Enabling Cardiac Rehabilitation at Home: A Web-Based Solution

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Cardiovascular diseases are alarmingly prevalent, impacting millions worldwide. Cardiac rehabilitation (CR) is a cornerstone of recovery, encompassing exercise, education, and lifestyle modifications. However, despite its proven benefits, adherence to and completion of CR programs remains suboptimal. Barriers such as cost, geographical constraints, and transportation difficulties hinder patient participation. In response, we pose the research question: How might we design a digital health solution to enhance accessibility and engagement in cardiac rehabilitation from the comfort of patients' homes? Leveraging design science research principles, we have meticulously crafted a web-based prototype. Our solution integrates personalized exercise regimens, educational modules, and progress tracking. By empowering patients to actively participate in their recovery journey, we aim to revolutionize CR delivery. This paper presents our ongoing progress, emphasizing the potential impact on patient outcomes and quality of life.

Keywords:
accessibility, adherence, cardiac rehabilitation (CR), cardiovascular diseases, design science research, digital health, exercise regimens, healthcare technology, home-based rehabilitation, patient-centric care, patient engagement, quality of life, remote monitoring, telehealth, web-based solution

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1 Introduction

Cardiovascular diseases (CVDs) pose a significant worldwide health challenge, affecting millions of individuals and placing substantial burdens on healthcare systems. In Australia, heart, stroke, and vascular diseases collectively impact approximately 5.2% of the population, equivalent to 1.3 million people (ABS, 2022). These conditions contribute to a staggering 25% of all deaths in the country (AIHW, 2023). Internationally, the picture is equally concerning, with CVDs being the leading cause of death, accounting for 32% of worldwide mortality (WHO, 2021). The prevalence of coronary heart disease and heart failure is rising, necessitating effective strategies for prevention, management, and rehabilitation.

Cardiac rehabilitation (CR) emerges as a pivotal component in the continuum of care for individuals with CVD. CR encompasses exercise training, risk factor management, and psychosocial counseling, aiming to optimize patient outcomes and enhance quality of life. Despite its proven benefits, CR remains underutilized, with participation rates commonly hovering below 50% (Beatty et al., 2023). Challenges such as geographical barriers, work commitments, and transportation difficulties contribute to this suboptimal adherence. Consequently, there is an urgent need to explore innovative approaches that enhance accessibility and engagement in CR.

Considering these challenges, our research question emerges: How might we design a digital health solution to enhance accessibility and engagement in cardiac rehabilitation from the comfort of patients' homes? This question is not only timely but also critical for addressing the gaps in CR delivery. By leveraging design science research principles, we have developed a web-based prototype solution that aims to revolutionize CR. Our approach integrates personalized exercise regimens, educational modules, and progress tracking, all accessible from the comfort of patients' homes. The potential impact of this solution extends beyond individual patients—it has the capacity to transform CR delivery, reduce disparities, and improve outcomes for people with CVD.

Our prototype represents a paradigm shift, aligning with the evolving landscape of digital health. By harnessing technology, we empower patients to actively participate in their recovery journey. The patient portal offers tailored content, evidence-based guidance, and interactive features. As we embark on this transformative path, we

emphasize that our solution is grounded in rigorous research methodologies. The principles of design science guide our every step, ensuring that evidence informs innovation. Through iterative development and user feedback, we strive to create a seamless, patient-centric experience that transcends geographical boundaries and fosters adherence.

In summary, our research endeavors to bridge the gap between evidence and practice. As we introduce this web-based cardiac rehabilitation solution—a demonstrable prototype—we invite stakeholders, including patients, clinicians, technology experts, and policymakers, to join us in this journey toward improved cardiovascular health. Together, we can unlock the full potential of CR, making it accessible, engaging, and impactful for all. We present a pilot study in this paper. The likes of extensive validation, user-testing, economic analysis and so on are out of scope for this paper but will be focused on in our future work.

2 Review of Relevant Works

Few tools have been developed at commercial scale to deliver at-home cardiac rehabilitation, and in this section we attempt to gain insights from them.

