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Integrating and Validating Heart Health Calculators in Medical Platforms

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“Striving to better, oft we mar what’s well.”
–William Shakespeare

“Nothing is more dangerous than an idea of it’s the only one you have.”
–Emil-Auguste Chartier

Abstract

We believe the underutilization of clinically validated algorithms for heart health assessment in current medical platforms undermines patient confidence in using associated screening instruments. The importance of earlier detection and improved health outcomes in heart disease motivated the development of these screening instruments. Available risk assessment tools are stand-alone online apps or screening devices that typically do not consider individual risk profiles. Combining risk estimation with screening instruments like Medsensio allows for targeted heart health assessment, potentially leading to earlier detection, resource optimization, and increased patient engagement.

The primary objective of this master project was to develop, test, and apply a screening tool in a medical framework.

This study presents the researcher's methodology for developing and evaluating risk prediction algorithms for heart disease. We followed a thorough process in developing the Medsensio Screening tool. A literature analysis informed the tool's design, ensuring it aligned with recent studies on preventative healthcare. The technique then comprised detailed design and implementation, internal testing, established algorithm utilization, rigorous integration evaluation, and in-depth user/physician workshops for input.

The primary outcome of this thesis is a functional risk assessment tool embedded within a state-of-the-art medical system. According to the findings, the Medsensio Screening Tool achieved higher acceptance rates than its web-based counterpart. User Evaluation further demonstrates that individuals trust the screening tool's output. Moreover, the tool uses LLMs to provide consumers with customized recommendations. Our results show that the LLM's recommendations generated considerable curiosity and inspired user trust, indicating a successful user experience.

This thesis not only demonstrates the successful integration of a risk assessment algorithm into a medical platform but also holds promise for the future of heart disease prevention. The study found that users highly accepted the tool and trusted its results, indicating a positive shift in patient engagement.

Additionally, the tool utilizes LLMs for personalized recommendations, a feature that could significantly enhance the tool's effectiveness. Future work will explore strategies to further enhance user experience, paving the way for a more proactive approach to heart health. Moreover, subsequent investigations should verify its effectiveness and evaluate its potential to positively influence medical results.

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My practical experiences profoundly influenced my decision to embark on my master's thesis journey. Having obtained my bachelor's degree in software engineering and worked for numerous Nepalese companies, I was driven by a deep-seated ambition to augment my skillsets and knowledge, aiming to make a significant societal impact. Recognizing the pivotal role of academic advancement in my industry, I resolved to enrol at UiT for a master's degree.

I am deeply indebted to my family for their encouragement and support. Their steadfast belief in my abilities bolstered my determination to pursue my academic aspirations, even in the face of the challenges of studying overseas.

I had the honour of working in a variety of positions during my master's program, including tech lead at Gearchecker AS, mentor at UiT, engineer at UiT, software developer at Futurum AS, and AI developer at Workability AS. I sincerely appreciate the chances and trust these companies have given me. In addition to helping me advance professionally, my time at UiT gave me priceless life experiences, including learning to ski, making new friends, and learning the basics of the Norwegian language.

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List of Abbreviations

AI artificial intelligence

API Application Programming Interface

ASCVD Atherosclerotic Cardiovascular Disease

BMI Body Mass Index

BRCA1 Breast Cancer 1

BRCA2 Breast Cancer 2

CVD Cardiovascular Diseases

FHIR Fast Healthcare Interoperability Resources

FRS Framingham Risk Score

GDPR General Data Protection Regulation

GPS General Practitioners

GUI Graphic User Interface

HDL High-Density Lipoprotein

HIPAA Health Insurance Portability and Accountability Act

HTTPS Hyper-Text Transfer Protocols

ICTS Information and Communication Technologies

JSON JavaScript Object Notation

LLMS Large Language Models

NLP Natural Language Processing

Npm Node Package Manager

PHP Hypertext Preprocessor

RRS Reynolds Risk Score

SHFM Seattle Heart Failure Model

1

Introduction

In recent years, the healthcare landscape has witnessed a surge in the development and utilization of cardiovascular risk calculators. These calculators are invaluable tools for evaluating an individual's risk of developing Cardiovascular Diseases (CVD) over a specified period, allowing for timely interventions and personalized care. Numerous studies, such as the Seattle Heart Failure Model, the Framingham Heart Study, and QRISK, have created specialized web-based calculators with intuitive features and interfaces. These screening tools empower healthcare practitioners and patients to predict individualized cardiovascular risk profiles, facilitating early interventions and personalized care[1]. Risk prediction models are helpful in the healthcare industry for determining who is more likely to get a particular disease. These models determine the likelihood of a patient developing a disease by examining various patient-specific risk factors, including age, family history, and lifestyle choices.[2]

These models can be used to design screening tools that may direct people toward more accurate testing or lifestyle modifications. This strategy could impact preventive actions against hospital admissions and potentially fatal cardiovascular events. It would help enhance each individual's health and lower the overall costs related to cardiovascular disease.CVD denotes a broad spectrum of conditions that impact the heart's vascular system and cardiac muscle, which distributes blood to the brain, heart, and other critical organs[1]. Congestive heart failure, strokes, and heart attacks are a few common types

1. (Cardiovascular Disease)

of cardiovascular disorders. Risk factors for CVD include obesity, physical inactivity, lipid abnormalities, hypertension, hyperglycemia, and tobacco use. While specific characteristics, like age, gender, and ethnicity, are unchangeable, people can significantly reduce risk by making lifestyle and behavioural modifications. Early detection and intervention are vital for reducing the effects of CVD, emphasizing the importance of timely healthcare strategies for improved outcomes and cost-effectiveness [3].

We have witnessed significant improvements in global life expectancy in this modern era. It is possible due to better healthcare services, advanced medical procedures, improved living standards, and increased health awareness [4]. However, alongside these achievements, there has been a concerning increase in chronic diseases, particularly diabetes and cardiovascular ailments [5]. In 2016, CVD was responsible for a significant 31 percent of global deaths, totalling 17.9 million, with a majority of these occurring in low and middle-income countries [4].

Notwithstanding the heavy burden of CVD mortality, several digital solutions are emerging that may help lower it. The digital solution enables low cost and scalability for screening tests and follow-up. Recognizing the need for early intervention in individuals at high risk of CVD, Information and Communication Technologies (ICTS) have become integral to our healthcare system [6]. These technologies have brought about patient-centric care, improved healthcare delivery, and empowered healthcare providers and patients. Mobile applications have emerged as transformative tools, significantly enhancing clinical outcomes and healthcare services for individuals with long-term health conditions [7]. Mobile applications stand out due to their affordability, intuitive user interfaces, ease of downloading, and compatibility with various mobile devices, including entry-level and low-cost models. In Mobile applications, many features are available, including messaging, calling, social networking, surfing, talking, playing games, consuming multimedia and utilizing sensors to collect data such as the number of steps per day[8]. It is also important to note that, among other large enterprises, Apple and Google have health-focused ecosystems and devote significant funding.

Moreover, research shows that smartphone microphones can do exciting things like monitoring coughs in people.[9]. The global mobile user count was 7.1 billion in 2021; estimates for 2022 show that the number has increased to 7.26 billion. By 2025, analysts predict there will be 7.49 billion mobile users worldwide[2]. The creation of patient-centric screening tools is a noteworthy endeavour that has the potential to benefit a considerable number of cardiac patients worldwide, especially considering the increasing proliferation of mo-

2. (Forecast number of mobile users worldwide from 2020 to 2025)

bile applications. These applications promote healthier behaviours, especially in managing cardiovascular disease, by influencing dietary habits, physical activity, eating behaviours, and physiological parameters. Additionally, app-based monitoring technologies have gained acceptance, particularly among heart failure patients [10], illustrating the potential of these tools in disease monitoring and management.

Acknowledging this importance, Healthcare professionals increasingly encourage healthcare applications as professional tools to aid in patient self-management, allowing patients to actively participate in their healthcare journey [11]. The government has initiated the development of healthcare applications, evidenced by recent Norwegian calls for tenders[3]. In addition, they have put several initiatives into place with the primary goal of using digital tools to promote independence and improve patient empowerment. However, the rapid proliferation of mobile health applications, with over 300,000 available and more added daily, poses a challenge for healthcare stakeholders who must navigate this landscape to find valuable solutions[4]. Many of these techniques lack scientific backing, which raises serious concerns. More specifically, there needs to be more scientific proof attesting to their effectiveness and usefulness. Another critical challenge is finding patient-centric screening tools that require low medical practitioner engagement, allowing patients to monitor and maintain their cardiovascular health. However, extensive research has demonstrated the positive influence that mobile applications have on encouraging people to embark on a healthy lifestyle proactively.[12][13][14][15][16]

Moreover,Large Language Models (LLMS) have emerged as a promising technology that could revolutionize healthcare communication. These advanced algorithms can process and evaluate enormous volumes of medical data, enabling them to produce succinct and understandable summaries of complex medical subjects. This capacity could significantly enhance patients' comprehension of their diagnosis, available treatments, and general state of health.

1.1 Problem Statement

The primary objective of this thesis is to produce and use a user-friendly screening tool that will augment current medical procedures and equipment by enabling patients to monitor their heart health actively.

A limited understanding of user perception of screening tools hinders the

3. (DHV - Digital home monitoring spread)
4. (Mobile Health App Data)

design of practical tools that can promote trust, comprehension, and potentially healthier lifestyles.

Sub-Problems

SP1: What criteria should be applied when choosing a suitable risk score algorithm?

For the Medsensio tool, choosing a reliable risk score algorithm is essential. We will leverage a thorough selection procedure to identify an appropriate pre-existing algorithm to ensure the project's timeline. We aim to review clinically validated cardiovascular risk score algorithms, compare their performance, and ensure that they are comprehensible to the users and seamlessly integrated within the Medsensio platform.

SP2: What strategy allows the incorporation of the new screening tool as an additional component into the state-of-the-art medical platform?

The new screening tool integrates well with the current platform by using the same architecture and Graphic User Interface (GUI) design, changing its algorithm to the necessary language, and unifying login and services.

SP3: How can we create a user interface for the Medsensio tool that combines artificial intelligence (AI) and GUI elements to give users comprehensible, practical, actionable heart health risk insights?

Presenting the findings of the Medsensio tool requires finding a middle ground between the advantages of AI for explanation and GUI for information presentation. We will design a GUI using both components to give people clear and helpful information about the risks of heart disease.

SP4: How can we assess whether the Medsensio Screening tool, which utilizes an LLM for recommendations, effectively supports patients in self-monitoring and self-managing their heart health?

Ensuring the efficiency of the Medsensio tool is a crucial component of this thesis. In order to evaluate its use and user confidence in the risk scores and recommendations, we will include both user groups and medical professionals. This input will direct changes and increase user confidence in the tool.

1.2 Thesis Structure

Chapter 1

This introduction chapter provides the necessary information and context for the study. It also addresses the limitations and articulates the problem statement. This also establishes the essential background information and explores vital foundational concepts that underpin this thesis.

Chapter 2

The second chapter includes use cases and the application's functional and non-functional requirements. This section describes the model foundation we used for the application's architecture and our online calculator search methodology.

Chapter 3

The third chapter includes the design choices made throughout the creation of the mobile applications and encompasses the implementation of the mobile application.

Chapter 4

This chapter concentrates on the user interface's development and design, particularly the integration of the LLM for recommendations.

Chapter 5

The fifth chapter will evaluate the Medsensio tool's efficacy, user confidence in risk scores, and the comprehensibility of LLM suggestions that involve medical experts and user groups.

Chapter 6

The sixth chapter offers suggestions for potential future development for the application while discussing the solution and findings from the fifth chapter.

Chapter 7

Chapter Seven brings the report's conclusions to a close and offers closing thoughts.

2

Requirement Specifications

2.1 Risk Prediction Algorithm

Risk prediction estimates the probability of diagnoses or health outcomes. These predictions are valuable instruments for healthcare providers making therapeutic decisions, ranging from acute interventions to long-term lifestyle recommendations. Quite the contrary, it helps people decide how to live their lives and how to treat, monitor, or follow up on their illnesses. It is critical to recognize that some risk prediction algorithms have limits. These constraints may show up as difficulties in forecasting the progression of illnesses like Alzheimer's disease, which has intricate, dynamic biological processes. On the other hand, a few risk prediction algorithms can offer insightful information for prophylactic measures. These algorithms, for example, may identify people with genetic predispositions, such as mutations in the Breast Cancer 1 (BRCA1) or Breast Cancer 2 (BRCA2) genes, and who may benefit from preventive medicines and early detection methods that could save their lives.

Using statistical analytic techniques and machine learning algorithms, risk prediction models find patterns in datasets that correspond with an individual's chance of getting heart failure over a given time frame. These datasets include physiological measurements (blood pressure, cholesterol levels), lifestyle factors (smoking status, food), medical history (prior heart issues, family history), and demographic data (age, gender). The degree to which these prediction algorithms undergo validation in extensive clinical contexts determines their validity and accuracy. Patients and healthcare professionals can decide on preventative measures with knowledge about estimated risk assessments for heart failure or other diseases over specific periods. Researchers have created many risk prediction models to determine the likelihood that individuals would experience heart failure over different periods, including one, three, or ten years.Some risk prediction algorithms that are in use today are ASCVD[1],Wells's criteria for DVT[2],CURB-65 and HEART score[3].

2.2 Factors Considered for Risk Score Algorithms to Predict Heart Failure

Many elements are essential to creating risk score algorithms for predicting heart failure to ensure accuracy and precision. All these elements work together to accurately assess a patient's risk of heart failure within a specific time frame.

2.2.1 Blood Pressure

Elevated blood pressure raises the chance of cardiac failure and other cardiovascular conditions.

2.2.2 Total Cholesterol and HDL Cholesterol

Both total and High-Density Lipoprotein (HDL) cholesterol are involved in the development of atherosclerosis, a significant risk factor for heart failure when cholesterol levels are abnormal.

2.2.3 Smoking

It is a well-known fact among experts that smoking speeds up the development of heart failure and raises the risk of cardiovascular disease.

1. (ASCVD (Atherosclerotic Cardiovascular Disease) 2013 Risk Calculator from AHA/ACC)
2. (Wells' Criteria for DVT)
3. (HEART Score for Major Cardiac Events)

2.2.4 Diabetes

Individuals who have diabetes mellitus are more prone to experience vascular damage and endothelial dysfunction, which increases the risk of heart failure. [17]

2.2.5 BMI

An elevated body mass index is linked to metabolic problems and increased cardiac strain, corresponding with a greater likelihood of heart failure.

2.2.6 Gender and Age

Several factors influence heart failure risk. These include gender and age, with men showing different risk profiles from women.

2.2.7 Family History of CVD

An early intervention strategy is crucial when there is a history of cardiovascular disease in the family since it suggests a genetic susceptibility to heart failure.

2.2.8 Ethnicity

Differences in the reactivity of various ethnic groups to cardiovascular illness can impact the likelihood of developing heart failure.

2.2.9 Previous History of CVD

Individuals with a prior history of cardiovascular problems are more susceptible to experiencing heart failure in the future.

2.2.10 Diet

The food we consume harms our health. Food with high amounts of refined sugars, saturated fats, and sodium not only increases the risk of cardiovascular disease but also raises the likelihood of developing heart failure. Making good dietary choices is essential to protect our hearts.

2.2.11 Stress

Prolonged stress accelerates the development of oxidative stress and inflammation in the heart, which leads to cardiac remodelling and heart failure.

2.2.12 Exercise

Regular workout is about more than staying fit. It offers cardioprotective advantages that significantly lower the risk of heart failure. By improving cardiovascular fitness and function, exercise can be an effective means of preserving cardiac health.

The abovementioned factors include social, lifestyle, and modifiable and non-modifiable aspects. While these variables are generally available and readily observable, it is crucial to remember that additional significant unknown influences can exist. Furthermore, some elements work in tandem with one another. For example, consistent exercise helps lower blood pressure. Taking lifestyle and changeable factors into account more deeply throughout the algorithm's building process allows for the creating self-sustaining cardiac scoring instruments to provide patients customized suggestions.

2.3 Requirements

Choosing an appropriate cardiovascular risk calculator is pivotal in patient-centric healthcare, emphasizing the importance of integrating established clinical tools into the healthcare ecosystem [11]

2.3.1 Functional Requirements

This section describes the critical elements for assessing and choosing a suitable cardiovascular risk calculator for incorporation into the Medsensio tool. These requirements are essential to guaranteeing patient-centred treatment and a smooth transition within the current healthcare infrastructure.

Risk Score Calculation

The calculator must accurately compute a patient's 10-year CVD risk score.

Data Input

The calculator should include modifiable and non-modifiable patient data points for assessing CVD risk. Considerations for it should include blood pressure, cholesterol, Body Mass Index (BMI), and severe mental disease, among other things.

