sessions per category (i.e., providers, controllers, supporters, acceptors). Lastly, participants put all the identified actors together, removed redundancies, and added missing actors, creating a broad overview of direct and indirect stakeholders involved in CR and CTR.

Based on the outcomes of the stakeholder identification session, we selected actors fitting the following criteria: (i) *athletes with established CAD* (human acceptors) who exercise more than 4 hours per week and finished CR within at most 1 year before the moment of the interview (Table 2), (ii) *human providers - directly impacted by CTR technologies and in direct contact with athletes* - related to cardiac health (e.g., cardiologist), exercising (e.g., physiotherapist), psycho-social therapies (e.g., psychologist) and general rehabilitation (e.g., nurse practitioner) (Table 1). In the end, 15 athletes and 12 HCPs were included. The number of participants aligns with recent research suggesting that 9-17 [CITATION Hennik22Qual \l 1033] or 15-30 [CITATION Squire24QualData \l 1033] participants can be sufficient to reach data saturation in qualitative studies that deal with homogenous populations (in our case cardiac athletes and HCPs working in CR), narrowly defined objectives (in our case CTR requirements for cardiac athletes) [CITATION Hennik22Qual \l 1033] and a structured interview guide [CITATION Squire24QualData \l 1033].

Patient recruitment was done over several weeks via the hospital by a clinician (second researcher), while healthcare professionals were recruited through the extended networks of the project's members from the same hospital. Informed consent was obtained, and each participant received a 20 Euro gift card as compensation.

Textbox 1. The roles of participating HCPs in the rehabilitation trajectory.

- **Sports physician** - conductor cardiopulmonary exercise testing, formulator of training recommendations (including any restrictions), consultations for discussion of test results and recommendations, supervisor of results of exercise stress tests [CITATION Saba2021ExerciseStressTest \l 1033]
- **Physiotherapist** - supervisor of the individually tailored exercise training program, supporter of a physically active lifestyle
- **Clinical psychologist** - assessment of the psychiatric problems (that were already present or developed after the cardiac event), supervisor psycho-educational prevention modules (group sessions), individual treatment of patients if necessary
- **Nurse practitioner in CR** - case manager (i.e., patient advocate that supports, guides, and coordinates patient care), intake session for discussion of lifestyle behavior/changes and individual goals, performing assessments for risk for anxiety and depression, end evaluation of CR program
- **Exercise instructor (department of physiotherapy)** - (similar to a physiotherapist) supervisor of the individually tailored exercise training program, supporter of a physically active lifestyle
- **Cardiologist** - treating physician of cardiac patients, referrer for cardiac rehabilitation, medication optimization, risk assessment

Semi-structured interviews

To incorporate athletes' values into technologies, we first need to identify these values. To do so, we conducted 25 individual, semi-structured interviews with 15 athletes (P1-15) (Table 2) and 10 HCPs (HCP1-10) (Table 1). Each interview was conducted following two variations of an interview script (one for athletes and one for HCPs) developed by looking at recent value-oriented studies [CITATION Bente2021CardiacsValues \l 1033], [CITATION Asbjørnse2020ValuesObeseTech \l 1033]. The interview guides explored themes such as the value of physical activity in athletes' lives, good and bad experiences in CR, information flows and relationships with HCPs, social support, and technology used for managing sports and health (Multimedia Appendix 1).

Two researchers conducted each interview, which lasted 60-70 minutes, and was audio recorded.

Recordings were used for verbatim transcriptions and translations from Dutch to English.

Table 1 - Other stakeholders (HCPs) participating in our studies; HCPs 1, 2, 3, 7, 8 participated in both focus groups and interviews; HCPs 11 and 12 only participated in focus groups; the rest of the HCPs participated only in the interviews

HCP ID	Years of experience	Expertise
HCP1	27	Sports physician
HCP2	3	Physiotherapist
HCP3	6	Sports physician in training
HCP4	16	Clinical psychologist
HCP5	14	Nurse practitioner in cardiac rehabilitation
HCP6	13	Exercise instructor (department of physiotherapy) and lifestyle coach
HCP7	27	Primary care physiotherapist
HCP8	>20	Physiotherapist
HCP9	12	Cardiologist
HCP10	10	Nurse practitioner in cardiac rehabilitation
HCP11	19	Cardiologist
HCP12	8	Nurse practitioner in CR

Card-sorting focus groups

One significant assumption of the VSD framework is that certain technologies or tools support certain values more promptly while being less suitable to address others [CITATION Friedman2006ValueSensitiveDesign \l 1033]. This suggests that more or less suitable “properties” or “features” can be designed into technologies to address specific human values. As mentioned in *Related work*, CTR interventions are complex systems comprised of healthcare services (such as education, coaching, and consultations) delivered through multi-modal technologies – often a combination of (commercial) wearable sensors and digital (mobile or desktop) applications [CITATION Kraal2014TelerehabinCR \l 1033], [CITATION Peretti2017TelerehabReview \l 1033]. We aim to derive high-level design recommendations for CTR technologies, however, we include both technology features and care service features as they heavily depend on each other - care service features dictate the content and features of used technologies (e.g., designing a platform monitoring individual sports training is different from designing a platform monitoring synchronous group training). Nonetheless, we stressed the importance of technology to our participants during the card-sorting activity – while some cards pertain to care service features (e.g., “to have face-to-face consultations”), participants were asked about ways technology could mediate or enable those features.

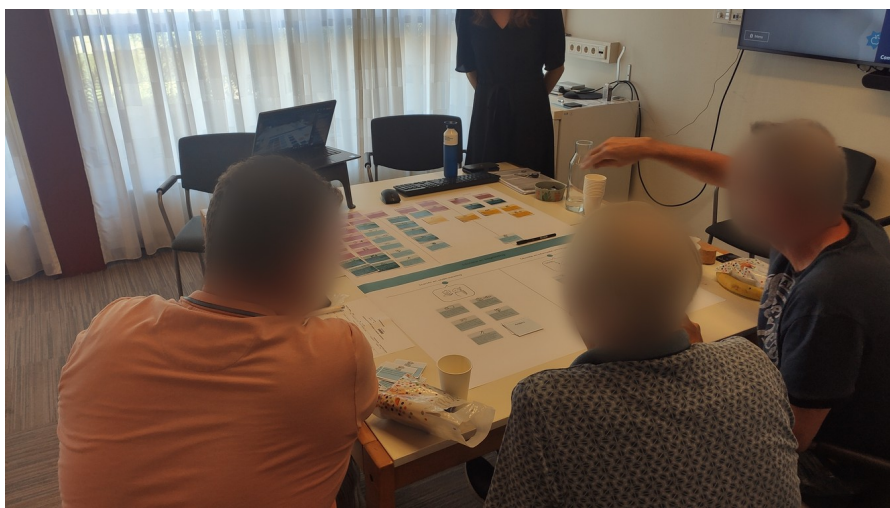


Figure 2 - Focus group 4 - patients interacting with cards during the card-sorting session

Table 2 - Athletes (patients) who participated in our study; all athletes participated in both interviews and focus groups except for P1 (absence due to injury) and P9 (lack of time availability) who only took part in interviews

Patient ID	Gender	Age	Employment, family, living situation	Practiced sports	Used monitoring technology	self-	Time since finishing program
P1	M	76	Retired; living with spouse	Tennis, cycling, fitness	Chest strap monitor	HR	Just finished program
P2	M	70	Retired; living with spouse	Table tennis, cycling	Bike computer, chest strap HR monitor, blood pressure monitor		5 months
P3	M	44	Employed; living with spouse	Mountain-biking, running, boxing, fitness	Smartwatch, ChatGPT (for training schemes)		Just finished program
P4	M	65	Retired; living with spouse	Cycling	Smartwatch, chest strap HR monitor, bike computer, Strava app, blood pressure monitor		4 months
P5	M	75	Retired; living with spouse	Tennis, padel, golf	Golf watch		1 month
P6	M	79	Retired; living alone, close to children	Running, competitions (e.g., track races)	Smartphone counter	step	1 year
P7	M	46	Employed; living alone, close to parents	Strength training, cycling	Fitness watch; cycling mobile app		Just finished program
P8	M	57	Employed; living with spouse and children	Running (competitive), tennis, mountain bike	Fitness watch and mobile app, bike computer		10 months
P9	M	54	Running, high-intensity training	Fitness watch and mobile app	Fitness watch and mobile app		7 months
P10	M	57	Employed; living with spouse and	Mountain bike, spinning	Fitness watch and mobile app, chest		2 months

Patient ID	Gender	Age	Employment, family, living situation	Practiced sports	Used monitoring technology	self-	Time since finishing program
P11	M	58	children Employed; living alone, close to siblings	Fitness, cardio, high-intensity training	Blood pressure monitor, watch	strap HR monitor, smart	2 months (did not participate in the physical training program)
P12	M	65	Employed; living with spouse	Running, mountain biking, padel	Fitness watch		4 months
P13	F	73	Retired; living with spouse	Cardio, strength training, spinning	Bike computer		Just finished program
P14	M	62	Employed; living with spouse	Fitness training, bodybuilding, cycling	Smartwatch		6 months (did not participate in the physical training program)
P15	M	68	Retired; living with spouse	Running, competitions ((ultra)marathons), cycling	Fitness watch, chest strap HR monitor		9 months

To further explore desired CTR features that could potentially support athletes in rehabilitation, six focus groups (FGs) were held. 13 out of the 15 athletes who participated in the interviews took part in the FGs. Athletes were divided homogeneously into four focus groups (FG1 had 4 participants). HCPs 1, 2, 3, 7, 8, 11 and 12 were divided into two additional focus groups (FG5 with 3 participants, FG6 with 4 participants). Each FG lasted 60 - 100 minutes and was facilitated by a clinician and a designer. The focus groups were exploratory, creative, and applied participatory methods from design thinking [CITATION Razzouk2021DesignThinking \l 1033]. All six focus groups were given the same assignment - a closed card sorting task of features of CTR interventions. Card sorting is a method that helps to understand the people we are designing for [CITATION spencer2009cardsorting \l 1033]. In our case, we aimed to understand what athletes would find most important and useful in CTR that suits their values. Therefore, HCPs were asked to respond from the athletes' perspective.

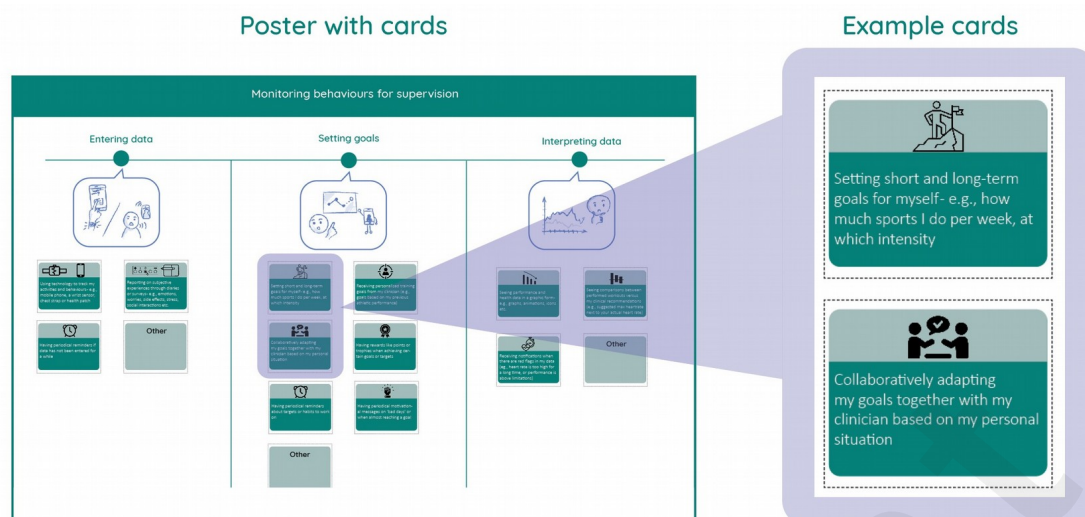


Figure 3 - A poster with cards related to monitoring behaviours. Two example cards are zoomed in on the right. Sketches depicting sub-categories (e.g., setting goals) were inspired by the user journey of a patient interacting with intelligent health interfaces [CITATION Knoche2022IntelligentDataDriven \l 1033]

We extracted features from recent studies reviewing telerehabilitation technologies [CITATION Morimoto2022WebPortalsTelerehab \l 1033], [CITATION Kinast2021TelemonitoringCardio \l 1033], [CITATION Peretti2017TelerehabReview \l 1033], [CITATION Kondratova2022VCRHCI \l 1033], [CITATION Clark2023MechanismsCTR \l 1033] as well as reviews of cardiac self-management eHealth and telemonitoring [CITATION Martinez2021Values \l 1033], [CITATION Martinez2020FrameworksTeleCR \l 1033]. To reduce the complexity of the resulting list of extracted features, they were divided into four main categories based on the composition of telerehabilitation systems, as described in the *Related work* section: *Education and assistance*, *Consultations, coaching, and guidance*, *Monitoring behaviors for supervision and oneself*, and *Co-experience (social aspect)*. Because the existing categories were still broad and lacked visual structure, each category was divided into sub-categories based on the user journey proposal of Knoche et al. [CITATION Knoche2022IntelligentDataDriven \l 1033] of patients using intelligent data-driven health technologies (Multimedia Appendix 2). Additionally, we provided empty cards for each category for extra suggestions.

The four categories were presented on posters containing individual cards depicting technology features (Figure 3). Participants were asked to work together to sort cards one by one on a canvas divided into three sections (i.e., *must have*, *nice to have*, *not needed*) (Figure 2 and Figure 4). Participants were asked to motivate their choice for each card, encouraging group discussions. The whole interaction was audio and video recorded with the consent of the participants.

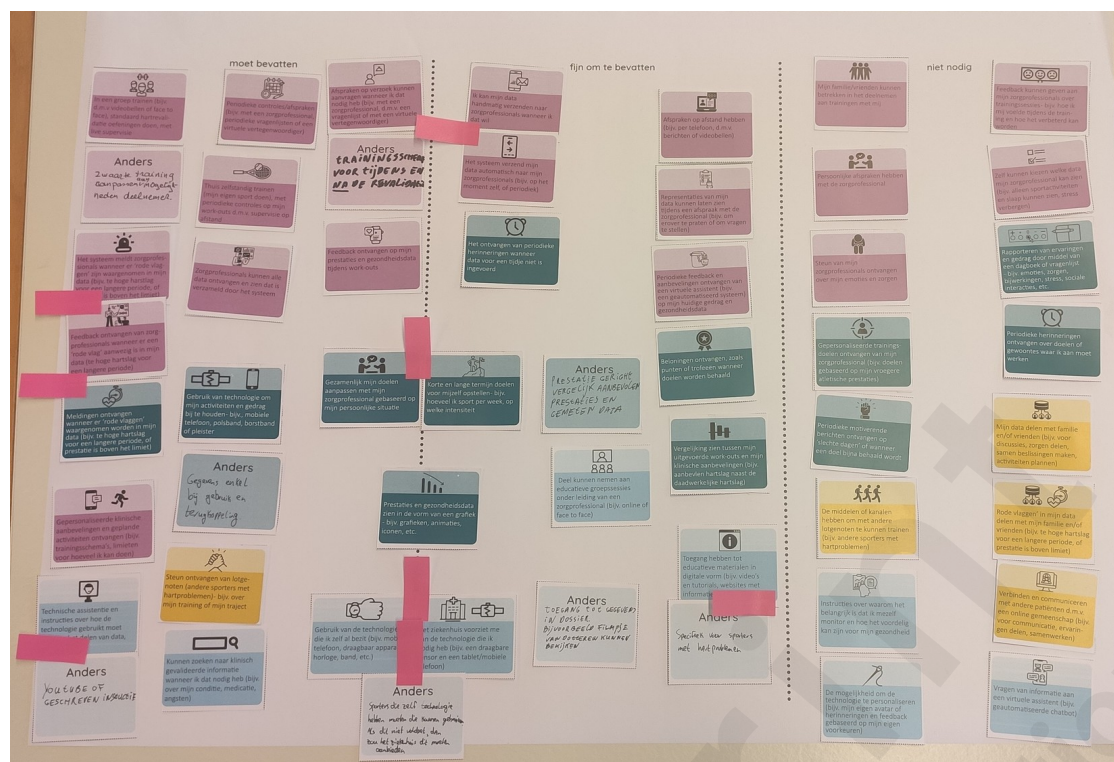


Figure 4 - An example depicting card-sorting activity outcomes from focus group 1: cards from different categories sorted in must have, nice to have and not needed, from left to right

Data Analysis: Defining Values and Matching Design Requirements

To ensure transparency and minimize researcher bias, the data analysis process was iterative and collaborative. Both the interview and focus group recordings were initially auto-transcribed using Amberscript. The transcriptions were then reviewed alongside the recordings to correct errors from the automatic transcription process and subsequently translated. Thematic analysis was conducted following Braun and Clarke's six-step framework [CITATION Byrne2022thematicanalysis \1 1033] to identify and analyze patterns in the data. First, researchers familiarized themselves with the data by reading the transcripts and notes taken during the interviews and focus groups multiple times.