Developed by researchers at the Australian eHealth Research Centre in collaboration with Queensland Health, Cardihab™ (CSIRO, 2019) is an online cardiac rehabilitation platform. It provides convenient access to rehabilitation tools remotely. The platform includes a web portal for clinicians and a smartphone application for patients. Patients can engage in rehab from the comfort of their homes, reducing the need for frequent outpatient clinic visits. Cardihab™ delivers core components of cardiac rehab, such as education, behavior modification, and psychological counseling, tailored to patients' clinical needs. Clinicians can remotely access patient data through the web portal, enhancing communication and outcomes. Notably, Cardihab™ was commercialized in 2017 after raising venture capital and has demonstrated comparable or better health outcomes compared to traditional rehabilitation programs (CSIRO, 2019).

Carda Health (CardaHealth, 2023) offers an at-home virtual cardiac rehab program. It provides treatments similar to those expected from in-person cardiac rehab programs. Patients can participate in exercises and receive support remotely, making it a convenient option for home-based rehabilitation (CardaHealth, 2023).

During the COVID-19 pandemic, novel approaches to cardiac rehabilitation, including hybrid models, have emerged (Dalal et al., 2021). These models combine virtual and in-person elements, allowing greater patient choice and potentially increasing uptake of cardiac rehab. While not specific commercial tools, hybrid models offer flexibility and adaptability for patients seeking home-based rehab (Dalal et al., 2021).

It is also important to understand the limitations and gaps in the existing solutions for at-home cardiac rehabilitation. Some limitations and gaps can be identified as follows.

Firstly, while home-based tools like Cardihab™ and Carda Health offer convenience, some patients may find it challenging to engage consistently. Factors such as technological literacy, motivation, and adherence can impact the effectiveness of these tools. As such there is a need for interventions that address these engagement barriers to enhance long-term outcomes (Dalal et al., 2021).

Secondly, commercial tools may not adequately account for cultural diversity (Cardihab, 2022). Patients from different backgrounds may have varying preferences, beliefs, and health practices. A weakness lies in the lack of culturally tailored content, potentially affecting patient engagement and outcomes. As such, adopting more culturally sensitive approaches in cardiac rehab tools would be beneficial.

Thirdly, despite the promise of remote tools, geographic disparities persist (Cardihab, 2022). Patients in rural or underserved areas, in addition to challenges with transportation, may also face challenges accessing reliable internet or mobile networks. It is therefore important to focus on equitable access as well to cardiac rehab, perhaps with a multimodal approach comprising of downloadable text resources and phone consultations in addition to material like videos.

Fourthly, while tools focus on physical aspects, they often overlook psychosocial support. Emotional well-being, anxiety, and depression play crucial roles in recovery (Dalal et al., 2021). Existing tools may lack comprehensive strategies for addressing these aspects. Therefore, adopting holistic approaches that integrate additional services as mental health support is also important.

Lastly, cost implications pose a major barrier. Although home-based rehab is cost-effective compared to traditional center-based programs (Dalal et al., 2021), there are still cost implications. Some patients may struggle with out-of-pocket expenses related to technology, subscriptions, or equipment. As such, it is important to minimize financial barriers and promote affordability.

Motivated by such gaps, we aimed to develop a web-based prototype enabling at-home cardiac rehab, that could potentially have more robustness and flexibility in terms of factors such as ease-of-use, cultural sensitivity, ease-of-access, and affordability.

3 Relevant Theories: Design Science Research Methodology (DSRM)

This study involves designing artifacts, and therefore, the principles of Design Science Research Methodology (DSRM) (Baskerville et al., 2018) are followed.

The process of DSRM is for systematically conceptualizing, designing, developing, and assessing artifacts so that the desirability of the artifacts can be maximized to meet the stakeholder needs. The process typically includes six steps: (1) Problem identification and motivation; (2) Defining the objectives for a solution; (3) Design and development; (4) Demonstration, (5) Evaluation, and (6) Communication. Research can be integrated in each, or all of the first five steps. Research can aim at understanding and solving any issues to maximize the desirability of the artifacts. The landmark publications (Hevner et al., 2010; Hevner & Wickramasinghe, 2018; Peffers et al., 2007) are useful for more details.

In summary, DSRM combines creativity, practicality, and scholarly rigor to produce actionable solutions for real-world challenges. Through DSRM, researchers can engage with stakeholders, create artifacts, and contribute to both theory and practice.