Target User Group

The selected calculator must be appropriate for the target user base, between 20 and 80 years old.

Modifiable Risk Factors

In order to promote behaviour modification and enhance heart health self-management, the calculator ought to take into account modifiable risk variables.

Integration Feasibility

The calculator's programming language and technological architecture should work together to integrate the current medical platform seamlessly.

2.3.2 Non-Functional Requirements

Accessibility

The intended user group should be able to navigate and use the calculator's UI easily.

Licensing

The licensing terms of the selected calculator should align with the project's needs (e.g., commercial, open-source).

Research Foundation

Academic research and clinical approval should back the calculator to ensure accurate risk assessment.

2.4 Requirement analysis for Cardiovascular Risk Calculator

The critical aspect of our decision to utilize the Qrisk3 algorithm in our study stems from its comprehensive inclusion of numerous parameters, as shown in Table 2.1. This expansive set of parameters proves instrumental, enabling us to consider diverse factors, including modifiable, non-modifiable, social, and lifestyle variables. This evaluation considers a broader spectrum of components than generally considered when assessing risk, enabling us to examine the variables influencing heart health in greater detail and from a broader perspective.

Table 2.1: Factors Influencing Cardiovascular Disease (CVD)

Modifiable	Non-modifiable	Social	Lifestyle
Blood Pressure	Age	Income	Smoking
Total Cholesterol	Gender	Social Deprivation	Diet
HDL Cholesterol	Family History of CVD	Environment	Exercise
Smoking	Ethnicity		Stress
Diabetes	Genetic Evidence		
BMI	Previous History of CVD		
Chronic Inflammation Markers			

We conducted a thorough study to determine which cardiovascular risk calculator is best for integration. This analysis considered various criteria, including license agreements, the intended user groups (i.e., patients vs. medical professionals), and the characteristics of the target demographic. Given the landscape's complexity, we must consider these variables to guarantee the best possible implementation. Some calculators are primarily tailored for healthcare professionals, facilitating precise risk assessments and clinical decision-making. On the other hand, there are calculators that encourage patients to manage their health actively. This is especially important when it comes to patient-centric healthcare[18].

Considering the extensive array of cardiovascular risk calculators[19], each with its unique features and accessibility, selecting an appropriate calculator is a critical decision in optimizing patient care. After thoroughly analyzing all the current cardiovascular risk calculators, the QRISK3 algorithm [4]emerged as the best fit for our study's goals. This analysis is a foundational exploration of the cardiovascular risk calculator landscape, underscoring their potential contributions to personalized patient care within the evolving healthcare paradigm. In clinical practice, the utilization of QRISK3 facilitates the computation of their 10-year CVD risk score. Since the original QRISK3 algorithm was written in C by ClinRisk under a GNU Lesser General Public License, we can quickly transform it into any other programming language based on our use case. One of the studies that compare these tools here [20] in the Saudi population proved that the Qrisk is easy to implement and applicable in their population-based study, which shows the applicability rate as 95.3 percent.

Table 2.2 summarizes the information utilized for the requirement analysis.

Name	License	Patient-cen.	Validated	Usage Scenario	Modifiable Factor	Population
Rajan's HF Calc.	Yes	No	No	Med. Staff	No	Not sure
Seattle HF Model	Yes	No	Yes	Med. Staff	No	European
ASCVD Estimator	Yes	Yes	Yes	Med. Staff/-Patients	Yes	Caucasian-African-American
Reynolds Risk	Yes	Yes	Yes	Med. Staff/-Patients	Yes	American
Framingham Risk	Yes	Yes	Yes	Med. Staff/-Patients	Yes	White-American
BCN Bio-HF Calc.	Yes	No	No	Med. Staff	No	European
Mayo Clinic Est.	Yes	Yes	Yes	Med. Staff/-Patients	No	Diverse group
AUS CVD Calc.	Yes	Yes	Yes	Med. Staff/-Patients	Yes	Australian
Heart in Amer.	Yes	Yes	Yes	Med. Staff/-Patients	Yes	American
Qrisk	Yes	Yes	Yes	Med. Staff/-Patients	Yes	British

Table 2.2: Factors responsible for the selection of algorithm

4. (Qrisk3 Web Calculator)

2.5 Reviewing Existing Risk Score Systems

In September 2023, we examined the literature for studies on cardiac risk assessment models. We used numerous online resources from the computer science and medical fields, such as AHA Journals, IEEE Xplore, Springer, Google Scholar, PubMed, and ScienceDirect. This search gathered a collection of scientific articles on the subject.

After an evaluation, we found a selection of these papers to be especially relevant to our objectives. Subsequently, we determined the best risk score method for our needs by conducting additional, in-depth analyses of these chosen studies. In addition to the calculator shown below, we discovered others, too.A few of them are from Frax[5], PREVENT Online Calculator[6], and Strong Heart[7].

2.5.1 Risk Calculators with License Availability

The following section overviews ten prominent cardiovascular risk calculators, considering factors such as licensing, research foundation, target audience, and accessibility. We will examine the functions and details these calculators employ to choose the best algorithm for creating our screening instrument.

Rajan's HF Risk Calculator

This section examines a risk calculator created by Rajan and Al Jarallah[21]. It is designed especially for hospitalized patients with reduced ejection fraction (HFrEF) and heart failure. When someone is already diagnosed with heart failure, they are said to have HFrEF, which is a weaker heart that is not pumping blood efficiently. The tool calculates the patient population's risk of dying from any cause (also known as all-cause mortality). There are various benefits to using this calculator. The initial benefit is that it just needs access to four commonly used clinical measurements: *haemoglobin (Hb)*,*ejection fraction (EF)*,*Brain hormone level (NT-proBNP)*, and *kidney function (eGFR)*. Second, its simplicity makes it easy to use in hectic clinical environments. However, it is crucial to be aware of the present restriction. Even though the calculator seems promising, large-scale clinical tests are needed to confirm its efficacy in predicting mortality related to heart failure[22].

5. (Frax Calculation Tool)
6. (Prevent Online Calculator)
7. (Strong Heart Study)

Seattle Heart Failure Model

The Seattle Heart Failure Model (SHFM), created by Dr. Levy at the University of Washington, is examined in this section[23]. The SHFM The SHFM is specifically intended to predict survival rates in people with *systolic heart failure (SHF)*. SHF develops when the heart muscle weakens and cannot pump blood adequately during contraction (systole). The SHFM has several benefits. First, it is simple to use and needs little information to work. Second, it can calculate the possible effects on a patient's long-term survival that different treatment approaches may have. Research has demonstrated that the SHFM is a reliable indicator of survival for SHF patients. It is crucial to recognize a limitation, however. Patients with European ancestry were the leading group used to validate the model. Its ability to predict survival for people of different ethnic backgrounds may be restricted, and more investigation is required to solve this.[24]

ASCVD Risk Estimator Plus

The American College of Cardiology (ACC)[8] developed the ASCVD Risk Estimator Plus, which estimates a patient's 10-year risk of Atherosclerotic Cardiovascular Disease (ASCVD), including coronary heart disease and stroke caused by plaque accumulation in the arteries[25]. It targets individuals who are at risk for AS-CVD (having high blood pressure or no history of ASCVD events) utilizing the Pooled Cohort Equations[26], which was validated in adults who are Caucasian and African American. Although it has advantages such as a standardized, evidence-based method that takes into account several risk factors for a thorough evaluation, its drawbacks include the possibility of lower accuracy for very young or older adults or those with certain medical conditions, as well as its reliance on the accuracy of data entered by users.

Reynolds Risk Score

Dr. Paul M. Ridker developed the Reynolds Risk Score (RRS), incorporating non-traditional criteria to improve women's CVD risk assessment in 10 years[27]. The RRS provides better accuracy than earlier techniques because it incorporates a blood test for inflammation (hs-CRP) and looks at a woman's family history of early-onset heart attacks. However, the RRS is currently validated for women only and requires a hs-CRP test, which may limit its applicability in some situations. However, the RRS is a big step forward since it gives women a more detailed risk assessment, which could result in more focused preventive measures.

8. (American College of Cardiology)

Framingham Risk Score

The Framingham Heart Study (Massachusetts, USA) produced the Framingham Risk Score (FRS)[9], which calculates an adult's 10-year risk of ASCVD. Researchers developed the FRS specifically for middle-aged white residents[28]. However, they have since modified the score for broader use, resulting in multiple versions, the latest being FRS 2008[29]. Age, blood pressure, cholesterol, diabetes, smoking, family history, and blood pressure are among the criteria that this score uses to determine the risk of ASCVD. Despite being flexible and used as a standard for other ratings, the FRS is not without limits. The accuracy of the score may be lower for non-White ethnicities and age categories that the original study underrepresented. Additionally, the score may only partially capture evolving medical and risk factors. Notwithstanding these drawbacks, the FRS's widespread validation, uniform methodology, usability, and easily accessible data make it a helpful instrument.

BCN Bio-HF Calculator

The Barcelona Bio-HF Calculator, created by experts at the Barcelona Hospital Clinic, calculates the likelihood of death in patients admitted for heart failure with reduced ejection fraction (HFrEF) from any cause[30]. By using blood biomarkers that represent heart function (NT-proBNP, ST2, hs-cTnT), together with conventional clinical parameters like age, sex, and functional class, this calculator seeks to enhance risk prediction. Hospitalized patients with HFrEF who have weaker hearts and difficulty pumping blood are the main target demographic for the Barcelona Bio-HF Calculator. Although using biomarkers in conjunction with conventional clinical criteria presents a potential benefit for enhanced risk prediction precision, a noteworthy constraint is the need for comprehensive validation. It takes extensive clinical investigations to verify the usefulness of this calculator in precisely forecasting heart failure-related death[31].

Mayo Clinic Risk Estimator

The Mayo Clinic CVD Risk Calculator, developed by researchers affiliated with the Mayo Clinic healthcare system, calculates the chance of getting ASCVD and recommends possible preventative measures[32]. Targeting adults aged 40-75 and younger adults (20-39 years old) with specific *Low-Density Lipoprotein (LDL)* cholesterol levels, the calculator considers various factors like medical history, family history, lifestyle habits, and physical exam findings to determine

9. (Framingham Heart Study (FHS))

a risk score. While it offers the unique advantage of estimating lifetime risk for younger adults with potentially high cholesterol, a significant limitation lies in the need for more public access to the tool and detailed data on its performance compared to other calculators, hindering a complete evaluation of its accuracy.

Australian CVD Risk Calculator

The National Heart Foundation of Australia created the Australian CVD Risk Calculator[10] for the *Australian Chronic Disease Prevention Alliance (ACDPA)*, which calculates an individual's 5-year risk of ASCVD in those between the ages of 45 and 79. It also includes individuals aged 35-79 who have diabetes and have not previously been diagnosed with ASCVD. This calculator uses a risk equation[33] calibrated adequately for the Australian population instead of general tools, which could result in more accurate risk predictions. It also considers diabetes-specific risk factors and socioeconomic disadvantage, offering a more thorough risk assessment. The focus on Australian statistics and risk factors suggests its success within the intended population.

Hearts in the Americas

Hearts in the Americas is a *Pan American Health Organization (PAHO)*[11]-led initiative which is leading a collaborative initiative called Hearts in the Americas to enhance primary healthcare systems throughout the area. Enhancing the mitigation and management of cardiovascular disorders and related risk factors is the specific goal of this regional program. It targets adults who are at risk of CVD using a risk calculator[34], especially those who may not have a history of CVD events like heart attack and stroke but may be at risk for conditions like diabetes, high blood pressure, or high cholesterol. The program's focus on bolstering primary healthcare, encouraging CVD prevention through its risk calculator, and identifying high-risk individuals holds promise for improving public health outcomes in the Americas, even though a concrete measure of overall performance remains to be determined.

Qrisk

QRISK is a web-based tool primarily intended for adults in the UK that calculates an individual's risk of having a stroke or heart attack over the next ten years,

10. (Australian cardiovascular disease risk calculator)
11. (HEARTS in the Americas)

producing a corresponding risk score. Figure 2.1 depicts the web-based tool of the open-source QRisk algorithm[12]. This tool is intended for individuals between the ages of 20 and 84, although younger adults (ages 18 to 19) may also utilize it under some circumstances. The first version of the QRISK model was developed in 2007[35] to estimate the 10-year risk of cardiovascular disease. It was accompanied by an updated model, QRISK2, in 2008[36]. It incorporated additional risk factors, including ethnic origin and specific medical conditions such as rheumatoid arthritis, type 2 diabetes, atrial fibrillation, and chronic renal disease. QRISK2 has undergone annual updates and recalibrations, and we now have the latest iteration, QRISK3[1], representing the culmination of continuous development.

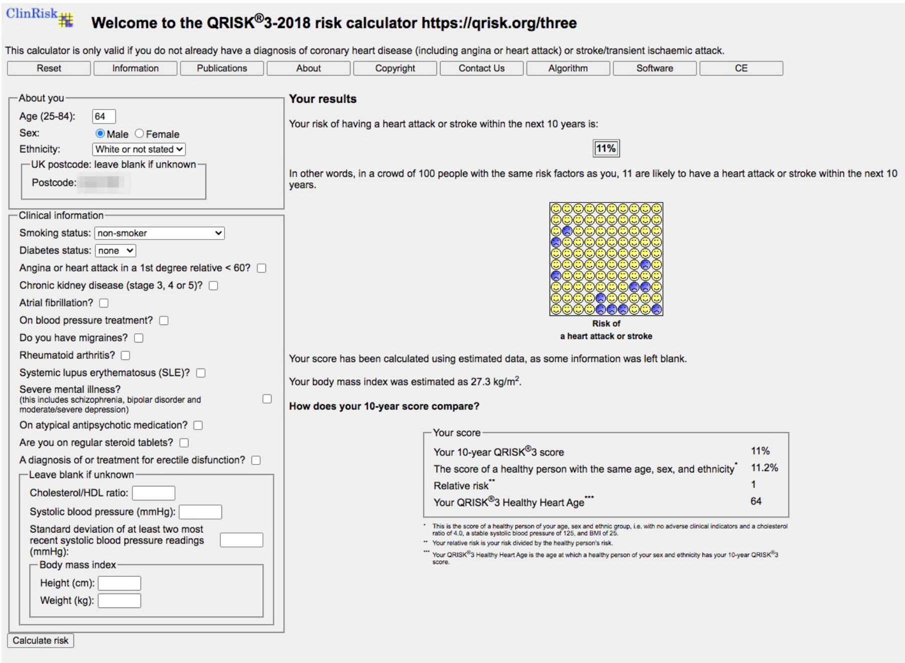

Figure 2.1: Qrisk Calculator Web Interface

In 2021, the QRISK3 model was externally validated[37] using primary care data from the *Clinical Practice Research Datalink (CPRD)*. This validation process confirmed the model's efficacy in predicting cardiovascular risk across the general population. Qrisk is based on data collected from many General Practitioners (GPS) throughout the UK who voluntarily contributed data to the QResearch database for medical research. QRISK was tailored to the UK population and initially designed for use within the UK healthcare system. ClinRisk Ltd owns the algorithm. The authors and sponsors disclaim responsibility for the clinical use or misuse of the risk score. According to their academic publication[1],

12. (STATINS AND CARDIOVASCULAR RISK – PART 3)

the developers thoroughly examined the software underpinning this calculator using a large amount of simulated patient data to ensure it aligned with the statistical software used in algorithm validation. ClinRisk Ltd considers including severe mental illness, migraine and erectile dysfunction in the algorithm, which are unique elements compared to other risk score algorithms. The QRISK algorithm generates a trustworthy risk score by considering several variables when estimating a person's risk of cardiovascular disease. This score gives heart patients important information and allows them to participate in their care actively.

QRISK3 emerges as a promising risk assessment tool. Its validity and accessible algorithm distinguish it, making it easily adaptable to our research objectives.

Table 2.3 demonstrates the link to each of the calculators described earlier.

Table 2.3: Access links to different calculators

Risk Calculator	**Reference**
Rajan's HF Risk Calculator	https://www.hfriskcalc.in/
Seattle Heart Failure Model	https://depts.washington.edu/shfm/app.php?width=1536&height=864
ASCVD Risk Estimator Plus	https://tools.acc.org/ascvd-risk-estimator-plus/#!/calculate/estimate/
Reynolds Risk Score	https://www.mdcalc.com/calc/3932/reynolds-risk-score-cardiovascular-risk-women
Framingham Risk Score	https://reference.medscape.com/calculator/252/framingham-risk-score-2008
BCN Bio-HF Calculator	https://ww2.bcnbiohfcalculator.org/web/calculations
Mayo Clinic	https://www.mayoclinic.org/medical-professionals/cardiovascular-diseases/calculators/cardiovascular-risk-calculator/itt-20534396
Australian CVD Risk Calculator	https://www.cvdcheck.org.au/calculator
Hearts In the Americas	https://www.paho.org/cardioapp/web/#/cvrisk
QRISK3	https://qrisk.org/

2.5.2 Results

The Qrisk model was chosen from the variety of available risk assessment calculators because it aligned with the research goal of examining a clinically proven risk score algorithm and the possibility for quick integration into the current medical platform. Moreover, adding new variables, including mental health, to the model's assessment could significantly improve its thoroughness and capacity to offer well-rounded recommendations.