Defining athletes' values: I.B.S. analyzed the interview transcriptions (n=25) to identify quotations about what athletes with CAD find important in life and care. Inductive coding was used to identify codes related to athletes' individual needs in exercising, CR, and lifestyle. These codes have been grouped under sub-themes illustrating more generic needs of the group (e.g., "exercise support for one's fitness level"). L.F. checked the identified needs for analysis validation. To define values, we followed their VSD definition of being *more generic ideals or drivers of athletes' needs* [CITATION Bente2021CardiacsValues \1 1033], [CITATION Pijnen2011Cehres \1 1033]. Consequently, according to the VSD methods, we developed a value-oriented coding manual by assigning a small description to each initial code related to a need (by re-reading the data) (Multimedia Appendix 3). Afterward, the needs were grouped based on underlying themes (i.e., desires) that could drive the specific needs – the values. L.F. verified the links between needs and values, and the coding manual together with representative codes were discussed within the group of authors. Codes that did not directly refer to athletes' needs (e.g., "miscommunication between healthcare professionals") were grouped under non-value-related themes and, because of the scope of this work, were not emphasized in this paper.

Sorting preferred CTR features: The results of the card-sorting activity were sorted based on the preference of each focus group: each feature received a score (2 - must-have, 1 - nice to have, 0 - not

needed), and was ordered from highest-scoring to lowest-scoring. If participants could not agree on a category, the scores were averaged. By ordering them by score in Microsoft Excel, we identified preferred CTR features from the most desired (highest scoring), to the least desired (lowest scoring). Participants' observations during the focus groups (either recorded or written on cards) were noted next to each corresponding feature to be used in the requirement definition phase.

Defining CTR requirements paired with values: The features (cards) that were a “must have” for at least two focus groups together with participant observations were clustered under themes representing requirements. Occasionally, participants within a group held differing opinions on specific features - some felt they did not need a feature, while others felt it must be included. We opted to incorporate disputed features as requirements if they provided substantial value to certain participants. For example, one athlete whose family resides at a distance and lacks a strong local social support system considers sharing data with family crucial. In contrast, other participants who lived with family did not consider this feature desirable. Given the importance of this feature for the mental peace and safety of some athletes, we included data sharing with family as a requirement.

Through small iterations during the analysis process, the emerging requirements were linked to one or more identified values. This enabled an iterative reflective process of requirement adaptation according to the expressed needs and values of athletes. These phases were conducted by B.S., with L.F. consistently checking after each iteration. The resulting list of requirements connected with values was checked and discussed within the rest of the research team. This led to defining high-level requirements and guidelines for a technology mediated CTR intervention that could support athlete values. Preferences and requirements about improvements to co-located CR services also surfaced in our focus groups. As these insights are out of the scope of our paper, they will be mentioned but not discussed in this work.

Reflexivity and Research Positionality Statement

To explore how CTR technologies can align with the values and needs of athletic patients, this study represented a collaborative effort between HCI researchers specializing in the social implications of interactive systems and human-data interaction in health and broader contexts, and clinicians with expertise in sports cardiology and cardiac rehabilitation. While this work is focused on technology design, the second author (i.e., clinician in training) was actively involved in all stages of the research ensuring the clinical validity of the derived conclusions, as well as the ethical integrity of the research.

Reflexivity was integral to mitigating biases and enhancing credibility throughout the research process. We recognized the potential influence of our prior knowledge and assumptions on study design and data interpretation. To address this, we conducted *collaborative discussions* with team members not involved in data collection or initial analysis to challenge assumptions and refine the design. The *stakeholder identification meeting* of clinicians outside of the research team ensured diverse views in participant selection. Furthermore, *data collection was conducted collaboratively* with multiple researchers present enabling diverse observations, reducing individual bias, and fostering critical reflection through team debriefs. The *iterative data analysis* enabled cross-checking the themes and values by multiple researchers to validate findings and ensure coherence. Finally, the *triangulation of perspectives* achieved by including both athletic patients and diverse HCPs minimized bias by incorporating varied experiences. This approach ensured a balanced and rigorous examination of the data.

Results

This section contains identified athlete values derived from the interviews, card-sorting outcomes, and CTR requirements derived from the card-sorting activity paired with athletes' values.

Semi-structured Interviews: Values of athletes in CR

The results from the interviews conducted with athletes and other stakeholders (n=25) have revealed the presence of 12 key themes encapsulating athletes' values within the context of CR and the broader context of personal health management. Each of these key values (i.e., high-level desire) was generally supported by multiple identified needs (i.e., demands described by participants concerning CR participation and health management). In some instances, a single need could be associated with multiple values. For instance, the need to “observe progress in one's physical performance during the recovery process” could be interconnected with values such as “a goal and performance-oriented approach” and “health and performance quantification”. Moreover, the identified values represent the overarching desires of athletes, while some needs might only pertain to some individuals. The subsequent sections will provide insights into findings related to each of the 12 identified key values clustered in 3 groups: *body-centric*, *care-centric*, and *data and technology-centric*. An overview of the values, needs and example quotes can be found in Table 3.

Body-centric values

V1. A dynamic lifestyle. Athletes are individuals who place a high value on physical activity and exercise. Participants view exercise as part of their identity, a way to cope with psychological struggles, a way to compete with oneself and push one's limit, and a way of being part of a community when it comes to social sports. However, of utmost significance, all participants value maintaining a healthy lifestyle and link exercise and sports with preserving vitality and good health. All participants position exercising highly among life values such as being with family and enjoying work and life. The lack of CR programs addressing the sports they value hinders their enjoyment and motivation to participate.

“That's really important - if I can do sports, that's the foundation of the day. Then I can move forward. [...] Maybe [I like] the adrenaline, I've always been active. Working on the farm from primary school, always at work, worked at the bakery, always training. I was at the athletics club in [city name], I went there twice a week. I have always been active. [...] [After the cardiac event] I had the fear that I could no longer exercise. That's a pretty awful thought. If I can't exercise anymore, what am I supposed to do?” (P6)

V2. Independence and confidence in one's body. Athletes value their individuality, independence, and self-efficacy. They are very sure of themselves and do not like to doubt their capacity to recover and return to their athletic capabilities and previous lifestyle. They express confidence in their recovery journey and rely less on clinicians, valuing their opinions alongside their own ability to discern their body's needs. Athletes know the value of physical activity and take pride in remaining fit despite older age. Consequently, they do not need external motivation. Still, they need facilitators to understand their limits and apply the clinical knowledge in the home environment, where they wish to safely exercise similarly to before hospitalization. Although very confident in “feeling” what their body needs, the CAD diagnosis can unbalance their “internal compass”.

“I've always had a positive perspective on life. [...] I immediately thought ‘This [i.e., heart attack] just happens to you and we're going to make the best of it. Seriously work on it.’ I

have tried very hard to function properly again. And I don't suffer anymore. [...] I feel myself if I really go too far. [...] She [i.e., the cardiologist] said 'You can just exercise, of course, you should never go crazy. That's never good. But no restrictions.' [...] She gave me that confidence." (P14)

V3. Coming to terms with one's condition. Most participants describe the diagnosis as unexpected due to their healthy lifestyle and absence of symptoms. The lack of control over their diagnosis, often with a family history of cardiac conditions, coupled with sudden fatigue and loss of physical fitness, can profoundly affect their and their family's outlook on life. Athletes have high ambitions of returning to their previous exercise capacity and find difficulty in accepting a "failing body". At the onset of CR, it is crucial for athletes to cultivate coping strategies to interpret their body's signals. Clear exercise limitations, such as maximum HR, help athletes establish boundaries. They require guidance on managing extreme fatigue and knowing when to pause and rest. Additionally, athletes prioritize resolving frictions with their families regarding safe exercise and activity levels. They achieve this by negotiating the specifics of where, when, and how much exercise they engage in. Their ultimate objective is to return to the routine and normality of everyday life.

"You actually want to pedal higher wattages, as much as possible. [...] I look next to me, to a colleague who had been practicing for a while. It was on 106. I thought 'I should be able to do that too', but that was quite disappointing...[...] You're on a racing bike. You are very fast on such a thing, and very far away. [...] I always have my phone and things with me, data, so they [i.e., family] can find me [...] I have that app from my odometer - it also tells my son where I am at that moment [...] those are the things I take with me to be able to cycle safely." (P4)

Care-centric values

V4. A goal and performance-oriented approach. Athletes find goals and performance important during the CR program. One crucial need is to return to previous athletic capabilities by having clear, progressive performance targets. Health and athletic goals intertwine, for instance, reaching target HRs and regaining the ability to mountain cycle. They value pushing their limits and making steady progress alongside clinical validation of their advancements. As a result, some participants find the exercise program too easy and the CR intervention less effective. They suggest adjusting exercises to match their intensity. Other patients found usefulness in regaining confidence under professional supervision. To reach their goals, some athletes utilize resources within their network, like personal trainers, friends, or relatives who are healthcare professionals.

"It [i.e., the exercise program] didn't make much sense. [...] It turned out that my condition was more than sufficient. Then the real question is 'why are we doing this?' [...] They actually slowed you down rather than stimulating you. [...] It didn't really help much. I honestly found it slowing me down a lot. Because I have to cycle for fifteen minutes to get here [i.e., hospital] and fifteen minutes back. And then I actually cycle even more intensively [commuting] than there [i.e., at the exercise program]." (P2)

V5. Concise, actionable guidelines. A significant number of athletes felt like they had been "left in a void" during CR: clinicians did not pay enough attention to their needs because athletes already knew the value of exercise. Most athletes expressed the need for clear, preferably quantifiable indications of exercise limitations (e.g., maximum HR they can reach), personalized variations of

sport-specific training schemes that make them feel safe but performant, and education on the influence of medication on performance. Some athletes found open-ended exercise limitations (e.g., “Do whatever feels good”) enough for safe sport resumption, while others found them confusing and insufficient.

“I still find it difficult to understand, what is very good with the beta blockers [i.e., medication used for secondary prevention]. [...] It’s still a difficult process to find out where to be in your exercise. And if they could have given some guidance in that, what can you do maybe with intervals, like boxing, which is very high interval training and where should you be. Should you be careful with some things or with your HR, or yeah, they didn’t think much about it.” (P3)

V6. Trustworthy, readily available support. Athletes express their challenges and objectives adeptly, valuing clinicians who offer clear, concise, and actionable solutions. They seek easily accessible healthcare services for emergencies or alarming symptoms – some have needed rescue during mountain cycling or gym workouts. They appreciate impromptu talks with physiotherapists during training and desire swift access to clinicians for direct, sincere responses to inquiries, without delays encountered in current e-consult systems. Moreover, athletes appreciate clinicians who give patients control over health-related decisions and involve them in the decision-making process regarding their health journey.

“If I send it [i.e., exercise recommendations] via email, it will quickly reach the person. We’ve had a conversation [i.e., consultation] and I’ll fill that in a bit afterward. It is annoying for people if they have to wait two weeks for a letter containing those recommendations. They have just received that advice, and then they actually can read it that evening, so I will send it that way.” (HCP3)

V7. Care with ‘a personal touch’. Although athletes are very open to exercising independently in the home environment and communicating from a distance with HCPs, they still appreciate personal approaches to healthcare. Many athletes mention they do not want to feel or be treated like a number and want to maintain face-to-face contact and human interrelations periodically during the rehabilitation period. Moreover, for some, there is a significant dip in morale after hospitalization, and empathy and reassurance are highly needed. Some patients described a lack of empathy from HCPs for being “fitter” than the general population and having better chances to recover.

“When I had a conversation with the nurse practitioner I noticed she was not serious. She said ‘Within 3 weeks you will forget you had a heart attack.’. It was a pity for me, so I was sad about it. I thought to myself - what do I have to do now? Where are the people? How can I find the people? But I was afraid to call the nurse to ask where because they were so busy. Then I think it’s a stupid question.” (P11)

V8. In and outside hospital oversight. Athletes are insecure about new exercise limitations, how much they can push themselves, and exercising safely outside the hospital environment. They mention being supervised as crucial for their confidence and reassurance, especially in the first few months after hospitalization. Within current CR, athletes participate in exercise programs not for lifestyle changes per se, but to feel supervised by HCPs and to have the feeling that they are doing the best they can for their health. Being supervised provides reassurance, security, confidence, and a feeling of being cared for.

“I think in the beginning, it's quite scary to do heavy exercise without any supervision. The defibrillator should do its job when there are hard issues. I think after the hospitalization you need some reassurance from somebody looking after you if there any issues.” (P3)

V9. Emotional support and sharing. Athletes do not need social support to maintain healthy behaviors. However, they appreciate the emotional support and opportunity to share their struggles and anxieties with their family and close ones, but also with HCPs such as the clinical psychologist. While not essential, they value the bonding opportunity of conversing with other cardiac patients. Yet, many participants do not encounter fellow athletes in their CR group. Participating in the focus group provided a pleasant chance for them to share treatment options, experiences, and their common passion for exercise.

“I think besides the rehabilitation program, the physical part, it was also nice to speak with people who also had an [heart] attack. Just to hear some experiences or like the medication I used - I had a lot of side effects and they said ‘Well, I also had that. But after a while it went away, or I tried another one or asked for injections.’ This was nice.” (P10)

Data and technology-centric values

V10. Health and performance quantification. Athletes possess advanced data literacy often using wearable sensors, bike computers, or mobile phones to track metrics like HR, distances, speed, and time. A few participants, however, prefer relying on their body awareness over sensing technology. In their rehabilitation, athletes diligently conduct routine checks such as blood pressure and HR measurements, along with hospital tests. One participant even maintains an Excel sheet where they record their blood pressure daily. After diagnosis, some athletes' relationship with wearable sensors shifts: they use data to reassure themselves about their health and recovery. They also value progress reports to gauge recovery, correlating their body's feedback with measurable improvements like lifting more weight or running faster.

[Interviewer: What do you like about your fitness watch?] “The monitoring it does, so you know anything like HR, but also the exercises themselves and seeing progress - that improves and then you are really happy. That's something I saw, there was a tremendous drop [i.e., in fitness] when I had surgery and the months before. It dropped significantly and now you see it. And now it's higher than even before the surgery. So that's really motivating, especially those things that you have to really work hard for to, you know, get one level up.” (P9)

V11. Clinical validation on information and data. Some athletes value data for performance measurements, but trust in wearable data diminishes post-diagnosis. One participant's distrust stems from the wearable's failure to detect their heart attack. Consequently, athletes place importance on clinicians giving meaning and validating data on vital signals. Athletes consider it crucial to discuss various measurements like blood pressure, HR (e.g., variability, zones), and performance metrics with their clinicians. They seek to derive meaning from these measurements in the context of their cardiac condition or medication intake. Some athletes remember sharing data overviews from fitness applications with their clinicians during consultations but acknowledge receiving little substantive feedback due to the brevity of the consultations. Moreover, athletes find it significant that the information they receive about their recovery process, cardiac intervention, or medication comes

from clinicians, not from other sources such as the Internet or other people.

“The most important thing for me was measuring [i.e., during CR]. Things are tested - what you do, and then you end up with that bike test again. Measuring is knowing, I say, that was very important to me in that rehabilitation. [...] I have to do it and measure it, and the healthcare provider can judge. What does that mean now, is that good or should I do something else? That is difficult by yourself. [...] I sometimes go to the doctor and then he sometimes says ‘take a look at ‘Thuisarts’ [i.e., a website with general healthcare knowledge]. But I’m not into it. If there is something wrong with me, I want an expert who can tell me something.” (P5)

V12. Reliable information systems. Even though athletes are willing to be supervised from a distance, exercise in their home environment, and communicate with clinicians through digital channels, they do require reliable information systems that facilitate the process instead of burdening it with technical issues. One important consideration is reliable sensors and data streams - some athletes do not fully trust data from commercial wearables and use additional devices (e.g., chest strap, blood pressure monitor). Moreover, they underline the importance of reliable infrastructures that can transmit data and information to and from clinicians without delay. They also stress the importance of user-friendly workout schedules that can be easily implemented with current technologies they already use.