4 Methodology

The DSRM-inspired methodology followed in this study is depicted in Figure 1. The participants of the design process are listed in Table 1. The subsections that follow are devoted for describing the various stages of the design process.

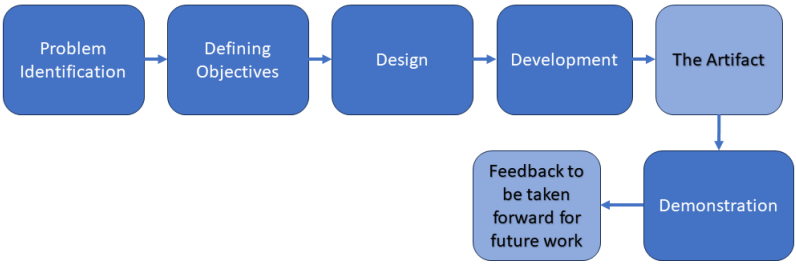

Figure 1: DSRM-inspired methodology followed in this study
Source: Own

Table 1: Sample table

Researcher's code	Description about the participant	Role in the project
C1	Senior Clinician (Doctor)	Clinician consultant
A1	Professor in Digital Health	Principal Investigator
R1	Research Fellow in Computer Science	Associate Investigator
R2	Research Fellow in Computer Science	Associate Investigator

4.1 Problem Identification

As the problem identification phase, researchers A1 and R1 met with C1, and discussed the needs for a digital health solution in the cardiac rehabilitation space. C1 highlighted the importance of cardiac rehabilitation. Then, C1 highlighted some trial digital health solutions they have attempted at his hospital. These solutions have been targeted at providing education and guidance to patients regarding certain hospital procedures they would undergo. Citing such trials, C1 emphasized the importance of similar solutions for cardiac rehabilitation. This discussion was

inspirational for future work. The outcome of this discussion was a list of strengths, weaknesses, opportunities, and threats that face digital health solutions for cardiac rehab (given in Figure 2).

4.2 Defining Objectives

Following problem identification, A1 sourced a seed grant for a 6-week mini project. It was decided to dedicate this funding to designing and developing a prototype digital health solution for cardiac rehab. Researchers R1 and R2 led this phase and planned suitable objectives to be delivered within 6 weeks (given in Figure 3).

4.3 Designing

As shown in Figure 3, it was agreed to design: (a) a web-based clinician-facing frontend; (b) a web-based patient-facing frontend, and (c) a database backend to collect as much data as possible. In this phase, R1 in consultation with A1 drew skeletal illustrations for each of the segments. Some examples are provided in Figures 4 and 5.

4.4 Development

In this phase, R2 developed the web-based front ends using HTML, following the designs planned in the previous phase. R1 developed the required database backends and also PHP interfaces to enable communications such as clinician and patient registration and login. Once developed, the frontend and backend were integrated, and the resulting website was hosted in a private hosting platform.

4.5 The Artifact

The artifact was the website resulting following the 'Development' phase. As discussed before, this website had a web-based clinician facing end, a patient-facing end, and a backend database. The clinician facing end gave the ability to register new clinicians and patients, to provide material to patients, and view progress and feedback made by patients. The patient facing end gave the ability to login as a unique patient, and then view and follow the provided material, and also provide feedback. Some screenshots of the artifact are provided in Figures 6 to 10.

4.6 Demonstration

A meeting was organized with an external expert in health, and the implemented website was demonstrated. Feedback was recorded along with the possible additions that might be possible going forward. A completed wishlist of possible additions to this solution recorded at the meeting is presented in Figure 11.

4.7 Feedback to be Taken Forward

The notable outcome of the 'Demonstration' phase was the wishlist presented in Figure 11. This wishlist helps flesh out the cardiac rehab solution to a much richer solution that would help derive insights and offer personalized care.

5 Results

Results are presented in Figures 2 to 11. These figures are the outcomes of the different phases of the design cycles discussed in Section 4. The figures are mostly self-explanatory. Further elaborations are avoided due to space restrictions.