2.6 User Interaction Analysis

2.6.1 Use-cases

Use cases are crucial resources for comprehending and recording a system's functional needs from the viewpoint of its users. Within the Medsensio screening tool framework, use cases describe how people and the system interact, clarifying the objectives, players, conditions, and progression of each scenario. By describing these use cases, stakeholders can learn more about the system's functioning and determine how well it meets user demands and goals.

Log In

In this use scenario, the user logs into the Medsensio Screening tool to start a session.

Goal

This use case aims to grant users secure, authorized access to the program to take advantage of its features.

Actor

The user attempting to access the Medsensio Screening tool is the leading actor in this scenario.

Requirements

The program must securely authenticate the user's credentials to confirm the user's identity. Once the authentication is complete, the user can access the main interface.

Flow

In this interaction, the user starts the procedure by going to the Medsensio Screening tool and choosing to log in. When the user chooses this option, the system prompts them to provide their password and username. The user then provides these credentials and sends them in for verification. The system then proceeds with a validation process, which involves verifying the credentials supplied with those kept in its user database. Suppose the comparison determines that the credentials submitted are legitimate. In that case, the application is made available to the user and redirected to the main interface, where further features are available. On the other hand, the system displays an error message in response if it finds that the credentials entered are erroneous during the validation procedure.

Suppose the system detects that the entered credentials are incorrect. When that happens, the system will ask users to re-enter their credentials, starting an iterative process that gives them several chances to correct the entry. Until the user enters a genuine login and password, the system will prompt them. Limiting access to the Medsensio Screening tool to authorized users who need credentials from the Medsensio platform and protecting user data helps maintain rigorous security protocols.

Selecting Qrisk module for risk assessment in Medsensio Screening tool

In this use case, the user chooses the QRisk module from various risk assessment modules to determine their risk of cardiovascular disease.

Goal

This use case aims to allow consumers to select the QRisk algorithm for individualized risk assessment based on their unique health data.

Actor

The leading actor in this scenario is the user attempting to use the Medsensio Screening tool to determine their risk of cardiovascular disease.

Requirements

The program should guarantee that users will encounter various risk assessment modules, including the QRisk module. Moreover, the system must guarantee a seamless transition to the assessment interface once the user selects the QRisk module. This calls for effective routing systems that smoothly transfer users from the central inventory of risk assessment modules to the QRisk module interface without interfering with or slowing down the user experience.

Flow

Per the specified guidelines, the user starts the process by going to the application's specific risk assessment section and indicating that they want to look at the accessible risk assessment tools. The system presents the user with a carefully curated set of risk assessment choices, including the QRisk module, as a response. In this interface, the user expresses agency by choosing the QRisk module from the supplied list, indicating their choice of this risk assessment instrument. The system recognizes it when the user selects it and starts the transition process, which smoothly takes the user to the assessment interface.

Filling the form

In this use case, the user fills out a form necessary for the QRisk assessment to provide pertinent health information.

Goal

This use case aims to gather extensive health data from users in order to enable precise risk assessment with the Medsensio Screening tool.

Actor

The user who enters their health information into the QRisk assessment form is the primary actor in this scenario.

Requirements

Users must be able to enter relevant health data more efficiently using the application's organized form. This form should include sections for vital health indicators such as blood pressure, cholesterol, age, gender, and smoking status. Users must be allowed to quickly and precisely enter data into the appropriate fields. Furthermore, the system must put validation procedures in place to carefully review user inputs and guarantee the quality and integrity of the data entered.

Flow

When the user chooses the QRisk module in the Medsensio Screening tool, the system takes them to the assessment form, where they can enter pertinent health information. The system displays fields labelled for different health parameters in this form, fully satisfying the user's input needs. The user then interacts with the form by entering their health information in the appropriate fields, following the structure and instructions provided. When the user finishes the data entry, the system performs a validation procedure to ensure the data is accurate and complete. After the successful validation procedure, the user should submit the form, which starts the assessment process.

Logging out

In this use case, the user logs out of the Medsensio Screening tool to end their session.

Goal

This use case aims to protect sensitive health data and preserve data privacy by ensuring the safe termination of user sessions.

Actor

The user who wants to terminate their session in the Medsensio Screening tool is the leading actor in this scenario.

Requirement

The program must provide users with an easy-to-use method for logging out of their accounts. When the user presses the log-out button, the system must immediately end the user's session and remove all locally stored session data. Furthermore, the log-out procedure must be simple and user-friendly to provide consumers with a clear and intuitive experience.

Flow

The user initiates the log-out procedure in compliance with the requirements by going to the application's profile or account settings area. The system initiates the log-out process by indicating to the user through this interface where there is a prominent choice to log out. Then, when the user clicks the log-out button, the system immediately ends the user's session. When a session ends, the system initiates a redirection process that, depending on the system's configuration, leads the user back to the main interface or the application's login page.

Viewing Data (Admin Side)

In this use case, an administrative user views and accesses aggregated data gathered from assessments for reporting and analysis purposes.

Goal

This use case aims to give administrators access to thorough assessment data insights, facilitating strategic planning and decision-making.

Actor

The primary actor in this scenario is the administrative user in charge of data analysis and reporting in the Medsensio Screening tool.

Requirements

The program must provide administrative users access to a specialized dashboard or user interface to view aggregated assessment results. This interface must prioritize clear and adaptable data presentation to allow administrators to filter, analyze, and visualize data based on predetermined criteria. Administrators should also be able to provide reports that highlight essential conclusions and patterns found in the assessment data. Existing medical platforms would have this feature in place.

Flow

Upon successful login, the system verifies the administrative user's credentials, allowing them to access the dashboard or interface. The administrative user navigates through this interface to the appropriate data viewing section, which prominently displays the aggregated assessment data. Users can refine the data view by applying filters or choosing criteria to meet their analytical needs. The administrative user thoroughly analyzes the data and derives valuable information for strategic planning and decision-making by utilising these insights.

View Recommendations

This scenario involves the user accessing tailored recommendations upon receiving their risk score to manage their cardiovascular health effectively.

Goal

The objective is to give the user individualized recommendations made by OpenAI based on their inputs.

Actor

The primary actor in this scenario is the user seeking personalized recommendations.

Requirement

The software must collect all necessary user inputs and use the OpenAI API key to provide customized recommendations. Moreover, the guidelines should be all-inclusive, emphasizing the importance of user-provided values about cardiovascular well-being and providing optimal techniques for preserving cardiac health.

Flow

Once users receive their risk score, they can browse recommendations by clicking the "View Recommendations" option. The application uses the OpenAI API key to initiate the required prompt, which produces the best possible response for the user. After that, a modal popup appears with the recommendations for the user to review. The user can exit the modal window after reviewing the suggestions.

2.6.2 Use-case diagram

An essential component of Unified Modeling Language (UML) notation is a use-case diagram showing how a system interacts with its external users or actors. Actors, typically represented by stick figures, interact with the system to achieve specific goals. These objectives take the form of use cases, represented by ellipses or circles, and show system functionalities from the actor's point of view. Associations, which are lines that link actors to use cases, show how information flows and can also include arrows to show how interactions occur. Use case diagrams are helpful for system design, stakeholder communication, and user demand capturing because they provide a succinct yet thorough understanding of a system's functionalities and how various user types interact with it. Figure 2.2 depicts a use case diagram for Medsensio Screening Tool.

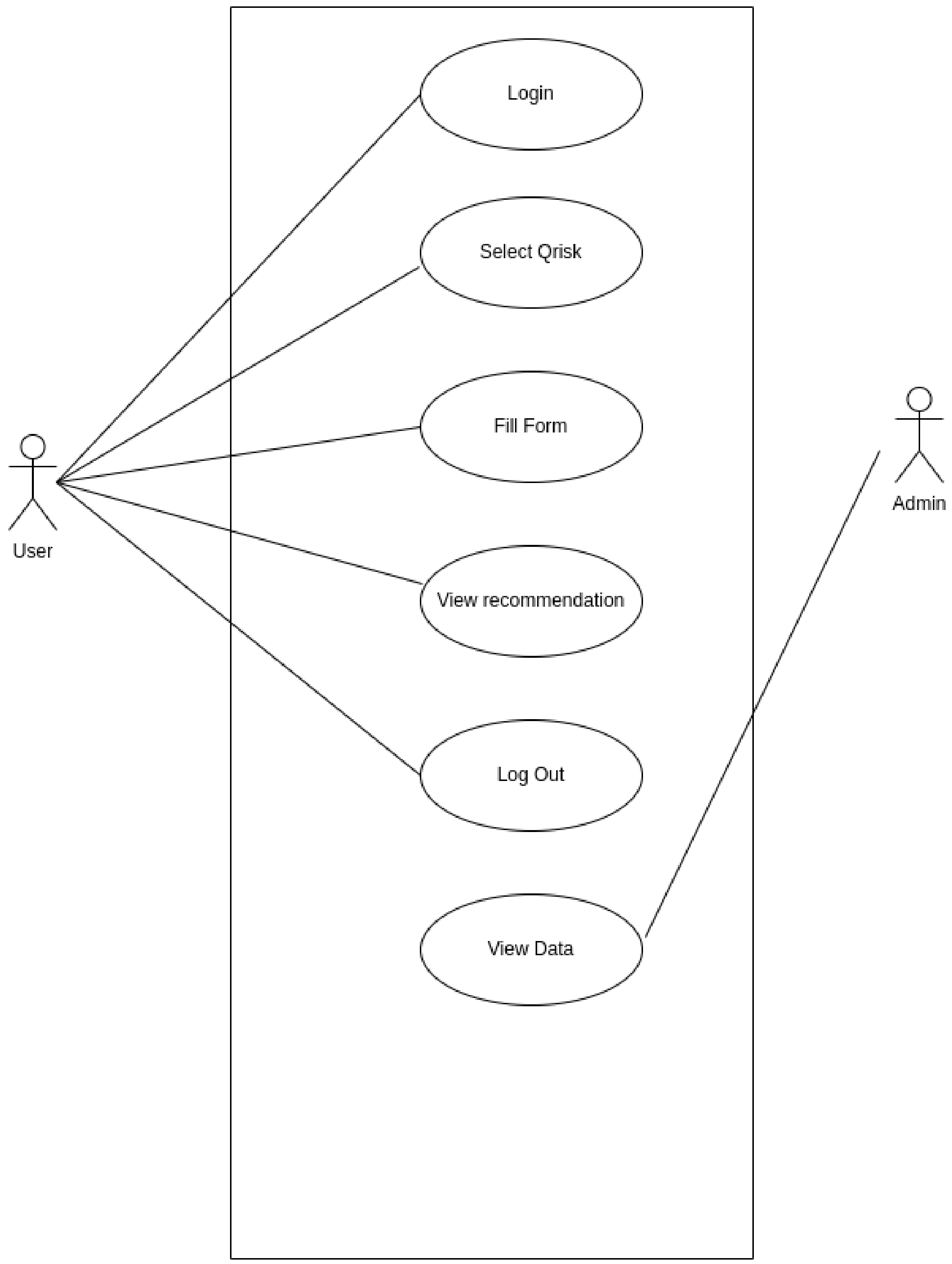

Figure 2.2: Use Case Diagram

2.6.3 Personas and usage scenarios

To comprehensively understand the user interactions and requirements of the Medsensio Screening Tool, personas and usage scenarios are invaluable tools for delineating user-profiles and their respective utilization patterns within the system. By crafting personas representative of potential user demographics and detailing usage scenarios, stakeholders can gain insights into the diverse needs, preferences, and behaviours of users, thereby informing the design and functionality of the Medsensio Screening Tool to better align with user expectations and objectives.

We generated the images below using the stable diffusion [13]. Creating visuals from natural text inputs is the method used in this technique. In particular, the text field's entries describing "Sarah", "David", and "Joe" produced visuals.

Personas

Sarah Thompson(Figure 2.3)

Age: 55

Occupation: Nurse Practitioner

Background: Sarah is a seasoned healthcare professional with over 20 years of experience in cardiovascular care. At a primary care clinic, she conducts health assessments and provides personalized recommendations to patients.

Goals: Sarah aims to utilize the Medsensio Screening Tool to efficiently assess patients' risk of cardiovascular disease and provide tailored interventions to mitigate risk factors.

13. (stable diffusion)

Figure 2.3: Sarah Thompson

David Rodriguez(Figure 2.4)

Figure 2.4: David Rodriguez

Age: 40

Occupation: IT Consultant

Background: David leads a busy lifestyle, juggling demanding work commitments and familial responsibilities. As a proactive individual, he values tools that enable him to monitor his health and make informed decisions regarding his well-being.

Goals: David seeks to leverage the Medsensio Screening Tool to gain insights into his cardiovascular health status and adopt lifestyle modifications to improve overall health outcomes.

John Doe (Figure 2.5)

Figure 2.5: John Doe

Age: 60

Occupation: Retired Navy

Background: John Doe is a proactive person who has a history of high blood pressure and cholesterol. He wants to actively manage his risk factors since he is concerned about the state of his heart.

Goals: John uses the Medsensio Screening Tool to determine his CVD risk. Using the tool's recommendations, he hopes to enhance his health and possibly lessen the need for additional procedures.

Usage Scenarios

Sarah's Health Assessment

Scenario

Sarah conducts a routine health examination for a 60-year-old patient with a history of hypertension and elevated cholesterol levels. She inputs the observations and known information about the patient into Medsensio in order to get the Screening Tool results as output. The results will help inform her about the optimal care for her patient in terms of disease risk reduction.

Action

Sarah identifies and selects the appropriate patient from the patient list in Medsensio. Known parameters about the patients are used as input for the Screening Tool in Medsensio. She measures the patient's blood pressure and inputs this into the Screening Tool. Eventually, she asks the patient about behavioural and familiar risk factors and inputs the results into the Screening Tool. The Screening Tool outputs a risk score, determining that this patient is at high risk for heart disease and is a suitable candidate for referral to further diagnostics within the specialist healthcare.

Outcome

The Medsensio Screening Tool generates a personalized risk score for the patient, accompanied by evidence-based recommendations for managing cardiovascular risk factors. The patient is at sufficiently high risk that referral to specialist care is the appropriate next step. Sarah performs the standardized physical examination workflow in Medsensio, which is attached to the risk report when referring the patient to a cardiologist for further diagnostics.

Sarah utilizes this information to devise a comprehensive care plan tailored to the patient's needs.

David's Self-Assessment

Scenario

Concerned about his family history of heart disease, David decided to conduct a self-assessment of his cardiovascular risk using the Medsensio Screening Tool.

Action

David downloads the Medsensio application on his smartphone and completes the risk assessment questionnaire, inputting his age, gender, lifestyle factors, and medical history.

Outcome

The Medsensio Screening Tool provides David with a detailed analysis of his cardiovascular risk profile, highlighting areas of concern such as elevated blood pressure and suboptimal cholesterol levels. With this information, David commits to making lifestyle changes, including adopting a heart-healthy diet and increasing his physical activity levels, to mitigate his risk of cardiovascular disease.

John's Self-Assessment

Scenario Knowing that he has a history of high blood pressure and cholesterol, he uses the Medsensio Screening Tool at home to proactively determine his risk of CVD.

Action John opens his mobile device to begin the Medsensio Screening Tool. He provides his medical history, including any current diagnoses of high blood pressure and cholesterol. He takes his blood pressure with a home monitor and enters the results into the Screening Tool. The application asks John questions concerning his food, degree of physical activity, and smoking, among other lifestyle behaviours. He replies truthfully to these inquiries to present a complete picture of his health.

Outcome

The Medsensio Screening Tool creates a customized risk score by analysing John's self-reported data.

Two Hypothetical Situations

Situation A: High-Risk Circumstance

The screening tool classifies John as having a high risk of developing CVD. Based on this high-risk classification, the tool suggests that John schedule a consultation with a healthcare provider for additional assessment.

Example B: Mid-Risk Result

The screening tool produces a moderate CVD risk score. The tool recommends lifestyle changes or provides educational materials to assist John in managing their risk factors and enhancing their general health.

Chapter Summary

This chapter outlines the risk calculator application's use cases and desired user demands. It provides further detail about the method we used to search for calculators online and describes the particular model selected as the basis for the application's design. This chapter also includes illustrative user interactions with the app to improve reader comprehension. Before embarking on the design process, we comprehensively investigated platform limitations, design principles, and user requirements. We aimed to find a delicate balance between utility, aesthetics, and usability, and we achieved this by creating and refining the interface design, drawing on insights gleaned from user personas and usage scenarios.