“[The most important thing to consider when developing a CTR system] To know that you have a good connection. The rest will take care of itself. [...] The moment I step on that [i.e., exercise bike], that data also ends up in the hospital [...] it could end up on a server in the hospital. You can, so to speak, watch it a few days later and then give feedback.” (P1)

Original Paper

Table 3 - Identified athlete values with paired needs and example quotes from the interview phase

Index	Value (theme)	Needs (sub-themes)	Example Quote
Body-centric			
V ₁	A dynamic lifestyle	• social bonding through sports • a way of remaining healthy • sports as part of one's identity • a psychological coping mechanism	<i>"I was raised with sports. It's my way of getting rest in my head." (P10)</i>
V ₂	Independence and confidence in one's body	• ability to exercise at home • control over one's life and health • confidence in oneself and one's goals • self-sufficiency to help others • vitality and athleticism despite age	<i>"I didn't have any anxiety or anything like that, so I didn't need reassurance that I could do that [CR]. [...] There was also not a lot of motivation required." (P9)</i>
V ₃	Coming to terms with one's condition	• acceptance of the diagnosis • adapting to new capabilities and setting boundaries for oneself • dealing with family anxiety • ability to recognize symptoms	<i>"8 hours. [i.e., of sport per week]. [...] There was nothing wrong. So that's why I ask myself 'did I do something wrong with sports? [...] How come I got this while I'm a sports fanatic?'" (P13)</i>
Care-centric			
V ₄	A goal and performance-oriented approach	• challenging oneself • exercises adapted to one's high fitness • returning to previous athletic capabilities and goals • seeing physical progress during CR	<i>"Anything that would get my condition back, I would have done. [...] So the motivation was very high. I never missed a single training. [...] I did more intervals and intervals became longer and that is incredibly motivating." (P9)</i>
V ₅	Concise, actionable guidelines	• transparent indications of symptoms • clear, quantifiable exercise limitations • tailored exercise plans	<i>"It was me guessing what I could do. And then asking 'is it OK if I run?' [...] The answer would always be 'yeah. If you feel like you can do that, you should do that'. [...] That's not very precise because it is a heart condition, right? So you don't want to overdo it." (P7)</i>
V ₆	Trustworthy, readily available support	• punctual follow-ups and feedback • collaboration when making health-related decisions • streamline communication • complete trust in clinicians	<i>"I think that the communication with the cardiologist is a bit slow - the E-consult. Every time you send a message, somebody else has to check it. [...] I put it through and you have to wait 2-3 days [...] and then he says 'Do this and come</i>

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Index	Value (theme)	Needs (sub-themes)	Example Quote
			<i>back to me in a week’, but they only keep the e-consult open for six days” (P3)</i>
V ₇	Care with 'a personal touch'	• human interaction • emotional support (from clinicians) • reassurance, encouragement and feedback (from clinicians)	<i>“You are put on a bike, and then they come with the heart rate monitor. They’re all busy, I know that. [...] They don't have to talk for an hour, but a short go-around would be nice.” (P6)</i>
V ₈	In and outside hospital oversight	• pre-program supervision and guidance • feel looked after by a healthcare professional/ ‘be part of something’ • feeling reassured and calm through supervision	<i>“I would start in the hospital [guidance], that would give me certainty that I am doing well. Then that could be phased out, so that at a certain point you only do it at home.” (P15)</i>
V ₉	Emotional support and sharing	• being around people with the same condition • sharing experiences with family and close ones	<i>“I think very important [i.e., the wife’s role in CR]. She knows exactly what happened to me. She knows the status of my heart and body, and how it has recovered.” (P14)</i>
Data and technology-centric			
V ₁₀	Health and performance quantification	• progress and performance measurements • routine measurements to check in with one's body • self-monitoring for staying within exercise limitations	<i>“It is important to measure where you are now. [...] Blood pressure, heart rate. [...] That gives confidence. Confidence in your own body gives you another chance to take the next step.” (P5)</i>
V ₁₁	Clinical validation on information and data	• checking sensor data with clinicians • discussing implications of data with clinicians • receiving clinically-validated information	<i>“ [...] I already googled about sports [in CR]. But then you get a bunch of different websites saying different things.” (P3)</i>
V ₁₂	Reliable systems information	• accurate sensors and data • easy-to-use, understandable systems • robust and simple infrastructure • technical support	<i>“I think that quite a lot of people now have a smartwatch. Especially athletes. And they can use their own smartwatch. I think that is really an added value. Not that they get another one and they don't know how it works.” (HCP2)</i>

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Card-Sorting Focus Groups: Preferred features of CTR systems

The card-sorting activity allowed participants to present an overview of desirable or undesirable CTR features for athletes. The characterization between *must have*, *nice to have* and *not needed* differs from group to group based on their personal needs, group dynamic, composition (patients versus HCPs), perceived independence in one's health management journey, and experience with technology. We present a summary of the card-sorting results (in full in Multimedia Appendix 4).

Consultations, coaching, and guidance

Participants considered periodic checks (either through electronic consultations or surveys), remote supervision of sport-specific training, as well as personalized content comprising sport-specific actionable guidelines as *must haves*. The detection of alarming symptoms in the collected data was deemed very important, as well as receiving actionable feedback on how to react to these symptoms or prevent them, especially during intense exercise. Frictions arose among athletes regarding remotely-supervised group training - most participants considered it essential at the beginning of the program, while two athletes believed that independent training is best as they can "go at their own pace". Support for in-person consultations was a *must have*, except for FG1 whose participants deemed it unnecessary as long as remote consultations were provided. A system that facilitated communication around exercise data between the athlete and HCPs and athlete-HCP feedback on training recommendations was considered a *must* or *nice to have*. Athletes had varying opinions on monitoring emotions and receiving emotional support from clinicians. Some viewed it as essential, especially when struggling to accept their condition, while others believed emotional support is better provided by family or friends. Lastly, recommendations from virtual assistants (e.g., automated recommendation systems) were generally ill-favored because of a lack of trust in their reliability.

Monitoring behaviors for supervision and oneself

Participants felt confident about receiving notifications when irregularities in their data were detected. Most participants preferred wearable sensor monitoring of physical activity to subjective self-reporting mostly because of the trust in and objectivity of sensor data as well as the familiarity with and pragmatic benefits of automatic data collection. Nonetheless, some participants recognized the added value of subjective data collection for clinical decision-making and de-personalization of data, and for expressing anxieties and insecurities related to data inaccuracies and safe sports. Athletes underlined the importance of support for collaboratively adapting individually set performance goals with HCPs. Receiving personalized goals from clinicians was disagreed upon - some athletes felt confident in setting their own goals, while others felt like clinical guidance is essential at the beginning of rehabilitation until confidence in one's athletic abilities is regained. Graphical representations of performance and health data, as well as parallels between actual performance and clinical recommendations, were labeled as *must* or *nice to have*. In line with the case studies describing experiences of athletes in CR [2, 75, 90],

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our participants expressed little to no interest towards motivational queues, rewards, and reminders because they already felt motivated enough to rehabilitate (exercising but also eating healthy and taking medication).

Education and assistance

Technical assistance and instructions on using CTR technologies were deemed a must by all participants, as well as having the possibility of integrating their own wearable sensors into the monitoring system for familiarity, convenience, and trust - HCPs underline that at times, athletes use superior sensors to equipment provided by the hospital. Access to digital information about being an athlete with CAD was important to most participants as similar reliable resources are not available online. Receiving information from virtual assistants (e.g., chatbots) was not needed because of a lack of trust in the clinical validity of the information - some clinicians regarded it as a nice addition that could alleviate the workload of HCPs. Similarly, some participants considered information about why monitoring is beneficial for health as common knowledge and, therefore, not necessary.

Co-experience (social aspect)

Peer-based support was appreciated only within the context of the program and, preferably, in person. Online communication with peers was not viewed as important as athletes felt confident in themselves and their existing support systems and expressed that they would not make use of online communities. Sharing data with family also scored low, with the exception of two participants who already shared location with loved ones for safety, alleviating anxiety, and shared decision-making. Virtual environments that facilitate training with peers were not highly valued as athletes already have social groups to train with or prefer training individually.

High-level CTR technology requirements paired with athlete values

The derived requirements indicate that technology can facilitate exercise monitoring, the interaction between patients, clinicians, and the monitored data, as well as mechanisms of remote coaching and remote consultations (Table 4). The independence that athletes display in their healthcare journey is echoed in the resulting specifications, which underscore their inclination to personalize and monitor their physical and recovery progress independently, diverging from standardized exercise regimes. The pragmatism and data-centric approach are evident in the need for precise exercise restrictions, recommendations, and progress measurements. Athletes prioritize a straightforward and informative system over motivational strategies like gamification or reward systems. The dynamic and disciplined lifestyle that they associate with their well-being and identity is manifested in the majority of the technology requirements. However, glimpses of the desired personal touch emerge in open data-gathering approaches or the request for individualized sport-specific feedback.

Moreover, although participants were encouraged to brainstorm ways technology could augment healthcare services, *technology was not consistently the preferred choice*. These

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insights are valuable for the HCI community as they first identify the preference for a hybrid CTR intervention, and second, they elucidate user scenarios where technology should not be imposed as a solution, thereby averting user frustrations or resistance. Participants found face-to-face mediation in co-located contexts most effective for the group, emotional support, or trust-building interactions. For instance, while peer support was appreciated in person, it was not preferred in online groups. Similarly, at the beginning of the program, in-person clinical consultations, group education sessions, and standardized exercise sessions were preferred for building confidence and bonding. Lastly, open communication was preferred over technology for social support in the home environment. These requirements relate to the values of “*care with a ‘personal touch’*” and “*emotional support and sharing*” as participants emphasized the importance of occasional human interaction in feeling supported by a healthcare system that prioritizes compassion and human connection. We use these insights to advance knowledge about technology-centric requirements in the context of CTR for athletes and we present them in the table below.

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Table 4 - Derived CTR technology requirements paired with athlete values, where `x` indicates a match between a feature and a value, cards used to derive the requirements and example notes or observations made during the card-sorting activity

Technology requirements	V ₁	V ₂	V ₃	V ₄	V ₅	V ₆	V ₇	V ₈	V ₉	V ₁₀	V ₁₁	V ₁₂	Related cards	Example FG notes
Supporting remote monitoring														
Remotely monitored sport-specific training (e.g., type of sport, duration, frequency, HR (zones), degree of effort) and biophysical measurements (e.g., blood pressure) - before, during, CR program	x							x					Training independently at home (own sports), with remote supervision	Start training at home with supervision – esp. after hospitalization (FG3) Impossible to monitor at home without technology (FG2)
													Monitoring activities and behaviours through sensors	
Exercise data collection and aggregation from athlete’s own wearable sensors (e.g., sports watches, chest straps, mobile applications)a; the hospital provides patients with sensors in case they do not use one								x		x		x	Using the technology I already own for self-monitoring	Sporters who have their own technology can use it; if they do not, then the hospital should provide it (FG1)
													Having the hospital provide me with the technology I need (e.g., a wearable sensor and a tablet/mobile phone)	
Simple, brief, open approach to subjective data collection gathering contextual information (e.g., symptom uncertainty, sport-related anxiety, questions about sensor data irregularities)							x	x	x				Reporting on subjective experiences through diaries or surveys - e.g., emotions, worries, side effects, stress, social interactions etc.	Not if long questionnaires are needed (FG2,4) Emotional support is very important (FG3) Look at the person as a whole and not only at their heart problem (FG5) Useful as explanation for data (FG6)
													Receiving clinician support about emotions and worries	
Technical instructions and online assistance in monitoring, syncing, sharing, and correctly interpreting the data (e.g., instructional videos or written information)												x	Technical assistance and instructions on how to use the technology, share the data etc	If there is a connection between commercial applications (e.g., Strava/Polar) then that needs to be explained (FG1) Necessary when “getting
													Instructions about why it is important to monitor myself and how it can benefit my	

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Technology requirements	V ₁	V ₂	V ₃	V ₄	V ₅	V ₆	V ₇	V ₈	V ₉	V ₁₀	V ₁₁	V ₁₂	Related cards	Example FG notes
													health	<i>stuck” or for less technical users (FG2)</i>
Continuous and automatic transmission of remote data to clinicians; opting for manual, discrete transmission is possible						x		x			x	x	Clinicians can receive and see all the data collected by the system	<i>Does not matter if data is sent automatically or manually, as long as any professional looks at the data (FG1)</i>
													The system automatically sends my data to my clinicians (e.g., in real time, or periodically)	<i>Do not mind sharing all the data, but it is nice if able to make a decision whether to share all the data or not (FG4)</i>
													I am able to manually send my data to clinicians whenever I want to	
Supporting human-data interaction														
Graphs displaying training progress (e.g., HR, intensity minutes) and sessions (e.g., duration, HR zones), contrasting with limitations and recommendations (e.g., exceeding max HR), for easy understanding by trainers, family, and clinicians			x		x					x			Seeing performance and health data in a graphic form - e.g., graphs, animations, icons etc.	<i>Rehabilitation is about progress - graphs are valuable to demonstrate the progress (FG1)</i>
													Seeing comparisons between performed workouts versus my clinical recommendations	<i>Makes the information clear and insightful (FG4)</i>
Instant alerts for exceeding clinical limitations during training (e.g., excessive time spent in HR zone 4)			x			x				x			Receiving notifications when there are red flags in my data (eg, heart rate is too high for a long time, or performance is above limitations)	<i>It feels safe to receive notifications about red flags (FG1)</i> <i>If the heart rate gets dangerously high during a workout, it is nice to receive a notification (FG2)</i>
													Receiving feedback on my performance and health data during my workouts	
Alerts for prolonged anomalies in data (e.g., exceeding limitations, signs of cardiac arrhythmia), with		x	x		x					x			The system notifies clinicians when there are red flags in my data (e.g., heart rate is too high for a	<i>Professionals should know if it is not going well (FG4)</i>

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Technology requirements	V ₁	V ₂	V ₃	V ₄	V ₅	V ₆	V ₇	V ₈	V ₉	V ₁₀	V ₁₁	V ₁₂	Related cards	Example FG notes
follow-up recommendations for action – either adjusting performance or seeking clinical assistance													long time, or performance is above limitations) Receiving feedback from clinicians when there is a red flag in my data (e.g., heart rate too high for too long)	<i>It is useful when the professional receives a notification - but the system should keep the responsibility with the patient (FG5)</i>
Selecting and sharing monitored data snippets (e.g., HR from a specific exercise session) with clinicians within the system, facilitating remote data-focused discussions											x		Sharing representations of my data during consultations to my clinician (e.g., to discuss it or ask questions) Receiving personalized training goals from my clinician (e.g., goals based on my previous athletic performance)	<i>Nice way for HCPs to get insights in the data, as well as for “passionate athletes” who keep track of their data. Collaboratively working on health goals and next steps is a must. (FG5)</i>
An overview of clinical test results such as exercise stress tests and clinical scans			x							x			Access to personal clinical details such as scans and tests made by the doctor * *empty card feature added by FG1	<i>Access to personal clinical details such as scans and tests made by the doctor (FG1) Connect collected data to program evaluations to observe progress (FG6)</i>
Sharing health and exercise data with family, including exercise location and alarming signals, for discussion, negotiation, and easing concerns			x						x				Sharing my data with my family and/or friends (e.g., for discussions, sharing concerns, making decisions together, planning activities) Sharing red flags in my data (e.g., heart rate is too high for a long time, or performance is above limitations) with my	<i>Beneficial for patients living alone, whose family wants to know how they are from a distance (FG2)</i>

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Technology requirements	V ₁	V ₂	V ₃	V ₄	V ₅	V ₆	V ₇	V ₈	V ₉	V ₁₀	V ₁₁	V ₁₂	Related cards	Example FG notes
													family or friends	
Supporting remote coaching														
Setting, storing, and reviewing personal health and sport-related goals; sharing them with clinicians for feasibility assessment and feedback and personalization	x	x		x				x			x		Collaboratively adapting my goals together with my clinician based on my personal situation	Preferably they do not want to receive them, but set their own goals and hear from a professional whether it is realistic; important to collaboratively set goals in the first 3 months (FG1) Setting goals motivates them to find out if they can do better every time (FG3)
													Setting short and long-term goals for myself - e.g., how much sports I do per week, at which intensity	
													Receiving personalized training goals from my clinician (e.g., goals based on my previous athletic performance)	
Tailored content including clinically validated, personalized training schemes tailored to one's sport, goals, current condition, and past performances	x		x	x	x						x		Personalized clinical recommendations and planned activities (e.g., training schemes and schedules, limitations for how much I can do)	Trainings personalized to the capabilities of the participant, including post-CR (FG1) The first 3 months, personalized training schemes (FG2) Want to know where personal limits are (FG3)
Annotating clinical training suggestions with feedback grounded in personal experiences		x					x						Being able to provide feedback to clinicians about the training sessions - e.g., how I felt during the training and how it can be improved	A must have as this is the essence of the CR training (FG5) Patients feel the need to reflect on their training, if it was too heavy for example (FG6)
Receiving clinical feedback on current performance (e.g., through annotations on remotely monitored exercise	x					x					x		Receiving support from clinicians regarding my emotions and worries	Important to know what they are doing well and what not, especially in the beginning when there is a
													Receiving feedback on my	

