Review

Monitoring of Cardiovascular Diseases: An Analysis of the Mobile Applications Available in the Google Play Store

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Abstract: Cardiovascular diseases have always been here, but there has been an increase in their numbers over time. Even though there are in the digital world a few applications to help with this kind of problem, there are not enough to fulfill the needs of the patients. This study reviews mobile applications that allow patients to monitor and report cardiovascular diseases. It presents a review of 14 mobile applications that were free to download in Portugal and classified and compared according to their characteristics. The selection criteria combined the following keywords: "patient", "cardiac/or heart", "report", and ("tracking" or "monitoring"). Based on the analysis, we point out the errors of the applications and present some solutions. To finish, we investigated how mobile applications can help patients track and self-report cardiovascular diseases.

Keywords: patient; cardiac; report; tracking; mobile applications

1. Introduction

These days, health is one of the most discussed topics. It constantly evolves, and people are always trying to improve further in health [1]. When talking about cardiovascular diseases, the statistics say that these problems are the leading cause of death globally [2,3], having an estimated 17.9 million deaths per year. CVD (cardiovascular diseases) are a group of blood vessels and heart disorders. The most common disorders are heart attacks and strokes. These disorders cause more than 80% of deaths with cardiovascular diseases, and one-third of these deaths occur in people under 70 years old [4]. Even though the treatment is improving, there are more cases of heart problems and deaths. It may be because a lot of our social life and work is conducted at home or because obesity has increased over the years, contributing significantly to cardiovascular problems [5–7]. Because of this, the population needs more help with these problems since only the evolution of health is not working [8]. Our world is becoming even more populated but still considering how we evolve. This problem should decrease instead of increase.

As technology is evolving, it also appears that a few mobile applications are trying to help patients with this kind of problem and not only such issues [9]. There are many applications related to health. According to a study in the first quarter of 2022, 52,565 healthcare and medical apps were available on Google Play Store [10]. Therefore, the main contribution of this research is to present a systematic review of the mobile applications that aim to help improve users' health. According to statistics, knowing that these problems are severe, one of the solutions that individuals may have is to use some of these applications. Cardiac problems need to be found early so the doctors can help the patient from an early phase of the disorder [6]. These applications are related to health and medical care and track and

report cardiovascular diseases to help patients follow the problem and help them report easier to the doctors.

This study briefly described all analyzed mobile applications and their objectives. In this study, 66 mobile applications were examined, and several were excluded as they did not fit the selection criteria. Only nine applications were not excluded.

In this study, it is possible to see applications distributed by categories, making it faster to conclude the type of the application. It is still possible to understand the purpose of mobile application development and its features. These applications were chosen using the keywords: "patient", "cardiac/or heart", "report", and ("track" or "monitoring") if they were free to download, register, and use, updated between 2019 and 2022, and available in English.

2. Related Work

Even though in this study we are talking about mobile applications related to tracking and self-reporting of cardiovascular diseases, there are a lot of other related works. The authors of [3] present an overview of the current literature on mobile technology related to the prevention and management of CVD. This study also evaluated how applications can be used with different cardiovascular prevention needs throughout all age groups.

In [11], the authors show us a mobile-phone-based study for CVD risk detection called CVDmagic. They used two non-laboratory-based approaches with inputs from local doctors corresponding to the Indian context. They also presented an analysis of an initial survey from a pilot deployment of CVDMagic.

The study [12] aimed to review the potential effectiveness, acceptability, and usefulness of patient-directed applications for cardiovascular disease self-management delivered and used primarily on a smartphone/tablet device. They wanted to know if standalone applications with low reliance on day-to-day clinician involvement can improve risk factor control and disease self-care and the patient's perspectives on preferred application features and perceived utility for supporting treatment adherence and healthier lifestyle behavior.

G. M. Coorey et al. [12] reviewed studies that have used mobile phone interventions to promote self-management of existing CVD. They will analyze the use of text messaging and mobile applications for all cardiovascular conditions to identify the potential of mobile phone features as effective interventions in the secondary prevention of CVD.

The authors of [13] aim to assess the potential benefit of digital health interventions on cardiovascular disease outcomes and risk factors compared with non-digital health interventions. They extracted CVD outcomes and risk factors for CVD such as weight, body mass index, blood pressure, and lipid levels from 51 full-text articles to elaborate on this study.