3

System Design and Development

This chapter will explain the decisions made during the project's design phase. It will mainly focus on detailing the technical aspects of the Medsensio Screening Tool, including the algorithm implementation, user interface design, and integration with the existing Medsensio platform.

3.1 Medsensio Architecture

3.1.1 Medsensio System Architecture

Medsensio adheres to a client-server architecture. Through a mobile app, the user interacts with the application; a robust backend system handles data processing and connectivity with many databases and external services. The mobile app and backend systems may communicate data seamlessly thanks to the Fast Healthcare Interoperability Resources (FHIR) standard, which also allows for integration with already-existing electronic medical records. A specialized authentication service (Auth) verifies user credentials on the backend. Figure 3.1 depicts the Medsensio Architecture.

The backend system consists of several crucial parts. Data communication with

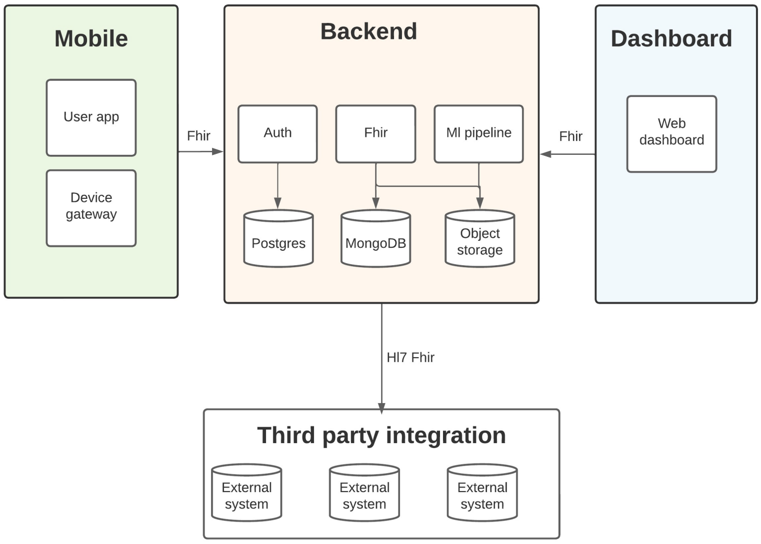

Figure 3.1: Medsensio Architecture

the mobile app and healthcare data sources is made more accessible by a dedicated FHIR service. Our advanced *machine intelligence (MI)* pipeline, a key component, is used for data translation, processing, and even producing predictions or insights using cutting-edge machine learning models. PostgreSQL manages relational data in data storage, whereas MongoDB serves specific data types or scenarios where flexibility is paramount. Large unstructured data items, such as medical scans or photographs, are supported by object storage. Third-party integration, or interface with external systems outside basic functionality, is made possible by the design. Examples of such systems include appointment scheduling software, public health databases, and other pertinent third-party applications. Lastly, an online dashboard offers medical practitioners a consolidated view of patient data and risk assessments produced by the mobile application. This enables thorough patient monitoring and may assist in making clinical decisions. As the Medsensio Screening Tool is the module integrated inside Medsensio, we considered this system design.

3.1.2 Medsensio GDPR Data Flow Architecture

This section illustrates a data flow architecture for Medsensio. Data sources like questionnaires, vital signs, and sensor data are obtained from patients and possibly from wearable sensor devices. The mobile app gathers this health information and potentially auscultation files (recordings of heart and lung sounds). Figure 3.2 depicts the Medsensio GDPR Data Flow Architecture.

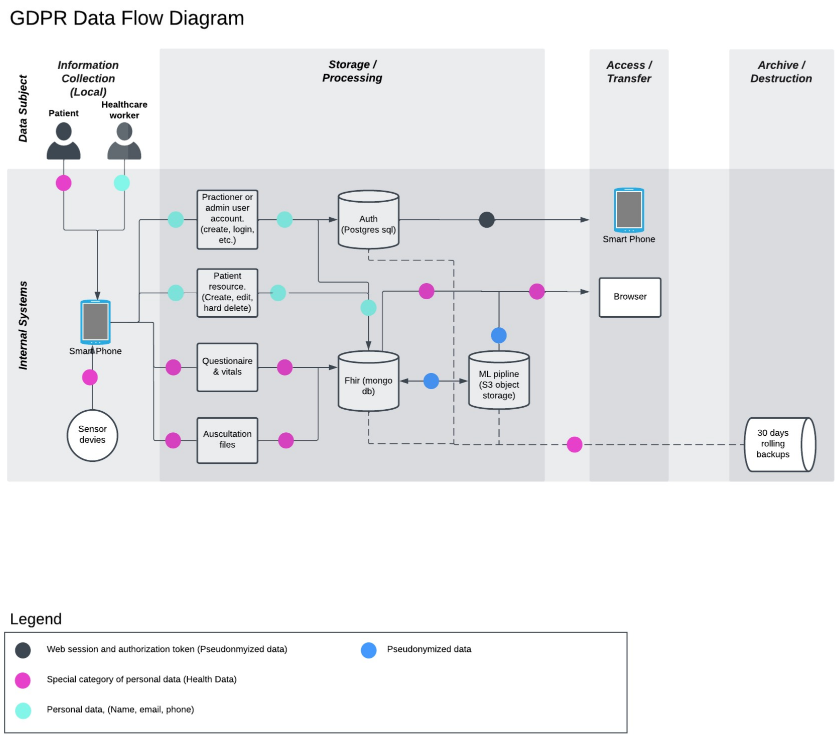

Figure 3.2: Medsensio Data Flow Architecture

To enable data sharing with other healthcare systems, we store FHIR-prepared data in a separate MongoDB database and retain primary healthcare data in Postgres (SQL). We also consider using an optional machine-learning pipeline deployed in the cloud for data analysis tasks. Through a safe web interface that can add, amend, and remove patient records, authorized healthcare providers can view and manage patient data—possibly pseudonymized for privacy. A rolling 30-day backup system may be in place for error correction or disaster recovery. This solution includes possible machine learning analysis, uses backend databases for storage, collects data via a mobile app, and offers authorized healthcare practitioners a secure web interface to manage patient health data.

Patient Input to AI Analysis and Dashboard Presentation

A feature of Medsensio's design is to facilitate patient self-monitoring. Vital signs, auscultation recordings, symptoms, and questionnaire responses are a few of the health data points that patients provide into the app (Input of vitals, auscultations, symptoms, questionnaire data). The program allows continuous monitoring and forecasting by sending this data to a backend server. A dedicated AI module analyzes the data, focusing on respiratory and heart health. We can create patient health forecasts and detect data trends over time with the help of this AI.

Figure 3.3 depicts the architecture for the Analysis of Patient Self-Monitoring.

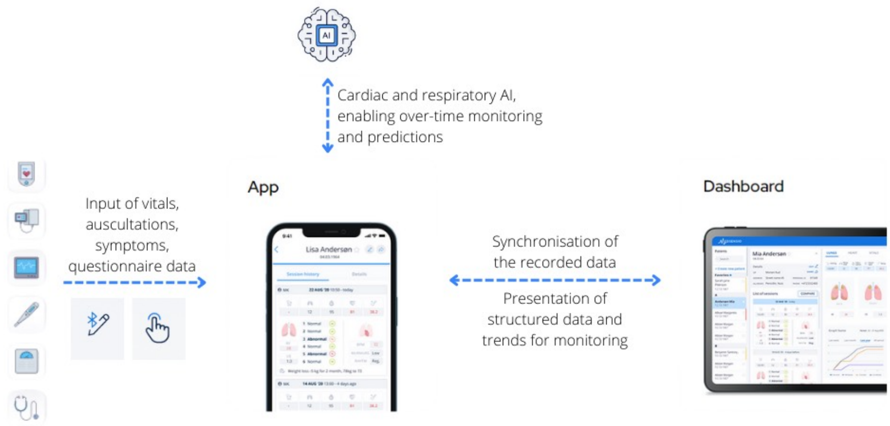

Figure 3.3: Architecture for Analysis for Patient Self-Monitoring

Once the data is collected and analyzed, the backend system organizes and prepares it for visualization. This structured data and trends are then presented on a dashboard, making it easily accessible for healthcare providers. With the help of AI-powered analysis, this method enables ongoing patient self-monitoring, which can significantly contribute to making informed healthcare decisions.

3.2 System Design-Medsensio Screening Tool

3.2.1 Functional and Non-functional Requirements for Medsensio Screening Tool

We specified this project's functional requirements, as outlined in Table 3.1.

Table 3.1: Functional Requirements

Requirements	**Grounds**
The application must start when opened by the user	The application must launch effectively for users to access and use its features.
The user must be able to sign in with the credentials	Users must sign in to the application because it requires them to create a user profile to utilize its features.
The user must be asked if they would like to share their data	Getting users' express agreement is crucial before handling and evaluating their personal information.
Data must be stored in backend to run the algorithm	For the screening tool to run the algorithm, user-provided data is needed in the database.
User must be provided with the form to fill up their vitals	Users must have access to a form on the application to enter their personal data.
The Application must run the algorithm to present the risk score	To compute the estimated risk, the risk score prediction algorithm needs to run in the background.
The Application must provide recommendations to the user	After the user enters their vitals, the application ought to offer suggestions for enhancing their well-being.
The Application must save the data from the user	To maintain the user profile and for future reference, the data that the user submits must be kept in the database.
The Application must allow user to log out	It should be possible for users to choose whether to use the program or log out.

We specified this project's non-functional requirements as described below.

Security Measures

By using strong network request management, the Medsensio React Native application emphasizes secure data delivery, including safe token management for storage and transmission, token-based authentication utilizing JavaScript Object Notation (JSON) Web Tokens (JWT), and Hyper-Text Transfer Protocols (HTTPS) encryption methods (SSL/TLS). Token refresh procedures are integrated into the program to provide continuous access, and error handling is integrated smoothly to address network and server difficulties. All API interactions are subject to uniform security regulations and error handling due to centralized interceptors and middleware. Medsensio guarantees patient data security with industry-leading practices by putting these protections in place and adhering to industry standards such as Health Insurance Portability and

Accountability Act (HIPAA) and General Data Protection Regulation (GDPR). As the Medsensio Screening tool functions as a component within the platform, it inherits all these security measures.

Data Protection and Compliance

Medsensio adheres to industry standards and puts vital security elements in place to protect data and comply with regulations. The program uses token-based authentication for user access control and HTTPS encryption for secure data delivery. Comprehensive input validation reduces security concerns, while secure storage protects sensitive data like client secrets. Error handling safeguards data confidentiality by sending out safe and instructive notifications. Furthermore, Medsensio complies with GDPR and HIPAA requirements, guaranteeing the lawful and moral management of patient data and respecting the privacy rights of users. Since the Medsensio Screening tool is integral to the current platform, it is bound by all these compliance and data protection protocols.

User-Friendly Interface

A key element impacting the Medsensio screening tool's adoption and effectiveness among cardiac patients is its accessibility. Interface design should prioritize intuitiveness and user-friendliness to accommodate users with different degrees of technological skill and accessibility needs. Implementing user-centred design concepts and conducting usability testing sessions can enhance the tool's interface for a better user experience. In addition, accessibility standards, like the *Web Content Accessibility Guidelines (WCAG)* principles, must be considered to guarantee inclusion and usability for people with impairments. The interface of the Medsensio Screening Tool complies with the design specifications of the larger Medsensio platform.

System reliability and availability

Medsensio recognizes the value of dependable and easily accessible healthcare services. The platform uses redundancy and fault-tolerant architecture to prioritize resilience, which reduces service interruptions and downtime. In order to ensure optimal system function, proactive monitoring, and performance optimization procedures spot possible problems before they develop. Medsensio uses industry best practices in reliability engineering and scalable infrastructure to further enhance platform responsiveness and uptime. They further enhance the application's dependability and availability by centralized error handling and constant performance testing, which promise that users will always have access to healthcare services. With this consideration, the user can also access the Medsensio Screening tool.

3.2.2 Introduction to Medsensio Screening tool

Based on the architecture explained above, the Medsensio Screening Tool is a response designed to meet the critical demand for precise and effective risk assessment techniques in cardiovascular health. Integrating this technology into the current medical platform makes personalized patient care and preemptive healthcare interventions possible. Figure 3.4 depicts the existing Medsensio Platform.

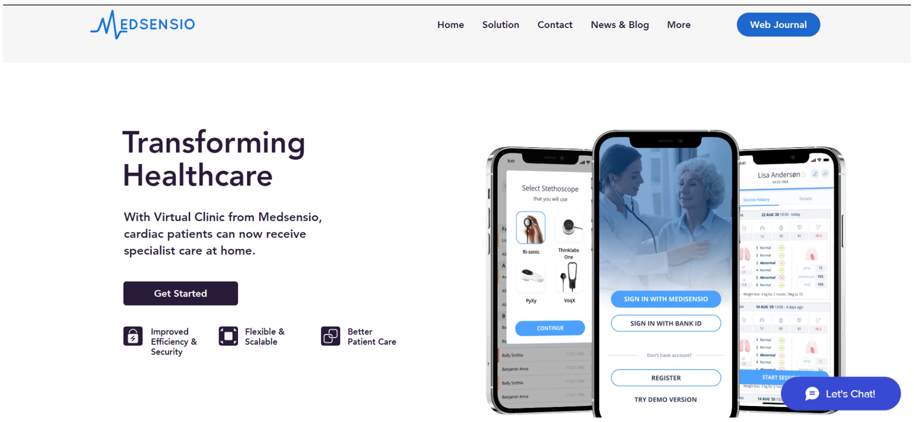

Figure 3.4: Medsensio Platform

Using an open-source algorithm is fundamental to creating the Medsensio Screening Tool. We made this decision after carefully evaluating the algorithm's effectiveness, accessibility, and adaptability. Through an open-source methodology, the development team upholds a collaborative and transparent mentality, using the combined experience of the broader scientific and technological community. In addition, translating the algorithm into JavaScript emphasizes a conscious attempt to conform to the technology ecosystem of the platform that runs on React Native, guaranteeing compatibility and easy integration. By carefully combining open-source values with technological compatibility, the Medsensio Screening Tool becomes a flexible and adaptive tool that has the potential to break through traditional barriers in the field of cardiovascular risk assessment.

3.2.3 Actors

Several actors are essential to the Medsensio Screening tool's operation and use within its ecosystem. These stakeholders include end users and the system's technological elements, and they work together to facilitate the screening tool's efficient implementation and functioning. The leading players in this scenario are Android users, Apple users, the screening tool itself, and the open AI. Each party plays a unique but connected role in the application's structure.

Android Users

Those who utilize Android-based mobile devices to connect with the Medsensio Screening tool comprise a sizable portion of the population. These users interact with the application to enter relevant personal health data, like gender, age, blood pressure, cholesterol, and smoking status. They engage with the application by supplying precise and thorough data to create an individual risk score. Additionally, Android users can use the application to browse other resources like lifestyle guidelines for reducing cardiovascular risk factors. Optimizing the application's design and functionality to guarantee a smooth and intuitive user experience requires a thorough understanding of Android users' preferences, behaviours, and usability expectations.

Apple Users

Comparably, another sizable user population using Apple-branded devices, like iPhones or iPads, to interact with the Medsensio Screening tool comprises Apple users. Like their Android counterparts, these users use the application UI to give vital health-related information to determine their unique risk scores. Apple consumers' interactions with the application ecosystem distinguish themselves through smooth integration with the iOS operating system, leveraging native features and user interface paradigms exclusive to the Apple ecosystem. Therefore, to maximize the application's usability and adoption among Apple users, considerations for platform-specific design rules and user experience concepts customized to Apple's ecosystem are essential.

Medsensio Screening tool

The Medsensio Screening tool functions as the application's computational engine, gathering user data from Android and Apple devices and processing it using advanced risk assessment algorithms to produce individual risk ratings for cardiovascular disease. The screening tool aims to enable users to control their cardiovascular health proactively. The tool provides risk evaluations along with tailored recommendations and treatments. The screening tool's accuracy, dependability, and efficiency are crucial factors in ensuring the application's effectiveness and credibility.

Open AI

One of the most important actors in the project framework is OpenAI. The goal is to provide heart patients customized guidance on managing their cardiovascular health. Each user receives an adapted set of recommendations based on their unique input parameters. Unlike traditional risk assessment techniques, our Medsensio screening platform integrates OpenAI. The connection thus reduces the need for direct interaction from medical professionals by generating customized suggestions based on user input parameters. OpenAI acts as an AI doctor by using its vast training data to make personalized suggestions for patients, improving the effectiveness and availability of medical care.

3.3 Medsensio Screening Tool Implementation

This section outlines the implementation of the Medsensio screening tool into the existing Medsensio platform.