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Technology requirements	V ₁	V ₂	V ₃	V ₄	V ₅	V ₆	V ₇	V ₈	V ₉	V ₁₀	V ₁₁	V ₁₂	Related cards	Example FG notes
data)													performance and health data during my workouts	<i>lot of insecurity</i> (FG3)
Multi-media, digital information resources about athletic patients with heart problems and how to deal with exercising while having a cardiac condition			x								x		Having access to educational materials in digital form (e.g., videos and tutorials, information web pages)	<i>Replacing brochures with digital material (brochures are “a bit passée” and repetitive)</i> (FG2)
													Being able to search for clinically validated information anytime I need to (e.g., about my condition, medication, fears)	<i>Internet information is scattered and unreliable - the need for information specifically for sporters with heart problems</i> (FG1)
Supporting remote consultations														
Periodic clinical check-ins on exercise management (e.g. updating knowledge on the exercise limits or exercise-related symptoms) through synchronous or asynchronous channels such as video calls, or online surveys			x			x		x			x		Having periodic checks/consultations (e.g. with a clinician, periodic surveys, or with a virtual agent)	<i>The need to be able to ask what is allowed and what is not allowed; preferably an e-consult for short questions</i> (FG1)
													Having remote consultations (e.g., by phone, through texting or video calling)	<i>Especially in the beginning of CR there should be face-to-face contact</i> (FG3)
E-consult functionality allowing users to ask specific questions to appropriate clinicians via chat functionalities						x	x	x					Request on-demand consultations whenever I need to (e.g. with a clinician, through a survey, or with a virtual agent)	<i>Being able to contact a professional when questions arise; could be a message/ e-mail/etc.</i> (FG4)

V₁ - A dynamic lifestyle
V₂ - Independence and confidence in one's body

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- V₃ - Coming to terms with one's condition
- V₄ - A goal and performance-oriented approach
- V₅ – Concise, actionable guidelines
- V₆ - Trustworthy, readily available support
- V₇ - Care with 'a personal touch'
- V₈ - In and outside hospital oversight
- V₉ - Emotional support and sharing
- V₁₀ - Health and performance quantification
- V₁₁ - Clinical validation on information and data
- V₁₂ - Reliable information system

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Discussion

Principal findings

Recent developments in the design of cardiac eHealth have encouraged HCI practitioners and designers to account for the patients' latent and hidden needs, desires, and life values [CITATION Tadas2020Barriers \l 1033], [CITATION Martinez2021Values \l 1033]. A recent scoping review on acceptance and adherence factors of CTR interventions emphasizes that early involvement of users in the design of CTR technologies is essential for designing meaningful and efficient interventions [CITATION Ramachandran2022AcceptanceCTR \l 1033]. Nonetheless, there has been a lack of HCI studies on acknowledging the needs and values of patient subpopulations in CTR [CITATION Brouwers2020CTR2 \l 1033], [CITATION Hwang2023CTRHF \l 1033], [CITATION Ramachandran2022AcceptanceCTR \l 1033]. In this study, we outline design requirements for technology-centric CTR interventions that attend to values of a distinctive cardiac population: *athletes with established CAD*. We employ methods from VSD and uncover 12 key values of this specific population supported by underlying needs. These values include "*independence and confidence in one's body*" and "*concise, actionable guidelines*," alongside technology features grouped into design requirements addressing these values. In the following sections, we discuss the implications for the value-oriented design of CTR technologies in the context of the athletic population. We first situate our findings in the context of existing CTR research for homogenous populations, then explore how alignments and conflicts among values can inform the design process and discuss design guidelines based on the connections inferred between athlete values and the identified design requirements.

CTR for Athletic Populations vs. Homogenous Patient Groups

Based on our findings and previous, related work, the core experience of being a cardiac patient is fundamentally the same for both athletes and general populations. However, the key difference is that athletes have distinct attitudes toward physical activity, and their identity and discipline around it shape their expectations of care, particularly regarding physical activity training, the main component of CR. As a result, while there are similarities, CTR technologies should be designed differently for athletes compared to general populations. For example, general populations typically track any physical activity, such as steps (e.g., MI-Pace [CITATION Ding2021MiPace \l 1033]) or standardized exercises (e.g., recommended aerobic exercises for CVD patients [CITATION Duff2018MedFit \l 1033]), whereas athletes prefer sport-specific tracking and feedback (e.g., for cycling, running or weight lifting). This difference can influence monitoring system design, as our participants preferred relying on their own high-performance wearables, which they are trained to use and are of better quality than standard hospital-issued devices, whereas CTR systems for homogenous populations are designed to offer patients standard monitoring devices (e.g., FitBit [CITATION Duff2018MedFit \l 1033], [CITATION Dinesen2019IntegrationofCR \l 1033], MioAlpha and Actigraph [CITATION Brouwers2017SmartCAD \l 1033], smartphone

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apps [CITATION Falter2020CRIdealTool \ 1033], Philips Health Watch [CITATION Ding2021MiPace \ 1033]). This can also affect personal insight platforms and clinician decision-support systems, shifting from generic goals like 10,000 steps/day (e.g., Shared Care Platform [CITATION Dinesen2018Telerehab \ 1033], HeartPortal [CITATION Joensson2019ParticipatoryCTR \ 1033]) or 150 activity minutes/week (e.g., [CITATION Duff2018MedFit \ 1033]) to sport-specific milestones based on frequency, distance, heart rate zones, and perceived effort.

Some needs remain the same, such as clear technical instructions and technical support for CTR platforms (e.g. the MedFit App [CITATION Duff2018MedFit \ 1033]), and seamless, continuous data transmission (e.g., SmartCareCAD [CITATION Brouwers2017SmartCAD \ 1033]). However, graphical data representations alongside exercise limitations are particularly relevant for athletes, as they need to moderate activity rather than increase it. Their familiarity with data tracking can make them more critical of inaccuracies and more confident in interpreting data, influencing their preference for precise alarm systems. In contrast, general populations may feel overwhelmed by excessive or highly technical data [CITATION Kondratova2022VCRHCI \ 1033].

While data-focused discussions with clinicians are valuable for all patients [CITATION Kjaerup2018DiagnosticAgent \ 1033], [CITATION Ding2021MiPace \ 1033], athletes require highly personalized exercise recommendations based on personal metrics, sports-specific testing, and clinical cardiology expertise. Additionally, information resources designed for general populations (e.g., ActiveHeart [CITATION Dinesen2019IntegrationofCR \ 1033]) need to be enriched with athlete-specific content to prevent misinformation. The need for periodic consultations and clinician validation remains constant with athletes and homogenous populations (e.g., [CITATION Dinesen2019IntegrationofCR \ 1033], [CITATION Dinesen2018Telerehab \ 1033], [CITATION Brouwers2017SmartCAD \ 1033], [CITATION Ding2021MiPace \ 1033]) but athletes may have more specialized questions, which could benefit from new communication methods such as pre-structured forms, data annotations, or digital messaging for tailored interactions. We discuss the specific implications for athletic CTR technologies in the following subsections.

Design implications for CTR technologies supporting athletes

Value contradictions, tensions, and design trade-offs

Aligning with VSD theory, we observe value interrelations and tensions at various levels of human experience - among athletes, as well as between athletes and homogeneous cardiac patient populations. The VSD framework acknowledges that human values do not exist in isolation [CITATION Friedma2019VSDBook \ 1033]. Framing a design process to engage constructively in the interconnectedness of human values is a matter of design thinking and can be mediated through design trade-offs, value conflicts, or value tensions [CITATION Friedman2017ValueDesignMethods \ 1033]. Such tensions, conflicts, and trade-offs have also been discussed in similar studies applying VSD methods to eHealth design [CITATION Joensson2019ParticipatoryCTR \ 1033], [CITATION Asbjørnse2020ValuesObeseTech \ 1033]. The term “value tension”

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encourages the design of solutions that balance opposing values, such that “the adjudication of the tension holds each value intact” [CITATION Friedma2019VSDBook \l 1033]. In our case, most athletes valued data from wearable sensors to get better at sports or re-calibrate internal feelings of exercise intensity, while other athletes (e.g., P13 or P14) trusted the physical “feeling” enough and did not consider fitness trackers necessary. Therefore, one design outcome can be a wearable sensor system that offers insights into one's performance and the meaning of data in the context of CAD after hospital dismissal when athletes lack confidence in their bodies the most. Subsequently, tracking one's training can become optional and periodical. On the other hand, a “design trade-off” conveys an approach in which designing for one value will diminish another value. For instance, designing a CTR technology that formalizes the role of a close family member and allows athletes to share personal data such as location and HR while exercising with them will come at the expense of the independence of other athletes who want to keep their experiences private. Offering this functionality for the safety and comfort of some athletes takes the form of a trade-off.

Our findings also align with prior research on cardiac patients' values. The 11 values of cardiac patients as a foundation for eHealth development identified by Bente et al [CITATION Bente2021CardiacsValues \l 1033] overlap with the 12 identified values in our study - e.g., “To have an overview of personal health data” overlaps with athletes' value of “Health and performance quantification”. Nonetheless, there are also value conflicts. For instance, one key value of Bente et al.'s population is “to be extrinsically motivated to accomplish goals or activities (related to health/lifestyle)” [CITATION Bente2021CardiacsValues \l 1033]. On the other hand, athletes value a “goal and performance-oriented approach” to rehabilitation and are very independent in their health journey. The term “value conflict” proposes that when values come into conflict, design resolutions can offer solutions responsive to both. In the context of CTR individualization, one solution can be offering a standardized CTR platform that encompasses two different modules: one for patients who need behavior change (including information about the importance of exercise, motivational queues, and reminders), and one for athletes (including a more performance and data-oriented interface comprising of sport specific goal setting, data overviews and means to address sport-related questions).

While our results mostly show generalizations of common themes and requirements, designers should be aware that values and needs are expressed through the lens of individual experiences [CITATION Pijnen2011Cehres \l 1033]. Two patients might have completely different rehabilitation experiences, while clinicians might benefit from solutions that patients do not necessarily need (e.g., virtual assistants that can ease clinicians' workload but are not perceived as trustworthy by athletes).

Connecting CTR technology requirements with athlete values

Preference for hybrid CTR and continuity of care. Our research reveals a preference for a hybrid CTR intervention incorporating human-to-human contact for peer bonding and clinical consultations. This preference is particularly pronounced during the post-hospitalization and early program stages, where there is a need for human interaction,

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emotional support, and sharing. They also indicate a need for activity supervision and recommendations that can help regain activity post-hospitalization, before the program starts. Similarly, previous research on homogeneous cardiac populations reveals that exposure to other patients can evoke feelings of safety, comfort, and camaraderie [CITATION Tadas2021Transitions \l 1033], [CITATION Clark2023MechanismsCTR \l 1033], and that support is needed in the post-hospitalization gap [CITATION Rawstorn2018UserPerceptionCTR \l 1033]. However, athletes quickly build confidence, and their need for human contact can decrease fast after the start of the program. Peer support is seen as a “nice to have”, but not necessary while athletes shift their priorities towards re-gaining their physical condition. Although previous research on homogeneous populations suggests introducing technology later in the rehabilitation process, as participants transition from program completion to self-management [CITATION Tadas2021Transitions \l 1033], [CITATION Tadas2023PatientData \l 1033], our study indicates that athletes are prepared to become independent sooner. This readiness occurs as soon as they regain physical strength and gain clarity regarding their new limitations, typically during the transition between post-hospitalization and the midpoint of the program. Our results indicate that while the need for supervision may decrease significantly after the program ends, some participants still expressed a need for structured training plans to continue their progress (Figure 5). We further discuss the identified categories of CTR technology requirements that surfaced from our study and the inferences with athlete values.

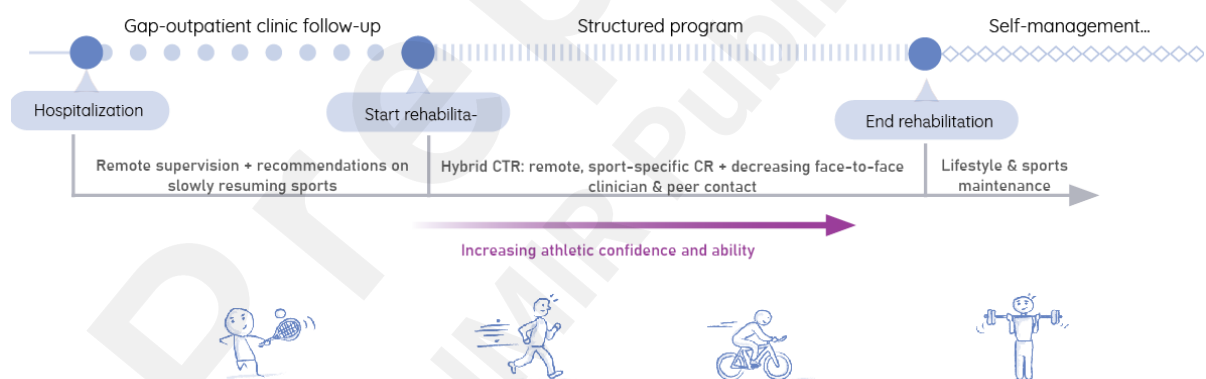


Figure 5 - For athletes, CTR provides chances to train in their sport at home before and during rehab under remote supervision, and having guidance after the program ends

Supporting remote monitoring. Our participants express attitudes similar to those found in research on recreational athletes: sports are integral to athletes' identity, well-being, and lifestyle [CITATION Tholander2015ExperienceSMartW \l 1033]. They resist the notion of being confined to a monotonous, standardized hospital-based program; however, their perception of safe sporting activities next to new physical limitations becomes distorted following the diagnosis. While athletes prioritize independence in their health journey, they still value dependable clinical support significantly. This includes receiving remote clinical monitoring of their sporting activities outside the hospital, as well as biophysical measurements, ensuring ongoing clinical oversight. While current telemonitoring in CTR focuses on patient adherence to exercise targets and symptom management [CITATION Dinesen2018Telerehab \l 1033], [CITATION

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Duff2018MedFit \l 1033], for athletes, its purpose would shift towards preventing overexertion and tailoring future training programs based on their heart's capabilities and symptoms. Moreover, current telemonitoring relies on step-counters, distance, or data indicating the presence of physical activity [CITATION Ramachandran2022AcceptanceCTR \l 1033], [CITATION Clark2023MechanismsCTR \l 1033]. However, a more nuanced approach is needed for athletes, incorporating detailed sport-specific parameters such as type of sport, intensity minutes, HR zones, and HR recovery, similar to insights found in sports apps like Strava or Join. Furthermore, while regular subjective data gathering, like diaries, was not considered essential, some athletes expressed a need for documenting anxieties, particularly those related to sports, symptoms, or specific workout instances. Such documentation could provide a personalized touch and reassurance. This could be facilitated through open methods of annotating sensor data, as recently discussed by Tadas et al. [CITATION Tadas2023PatientData \l 1033] or Akinsiku et al. [CITATION Akinsiku2021ExperientialInfo \l 1033]. As already documented, athletes are accustomed to self-monitoring - they already have preferences and high expectations related to reliable monitoring systems [CITATION Tholander2015ExperienceSMartW \l 1033], [CITATION Pandey2019ATHletesTracking \l 1033]. Our findings show that both athletes and HCPs prefer using the athlete's wearable sensors because of familiarity, perceived device quality, and accuracy. Despite potential challenges like data inconsistencies and integration issues, leveraging existing resources can save costs and offer valuable historical insights predating diagnosis.

Supporting human-data interaction. Previous literature has underlined the trained capacity of recreational athletes to be aware of signals sent by their bodies, using data from wearable sensors (mostly HR) to re-calibrate internal feelings of embodied experience [CITATION Pandey2019ATHletesTracking \l 1033], [CITATION Tholander2015ExperienceSMartW \l 1033]. Our research confirms these findings, with a majority of participants utilizing wearable sensors during training for self-reflection and internal re-calibration. Some athletes even assert their deep trust in their body's response to exertion, suggesting they rely more on familiarity than data. However, this equilibrium shifts post-hospitalization, when even basic activities become challenging. Accepting one's limitations and adapting to new boundaries is crucial. Athletes undergo a re-calibration process by re-learning how data, symptoms, and bodily sensations relate to and mutually influence one another. Graphical representations of physical and athletic progress next to clinical validation can facilitate the creation of "in-the-moment knowledge" [CITATION Tadas2020Barriers \l 1033] and facilitate the re-calibration process. Access to clinical tests (e.g., exercise stress tests), data representations incorporating clinical limitations, such as maximum allowed HR, real-time notifications for exceeding limitations during exercise, and alerts for clinicians and athletes regarding data anomalies can facilitate accepting one's condition. An example of real-time training feedback based on optimal training zones is present in the work of Geurts et al. [CITATION Geurts2016GamfieldTelerehab \l 1033]. These enhancements become indispensable as wearable data evolves beyond mere performance metrics [CITATION Pandey2019ATHletesTracking \l 1033] following a diagnosis. However, some athletes express skepticism regarding the accuracy and reliability of the data, recognizing that

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their sensors are not medical devices [CITATION Andersen2023DataWorkConsumer \l 1033]. As a result, they seek clinical validation and aspire to engage in data-driven discussions with their clinicians, even during brief online consultations. Therefore, a CTR system could streamline the process by enabling easy access to data from specific time periods during these e-consults. Additionally, in contrast with findings of homogeneous cardiac populations being open to sharing collected data with peers [CITATION Tadas2023PatientData \l 1033], our participants found sharing wearable sensor data with peers irrelevant both before and after their diagnosis. Previous studies similarly indicate that the social value of recreational athletes' practice is not found through online communities or peer data sharing [CITATION Tholander2015ExperienceSMartW \l 1033], [CITATION Dionigi2012FamilyInfluencesMAs \l 1033]. Finally, while the family may play a less active role in an athlete's physical recovery, they are significantly involved in mediating anxiety and emotional healing. Designers must consider the social dynamics inherent in a CTR system and its monitored data, as discussed by Andersen et al. [CITATION Andersen2020WearablesForCardiacs \l 1033]. They can address family safety concerns and partner anxiety through location sharing and negotiation mechanisms akin to features in apps like Strava or Apple Fitness. To streamline and enhance conversations and reflections about data, designers should implement strategies that cater to low levels of data literacy and effectively communicate progress or trends, as evidenced by prior research [CITATION Gupta2020ObjectiveDataCons \l 1033], [CITATION Seals2022CTRSclerosisClinsPercep \l 1033].