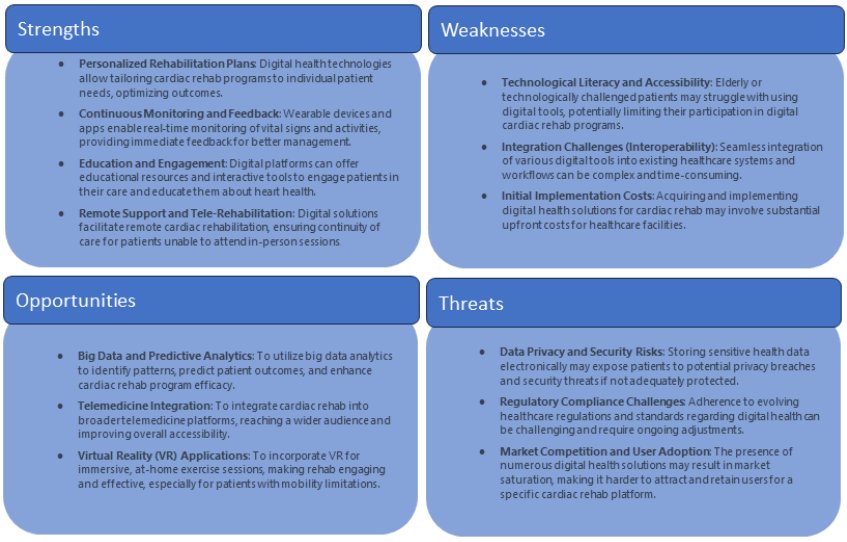

Figure 2: Strengths, weaknesses, opportunities and threats for digital health solutions in cardiac rehab, outcome of 'Problem Identification' phase

Source: Own

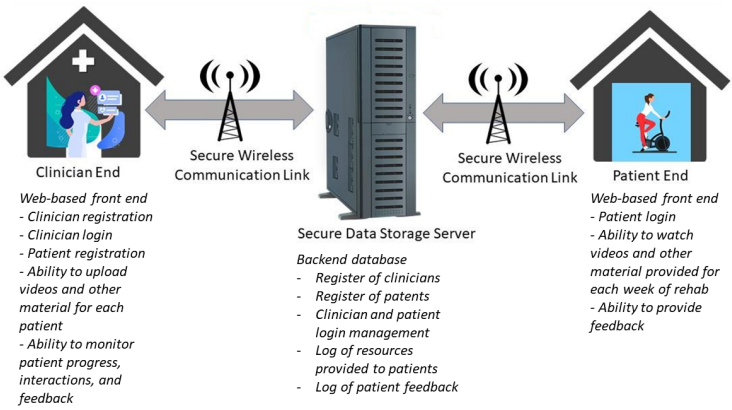

Figure 3: Objectives planned to be delivered within 6 weeks, outcome of 'Defining Objectives' phase

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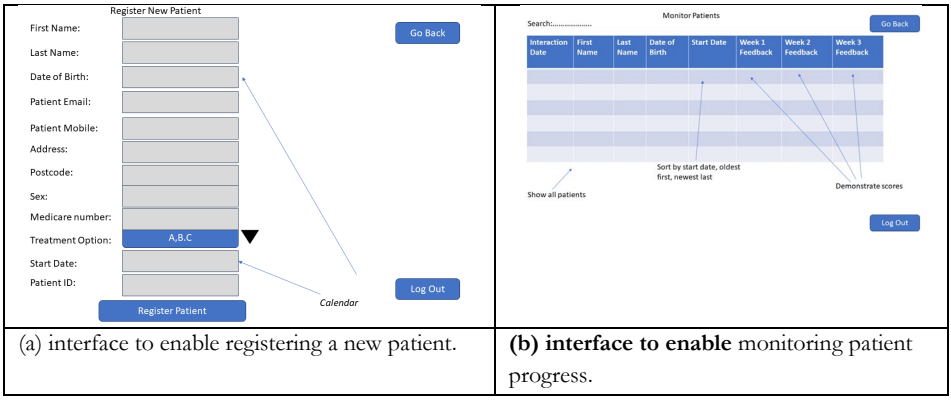

(a) interface to enable registering a new patient.

(b) interface to enable monitoring patient progress.