3.3.1 Software and Tools

JavaScript

JavaScript is a popular, flexible programming language often used to create interactive web apps. Initially written in PHP, we converted the Qrisk algorithm to JavaScript to facilitate integration with the React Native framework, which is built using JavaScript.

Npm

Node Package Manager (Npm) is the package management for the JavaScript programming language. Regular use of Node.js apps includes installing, organizing, and distributing reusable code packages. To add libraries, start and stop the Qrisk Screening tool, React Native application's development environment, utilize Npm.

Yarn

Yarn is another JavaScript package manager developed by Facebook. It seeks to outperform npm by offering quicker and more dependable package installations, caching, and parallel dependency resolution. In the early prototyping phases, we developed the first iteration of the Qrisk screening tool prototype using npm. However, as we attempted to facilitate integration, the next iteration switched to yarn.

Node.js

JavaScript runtime environment Node.js is open-source and cross-platform, which enables JavaScript´s code execution outside a web browser. One of its everyday purposes is creating fast and scalable server-side applications.

Node.js allows non-blocking, event-driven I/O operations, making it perfect for real-time applications that require high concurrency and low latency. Within its vast ecosystem of libraries and packages, developers can find many tools and resources to accelerate development processes, all under the direction of npm.

React.js

We used React.js as our main framework to guide the application's creation. The open-source React JavaScript framework makes single-page application development easier. Interestingly, we can use this framework for server-side rendering and client-side operations.

Moreover, React Native has become a crucial instrument for optimizing the creation of applications for the iOS and Android platforms. React Native is a Facebook product that streamlines the building of cross-platform applications by utilizing a single code base that may be written in TypeScript or JavaScript and allows integration of online content into the application interface.

The Qrisk screening tool's foundation is React Native, which we use for everything from background data retrieval from the database to designing the user interface.

Especial Packages Installed In React Native

This section discusses special packages installed in react native when developing the screening tool.

@react-native-async-storage/async-storage

This package offers an asynchronous, persistent, key-value storage system is not secured for React Native applications. It allows programmers to save data locally on the user's device and offers a straightforward Application Programming Interface (API) for asynchronously reading, storing, and managing data. Asynchronous storage is essential for mobile applications to function smoothly and avoid stopping the main thread when retrieving stored data.

@react-navigation/native

This package is a critical component of the React Navigation library, which offers a navigational solution for React Native applications. Navigation is crucial for mobile applications to function correctly and allow users to easily switch between screens and app parts.. React Navigation improves the user experience by providing simple navigation flows and a declarative API for creating navigation structures such as stack, tab, drawer, and modal navigators.

@reduxjs/toolkit and react-redux

Redux is a scalable and predictable state container for JavaScript applications. Developers frequently use it in conjunction with React to manage application state. A package called @reduxjs/toolkit makes it easier to use Redux by offering tools to make typical Redux patterns—like making reducers, actions, and store configurations—more efficient. The companion package react-redux makes it easy to integrate React applications with Redux by allowing components to talk to the Redux store and listen to changes in state. It guarantees effective state management and data flow across the entire application.

@react-navigation/native-stack

Specifically designed to handle stack-based navigation in React Native applications, this package extends the React Navigation framework. Stack navigation is a popular style of screen organization that enables users to move forward and backwards through a linear sequence of displays. With layered navigation, header customization, and transition animations, @react-navigation/native-stack offers a straightforward API for creating and managing stack navigators.

react-native-screens

This package provides native primitives for drawing screens, optimizing memory utilization, and screen transitions in React Native applications. React-native screens enhance the responsiveness and performance of screen navigation and rendering by utilizing native components rather than JavaScript-based ones, which leads to seamless user experiences and less memory overhead. It is standard procedure to incorporate screen transitions and animations with navigation tools such as React Navigation to improve their performance.

Hardware

The project uses an Intel Xeon E5-1650 v4 CPU to create a powerful processing environment for intensive software development tasks. The 12-core CPU with hyperthreading (24 threads) and 31 GiB of RAM guarantees efficient resource allocation. The system also uses a 234 GB storage disk with plenty of space for future needs. The Ubuntu 22.04.1 LTS (64-bit) operating system offers a reliable and secure basis for project development.

3.3.2 Qrisk3 Algorithm: A Detailed Review

We can find the original Qrisk algorithm here [1], which we converted to Javascript to integrate into the Medsensio code base. The Medsensio Screening Tool development only concentrated on the male algorithm to speed up the integration process, even though different algorithms exist for male and female populations.

The given algorithm is a function named *cvd_male_raw*. This function computes a CVD risk score based on input parameters, including patient demographics, medical history, and health indicators. The first step in the procedure is initializing an array survivor and the two conditional arrays, Iethrisk and Ismoke. We can compute the risk score using these arrays to hold coefficients depending on risk factors, including age, BMI, smoking status, and medical history.

The technique then centres continuous variables and performs fractional polynomial transforms to prepare them for computation. The algorithm then determines a sum (a) based on the input parameters, which include blood pressure, age, BMI, smoking status, and several boolean variables that reflect risk factors and medical conditions. We can use the coefficients from the conditional arrays,

1. (Qrisk Algorithm)

the interaction terms, and the continuous values to compute the sum (a). The program computes the risk score using the computed total (a) and displays the result as a percentage.

In conclusion, the *cvd_male_raw* function implements an equation for calculating the likelihood of cardiovascular disease based on patient data. The technique uses a variety of risk factors, conditional arrays, and interaction terms to compute a risk score that evaluates the patient's cardiovascular health.

3.3.3 Algorithm Implementation

The algorithm used in the Medsensio Screening Tool's risk assessment is crucial since it provides the framework for precise risk prediction and assessment of cardiovascular disease.

Moreover, translating the algorithm from PHP to JavaScript is a crucial task that we must be perform carefully. This is to guarantee that it will operate with the React Native environment, the chosen technology stack of the Medsensio medical platform. The original PHP algorithm was translated and modified into JavaScript to guarantee compatibility with the React Native framework. This adaption considered the unique specifications and features required by the React Native environment. We focused on the essential features of the current code because any changes, no matter how small, can affect the risk score.

Several issues complicated the development process, such as understanding the medical terms used as inputs for the algorithm and platform-specific complexities in the React Native framework. Working with Medsensio's physicians solved these difficulties iteratively. Furthermore, the Medsensio team was very helpful in tackling problems unique to the React Native technology.

3.4 Medsensio Screening Tool Integration

The Medsensio Screening Tool was developed using the React Native framework and integrated into the current codebase. This strategy ensured that integration with the platform's current features went well. We updated the shared repository with necessary resources for the screening tool, such as text, photos, reducers, and sagas, which are unique to React Native development. This centralized method made version control and collaboration more effective.

The design step involves creating a localized version of the production environment for development purposes, which allows the Medsensio Screening Tool to be built inside the React Native-developed Medsensio codebase.

We built the tool as a modular component using the platform's React Native codebase to achieve seamless integration. This method reduces the possibility of conflicts with current features by promoting code reuse and guaranteeing that the screening tool follows accepted design patterns. The screening tool also takes advantage of platform features like user authentication. The tool does not save user input now. However, its architecture allows for future integration, which means it is possible to implement more sophisticated functionalities using the data gathered. This centralized method streamlines version management for various materials and ensures consistency in appearance. The emphasis on modularity and using already-existing platform services creates the framework for upcoming improvements.

3.4.1 Integration and Interoperability with existing medical system standards such as FHIR.

FHIR[38] stands for Fast Healthcare Interoperability Resources. It is a standard for electronically transferring medical records. The goal of FHIR is to make it easier for various healthcare systems and apps to communicate with one another. Thanks to its foundation in cutting-edge web technologies like *Representational State Transfer Application Programming Interface (RESTful APIs)* and JSON, FHIR is easier to use and integrates with existing systems more efficiently. To facilitate smooth communication across different healthcare entities, such as *Electronic Health Record (EHR)*systems, mobile applications, medical devices, and other healthcare IT systems, FHIR offers a standardized method to represent and share healthcare data. Notably, FHIR is currently in use, with systems like DIPS in Norway and medical platforms like Medsensio adopting it. It is also important to note that FHIR is the foundation of EPIC, a well-known healthcare system.

Integrating the risk assessment tool with the current Medsensio platform is an essential part of the development process, which requires strict coding standards and close attention to detail.

Obtaining the coding of the Medsensio platform provided the basis for developing the Medsensio Screening Tool inside the current structure. We set up a local development environment that replicated the essential features of the production environment to aid in efficient development and testing. We developed New components tailored to the screening tool alongside pre-existing components used by other Medsensio platform functionalities.

Setting up several environment variables that the Medsensio team gave was part of configuring this local environment. The variables *API_HOST*, *FHIR_API_URL*, *FHIR_API_URL_PURE*, *CLIENT_ID*, *SUBSCRIPTION_URL* and *CLIENT_SECRET* serve as crucial interfaces that facilitate smooth communication between the risk assessment tool and the backend services of the Medsensio platform.

One of the many difficulties that we faced was naming conflicts. A folder called "patient-screen," for example, that was added to the Medsensio codebase to serve as a screening tool clashed with two other folders called "patient-list" and "patient-session-list." To fix this problem, we renamed the files inside the folders "form-one" and "form-two" to comply with the platform's naming guidelines. This change avoided misunderstanding by clarifying that the "patient-screen" subdirectory refers to the recently developed Medsensio screening tool while maintaining code consistency. We followed Medsensio's naming convention to prevent mistakes because similar issues occurred with variable names. Another difficulty was Medsensio's coding style. When creating new parts for the screening tool, Following Medsensio's established code patterns and stylistic conventions was essential. This reduced compatibility problems and guaranteed smooth integration. The Medsensio Screening Tool has effectively included several new elements. The "result-screen-recommendation" component is a prime illustration. This section concentrates on providing users with individualized recommendations, a crucial component of the Medsensio Screening Tool. The tool uses user-submitted screening data and OpenAI's capabilities to provide personalized health advice. After analyzing this data, OpenAI's sophisticated language model makes recommendations especially pertinent to each user's unique health profile. Furthermore, minor elements such as "result-screen-header" and "result-screen-display-one" were created for the Medsensio Screning Tool that aligns with the Medsensio platform's current visual style, promoting a unified user experience. We ensured consistency in these sections by replicating Medsensio's standard design styles. The Medsensio Screening tool, integrated with current medical platforms, might lessen the hassle of continually entering different data. In this case, users only need to enter a few parameters; the system can provide the rest automatically. It might minimise the need for direct physician engagement by providing prompt interventions, real-time notifications, and messaging choices regarding any possible problems. Thus, it is more effective than its online equivalent.

3.4.2 Deployment

Comprehensive integration testing was not possible within the project duration due to time restrictions and the intrinsic complexity of the Medsensio codebase. It would have taken much time to efficiently integrate all the parts with the Medsensio platform to produce a working prototype. Nevertheless, we used a different strategy to show how the screening tool for this thesis works. We created a separate functioning codebase apart from the Medsensio platform. This standalone version allowed us to install the Android APK file for Android users and conduct extensive testing. Although the application was tested on the iOS platform, no iOS device version was created—this was done to expedite the process. By avoiding the requirement for Medsensio permission access, we successfully validated the standalone prototype's functionality and ensured it was error-free.

3.4.3 Consistency Test

We carried out a comprehensive consistency test to ensure that the newly created screening tool within the Medsensio platform, which uses React Native, gives consistent results with the original web-based QRisk algorithm, which is written in Hypertext Preprocessor (PHP). This is important because even minor implementation differences can significantly impact the results of risk assessments.

We employed a series of pre-defined test cases to compare the outcomes produced by both implementations. Our investigation found ten per cent differences in the risk ratings generated.

We conducted several controlled experiments to assess the consistency between the recently created Medsensio screening tool and the original web-based QRisk algorithm. Using a defined set of six parameters explained in Table 3.2, we chose a targeted testing strategy to enable practical evaluation while capturing a representative range of possible user inputs. For every test case, the results produced by both implementations were painstakingly recorded and contrasted to evaluate consistency.

Table 3.3 shows the risk scores both algorithms produce in every test case. Through test result analysis, we found a high level of consistency between the original QRisk algorithm and the Medsensio screening tool. In almost 90 percent of the test instances, the risk scores from the two implementations were the same.

It is crucial to remember algorithms' inherent complexity. As we observed in roughly 10 percent of the test cases, even the most minor modifications can lead to variations. These differences, although small, highlight the need for further investigation and understanding. Recognizing the importance of our work, there is a need for conducting additional research. This research will be instrumental in determining the reasons for the observed differences, ensuring a consistent risk assessment experience. The method's implementation will

Table 3.2: Parameters used for Consistency Test

Parameters	1st test	2nd test	3rd test	4th test	5th test	6th test
	33	30	35	40	31	50
Age	33	30	35	40	31	50
Ethnicity	Chinese	Other Asian	Black African	Pakistani	Other Ethnic Group	Indian
Smoking status	Ex-smoker	Ex-smoker	Light Smoker	Ex-smoker	Non-smoker	Ex-smoker
Heart Attack < 60 years	No	No	No	Yes	No	No
Blood Pressure treatment	No	No	No	No	Yes	No
Erectile dysfunction	No	No	No	No	No	No
Migraine	Yes	No	No	Yes	No	No
Systemic Lupus Erythematosus	No	No	No	No	No	No
Severe Mental Illness	No	No	No	No	Yes	No
Atypical Antipsychotic Medication	No	No	No	No	No	No
Regular Steroid tablets	No	No	Yes	No	No	No
Chronic kidney disease	No	No	Yes	No	No	No
Atrial fibrillation	No	No	No	Yes	No	No
Rheumatoid arthritis	No	No	No	No	No	No
Systolic blood pressure	133	130	136	118	136	128
Cholesterol/HDL ratio	4	3	6	4	7	3
Height	178	175	172	178	180	168
Weight	78	72	68	74	72	69
Type-1 diabetes	Yes	No	No	No	Yes	No
Type-2 diabetes	No	No	No	No	No	No

be revised to address and overcome these inconsistencies. We will carry out a thorough review before the deployment to actual users. This validation will include a detailed analysis of every parameter and how it affects the program's overall structure. Due to this multi-step testing and validation process, end users can only access products that consistently produce risk scores using the original QRisk algorithm.

Test Number	Qrisk web version	Medsensio Screening Tool
1st Test	3.4%	3.4%
2nd Test	0.3%	0.3%
3rd Test	5.0%	5.0%
4th Test	14.4%	27.0%
5th Test	8.4%	8.4%
6th Test	5.6%	7%

Table 3.3: Risk Scores for Qrisk web version and Medsensio Screening Tool

4

Large Language Model

4.1 Large Language Model and Prompt Engineering

4.1.1 Large Language Model

LLM constitute a class of foundational models trained on extensive datasets. These models can understand and produce natural language and other types of content and can execute a diverse array of tasks[1].LLMs represent a significant development in AI and Natural Language Processing (NLP). People can easily access them via interfaces like OpenAI's Chat GPT-3 and GPT-4. Google's bidirectional encoder representations from transformers (BERT/RoBERTa), Meta's Llama models, and PaLM models are more examples. Some uses in the medical field are to create medical documentation, clinical decision assistance, healthcare chatbot development, clinical research facilitation, and telemedicine enhancement.

4.1.2 Prompt Engineering

The skill of creating compelling prompts that direct the model to produce desired responses is known as "prompt engineering." It bridges the gap between

1. Large language models

model comprehension and user intent, which is essential to optimizing the efficacy of the language model[39]. A poorly constructed prompt may result in inaccurate or unsatisfactory responses, whereas a well-designed prompt can significantly increase the quality and relevancy of the model's output.

Prompt engineering empowers the developers to create, enhance, and optimize input prompts that convey their purpose to an LLM like ChatGPT. This skill is not just a requirement but a tool that enables users to get precise, pertinent, and well-organized responses from the model, putting them in control of the conversation. The dynamic nature of language models requires programmers to acquire quick technical skills. Achieving optimal outcomes across many applications and optimizing the utility of LLMs such as ChatGPT are becoming increasingly critical.

Prompts are the primary method of communication between the user and the model. They direct the model to provide replies that are consistent with the user's intentions. Comprehending the complexities of prompt engineering is essential to establishing purposeful and fruitful interactions with a model since the prompts' quality directly influences the quality of the generated responses.

Anticipating the model's interpretation and response to the input is crucial to creating prompts. During this process, stakeholders carefully analyze the model's biases, the training set's attributes, and other constraints that may affect the model's generation and understanding capabilities.

4.2 Personalized Recommendation System Design

The Medsensio Screening Tool's incorporation of OpenAI marks a substantial improvement in offering customers individualized advice for efficiently managing their heart health. This section outlines how OpenAI is implemented within the software architecture, emphasizing algorithmic integration and UI improvement to guarantee smooth communication and recommendation delivery.