Supporting remote coaching. A key finding of our study highlights athletes' perception of inadequate care in co-located CR, as their exercise needs are overlooked due to the assumption that they are "fitter" than other patients. Unlike in homogeneous populations where low motivation contributes to poor program adherence [CITATION Rodrigues2021Barriers \l 1033], athletes' enjoyment and willingness to attend are hindered by not being guided to exercise at the desired intensity. As cardiac patients are keen on returning to normality [CITATION Tadas2021Transitions \l 1033], athletes are eager to reclaim their peak physical condition. In their pursuit, they merge health and athletic objectives, such as aiming to increase their personal best timing to eventually participate in a half-marathon. While goal-setting is addressed in current CTR designs, nonetheless, clinicians are the main initiators or coordinators of physical activity goals (e.g., [CITATION Dinesen2019IntegrationofCR \l 1033]). Catering to athletes' independence and autonomy, athlete-centered CTR interventions should empower athletes to establish their sport-specific performance goals, incorporating motivators and metrics (e.g., desired running distance), while facilitating clinician feedback and adjustments. In line with our findings, recent research on consumer wearable systems for sports highlights the significance of incorporating sport-specific goals and recommendations as a crucial design enhancement [CITATION Mencarini2019WearablesSport \l 1033].

To support values such as "To be extrinsically motivated to accomplish goals" [CITATION Bente2021CardiacsValues \l 1033], current CTR interventions focus on enhancing program engagement through persuasive strategies (e.g., multi-media content [CITATION Sankaran2019MotivationCTR \l 1033] or collaborative gamified experiences

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[CITATION Dithmer2016HeartGame \l 1033]). Alternatively, athletes do not require external motivators such as rewards or gamification but rather need facilitators such as personalized, sport-based training content with adapting intensity that can be static (e.g., textual) but rich in clinically valid information such as intensity specificity and limitations. The CTR platform developed by Sankaran et al. [CITATION San18 \l 1033] provides a notable example of detailed visualizations depicting exercise prescriptions and progress, which could be customized for the athletic population. A crucial design feature could also involve aligning clinically suggested exercise schemes with data from the performed workout for comparison, enabling athletes to offer feedback to clinicians based on their personal experiences with the suggested exercises. Finally, to ensure a clinically validated understanding of their specific situation, CTR platforms should offer personalized information resources on exercising with established CAD. Athletes currently rely on inconsistent and potentially unsafe online sources for safe exercise.

Supporting remote consultations. Athletes experience a high level of anxiety after hospitalization, and receiving care with a personal touch can alleviate mental struggles. These values can be addressed by facilitating person-to-person care tailored to the patient's values, beliefs, and life goals [CITATION Martinez2021Values \l 1033]. As athletes regain confidence, reacquaint themselves with their limits, and re-calibrate their internal sense of “body safety”, their inquiries to clinicians become more specific and brief (e.g., regarding symptoms, medication, or limitations). Unfortunately, some athletes struggled with alleviating their anxieties in the program and found relationships with clinicians cold or inaccessible. To maintain personal connectivity with the healthcare system and avoid depersonalization of remotely gathered data [CITATION Primenko2020Depersonalization \l 1033], CTR technologies for athletes ought to incorporate periodic “check-in points” - online consultations via synchronous or asynchronous methods. Some participants propose periodic surveys concerning symptoms or physical recovery. Additionally, athletes occasionally express the need to ask situational questions through chat functionalities or features akin to e-consultations. Such findings align with current HCI investigations of cardiac telehealth that emphasize the benefits of harnessing HCP-patient relationships through remote care [CITATION Bente2021CardiacsValues \l 1033], [CITATION Dinesen2018Telerehab \l 1033], [CITATION Beleigoli2021CoDesignCTR \l 1033], [CITATION Clark2023MechanismsCTR \l 1033].

Suggestions for Future Work and Limitations

Considering the significant individual and public health challenges posed by CVDs, along with increasing medical knowledge on the risks of physical exertion in cardiac recreational athletes, CTR interventions must move beyond one-size-fits-all approaches toward highly personalized, data-driven, and athlete-centered rehabilitation experiences that empower patients to safely return to peak performance. Future research should focus on translating the identified design implications and requirements into CTR solutions tailored for athletes, followed by iterative validation and implementation with key stakeholders, including athletes, caregivers, and clinicians. Operationalizing VSD in the design of complex CTR interventions will take more than making connections between

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values and feature requirements [CITATION Martinez2021Values \l 1033]. Future work can investigate the translation of value-sensitive requirements to CTR design and validation by using, for instance, Van de Poel's value hierarchies [CITATION VanDePoel2013ValueHyrarchy \l 1033] and validating value-sensitive CTR in actual effectiveness trials with methods such as the Multiphase Optimization Strategy (MOST) [CITATION Collins2018MOST \l 1033].

Our findings contain a broad understanding of the problem at hand because of the nature of the qualitative methods. However our study had some limitations. All participants were Dutch, either being treated or working at the same hospital. We especially acknowledge the gender imbalance in our recruited patients (only one was a woman), as the under-representation of women in CR research is a documented, fundamental problem [CITATION Cugusi2019GenderImbalance \l 1033]. One constraint was the inclusion criterion, limiting enrolment to participants who completed the CR program within one year before the study's start, which restricted opportunities to include more women. Nonetheless, we recognize this might be a systemic problem related to women's diagnosis, referral patterns, or adherence to CR programs [CITATION Kristofferzon2007WOMenandmenCR \l 1033], [CITATION Jackson2005Referral \l 1033]. These considerations may limit the generalizability for more diverse groups such as women, or athletes being treated in other cultures/countries/jurisdictions. Future research should investigate the values and needs of such groups.

We included only patients who exercised at least four hours per week before diagnosis, but our findings may also apply to less athletic but active individuals. While athletes have distinct values and needs compared to homogeneous cardiac populations, some preferences overlap, warranting further research on their generalizability to a higher sample of active patients. Additionally, the values of athletes with established CAD should be examined alongside those of healthy recreational athletes to better understand implications for fitness and health-tracking technologies for cardiac athletes.

CTR is a complex combination of face-to-face and remote services, requiring consideration of technological (e.g., data representations), service (e.g., consultations), and functional features (e.g., sensors vs. surveys). Design choices in this study were shaped by the interviewed population, making some requirements broad and exploratory. Future research should explore athletes' preferences for specific CTR functionalities (e.g., alarms for red flags in data). Additionally, accessibility should be a key consideration - e.g., one participant with a hearing disability emphasized the need for reliable video streaming to support lip-reading, highlighting the importance of inclusive design in CTR interventions.

Finally, within HCI literature, there is criticism of ethnographic studies being evaluated on the implications they can have for design - this can give rise to the idea that design is the endpoint of the research [CITATION Berkel2023ImplicationsDesign \l 1033], [CITATION Dourish2006ImplicationsDesign \l 1033]. Our study indicates opportunities for reorganizing and leveraging existing CR services for athletes' rehabilitation that could be explored further in future research. While beyond this paper's scope, discussions on

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implications for policymakers and healthcare institutions warrant attention in future work.

Conclusion

This study contributes to understanding how CTR technologies can address the needs and values of athletes with established CAD. Our results show that for the independent, highly active athletic population, CTR interventions should be more focused on *remote performance tracking, clear data reports, and communication channels that enable shared decision-making between athletes and clinicians*. We propose *design considerations for value-oriented CTR technologies* aimed at the athletic population and encourage designers to account for the contrasting values and needs of different stakeholders in the design process. From a practical standpoint, these findings can inform the development of CTR platforms that better align with athletes' expectations by integrating performance feedback, sport-specific metrics, and adaptive supervision. Clinicians and technologists can collaborate to leverage these insights and personalize remote rehabilitation care models that gradually shift from structured guidance to independent athlete-led monitoring. Additionally, healthcare institutions can use these results to refine hybrid rehabilitation programs, balancing digital autonomy with strategic in-person evaluations to optimize adherence and safety. Future implementations should prioritize accessibility, interoperability with wearable devices, and customizable consultation models to enhance athlete-centered care in CTR.

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Bibliography

- CITATION Wilkins2017CVDStatistics \l 1033 : , [1],
CITATION Pelliccia2021CRGuidelines \l 1033 : , [2],
CITATION Anderson2016CRReview \l 1033 : , [3],
CITATION Kondratova2022VCRHCI \l 1033 : , [4],
CITATION Peretti2017TelerehabReview \l 1033 : , [5],
CITATION Nilsson2023PerceptionsCTR \l 1033 : , [6],
CITATION Davis2014RemoteMonitoringPmCare \l 1033 : , [7],
CITATION Morimoto2022WebPortalsTelerehab \l 1033 : , [8],
CITATION Munteanu2019DesigningOlderAdults \l 1033 : , [9],
CITATION Tsai2020TechAnxietyResistance \l 1033 : , [10],
CITATION Tadas2023PatientData \l 1033 : , [11],
CITATION Churchill2020CVCareMA \l 1033 : , [12],
CITATION Aengevaeren2017ExerciseAndCAD \l 1033 : , [13],

Original Paper

CITATION Mittleman1993InfractionAthlete \ 1033 : , [14],
CITATION Culic2023InfractionPhysicalExer \ 1033 : , [15],
CITATION Culic2023InfractionPhysicalExer \ 1033 : , [15],
CITATION Claessen25Athletes \ 1033 : , [16],
CITATION Pelliccia2021CRGuidelines \ 1033 : , [2],
CITATION McKinney2019Athletes \ 1033 : , [17],
CITATION Kinast2021TelemonitoringCardio \ 1033 : , [18],
CITATION Kakria2015HealthMonitoring \ 1033 : , [19],
CITATION Worringham2011CRExercisemonit \ 1033 : , [20],
CITATION Canniere2020ECGWearableCR \ 1033 : , [21],
CITATION Thijs2019PAInCRAfterSurgery \ 1033 : , [22],
CITATION Pavy2016CRActivePatients \ 1033 : , [23],
CITATION Borjesson2019RecommendationsMA \ 1033 : , [24],
CITATION Sankaran2019MotivationCTR \ 1033 : , [25],
CITATION San16 \ 1033 : , [26],
CITATION San18 \ 1033 : , [27],
CITATION Pavy2016CRActivePatients \ 1033 : , [23],
CITATION Quazi2022HCIPersonalizedEhealth \ 1033 : , [28],
CITATION Kondratova2022VCRHCI \ 1033 : , [4],
CITATION Falter2020CRIdealTool \ 1033 : , [29],
CITATION Beleigoli2021CoDesignCTR \ 1033 : , [30],
CITATION Martinez2021Values \ 1033 : , [31],
CITATION Hwang2023CTRFHF \ 1033 : , [32],
CITATION Brouwers2020CTR2 \ 1033 : , [33],
CITATION Friedman2013VSDFW \ 1033 : , [34],
CITATION Martinez2021Values \ 1033 : , [31],
CITATION Friedma2019VSDBook \ 1033 : , [35],
CITATION Martinez2020FrameworksTeleCR \ 1033 : , [36],
CITATION Song2020MobileCTRPerceptions \ 1033 : , [37],
CITATION And17 \ 1033 : , [38],
CITATION Maddison2019CTRPerceptions \ 1033 : , [39],
CITATION Snoek2021CTRElderly \ 1033 : , [40],
CITATION Pavy2016CRActivePatients \ 1033 : , [23],
CITATION Placeholder1 \ 1033 : , [41],
CITATION Hathorn2021FirefighterCR \ 1033 : , [42],
CITATION Weber2018CaseStudyCyclist \ 1033 : , [43],
CITATION Placeholder1 \ 1033 : , [41],
CITATION Andersen2020WearablesForCardiacs \ 1033 : , [44],
CITATION Pandey2019AthletesTracking \ 1033 : , [45],
CITATION Tholander2015ExperienceSMartW \ 1033 : , [46],
CITATION Tadas2020Barriers \ 1033 : , [47],
CITATION Dionigi2012FamilyInfluencesMAs \ 1033 : , [48],
CITATION Bente2021CardiacsValues \ 1033 : , [49],
CITATION Hartrevalidatie \ 1033 : , [50],
CITATION EACPR2010SecondPrev \ 1033 : , [51],
CITATION Brouwers2020CTR2 \ 1033 : , [33],

Original Paper

CITATION Hwang2023CTRFH \ 1033 : , [32],
CITATION Tadas2023PatientData \ 1033 : , [11],
CITATION Cramer2015InterventionsStroke \ 1033 : , [52],
CITATION Ramachandran2022AcceptanceCTR \ 1033 : , [53],
CITATION BurrIDGE2017Telehealth \ 1033 : , [54],
CITATION Conroy2020Telerehab \ 1033 : , [55],
CITATION Falter2020SensorsCTR \ 1033 : , [56],
CITATION Afyouni2019GamifiedTelerehab \ 1033 : , [57],
CITATION Dinesen2019HeartPortal \ 1033 : , [58],
CITATION Melholt2018ActiveHeart \ 1033 : , [59],
CITATION Kjaerup2018DiagnosticAgent \ 1033 : , [60],
CITATION Martinez2020FrameworksTeleCR \ 1033 : , [36],
CITATION Clark2023MechanismsCTR \ 1033 : , [61],
CITATION Duff2018MedFit \ 1033 : , [62],
CITATION Athilingam2016HeartMapp \ 1033 : , [63],
CITATION Brouwers2017SmartCAD \ 1033 : , [64],
CITATION Morimoto2022WebPortalsTelerehab \ 1033 : , [8],
CITATION Dithmer2016HeartGame \ 1033 : , [65],
CITATION Ding2021MiPace \ 1033 : , [66],
CITATION Hal18 \ 1033 : , [67],
CITATION And17 \ 1033 : , [38],
CITATION Nilsson2023PerceptionsCTR \ 1033 : , [6],
CITATION Rawstorn2018UserPerceptionCTR \ 1033 : , [68],
CITATION Holeman2020HCDHealth \ 1033 : , [69],
CITATION Min2023EpilepsyCare \ 1033 : , [70],
CITATION Cha2023DiabeticParents \ 1033 : , [71],
CITATION Sepehri2023BulgingBinder \ 1033 : , [72],
CITATION Bhat2023CaregiversChronic \ 1033 : , [73],
CITATION Joensson2019ParticipatoryCTR \ 1033 : , [74],
CITATION Beleigoli2021CoDesignCTR \ 1033 : , [30],
CITATION Khanshan2023DEDCTR \ 1033 : , [75],
CITATION Dinesen2019IntegrationofCR \ 1033 : , [76],
CITATION Friedman2006ValueSensitiveDesign \ 1033 : , [77],
CITATION Friedman2017ValueDesignMethods \ 1033 : , [78],
CITATION Pijnen2011Cehres \ 1033 : , [79],
CITATION Cenci2023AIAppDementiaVSD \ 1033 : , [80],
CITATION Asbjørnse2020ValuesObeseTech \ 1033 : , [81],
CITATION Giacomini14HCD \ 1033 : , [82],
CITATION ICPHR13PHR \ 1033 : , [83],
CITATION Hoven2015ValuesInTechDesign \ 1033 : , [84],
CITATION Mantzana2017IGOHCaps \ 1033 : , [85],
CITATION Hennik22Qual \ 1033 : , [86],
CITATION Squire24QualData \ 1033 : , [87],
CITATION Hennik22Qual \ 1033 : , [86],
CITATION Saba2021ExerciseStressTest \ 1033 : , [88],
CITATION Kraal2014TelerehabinCR \ 1033 : , [89],