Figure 4: Some designs employed for the clinician-facing interface

Source: Own

Figure 5: The design employed for the patient-facing interface to display videos
Source: Own

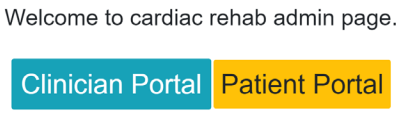

Figure 6: The welcome page to both clinicians and patients
Source: Own

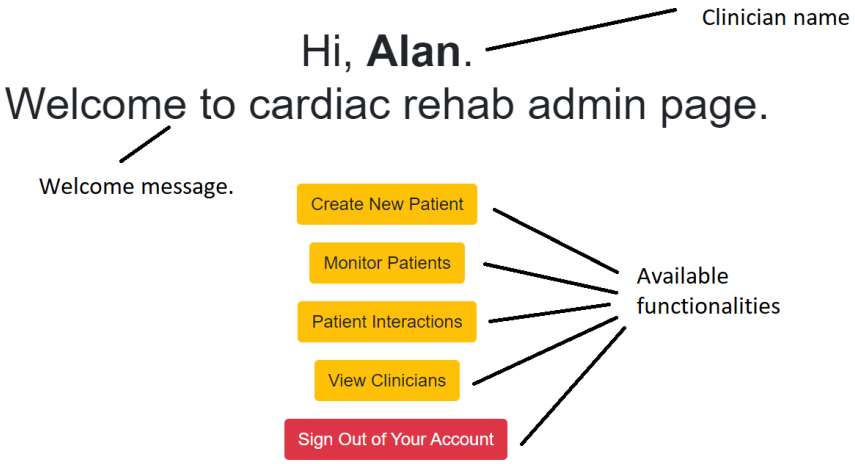

Figure 7: The main page inside the clinician portal
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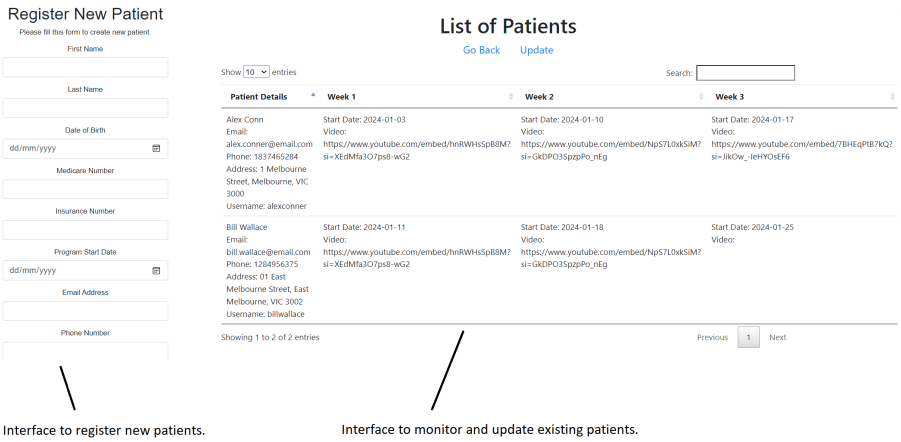