We considered the overall design goals when developing the OpenAI integration strategy for the Medsensio Screening Tool. The project successfully integrated AI-powered recommendation capabilities into the existing framework, enhancing its functionality.

The efficacy and comprehensibility of the resulting recommendations are given top priority in designing the algorithmic integration with OpenAI.The OpenAI prompt is prepared to direct the model to produce pertinent and valuable health advice based on the individual user's data points. To ensure the recommendations are specifically related to the user's health profile, the prompt, for example, can clarify the values the user entered (e.g., BMI, cholesterol). Enhancing the recommendations' perceived value and trustworthiness requires focusing on user-specific data.

A clear and helpful presentation of the OpenAI-generated recommendations largely depends on the UI. The recommendation display shows the customized suggestions in a modal window. The text summaries in this modal window should be clear and succinct, outlining the suggestions and supporting evidence. This summary can include the user's input values directly to improve clarity. For example, the response starting with "Based on your BMI " makes it more personal to the user. Visual aids like icons or bullet points to highlight important ideas can further enhance user comprehension and engagement.

Although incorporating OpenAI's capabilities into the Medsensio Screening Tool offers intriguing opportunities, the tool currently has a limited scope of user input parameters. Therefore, the tool's capacity to fully utilize OpenAI's capabilities may only be limited if we broaden the range of user input data points. The prototype is limited to three health data points: blood pressure, cholesterol, and BMI. More user data points, such as age, family medical history, and lifestyle choices like exercise and smoking, might be added to the design to give even more comprehensive and distinctive recommendations. Increasing the amount of user data the model considers may result in more insightful and valuable suggestions. The explainability and transparency of the model present another possible limitation. The current implementation uses a potent language model (GPT-3.5-turbo-instruct) to produce suggestions. That said, this model may not only sometimes provide a clear explanation for its recommendations. Subsequent research endeavours may investigate methods to enhance the interpretability of the model, facilitating users' comprehension of the reasoning underlying the system's suggestions, which may boost user assurance and faith in the suggestions made.

4.2.1 User Interface Design

The user interface design for the risk score tool in the Medsensio Screening Tool greatly influences user engagement and the overall user experience. This section describes the procedure for creating a Figma interface that follows the established Medsensio user interface design.

We created the wireframes and mockups using Figma's toolbox to represent the risk-scoring tool interface's design, organization, and functionality. These graphic depictions functioned as blueprints, directing the design process and enabling feedback from stakeholders and iteration cycles. Important design components, including buttons, navigation menus, input fields, and data visualizations, were placed and styled carefully to improve readability, coherence, and clarity.

Moreover, the design artefacts produced by Figma demonstrate the development of design concepts and iterations, thereby capturing the spirit of the user interface. These artefacts, including wireframes and mockups, offer concrete proof of design thinking by emphasizing important layout choices, navigational elements, and design judgments.

We used the iterative design to create the Figma interface, with input from Medsensio stakeholders and results from usability tests, including both Medsensio stakeholders and a group of fellow students. This ultimately resulted in a streamlined interface design that aligns with the medical platform's current UI standards. The interface smoothly blends into the larger medical platform environment by following known design patterns, colour schemes, and typographic rules, giving users a sense of comfort and consistency.

The upcoming sections will show the finalized user interface of the risk scoring tool and provide an insight into the design process through visual representations of the interface design artifacts from Figma. These artifacts will offer a concrete example of the design concepts, layout factors, and navigational elements covered in this subject.

Figures 4.1 and 4.2 depict the UI of the Medsenio platform, whereas Figures 4.3,4.4 and 4.5 depict the UI for the screening tool.