Original Paper

- CITATION Razzouk2021DesignThinking \ 1033 : , [90],
 CITATION spencer2009cardsorting \ 1033 : , [91],
 CITATION Knoche2022IntelligentDataDriven \ 1033 : , [92],
 CITATION Kinast2021TelemonitoringCardio \ 1033 : , [18],
 CITATION Byrne2022thematicanalysis \ 1033 : , [93],
 CITATION Brouwers2020CTR2 \ 1033 : , [33],
 CITATION Falter2020CRIdealTool \ 1033 : , [29],
 CITATION Dinesen2018Telerehab \ 1033 : , [94],
 CITATION Joensson2019ParticipatoryCTR \ 1033 : , [74],
 CITATION Tadas2021Transitions \ 1033 : , [95],
 CITATION Akinsiku2021ExperientialInfo \ 1033 : , [96],
 CITATION Geurts2016GamfieldTelerehab \ 1033 : , [97],
 CITATION Andersen2023DataWorkConsumer \ 1033 : , [98],
 CITATION Gupta2020ObjectiveDataCons \ 1033 : , [99],
 CITATION Seals2022CTRSclerosisClinsPercep \ 1033 : , [100],
 CITATION Rodrigues2021Barriers \ 1033 : , [101],
 CITATION Mencarini2019WearablesSport \ 1033 : , [102],
 CITATION Primenko2020Depersonalization \ 1033 : , [103],
 CITATION VanDePoel2013ValueHyrarchy \ 1033 : , [104],
 CITATION Collins2018MOST \ 1033 : , [105],
 CITATION Cugusi2019GenderImbalance \ 1033 : , [106],
 CITATION Kristofferzon2007WOmenandmenCR \ 1033 : , [107],
 CITATION Jackson2005Referral \ 1033 : , [108],
 CITATION Berkel2023ImplicationsDesign \ 1033 : , [109],
 CITATION Dourish2006ImplicationsDesign \ 1033 : , [110],
- [1] E. Wilkins, L. Wilson, K. Wickramasinghe, P. Bhatnagar, J. Leal, R. Luengo-Fernandez, R. Burns, M. Rayner and N. Townsend, European Cardiovascular Disease Statistics 2017, European Heart Network, 2017.
 - [2] A. Pelliccia, S. Sharma, S. Gati, M. Bäck, M. Börjesson, S. Caselli, J. P. Collet, D. Corrado, J. A. Drezner, M. Halle, D. Hansen, H. Heidbuchel, J. Myers, J. Niebauer, M. Papadakis, M. F. Piepoli, E. Prescott and J. W. Roos-Hesselink, "Guidelines on sports cardiology and exercise in patients with cardiovascular disease," *European heart journal*, vol. 42, no. 1, p. 17–96, 2021.
 - [3] L. Anderson, N. Oldridge, D. R. Thompson, A. D. Zwisler, K. Rees, N. Martin and R. S. Taylor, "Exercise-Based Cardiac Rehabilitation for Coronary Heart Disease: Cochrane Systematic Review and Meta-Analysis," *Journal of the American College of Cardiology*, vol. 67, no. 1, pp. 1-12, 2016.
 - [4] I. Kondatrova and H. Fournier, "Virtual Cardiac Rehabilitation in a Pandemic Scenario: A Review of HCI Design Features, User Acceptance and Barriers," 2022.
 - [5] A. Peretti, F. Amenta, S. Tayebati, G. Nittari and S. Mahdi, "Telerehabilitation: Review of the State-of-the-Art and Areas of Application," *JMIR Rehabil Assist Technol*, vol. 4, no. 2, 2017.
 - [6] U. Nilsson, B. Öberg and M. Bäck, "Patients' Perceptions of Exercise-Based Cardiac Telerehabilitation after a Myocardial Infarction—A Qualitative Study," *International Journal of Environmental Research and Public Health*, vol. 20, no.

Original Paper

- 7, 2023.
- [7] M. Davis, M. Freeman, J. Kaye, N. Vuckovic and D. Buckley, "A Systematic Review of Clinician and Staff Views on the Acceptability of Incorporating Remote Monitoring Technology into Primary Care," *Telemedicine and e-Health*, vol. 20, no. 5, pp. 428-438, 2014.
 - [8] Y. Morimoto, T. Takahashi, R. Sawa, M. Saitoh, T. Morisawa, N. Kagiya, T. Kasai, B. Dinesen, M. Hollingdal, J. Refsgaard and H. Daida, "Web Portals for Patients With Chronic Diseases: Scoping Review of the Functional Features and Theoretical Frameworks of Telerehabilitation Platforms," *J Med Internet Res*, vol. 24, no. 1, p. e27759, 2022.
 - [9] C. Munteanu, B. Axtell, H. Rafih, A. Liaqat and Y. Aly, "Designing for Older Adults: Overcoming Barriers to a Supportive, Safe, and Healthy Retirement," *The Disruptive Impact of FinTech on Retirement Systems*, pp. 104-126, 2019.
 - [10] T. Tsai, W. Lin, Y. Chang, P. Chang and M. Lee, "Technology anxiety and resistance to change behavioral study of a wearable cardiac warming system using an extended TAM for older adults," *PLOS ONE*, vol. 15, no. 1, 2020.
 - [11] S. Tadas, J. Dickson and D. Coyle, "Using Patient-Generated Data to Support Cardiac Rehabilitation and the Transition to Self-Care," *Conference on Human Factors in Computing Systems - Proceedings*, p. 16, 2023.
 - [12] T. W. Churchill and A. L. Baggish, "Cardiovascular Care of Masters Athletes," *Journal of cardiovascular translational research*, vol. 13, 2020.
 - [13] V. L. Aengevaeren, A. Mosterd, T. L. Braber, N. H. J. Prakken, P. A. Doevendans, D. E. Grobbee, P. D. Thompson, T. M. H. Eijssvogels and B. K. Velthuis, "Relationship Between Lifelong Exercise Volume and Coronary Atherosclerosis in Athletes," *Circulation*, vol. 136, 2017.
 - [14] M. M. T. G. S. J. G. R. M. J. Mittleman MA, "Triggering of acute myocardial infarction by heavy physical exertion. Protection against triggering by regular exertion. Determinants of Myocardial Infarction Onset Study Investigators," *The New England journal of medicine*, vol. 329, no. 23, 1993.
 - [15] V. Čulić, A. Alturki, R. Vio, R. Proietti and A. Jerončić, "Acute myocardial infarction triggered by physical exertion: a systematic review and meta-analysis," *Eur J Prev Cardiol.*, vol. 30, no. 9, pp. 794-804, 2023.
 - [16] G. Claessen, T. M. H. Eijssvogels, C. M. Albert, A. L. Baggish, B. D. Levine, E. Marijon, E. D. Michos and A. L. Gerche, "Coronary atherosclerosis in athletes: emerging concepts and preventive strategies," *European Heart Journal*, p. ehae927, 2025.
 - [17] J. McKinney, J. Velghe, J. Fee, S. Isserow and J. Drezner, "Defining Athletes and Exercisers," *Am J Cardiol.*, vol. 123, no. 3, pp. 532-535, 2019.
 - [18] B. Kinast, M. Lutz and B. Schreiweis, "Telemonitoring of real-world health data in cardiology: A systematic review," *International Journal of Environmental Research and Public Health*, vol. 18, 2021.
 - [19] P. Kakria, N. Tripathi and P. Kitipawang, "A real-time health monitoring system for remote cardiac patients using smartphone and wearable sensors," *International Journal of Telemedicine and Applications*, 2015.
 - [20] C. Worringham, A. Rojek and I. Stewart, "Development and Feasibility of a

Original Paper

- Smartphone, ECG and GPS Based System for Remotely Monitoring Exercise in Cardiac Rehabilitation," *PLOS ONE*, vol. 6, p. e14669, 2011.
- [21] H. De Cannière, F. Corradi, C. Smeets, M. Schoutteten, C. Varon, C. Van Hoof, S. Van Huffel, W. Groenendaal and P. Vandervoort, "Wearable Monitoring and Interpretable Machine Learning Can Objectively Track Progression in Patients during Cardiac Rehabilitation," *Sensors 2020*, Vol. 20, Page 3601, 2020.
- [22] I. Thijs, L. Fresiello, W. Oosterlinck, P. Sinnaeve and F. Rega, "Assessment of Physical Activity by Wearable Technology During Rehabilitation After Cardiac Surgery: Explorative Prospective Monocentric Observational Cohort Study," *JMIR mHealth and uHealth*, vol. 7, no. 1, 2019.
- [23] B. Pavy, J. Darchis, E. Merle and M. Caillon, "La réadaptation cardiaque des patients « sportifs » [Cardiac rehabilitation in "sports" patients]," *Ann Cardiol Angeiol (Paris)*, vol. 65, no. 5, pp. 311-317, 2016.
- [24] D. M. N. J. L. A. S. C. S. E. H. M. A. E. B. A. C. F. C. S. P. M. P. A. R. H. S. L. S. S. v. B. F. P. A. Borjesson M, "Recommendations for participation in leisure time or competitive sports in athletes-patients with coronary artery disease: a position statement from the Sports Cardiology Section of the European Association of Preventive Cardiology (EAPC)," *Eur Heart J.*, vol. 40, no. 1, pp. 13-18, 2019.
- [25] S. Sankaran, K. Luyten, D. Hansen, P. Dendale and K. Coninx, "Motivation through Intelligibility in Cardiac Tele-rehabilitation," *Interacting with Computers*, vol. 31, no. 2, pp. 122-137, 2019.
- [26] S. Sankaran, K. Luyten, D. Hansen, P. Dendale and K. Coninx, "A grounded approach for applying behavior change techniques in mobile cardiac tele-rehabilitation," *ACM International Conference Proceeding Series*, Vols. 29-June-2016, 2016.
- [27] S. Sankaran, K. Luyten, D. Hansen, P. Dendale and K. Coninx, "Have You Met Your METs? – Enhancing Patient Motivation to Achieve Physical Activity Targets in Cardiac Tele-rehabilitation," *Proceedings of the 32nd International BCS Human Computer Interaction Conference, HCI 2018*, 2018.
- [28] S. Quazi and J. Malik, "A Systematic Review of Personalized Health Applications through Human–Computer Interactions (HCI) on Cardiovascular Health Optimization," *Journal of Cardiovascular Development and Disease 2022*, vol. 9, p. 273, 2022.
- [29] M. Falter, M. Scherrenberg and P. Dendale, "Digital Health in Cardiac Rehabilitation and Secondary Prevention: A Search for the Ideal Tool," *Sensors*, vol. 21, no. 1, 2020.
- [30] A. Beilegoli, S. Champion, R. Tirimacco, K. Nesbitt, P. Tideman and R. Clark, "A co-designed telehealth-based model of care to improve attendance and completion to cardiac rehabilitation of rural and remote Australians: The Country Heart Attack Prevention (CHAP) project," *J Telemed Telecare*, vol. 27, no. 10, pp. 685-690, 2021.
- [31] R. Cruz-Martínez, J. Wentzel, B. Bente, R. Sanderman and J. van Gemert-Pijnen, "Toward the Value Sensitive Design of eHealth Technologies to Support Self-management of Cardiovascular Diseases: Content Analysis," *JMIR Cardio*, vol. 5, no. 2, p. e31985, 2021.

Original Paper

- [32] R. Hwang, E. Gane and N. Morris, "No transport? No worries! Cardiac telerehabilitation is a feasible and effective alternative to centre-based programs.," *Heart Fail Rev*, vol. 1, pp. 1277-1284, 2023.
- [33] R. Brouwers, H. van Exel, J. van Hal and e. al., "Cardiac telerehabilitation as an alternative to centre-based cardiac rehabilitation.," *Neth Heart J*, vol. 28, p. 443–451, 2020.
- [34] B. Friedman, P. Kahn, A. Borning and A. Huldtgren, "alue Sensitive Design and Information Systems. In: Doorn, N., Schuurbiens, D., van de Poel, I., Gorman, M. (eds) Early engagement and new technologies: Opening up the laboratory," *Philosophy of Engineering and Technology*, vol. 16, 2013.
- [35] B. Friedman and D. G. Hendry, Value Sensitive Design: Shaping Technology with Moral Imagination, The MIT Press, 2019.
- [36] R. Cruz-Martínez, J. Wentzel, R. Asbjørnsen, P. Noort, J. van Niekerk, R. Sanderman and J. van Gemert-Pijnen, "Supporting Self-Management of Cardiovascular Diseases Through Remote Monitoring Technologies: Metaethnography Review of Frameworks, Models, and Theories Used in Research and Development," *J Med Internet Res*, vol. 22, no. 5, p. e16157, 2020.
- [37] Y. Song, C. Ren, P. Liu, L. Tao, W. Zhao and W. Gao, "Effect of Smartphone-Based Telemonitored Exercise Rehabilitation among Patients with Coronary Heart Disease," *J Cardiovasc Transl Res*, vol. 13, no. 4, pp. 659-667, 2020.
- [38] L. Anderson, G. Sharp, R. Norton, H. Dalal, S. Dean, K. Jolly, A. Cowie, A. Zawada and R. Taylor, "Home-based versus centre-based cardiac rehabilitation," *Cochrane Database Syst Rev*, 2017.
- [39] R. Maddison, J. C. Rawstorn, R. A. H. Stewart, J. Benatar, R. Whittaker, A. Rolleston, Y. Jiang, L. Gao, M. Moodie, I. Warren, A. Meads and N. Gant, "Effects and costs of real-time cardiac telerehabilitation: randomised controlled non-inferiority trial," *Heart (British Cardiac Society)*, vol. 105, no. 2, pp. 122-129, 2019.
- [40] J. A. Snoek, E. I. Prescott, A. E. van der Velde, T. M. H. Eijsvogels, N. Mikkelsen, L. F. Prins, W. Bruins, E. Meindersma, J. R. González-Juanatey, C. Peña-Gil, V. González-Salvado, F. Moatemri, M. C. Iliou, T. Marcin, P. Eser, M. Wilhelm and A. Van't Hof, "Effectiveness of Home-Based Mobile Guided Cardiac Rehabilitation as Alternative Strategy for Nonparticipation in Clinic-Based Cardiac Rehabilitation Among Elderly Patients in Europe: A Randomized Clinical Trial," *JAMA Cardiology*, vol. 6, no. 4, pp. 463-468, 2021.
- [41] J. Schmid, J. Adams and D. & Cheng, "Cardiac rehabilitation of a 77-year-old male runner: consideration of the athlete, not the age," *Proceedings (Baylor University. Medical Center)*, vol. 22, no. 1, 2009.
- [42] B. Hathorn and L. Rodgers, "Cardiac rehabilitation testing of a high-intensity performance athlete firefighter after myocardial infarction, placement of stents and an implantable cardioverter-defibrillator," *Proceedings (Baylor University. Medical Center)*, vol. 35, no. 2, pp. 219-221, 2021.
- [43] N. Weber, A. Weber, P. Carbone, A. Lawrence, T. Bilbrey, J. M. Schussler and J. Adams, "High-intensity, sport-specific cardiac rehabilitation training of a 22-year-old competitive cyclist after spontaneous coronary artery dissection.,"

Original Paper

- Proceedings (Baylor University. Medical Center)*, vol. 31, no. 2, p. 207–209, 2018.
- [44] T. Andersen, H. Langstrup and S. Lomborg, "Experiences With Wearable Activity Data During Self-Care by Chronic Heart Patients: Qualitative Study," *J Med Internet Res*, vol. 22, no. 7, p. e15873, 2020.
- [45] M. Pandey, M. Nebeling, S. Y. Park and S. Oney, "Exploring Tracking Needs and Practices of Recreational Athletes," 2019.
- [46] J. Tholander and S. Nylander, "Snot, sweat, pain, mud, and snow - performance and experience in the use of sports watches," *Conference on Human Factors in Computing Systems - Proceedings*, Vols. 2015-April, pp. 2913-2922, 2015.
- [47] S. Tadas and D. Coyle, "Barriers to and Facilitators of Technology in Cardiac Rehabilitation and Self-Management: Systematic Qualitative Grounded Theory Review," *J Med Internet Res*, vol. 22, no. 11, p. e18025, 2020.
- [48] R. Dionigi, J. Fraser-Thomas and J. Logan, "The nature of family influences on sport participation in Masters athletes," *Annals of Leisure Research*, vol. 15, no. 2, pp. 366-388, 2012.
- [49] B. E. Bente, J. Wentzel, R. G. H. Groeneveld, R. V. H. I. Jzerman, D. R. de Buissonjé, L. D. Breeman, V. R. Janssen, R. Kraaijenhagen, M. E. Pieterse, A. W. M. Evers and J. E. W. C. & van Gemert-Pijnen, "Values of Importance to Patients With Cardiovascular Disease as a Foundation for eHealth Design and Evaluation: Mixed Methods Study," *JMIR Cardio* 2021, vol. 5, no. 2, p. e33252, 2021.
- [50] Hartstichting, "Hartrevalidatie," [Online]. Available: <https://www.hartstichting.nl/hart-en-vaatziekten/behandelingen/hartrevalidatie>. [Accessed 3 2024].
- [51] E. C. U. European Association of Cardiovascular Prevention and Rehabilitation Committee for Science Guidelines, M. F. Piepoli, F. Carré, P. Heuschmann, U. Hoffmann, M. Verschuren, J. Halcox, G. P. Document Reviewers, H. Saner, D. Wood and Pie, "Secondary prevention through cardiac rehabilitation: physical activity counselling and exercise training: key components of the position paper from the Cardiac Rehabilitation Section of the European Association of Cardiovascular Prevention and Rehabilitat," *European heart journal*, vol. 31, no. 16, pp. 1967--1974, 2010.
- [52] S. Cramer, "Interventions to Improve Recovery after Stroke," *Stroke: Pathophysiology, Diagnosis, and Management*, pp. 972-880, 2015.
- [53] H. Ramachandran, Y. Jiang, J. Teo, T. Yeo and W. Wang, "Technology Acceptance of Home-Based Cardiac Telerehabilitation Programs in Patients With Coronary Heart Disease: Systematic Scoping Review," *J Med Internet Res*, vol. 24, no. 1, p. e34657, 2022.
- [54] J. H. P. Burridge, A. C. W. D. P. C. G. Lee, R. P. Turk, M. P. Stokes, J. P. Whittall, R. P. Vaidyanathan, P. P. M. Clatworthy, A.-M. P. Hughes, C. M. Meagher, E. P. Franco and L. P. Yardley, "Telehealth, Wearable Sensors, and the Internet: Will They Improve Stroke Outcomes Through Increased Intensity of Therapy, Motivation, and Adherence to Rehabilitation Programs?," *Journal of Neurologic Physical Therapy*, vol. 31, pp. S32-S38, 2017.
- [55] S. Conroy, S. Harcum, L. Keldsen and C. Bever, "Novel use of existing