Figure 8: Some interfaces inside the clinician portal

Source: Own

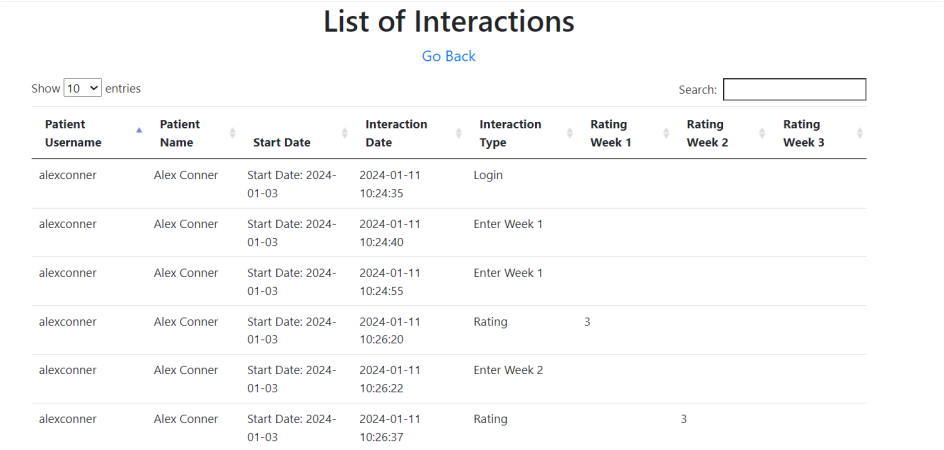

Figure 9: Interface in clinician's portal to monitor patient interactions

Source: Own

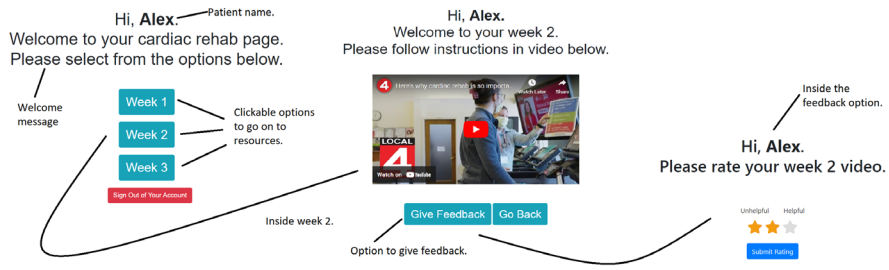

Figure 10: Some interfaces inside the patient portal

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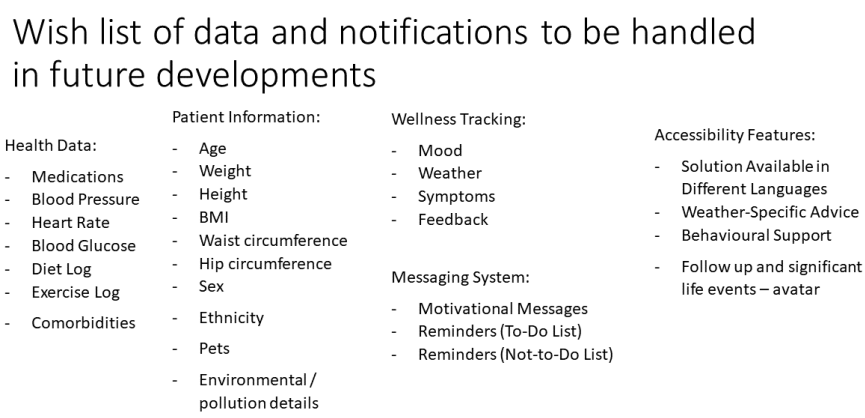

Figure 11: The wish list of data and notifications to be handled in future work

Source: Own

6 Discussion and Conclusions

The study presented the DSRM-inspired approach adopted to design and develop a web-based digital health platform to enable at-home cardiac rehab, in an attempt to answer the following research question: How might we design a digital health solution to enhance accessibility and engagement in cardiac rehabilitation from the comfort of patients' homes? The methodology followed was detailed, and the outcomes of each design phase were outlined. The study made a twofold contribution: A contribution to practice and a contribution to theory.

As a contribution to practice, our study developed a web-based prototype to enable cardiac rehab at home. Our solution includes a clinician-facing interface, a patient-facing interface, and a database backend to capture interactions. Snapshots of our development were presented in this paper, and the methodology followed was detailed. As such, our work would serve inspirational for technology design in many healthcare fronts.

As a contribution to theory, our work presented a list of factors (Figure 11) that could contribute many a digital health solution to become a fleshed out tool that captures important information about patients to enable deriving insights and personalization.

Limitations of this study include the limited scope and the limited time – this paper reports the outcomes of a 6-week project. Our future work would attempt to flesh out the current development through a more elaborate research project.

Given the increasing prevalence of cardiac issues globally, CR is becoming increasingly important to ensure strong clinical outcomes, high patient satisfaction and high value care. The proposed digital health solution to support superior cardiac rehab, serves to support a healthcare value proposition of better quality of care, better access to care and that high value care ensues. Moreover, the approach adopted ensures that responsible healthcare delivery results. Taken together this ensures high patient satisfaction and strong clincial outcomes.

Acknowledgements

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