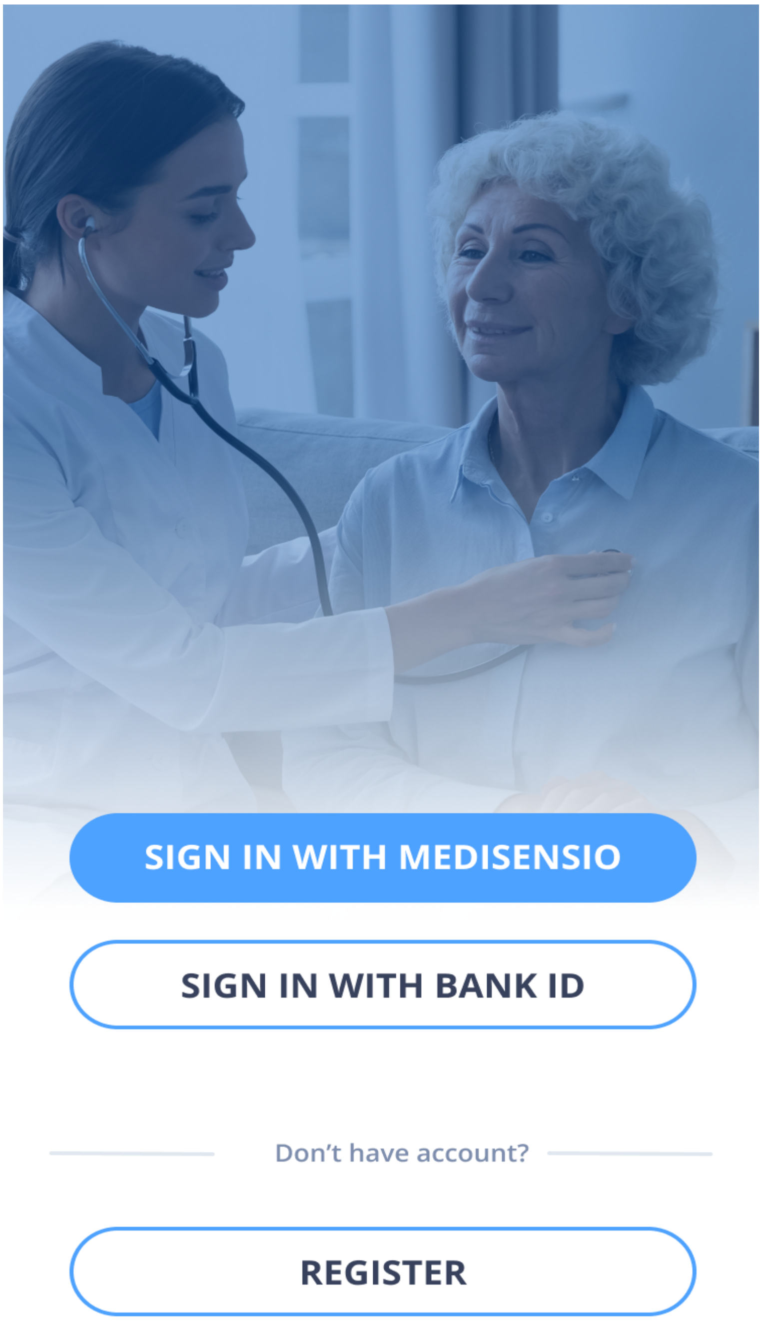

Figure 4.1: Medsensio Login Page

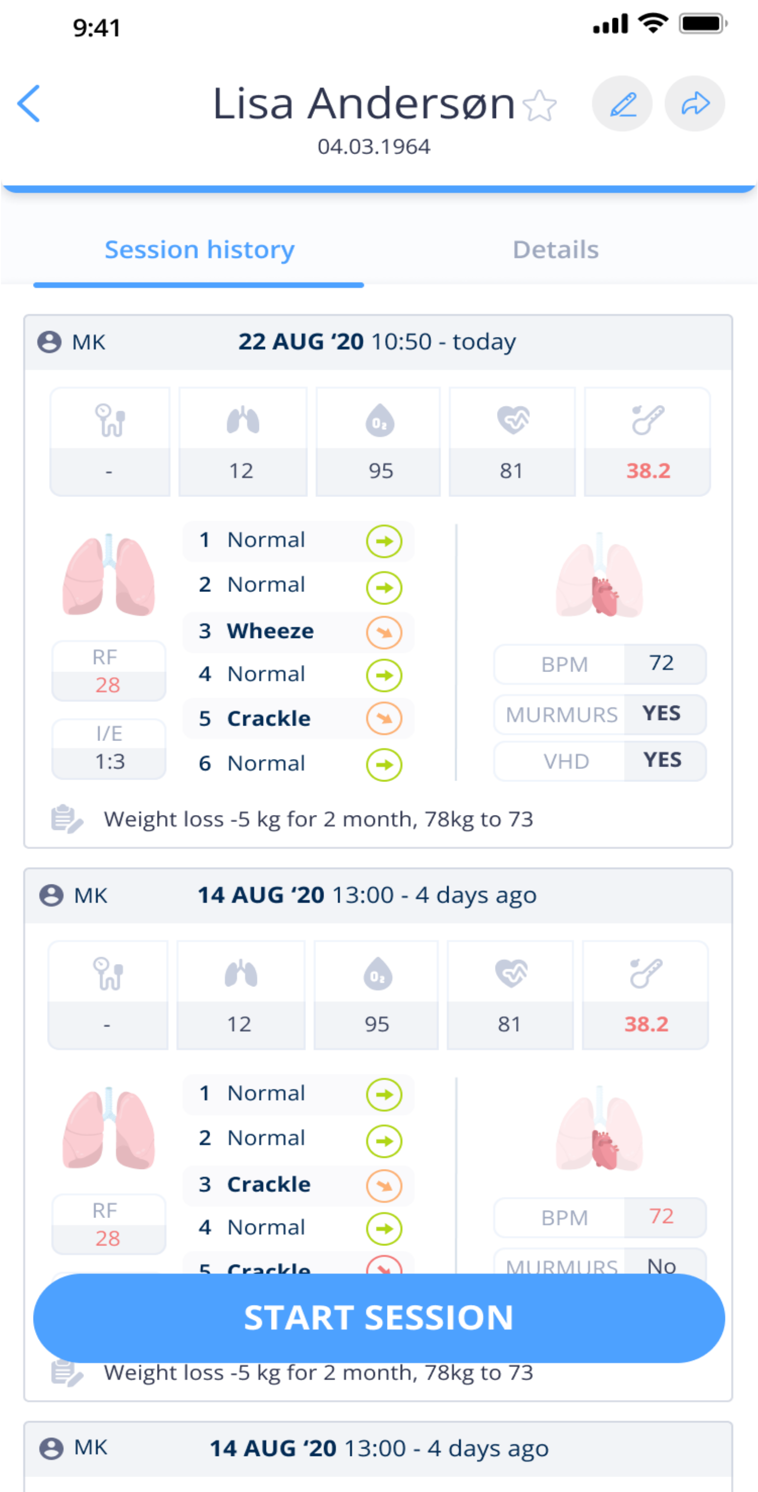

Figure 4.2: Medsensio UI

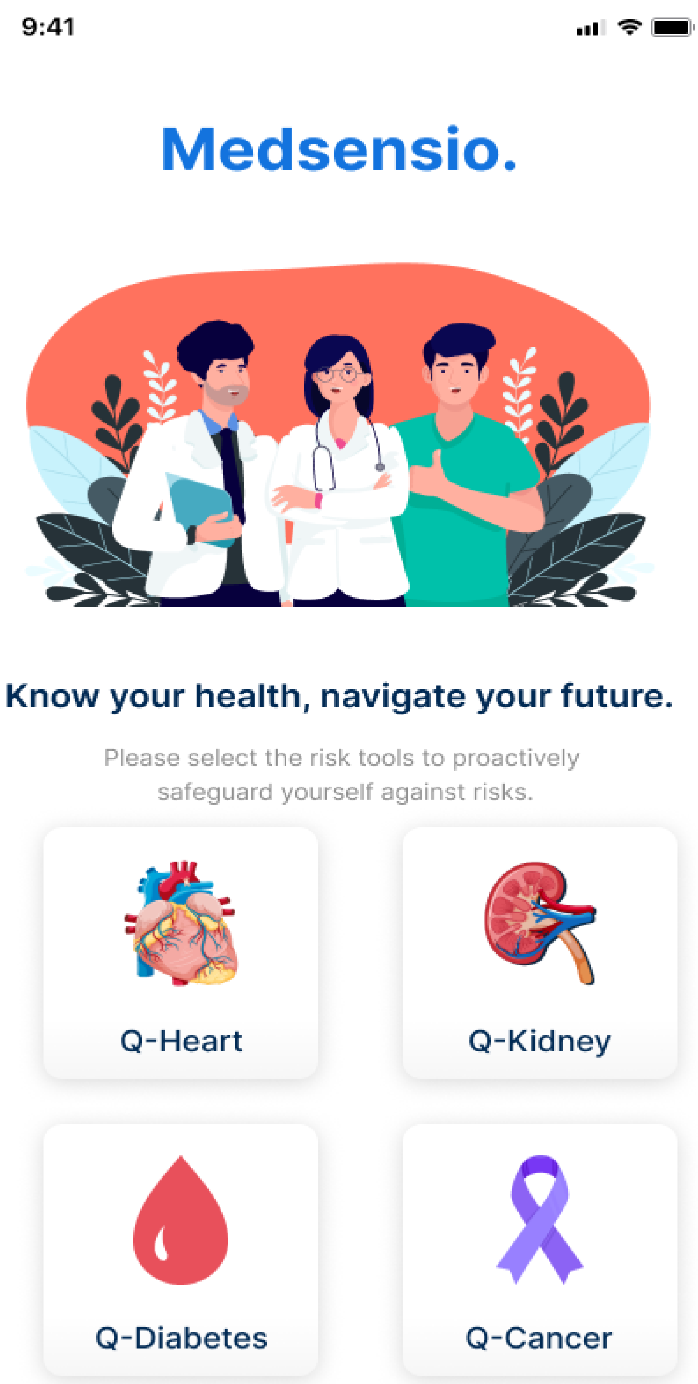

Figure 4.3: Newly created screening tool UI

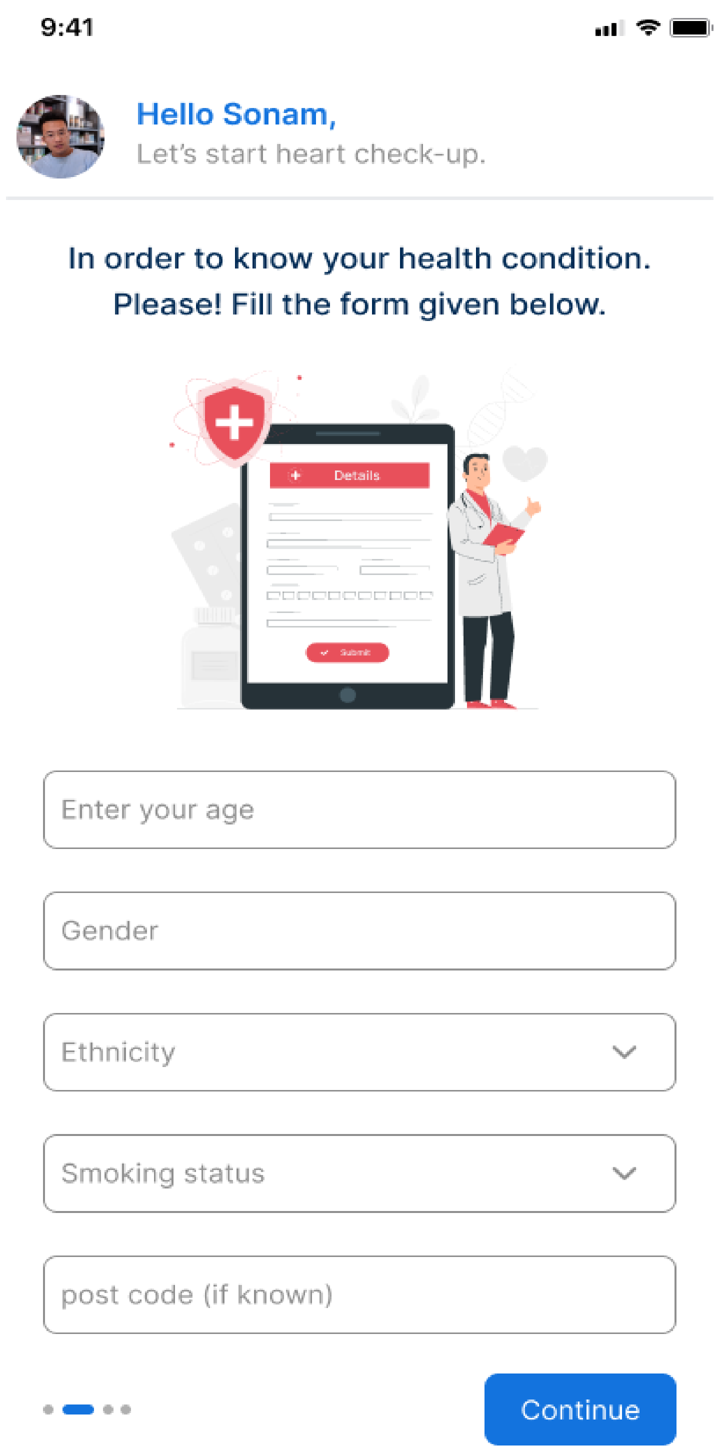

Figure 4.4: Newly created screening tool UI

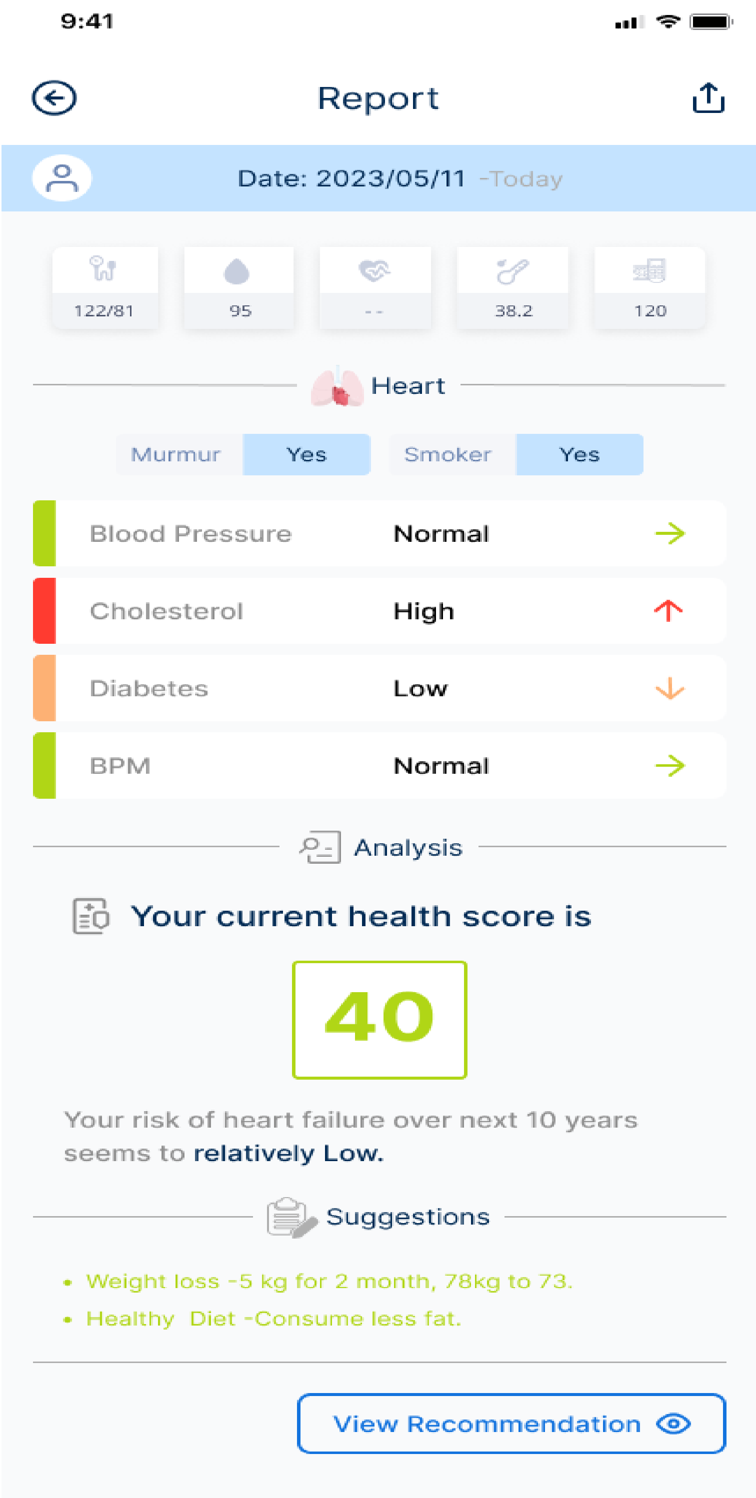

Figure 4.5: Newly created screening tool UI

4.2.2 Development in React Native

After converting the risk score algorithm, the development process moved to creating components based on the Figma-crafted UI design. Every element, including the form field with checkboxes to prompt user input, followed the layout outlined in the design. We use the efficient useState hooks to control the application state, ensuring the consistency of these components. Similarly, we use useDispatch to streamline sending actions to the Redux store. When users filled in input fields, their values were recorded by dispatched actions in the Redux store, allowing them to be used as parameters later in the algorithm.

The riskCalculator.js file included the risk calculation algorithm, which reducer.js used to incorporate into the Redux framework. After collecting user inputs, the function calculates the risk score using inputs received as a parameter. We displayed the computed risk score visually on the application's result screen.

We created the additional components to show user input values and provide contextual feedback about their normalcy to improve the user experience. These elements let users know if the input values they entered were above normal thresholds, below normal thresholds, or inside acceptable ranges.

During this iterative phase, we created several screens to maximize user navigation and interaction. React Native's navigation stack functionality allowed for smooth screen changes, guaranteeing a seamless user experience. Furthermore, Medsensio kept all necessary files, including fonts and pictures, arranged in their directories for easy access and incorporation into the software.

Careful attention to these design and development factors created the risk assessment tool to provide users with informative and intuitive interfaces and an accurate calculation of risk ratings, ultimately improving overall usability and engagement. In conclusion, the *cvd_male_raw* function implements an equation for calculating the likelihood of cardiovascular disease based on patient data. The technique uses a variety of risk factors, conditional arrays, and interaction terms to compute a risk score that evaluates the patient's cardiovascular health.

4.3 Personalized Recommendation System Implementation

4.3.1 Axios

Axios is a NodeJS library that handles HTTP requests. It is a flexible and robust HTTP client that allows JavaScript to communicate with the OpenAI API. For making asynchronous HTTP queries from web browsers and Node.js environments, Axios offers a straightforward but effective interface with capabilities like automated JSON data transformation, request and response interception, and reliable error-handling techniques.

The OpenAI API endpoints can be accessed using the following HTTP request methods:

GET

This protocol facilitates the retrieval of information from the OpenAI servers. Examples of this type of retrieval include pre-trained language models, dataset queries, and model outputs obtained in response to inputs.

POST

The POST method is essential for supplying text prompts, parameters, or configurations to produce data when submitting data to the OpenAI API.

Using these HTTP request methods and the Axios library, the OpenAI API can be easily accessed. It allows for the submission of text prompts, the retrieval of model outputs, and dynamic interaction with state-of-the-art NLP capabilities.

The Medsensio Screening Tool uses OpenAI's features and API to generate suggestions. In order to assure compliance with OpenAI's format criteria, user-entered data items, including Systolic Blood Pressure, BMI, and Cholesterol level, are first prepared. After that, OpenAI's API receives the prepared data via an HTTP POST request, which utilizes Axios to send requests over HTTP to the OpenAI API by provisioning the necessary parameters in the request header. The request includes a prompt specifically designed to direct the model towards producing individualized health advice. After processing the prompt and user data, OpenAI's GPT-3.5-turbo-instruct model provides customized recommendations based on the user's health profile. After receiving the response from OpenAI, the pertinent health suggestions are extracted and structured. When the user selects the "View Recommendation" button, the fetchRecommendations function is triggered to retrieve and display the recommendations within a modal window on the mobile application. This procedure ensures that we utilize the most recent user input. Figure 4.8 depicts the recommendations generated by AI considering the BMI of the user.

Adding customized prompts and unique model identifiers to the request directs OpenAI's recommendation-generating procedure, which allows for extracting relevant insights from user-specific factors. However, several difficulties plagued the installation process. These included situations where the AI model produced either unnecessary or subpar responses, restrictions on tokens that led to truncated responses, times when the server became unresponsive because it was using outdated models, and occasionally, mistakes where the model did not consider user input when creating recommendations.

In response to these difficulties, we implemented an iterative strategy for testing and improvement. These difficulties were resolved through a series of iterations, creating a robust implementation framework. We can distinguish the final version that shows user recommendations produced by OpenAI that are pleasing and contextually appropriate from the initial version of the response. These AI-driven suggestions encourage user participation and give people more agency to manage their cardiovascular health.

Figure 4.6 depicts the prompt written to generate the recommendation from the Open AI model, and Figure 4.7 depicts the code that makes the HTTP request to the Open AI model.

```
import axios from 'axios';

const fetchRecommendations = async (initialBMI, initialCholesterol,initialBloodPressure) => {
    console.log(initialBMI);
    console.log(initialCholesterol);
    console.log(initialBloodPressure);

  try {
    const maxTokens = 200;
    const requestBody = {
      prompt: `As a medical assistant, must provide personalized health recommendations based on input
      obtained after each parameter.The value will be inside curly braces after $ sign for each parameter.
      Based on those parameters generate tailored recommendations to improve user's health and well-being.
      You must display the value inside the placeholder for each parameter to the user in the recommendation
      and argue that their value is either less or more or normal and  generate the recommendation accrodingly.
      1. Body Mass Index (BMI):${initialBMI}
      2. Systolic Blood Pressure (in mmHg):${initialBloodPressure}
      3. Total Cholesterol (in mg/dL):${initialCholesterol}

       `,
      model: 'gpt-3.5-turbo-instruct',
      max_tokens: maxTokens,


    };
```

Figure 4.6: Prompt Engineering For Recommendation

```javascript
    const response = await axios.post(
      'https://api.openai.com/v1/completions',
      requestBody,
      {
        headers: {
          'Content-Type': 'application/json',
          Authorization: 'Bearer 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',
        },
      }
    );

    const responseData = response.data.choices[0].text.trim();


    return responseData;
  } catch (error) {
    console.error('Error fetching recommendations:', error.response.data);
    throw error; // Handle errors in the caller function
  }
};

export default fetchRecommendations;
```

Figure 4.7: HTTP Request to Open AI

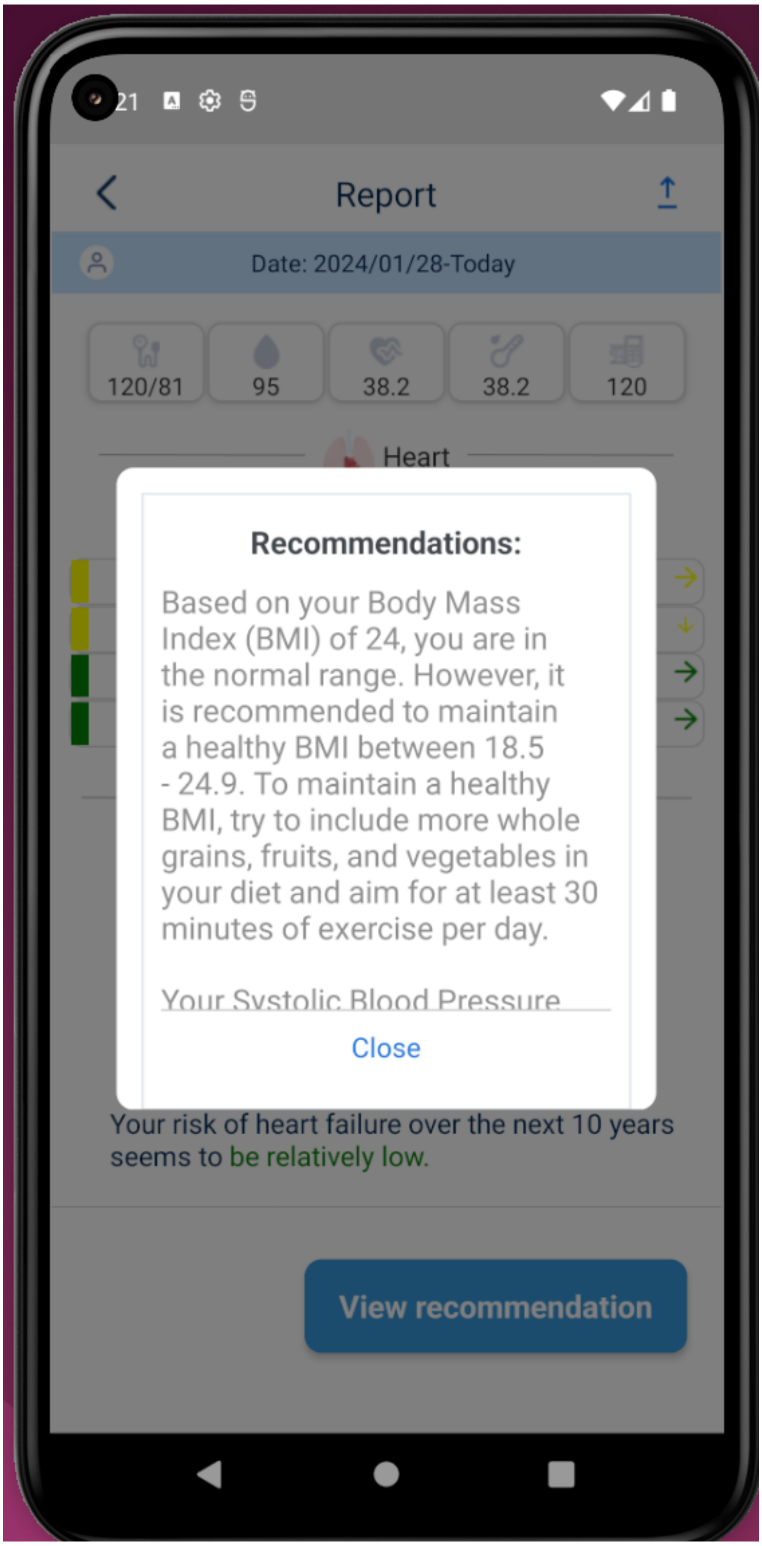

Figure 4.8: AI generated recommendation

5

User Evaluation of the Screening Tool

We conducted user testing, in which we showed the participants the recently created screening tool and gathered their input via open-ended survey questions.

In this study, we did not involve actual platform users in the initial validation phase because the emphasis was on determining whether the risk assessment tool should be included in the Medsensio platform. As an alternative, a group of people(friends, stakeholders, and other students) acquainted with the Medsensio platform were used to test the tool. Before conducting more extensive user testing with the actual Medsensio user base, we may evaluate the tool's suitability for integration using this initial testing in a controlled setting.

5.1 Methodology

This thesis uses qualitative methods to evaluate the usefulness of the recently created risk assessment tool within the Medsensio platform. This method were deemed most suitable for collecting subtle insights and comprehending the views and experiences of the target user group.

Three main questions were the focus of this qualitative evaluation.

1. How practical is the recently created Medsensio platform risk assessment tool?

We performed semi-structured interviews with users who were acquainted with the Medsensio platform in order to evaluate usability. The main discussion topics during the interviews were the tool's user interface, usability, and task completion efficiency.

2. To what extent does the LLM-based recommendation system assist users in finding relevant and valuable suggestions?

To assess the LLM recommendation system's efficacy, we examined user comments regarding the usefulness and pertinence of its suggestions.

3. Do users feel optimistic about the tool fulfilling their demands on the Medsensio platform?

We examined interview transcripts and user-written reviews to learn how valuable users thought the tool was. Users discussed the tool's possible advantages and how it enhanced the functionality of the Medsensio platform.

During the test, we asked a series of questions to learn more about users' opinions regarding the screening tool's efficacy as a self-monitoring and self-management tool for enhancing health outcomes.

We gathered twenty participants to assess the usefulness and usability of the newly built risk assessment tool. These participants included educators with expertise in the health area, software engineers with experience developing mobile applications, and medical professionals from the Medsensio platform. Together, they represented a broad spectrum of prospective end-users within the Medsensio ecosystem. Even though we could not get precise age information for every participant, we ensured the group included people from professional and academic backgrounds to get a range of user viewpoints regarding the tool's incorporation into the Medsensio platform. Personal relationships within our professional and academic networks recruited individuals who completed the evaluation tasks.

The section below provides a comprehensive analysis of the user feedback.

5.2 User Feedback Analysis

5.2.1 Satisfaction with the Risk Assessment Process

Finding: The figure (5.1) below illustrates that 90 percent of users perceive the overall risk assessment process as simple and intuitive.

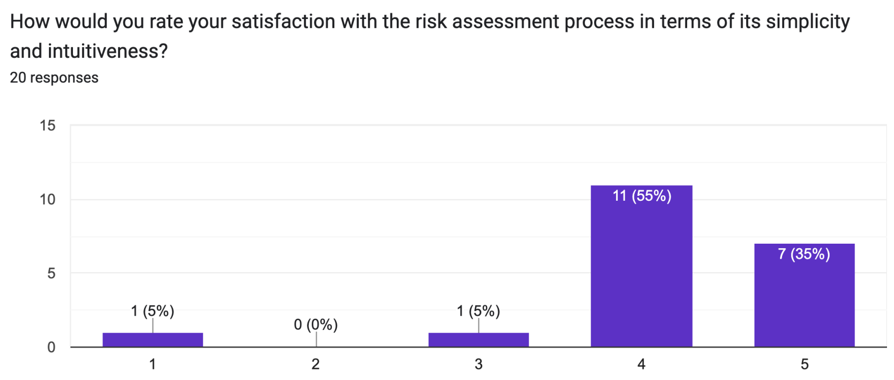

Figure 5.1: Feedback for simplicity and Intuitiveness

5.2.2 Ease of Navigation

Finding:

The following figure (5.2) shows that 85 percent of users think navigating through each step of the risk assessment process is easy.