Original Paper

- technology: A preliminary study of patient portal use for telerehabilitation," *Journal of Telemedicine and Telecare*, vol. 28, no. 5, pp. 380-38, 2022.
- [56] M. Falter, M. Scherrenberg and P. Dendale, "Digital Health in Cardiac Rehabilitation and Secondary Prevention: A Search for the Ideal Tool," *Sensors (Basel, Switzerland)*, vol. 21, no. 1, pp. 1-11, 2020.
- [57] I. Afyouni, A. Einea and A. Murad, "Towards an adaptive gaming framework for telerehabilitation," *ACM International Conference Proceeding Series*, pp. 305-306, 2019.
- [58] B. Dinesen, L. Dittmann, J. Gade, C. Jørgensen, M. Hollingdal, S. Leth, C. Melholt, H. Spindler and J. Refsgaard, ""Future Patient" Telerehabilitation for Patients With Heart Failure: Protocol for a Randomized Controlled Trial," *JMIR Res Protoc*, vol. 8, no. 9, p. e14517, 2019.
- [59] C. Melholt, K. Joensson, H. Spindler, J. Hansen, J. J. Andreasen, G. Nielsen, A. Noergaard, A. Tracey, C. Thorup, R. Kringelholt and B. I. Dinesen, "Cardiac patients' experiences with a telerehabilitation web portal: Implications for eHealth literacy," *Patient Education and Counseling*, vol. 101, no. 5, pp. 854-861, 2018.
- [60] M. Kjærup, S. Kouzeli, M. B. Skov, J. Kjeldskov, C. S. Skov and P. & Søgaaard, "Diagnostic agents: Collaborative interpretation for cardiac patients at home," *Conference on Human Factors in Computing Systems - Proceedings*, Vols. 2018-April, 2018.
- [61] A. M. Clark, B. J. Sousa, C. F. Ski, J. Redfern, L. Neubeck, S. Allana, A. Peart, D. MacDougall and D. R. & Thompson, "Main Mechanisms of Remote Monitoring Programs for Cardiac Rehabilitation and Secondary Prevention: A SYSTEMATIC REVIEW," *Journal of Cardiopulmonary Rehabilitation and Prevention*, vol. 43, no. 6, pp. 412-418, 2023.
- [62] O. Duff, D. Walsh, S. Malone, L. McDermott, B. Furlong, N. O'Connor, K. Moran and C. & Woods, "MedFit App, a Behavior-Changing, Theoretically Informed Mobile App for Patient Self-Management of Cardiovascular Disease: User-Centered Development," *JMIR Formative Research*, vol. 2, no. 1, 2018.
- [63] P. Athilingam, M. A. Labrador, E. F. Remo, L. Mack, A. B. San Juan and A. F. & Elliott, "Features and usability assessment of a patient-centered mobile application (HeartMapp) for self-management of heart failure," *Applied nursing research : ANR*, 32, p. 156–163, 2016.
- [64] R. Brouwers, J. Kraal and S. e. a. Traa, "Effects of cardiac telerehabilitation in patients with coronary artery disease using a personalised patient-centred web application: protocol for the SmartCare-CAD randomised controlled trial," *BMC Cardiovasc Disord*, vol. 17, no. 46, 2017.
- [65] M. Dithmer, J. O. Rasmussen, E. Grönvall, H. Spindler, J. Hansen, G. Nielsen, S. B. Sørensen and B. & Dinesen, ""The Heart Game": Using Gamification as Part of a Telerehabilitation Program for Heart Patients," *Games for health journal*, vol. 5, no. 1, pp. 27-33, 2016.
- [66] E. Y. Ding, N. Erskine, W. Stut, D. D. McManus, A. Peterson, Z. Wang, J. Escobar Valle, D. Albuquerque, A. Alonso, N. F. Botkin, Q. R. Pack and D. D. & McManus, "MI-PACE Home-Based Cardiac Telerehabilitation Program for Heart Attack Survivors: Usability Study," *JMIR human factors*, vol. 8, no. 3, 2021.

Original Paper

- [67] I. Hallberg, A. Ranerup, U. Bengtsson and K. Kjellgren, "Experiences, expectations and challenges of an interactive mobile phone-based system to support self-management of hypertension: patients' and professionals' perspectives," *Patient Prefer Adherence*, vol. 28, pp. 467-476, 2018.
- [68] J. Rawstorn, N. Gant, A. Rolleston, R. Whittaker, R. Stewart, J. Benatar, I. Warren, A. Meads, Y. Jiang and R. Maddison, "End Users Want Alternative Intervention Delivery Models: Usability and Acceptability of the REMOTE-CR Exercise-Based Cardiac Telerehabilitation Program," *Arch Phys Med Rehabil*, vol. 99, no. 11, pp. 2373-2377, 2018.
- [69] I. Holeman and D. Kane, "Human-centered design for global health equity," *Information Technology for Development*, vol. 26, no. 3, pp. 477-505, 2020.
- [70] A. Min, W. R. Miller, L. M. Rocha, K. Börner, R. Brattig Correia and P. C. & Shih, "Understanding Contexts and Challenges of Information Management for Epilepsy Care," *Conference on Human Factors in Computing Systems - Proceedings*, no. 23, p. 15, 2023.
- [71] Y. J. Cha, A. Wou, A. Saxena, J. Lee, M. W. Newman and S. Y. Park, "{It's Like an Educated Guessing Game: Parents' Strategies for Collaborative Diabetes Management with Their Children," *Conference on Human Factors in Computing Systems - Proceedings*, no. 23, p. 15, 2023.
- [72] K. Sepehri, L. Holsti, S. Niasati, V. Chan and K. E. & MacLean, "Beyond the Bulging Binder: Family-Centered Design of a Digital Health Information Management System for Caregivers of Children Living with Health Complexity," *Conference on Human Factors in Computing Systems - Proceedings*, no. 23, 2023.
- [73] K. S. Bhat, A. K. Hall, T. Kuo and N. Kumar, ""We are half-doctors": Family Caregivers as Boundary Actors in Chronic Disease Management," *Proceedings of the ACM on Human-Computer Interaction*, no. CSCW1, 2023.
- [74] K. Joensson, C. Melholt, J. Hansen, S. Leth, H. Spindler, M. V. Olsen and B. & Dinesen, "Listening to the patients: using participatory design in the development of a cardiac telerehabilitation web portal," *mHealth*, vol. 5, no. 0, 2019.
- [75] A. Khanshan, L. Giling, P. Markopoulos and P. & van Gorp, "A Case Study of Data-Enabled Design for Cardiac Telemonitoring," *ACM International Conference Proceeding Series*, no. 23, 2023.
- [76] B. Dinesen, G. Nielsen, J. Andreasen and S. H, "Integration of Rehabilitation Activities Into Everyday Life Through Telerehabilitation: Qualitative Study of Cardiac Patients and Their Partners," *J Med Internet Res*, vol. 21, no. 4, p. e13281, 2019.
- [77] B. Friedman, P. Kahn, A. Borning, P. Zhang and D. Galletta, *Value Sensitive Design and Information Systems, The Handbook of Information and Computer Ethics*, 2006.
- [78] B. Friedman, D. Hendry and A. Borning, "A Survey of Value Sensitive Design Methods," *Foundations and Trends® in Human-Computer Interaction*, vol. 11, no. 2, pp. 63-125, 2017.
- [79] J. Gemert-Pijnen, N. Nijland, M. Limburg, H. Ossebaard, S. Kelders, G. Eysenbach and E. Seydel, "A Holistic Framework to Improve the Uptake and Impact of eHealth Technologies," *Journal of medical Internet research*, vol. 13, p.

Original Paper

- e111, 2011.
- [80] A. Cenci, S. Ilskov and N. e. a. Andersen, "The participatory value-sensitive design (VSD) of a mHealth app targeting citizens with dementia in a Danish municipality," *AI and Ethics*, vol. 1, pp. 1-27, 2023.
 - [81] R. Asbjørnsen, J. Wentzel, M. Smedsrød, J. Hjelmæsæth, M. Clark, N. L. Solberg and J. Van Gemert-Pijnen, "identifying Persuasive Design Principles and Behavior Change Techniques Supporting End User Values and Needs in eHealth Interventions for Long-Term Weight Loss Maintenance: Qualitative Study," *J Med Internet Res*, vol. 22, no. 11, p. e22598, 2020.
 - [82] J. Giacomini, "What is Human Centred Design?," *Design Journal*, vol. 17, no. 4, pp. 606-623, 2014.
 - [83] International Collaboration for Participatory Health Research (ICPHR), "Position Paper 1: What is Participatory Health Research?," International Collaboration for Participatory, Berlin, 2013.
 - [84] J. van den Hoven, P. Vermaas and I. van de Poel, *Handbook of ethics, values, and technological design: Sources, theory, values and application domains*, Springer Netherlands, 2015.
 - [85] V. Mantzana, M. Themistocleous, Z. Irani and V. Morabito, "Identifying healthcare actors involved in the adoption of information systems," *European Journal of Information Systems*, vol. 16, no. 1, pp. 91-102, 2007.
 - [86] M. Hennik and B. N. Kaiser, "Sample sizes for saturation in qualitative research: A systematic review of empirical tests," *Soc Sci Med*, p. 292:114523, 2022.
 - [87] C. M. Squire, K. C. Giombi, D. J. Rupert, J. Amoozegar and P. Williams, "Determining an Appropriate Sample Size for Qualitative Interviews to Achieve True and Near Code Saturation: Secondary Analysis of Data," *J Med Internet Res*, p. 26:e52998, 2024.
 - [88] M. G. S. A. M. B. e. a. Saba, "Correlation Between the 6-Min Walk Test and Exercise Tolerance Test in Cardiac Rehabilitation After Coronary Artery Bypass Grafting: A Cross-sectional Study," *Cardiology and Therapy*, vol. 10, no. 1, pp. 201-209, 2021.
 - [89] J. J. Kraal, N. Peek, M. E. van den Akker-Van Marle and H. m. & Kemps, "Effects of home-based training with telemonitoring guidance in low to moderate risk patients entering cardiac rehabilitation: short-term results of the FIT@Home study," *European Journal of Preventive Cardiology*, vol. 21, pp. 26-31, 2014.
 - [90] R. Razzouk and V. Shute, "What Is Design Thinking and Why Is It Important?," *Review of Educational Research*, vol. 82, no. 1, pp. 330-348, 2021.
 - [91] D. Spencer and J. Garrett, *Card Sorting: Designing Usable Categories*, Rosenfeld Media, 2009.
 - [92] H. Knoche, A. Abdul-Rahman, L. Clark, V. Curcin, Z. Huo, L. H. Iwaya, O. Lemon, R. Mikulík, T. Neate, A. Roper, M. M. Skovfoged, N. Verdezoto, S. Wilson and H. & Ziadeh, "Identifying Challenges and Opportunities for Intelligent Data-Driven Health Interfaces to Support Ongoing Care," *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*, 2023.
 - [93] D. Byrne, "A worked example of Braun and Clarke's approach to reflexive thematic analysis.," *Quality and Quantity*, vol. 56, no. 3, pp. 1391-1412, 2022.

Original Paper

- [94] B. Dinesen and H. Spindler, "The Use of Telerehabilitation Technologies for Cardiac Patients to Improve Rehabilitation Activities and Unify Organizations: Qualitative Study," *JMIR Rehabil Assist Technol*, vol. 5, no. 2, p. e10758, 2018.
- [95] P. C. F. E. G. T. L. S. C. D. Tadas S, "Transitions in Technology-Mediated Cardiac Rehabilitation and Self-management: Qualitative Study Using the Theoretical Domains Framework," *JMIR Cardio*, vol. 5, no. 2, p. e30428, 2021.
- [96] A. Akinsiku, Y. Graham, I. Avellino and H. Mentis, "It's not just the movement: Experiential information needed for stroke telerehabilitation," *Conference on Human Factors in Computing Systems - Proceedings*, 2021.
- [97] E. Geurts, D. Hansen, K. Coninx and P. & Dendale, "Back on bike: The BoB mobile cycling app for secondary prevention in cardiac patients," *Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services*, pp. 135-146, 2016.
- [98] T. O. Andersen, J. Fritsch and S. & Matthiesen, "Patient Data Work with Consumer Self-tracking: Exploring Affective and Temporal Dimensions in Chronic Self-care," *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST*, vol. 488 LNICST, pp. 666-680, 2023.
- [99] A. Gupta, T. Heng, C. Shaw, D. Gromala, J. Leese and L. & Li, "Oh, i didn't do a good job: How objective data affects physiotherapist-patient conversations for arthritis patients," *ACM International Conference Proceeding Series*, pp. 156-165, 2020.
- [100] A. Seals, G. Pilloni, J. Kim, R. Sanchez, J. R. Rizzo, L. Charvet, O. Nov and G. & Dove, "'Are They Doing Better In The Clinic Or At Home?': Understanding Clinicians' Needs When Visualizing Wearable Sensor Data Used In Remote Gait Assessments For People With Multiple Sclerosis," *Conference on Human Factors in Computing Systems - Proceedings*, 2022.
- [101] T. Cohen Rodrigues, D. de Buissonjé, M. Keesman, T. Reijnders, J. van der Geer, V. Janssen, R. Kraaijenhagen, D. Atsma and A. Evers, "Facilitators of and Barriers to Lifestyle Support and eHealth Solutions: Interview Study Among Health Care Professionals Working in Cardiac Care," *J Med Internet Res*, vol. 23, no. 10, p. e25646, 2021.
- [102] E. Mencarini, A. Rapp, L. Tirabeni and M. & Zancanaro, "Designing Wearable Systems for Sports: A Review of Trends and Opportunities in Human-Computer Interaction," *IEEE Transactions on Human-Machine Systems*, vol. 49, no. 8, pp. 314-325, 2019.
- [103] D. Primenko, A. Spevakov and S. Spevakova, "Depersonalization of Personal Data in Information Systems," *Lecture Notes in Electrical Engineering*, vol. 641 LNEE, pp. 763-770, 2020.
- [104] I. van De Poel, "Translating Values into Design Requirements," *Philosophy of Engineering and Technology*, vol. 15, pp. 253-266, 2013.
- [105] L. Collins, *Optimization of Behavioral, Biobehavioral, and Biomedical Interventions*, Cham: Springer International Publishing, 2018.
- [106] L. Cugusi and G. Mercurio, "A systematic overview to quantify the gender imbalance in cardiovascular rehabilitation trials," *European Journal of Preventive*