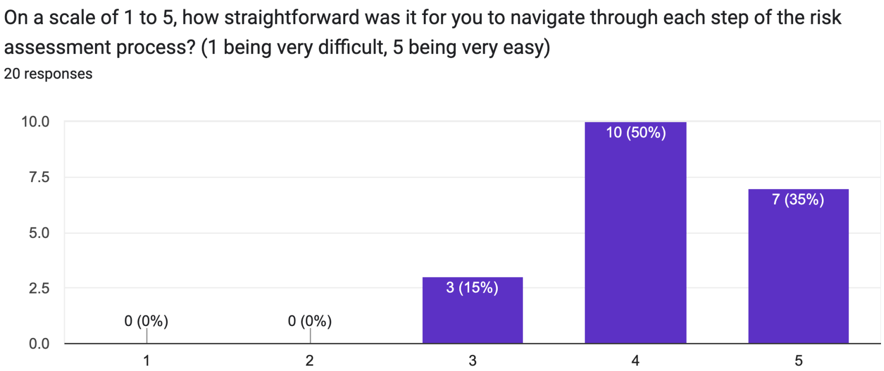

Figure 5.2: Feedback for user flow

5.2.3 Clarity and Effectiveness of Instructions

Finding:

The following figure (5.3) shows that 85 percent of people believe the directions in the screening tool are understandable and useful when completing the evaluation.

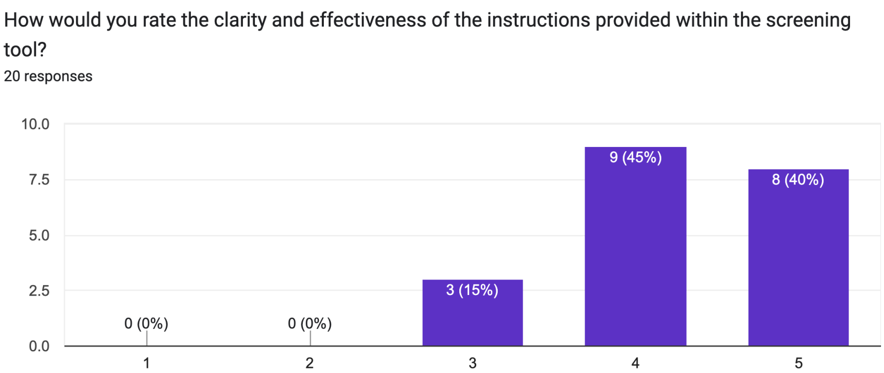

Figure 5.3: Feedback for instruction's clarity and effectiveness

5.2.4 Value of AI-generated Recommendations

Finding:

The figure below (5.4) shows that 65 percent of users think the recommendations made by AI are relevant and valuable.

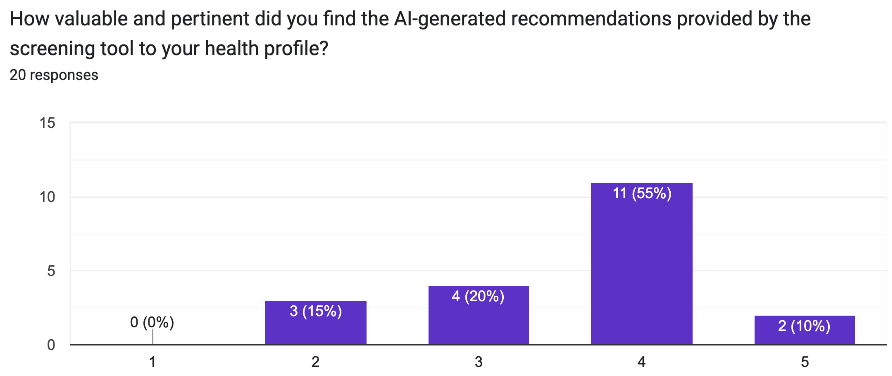

Figure 5.4: Feedback for AI-generated recommendation

5.2.5 Overall Experience of using Screening tool

Finding:

The figure below(5.5) illustrates that 90 percent of users express satisfaction with the overall experience of utilizing such a screening tool, which aids them in leading a healthy lifestyle.

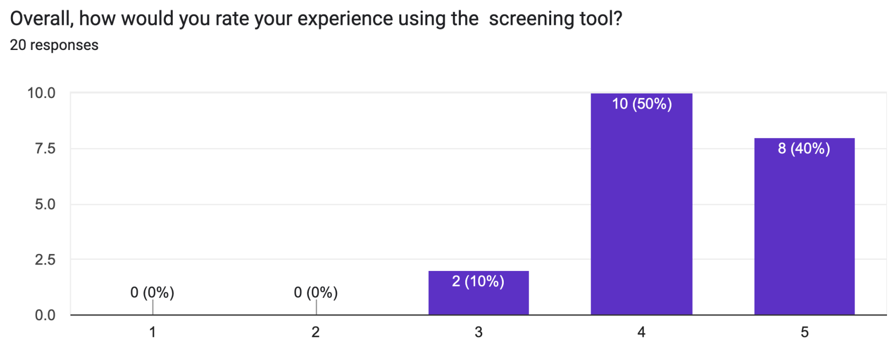

Figure 5.5: Feedback for overall experience

Additionally, the analysis of feedback from users produced several recommendations for improving the tool's efficacy and usability, which we gathered through transcripts of semi-structured interviews and the open-ended responses gathered via the Google Form survey. Users suggested adding info labels on input parameters for clarification, establishing tool tips and helpful text or videos to provide further instruction, and giving more significant details about data interpretation and actionable insights. They also recommended enhancing the user interface to make it more understandable and intuitive, highlighting the significance of ongoing development and pushing for additional user-specific information. Moreover, users suggested refining the UI and notification system to deliver recommendations more effectively. While some users expressed satisfaction with the tool's current state, others deferred offering suggestions until its finalization. These insights highlight areas for refinement and optimization to better align the tool with user needs and preferences.

6

Discussion

6.1 Thesis summary

Assessing heart failure within a specific timeframe is a practical self-care approach. While they cannot replace long-term behaviour change, self-assessment tools like the Medsensio Screening tool provide an affordable and scalable initial screening method to increase knowledge of cardiovascular health concerns and encourage people to lead better lifestyles. This thesis examines clinically validated heart assessment calculators that encourage healthy living by raising cardiac health awareness. It includes thoroughly examining the theoretical foundations required to comprehend key ideas, an extensive analysis of relevant literature, and a requirements analysis.This thesis outlines the planning and execution of incorporating a screening tool into a state-of-the-art medical platform.

We conducted a thorough user evaluation to evaluate the new tool's usability and efficacy within the Medsensio platform. We chose a non-patient user group because exposure to potentially alarming risk scores may cause psychological distress. This group included students, friends, professors, mentors, and medical professionals not directly affiliated with patient care. Using this method, we obtained vital information about how users perceived the risk score system based on their feedback and the suggestions made by the LLM. Future studies should prioritize user safety while investigating the tool's usability and possible advantages with a more extensive Medsensio user base.

In order to evaluate the Medsensio Screening tool's potential, this thesis looked into four essential aspects. A clinically validated risk score algorithm (Qrisk) was initially selected to provide a risk score (SP1). We designed the Medsensio Screening tool for seamless integration within the existing medical platform architecture. With open AI, the tool uses user data to customize health suggestions and inform users about their health status(SP2). The UI we designed for the Medsensio tool leverages AI and GUI elements to provide users with comprehensible, actionable, and practical information about their cardiovascular health risks (SP3). Finally, user feedback confirmed the Medsensio tool's effectiveness as a self-monitoring and self-management tool for heart health evaluation. Interestingly, users showed more trust in using the tool when integrated into the medical platform compared to its web-based counterpart. The survey's findings also point to user confidence in the tailored suggestions (SP4) driven by LLM.

While the user evaluation results provide valuable insights into the tool's functionality, further research is needed to explore potential user empowerment and reduced reliance on healthcare professionals. Additionally, user evaluation revealed that AI-generated health recommendations, detailed in the Evaluation chapter, were perceived as valuable and potentially empower users for proactive health management.

6.2 Strength and Limitations

Strength

This thesis strengthens the potential benefits of the Medsensio Screening tool and advances the field of preventative healthcare through its key strengths. Firstly, the thesis goes beyond utilising an algorithm for independent risk evaluation. The smooth integration of the Medsensio Screening tool into a state-of-the-art medical platform illustrates a comprehensive, end-to-end solution. Patients and healthcare providers benefit from this method's practicality and ease of usage. Healthcare providers may effectively integrate the tool into their current workflow, while patients gain from a comfortable and familiar platform to obtain their risk assessment.

The thesis highlights the tool's potential for practical use and tackles the crucial usability issue in a larger healthcare ecosystem by incorporating it into an actual medical platform. It raises the possibility of acceptance and implementation in clinical settings going well.

Additionally, this thesis investigates the innovative use of LLMs as a preventative healthcare instrument. It paves the way for more research on the role of LLMs in encouraging user participation and self-management of health by providing individualized health recommendations. By adding a layer of innovation to the Medsensio screening tool, this research into LLMs may permit users to adopt a proactive approach to preserving their health and welfare.

Limitation

Although user tests show that the Medsensio tool has received generally positive feedback, we must consider a few restrictions. First, consumers need more confidence in the algorithm's outcomes, which emphasizes the need for additional study on improving user confidence and openness in risk assessment tools driven by AI. Second, some users may become anxious about their cardiovascular health as a result of high-risk scores. Future research will examine instructional materials and stress the value of consulting with medical professionals to address possible user anxiety. The concern draws attention to a possible flaw in the present user study. It highlights the importance of thoroughly assessing the user experience, especially considering the possible psychological effects of becoming aware of hazards.

Maintaining consistent user involvement and compliance with tailored recommendations is still tricky. More studies are required to create tactics that encourage sustained user involvement and encourage people to adhere to advised health interventions. This drawback implies that the user experience may need continuing support methods beyond initial adoption to maintain long-term efficacy. Moreover, due to restrictions in the training data or the underlying algorithms, AI-generated recommendations may differ, possibly producing erroneous or deceptive advice that could deliberately harm users. For instance, recommendations disregarding a person's unique medical history or particular medical circumstances may be harmful.

This preliminary assessment's main areas of attention were the overall tool usability and user experience. Further assessment of the long-term benefits of the Medsensio tool for user health outcomes, including possible enhancements in cardiovascular risk factors and self-management practices, is necessary. It also takes more development work to turn the Medsensio Screening tool into an utterly viable product. Regulatory approvals, such as those required by the *Medical Device Regulation (MDR)*, must be obtained for this process, and compliance with all relevant medical device standards must be guaranteed.

6.3 Contributions

Users can examine their heart health using a variety of easily accessible online clinically certified risk assessment calculators. However, people are frequently discouraged from using these tools because they must determine how reliable these websites are. Adding these clinically proven instruments to reputable medical platforms makes consumers more likely to trust and use the system with assurance.

This master's thesis significantly contributes to creating the Medsensio screening tool. Medsensio can now customize this tool to meet its requirements, improving its long-term usability and efficacy. This thesis evaluated the component's efficacy within the Medsensio platform through a user evaluation with typical user groups, building upon a well-approved and confirmed component. This initiative is a valuable resource for other medical platforms considering creating customized screening tools along similar lines. The thorough explanation of the procedures of using open-source algorithms provides valuable guidance for academics and developers starting such initiatives.

This master's thesis advances the field of study by examining how an AI-generated health recommendation system functions as a user risk assessment tool. The evaluation's findings offer critical new perspectives on how users view these suggestions. This study actively demonstrates the integration of LLMs like OpenAI with risk calculators within real-world healthcare platforms.

6.4 Future work

The Medsensio Screening tool serves as a proof of concept, demonstrating that including a particular risk assessment algorithm in the Medsensio platform is appropriate.There are many exciting opportunities to improve the functionality and user experience of the Medsensio Screening tool. In the future, it might be possible to automatically retrieve data from the current database, doing away with manual parameter entry requirements, such as age. Incorporating a notification system may also notify medical personnel when a user's risk score rises above a predetermined level. The tool's potential also includes a lifestyle coaching system that monitors risk scores and guides users for better health results.

The Medsensio Screening tool is now prepared to apply several additional clinically verified algorithms as modules, building on the success of integrating the Qrisk algorithm as one of the modules. These additional algorithms can evaluate disorders other than cardiac health, such as kidney failure and cancer.

Additionally, creating personalized health plans based on user risk ratings creates opportunities for tailored guidance intended to maximize heart health preservation.

Including a notification system with the Medsensio Screening tool can improve proactive patient care even more. This technology promotes early intervention and may enhance patient outcomes by starting suitable medicines on time and automatically notifying healthcare experts of users who are deemed high-risk based on their estimated scores. Investigating the best layout and timing for these alerts in the future will be imperative. Research may examine the best ways to communicate to encourage behaviour change and reduce user annoyance. Studies should also examine how these notifications affect user adherence and general health outcomes in the long run.

Other promising direction for improving the user interface is moving from static result screens to dynamic displays enhanced with information from the Medsensio platform's database. By following this path, people can obtain increasingly detailed health data with less personal health information input, giving them a comprehensive picture of their present state of health. This may improve user experience and encourage well-informed decision-making.

More research is required to maximize the Medsensio Screening tool's integration into the heart disease monitoring, treatment, and follow-up ecosystem, even though it shows promise for remote patient monitoring and improved communication between patients and healthcare professionals. Further investigation in this area could take numerous forms:

Optimizing Risk Score Integration:

Research must discover the most effective frequency and method of communicating risk scores to healthcare practitioners to ensure early response while reducing information overload.

Impact on Clinical Workflow:

Research could investigate how the instrument can be easily incorporated into clinical workflows to minimize disturbance and increase staff productivity.

Verification of AI Recommendations:

Further study is required to define the best practices and verify AI-generated recommendations, consider patient safety, and streamline operations for healthcare personnel.

Subsequent studies may examine LLMs' capacity to function as conversational health assistants, actively addressing users' health-related questions, elucidating risk factors, and assisting them in adopting healthier lives. Furthermore, in mental health, LLMs may even provide preliminary tests and minimal emotional support, serving as a helpful resource for people reluctant to seek professional assistance. By integrating LLMs into the verification process, we can progress towards a more all-encompassing and patient-focused methodology, guaranteeing well-informed decision-making based on robust AI results.

7

Conclusion

This thesis explored integrating a risk assessment tool into a medical platform and how LLMs could provide individualized health recommendations. When compared to web-based alternatives, users showed a clear preference for the integrated Medsensio Screening tool, and the thesis investigated the new application of LLMs to provide users with self-management techniques. Although preliminary analyses indicated a general agreement between the Medsensio Screening tool and the original web-based calculator, more investigation is required before the tool's release to end users to guarantee the instrument's complete efficacy, including the LLM recommendations. Subsequently, the research should focus on assessing the long-term effects of the LLM guidelines on overall health and user self-management outcomes. The Medsensio Screening tool has the potential to be an essential tool in the larger medical platform by addressing these issues and enabling people to manage their heart health actively.

Appendices

/A

Declaration of the usage of AI tools

For my master project, I acknowledge the use of generative artificial intelligence below for the following purposes:

Generative Artificial Intelligence

1.(https://gemini.google.com/)

2.(https://chatgpt.com/)

3.(https://app.grammarly.com/)

4.(https://stablediffusionweb.com/app/image-generator)

Purposes:

Report part

1. To express the complex medical information coherently to get the idea.

2. To get suggestions on evaluating the problem from different angles.

3. To improved the text and correct the grammatical errors.

4. To fix the errors in the Latex template, automate the generic process in Latex, for instance , creating tables with our information.

5. To get suggestions on maintaining the academic tone and style for our text.

6. To generate the image

Code part:

1. To find the bugs and resolve them.

2. To get suggestions on platform-specific code. For instance, code fixing react native issues in Linux

3. To refactor the code.

4. To get support in the algorithm conversion process: For instance, write the equivalent Javascript version of this original PHP version of the algorithm, as shown below. As the floating point numbers were too long to re-type, use GPT and verify it later.

Original version:

double survivor[16] = 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.977268040180206, 0, 0, 0, 0, 0 ;

Javascript version:

const survivor = [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.977268040180206, 0, 0, 0, 0, 0];

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