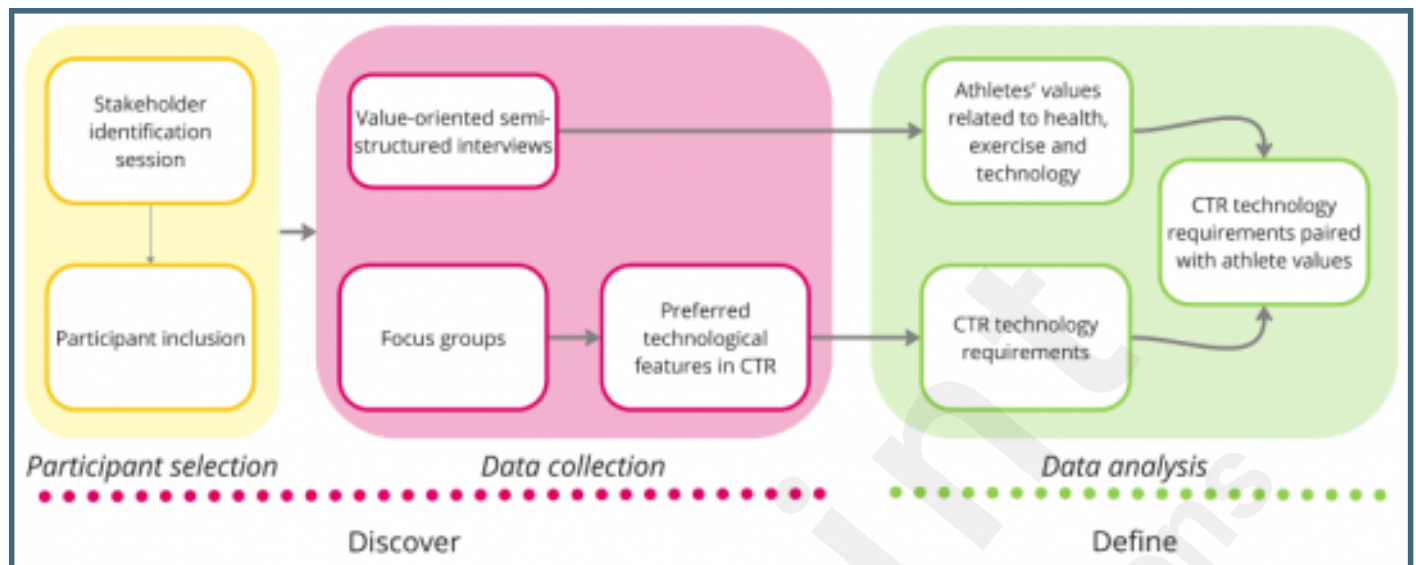
Original Paper

- Cardiology*, vol. 26, no. 7, pp. 776-781, 2019.
- [107] M. L. R. C. M. Kristofferzon, "Striving for balance in daily life: experiences of Swedish women and men shortly after a myocardial infarction," *Journal of Clinical Nursing*, vol. 16, no. 2, pp. 391-401, 2007.
- [108] L. Jackson, J. Leclerc, Y. Erskine and W. Linden, "Getting the most out of cardiac rehabilitation: A review of referral and adherence predictors," *Heart*, vol. 91, no. 1, pp. 10-14, 2005.
- [109] N. van Berkel and K. Hornbæk, "Implications of Human-Computer Interaction Research," *Interactions*, vol. 30, no. 2, pp. 50-55, 2023.
- [110] P. Dourish, "Implications for design," *Conference on Human Factors in Computing Systems - Proceedings*, vol. 1, pp. 541-550, 2006.
- [111] R. W. M. Brouwers, A. Brini, R. W. F. H. Kuijpers, J. J. Kraal and H. M. C. & Kemps, "Predictors of non-participation in a cardiac telerehabilitation programme: a prospective analysis," *European heart journal. Digital health*, vol. 3, no. 1, pp. 81-89, 2021.

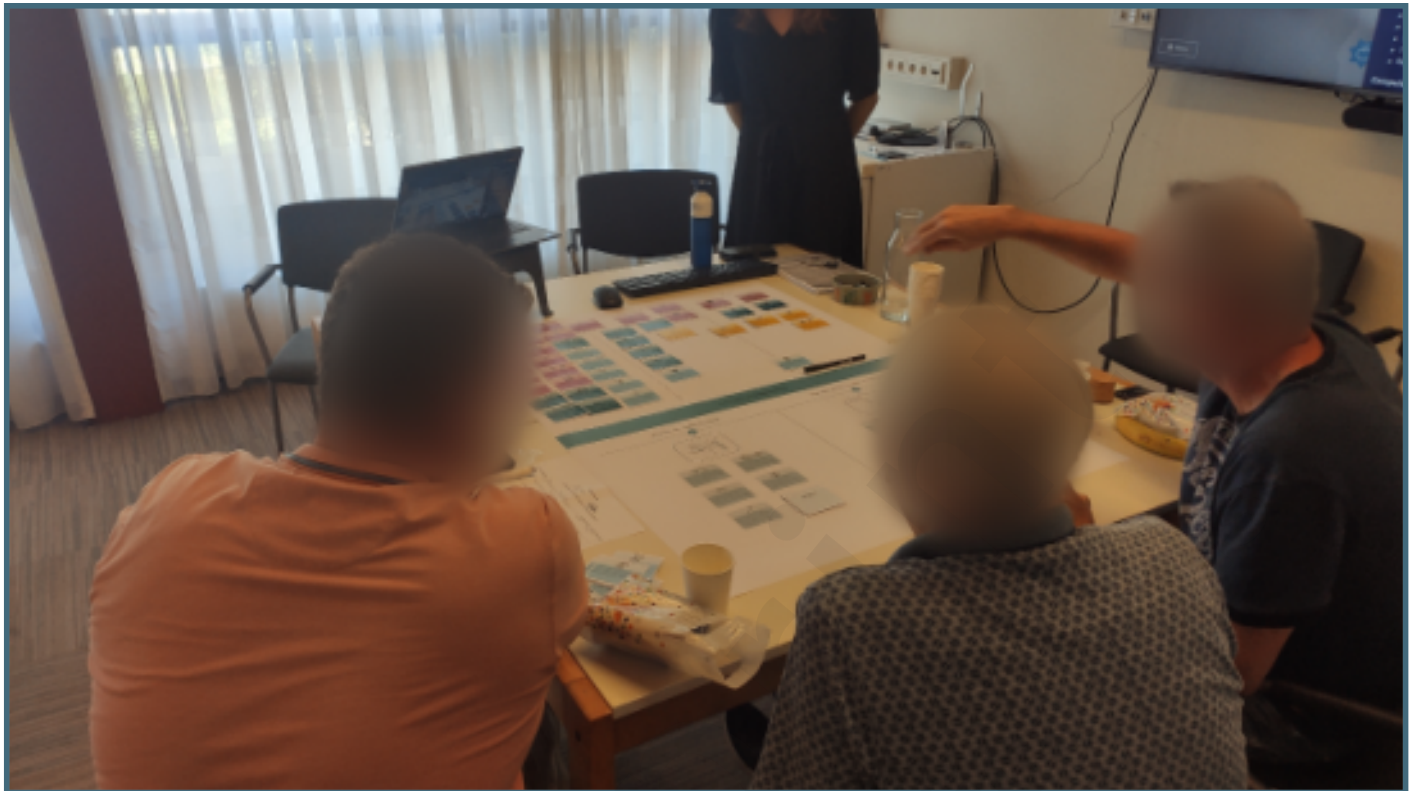
Supplementary Files

Figures

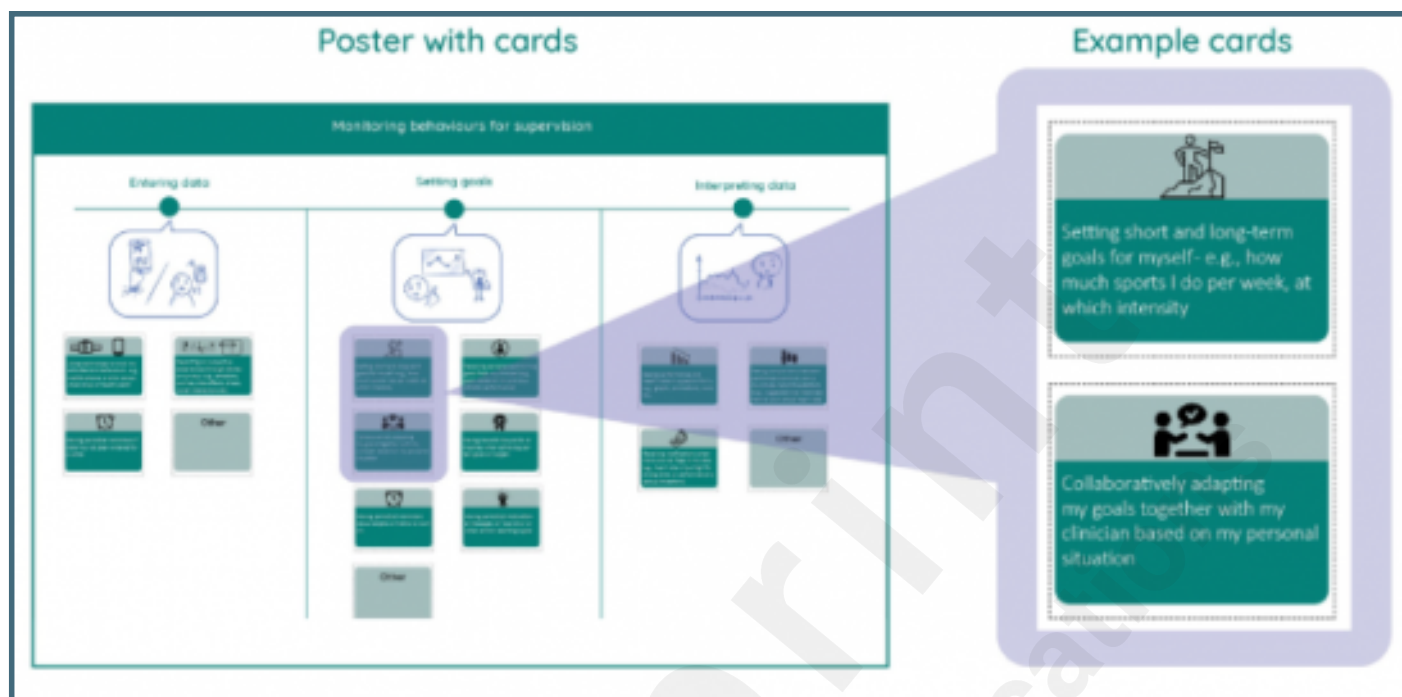
The structure of our study divided in two phases: (1) discover, including participant selection and data collection, and (2) define, including data analysis.



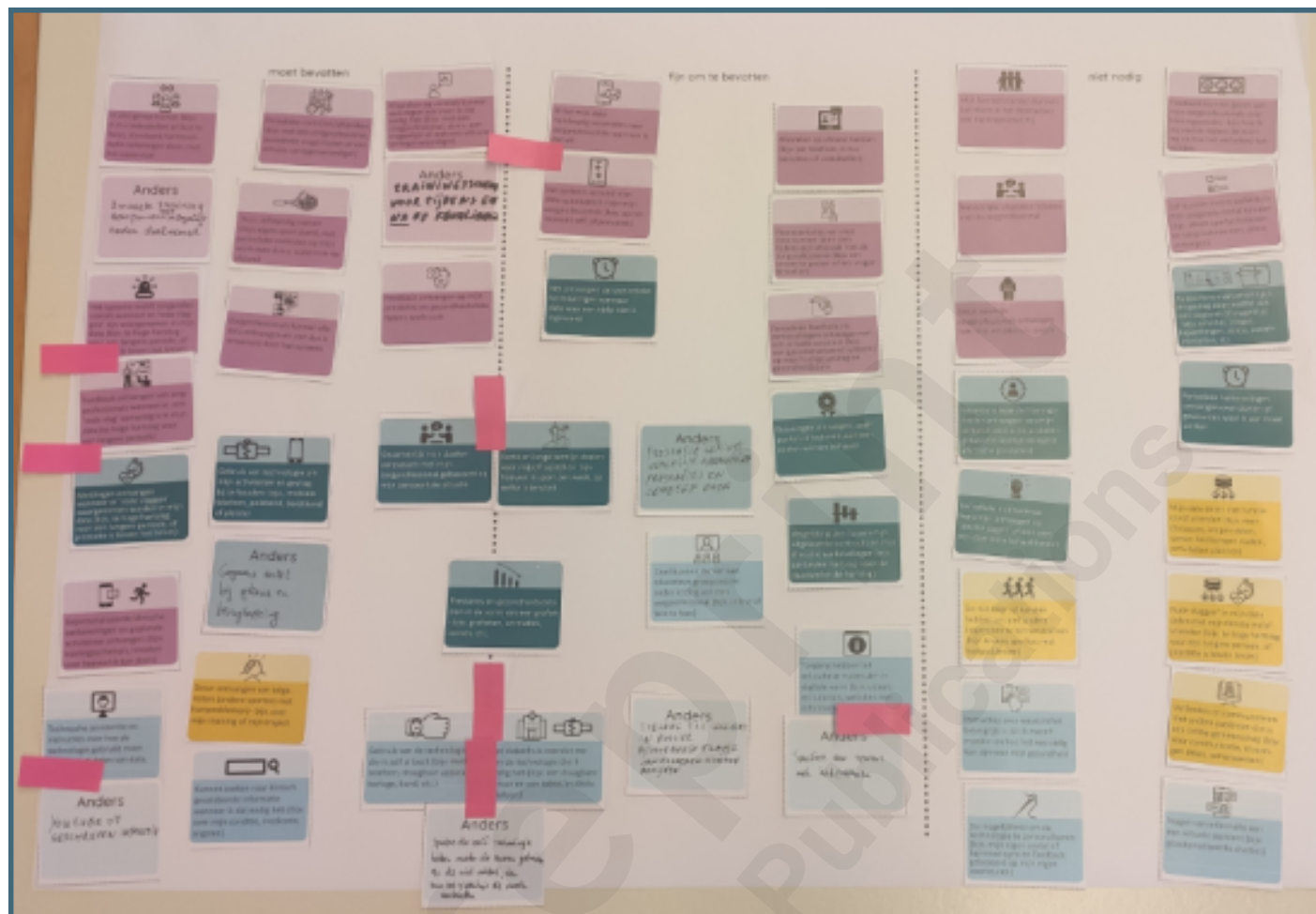
Focus group 4 - patients interacting with cards during the card-sorting session.



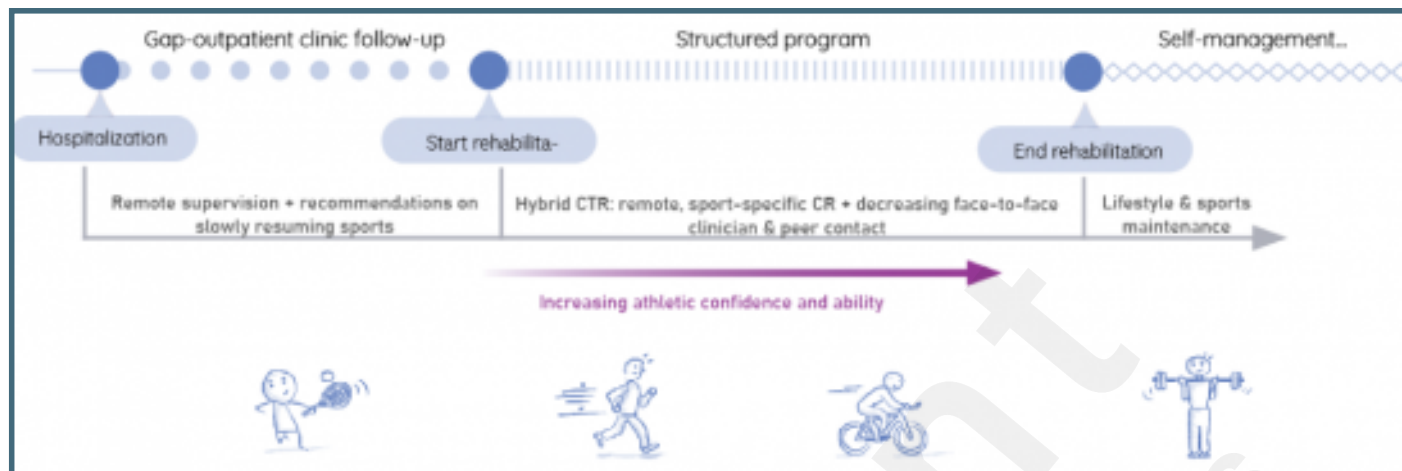
A poster with cards related to monitoring behaviours. Two example cards are zoomed in on the right. Sketches depicting sub-categories (e.g., setting goals) were inspired by the user journey of a patient interacting with intelligent health interfaces [92].



An example depicting card-sorting activity outcomes from focus group 1: cards from different categories sorted in must have, nice to have and not needed, from left to right.



For athletes, CTR provides chances to train in their sport at home before and during rehab under remote supervision, and having guidance after the program ends.



Multimedia Appendixes

This document contains interview scripts for athletes and healthcare professionals.

URL: <http://asset.jmir.pub/assets/b5f6c00eb099d3b86478ba47243dc700.docx>

This document contains the cards used in the card-sorting focus groups.

URL: <http://asset.jmir.pub/assets/96f02f98545b09c1c1e0fcfe9983122.pdf>

This document contains the codebook developed after analyzing the interview results and example quotes.

URL: <http://asset.jmir.pub/assets/65e9e95e1e280cd48122fe233ac6f165.docx>

This document contains the card sorting activity results - all cards sorted from most needed to least needed.

URL: <http://asset.jmir.pub/assets/15e20144b9dc700404f61e6691dd272a.pdf>