In [14], the authors presented M4CVD: Mobile machine learning Model for Monitoring Cardiovascular Disease, a system designed especially for mobile devices that facilitate cardiovascular disease monitoring. This system has wearable sensors to collect observable vital signs and trends contextualized with data from clinical databases.

The study [15] proposed a fast and efficient mechanism of cardiovascular disease detection from ECG signals. Unlike the existing ECG that can only detect CVD anomalies from hundreds of sample points, the proposed mechanism identifies cardiac abnormality from only five samples.

The authors of [16] aimed to establish the effectiveness of interventions delivered by mobile phones to improve adherence to medication prescribed for the primary prevention of CVD in adults. They collected data from databases such as CENTRAL, MEDLINE, and EMBASE and searched for two clinical trials.

In clinical settings, F. Lobelo et al. [17] reviewed mobile health technology's validity, utility, and feasibility and proposed an organizational framework to support physical activity assessment, counseling, and referrals to community resources for cardiovascular disease risk reductions interventions.

3. Methodology

3.1. Research Questions

For this review, the three main questions were: (RQ1) Which mobile applications for health track those related to CVD? (RQ2) How can these mobile applications help the users in self-report? (RQ3) Are any of these applications available in scientific studies?

3.2. Inclusion Criteria

Mobile applications could only be considered for this article if they were (1) free to download, (2) free to register and use, (3) focused on health tracking/monitoring related to CVD, (4) available in English, and (5) updated within the last three years.

3.3. Search Strategy

While making this study, the applications that were analyzed consisted of a search made in Google Play Store with keywords such as "patient", "cardiac/or heart", ("track" or "monitoring"), and "report". The applications in the study were all installed and tested to verify the characteristics we were looking for. This study was conducted in Portugal on 4 April 2022.

3.4. Extraction of Study Characteristics

After analyzing information about each selected application, the following characteristics were collected: name, short functionalities' description, country of development, year of the last update, and the category regarding the Google Play Store classifications, which are presented in Table 1.

Table 1. Extraction of study characteristics.

Name	Description	Country	Year	Category
Blood Pressure Diary [18]	Graphics with inserted blood pressure over time and information about blood pressure	China	2022	Medical Care
Blood pressure record diary [19]	Graphics with inserted blood pressure over time and blood pressure information	Germany	2022	Medical Care
BloodPressureTracker BP Info [20]	Track of the blood pressure using graphs with inserted blood pressure over time and information about this	Pakistan	2022	Medical Care
HRV Camera ECG BLE [21]	Check: Heart rate (Pulse), Heart Rate Variability (HRV), Fitness and Stress level, Cardio calculations track progress, and more using camera, ECG, or BLE device	Romania	2022	Health and Fitness
MDCalc Medical Calculator [22]	Gives brief summaries of the critical studies concerning the medical calculator	USA	2022	Medical Care
Medocity Home Health: Patient Virtual Care [23]	Medication track, nutrition, and vital signs measurement	USA	2022	Medical Care
National Cardiac Center [24]	Contact with doctors and CVD information	Nepal	2022	Health and Fitness
TruMonitor [25]	Undertake realistic medical simulation training without the need for expensive/high-fidelity mannequins	United Kingdom	2022	Medical Care
Unique Heart Rate Monitor [26]	Measure heart rate with great accuracy, analyze resting and working heart rate	China	2022	Health and Fitness
Wave:health & Symptom tracker [27]	Vital signs track, graphics with inserted data and medication control	USA	2022	Health and Fitness
Cardiograph [28]	Measure the heart rate, obtain accurate results with brand new measurement algorithm	Bulgaria	2021	N/D
Da linha cardíaca e diário [29]	Graphics with inserted blood pressure over time	N/D	2021	Medical Care
CardioSmart Heart Explorer [30]	This app is designed to enhance the clinician/patient relationship at the point of care	USA	2020	Medical Care
Health-Pie Digital Nurse [31]	Track of medications, vaccines, and vital signs	India	2020	Health and Fitness

4. Results

Figure 1 shows that only fourteen were eligible from the initial ninety-six applications. These identified applications were installed and tested and compared to what the author was trying to put into the market by reading the description and testing to make sure they were true. After selecting the mobile applications, the different functionalities were mapped in Table 2, verifying that the most monitored parameter is the Blood Pressure, and the most available functionality is the event's report.
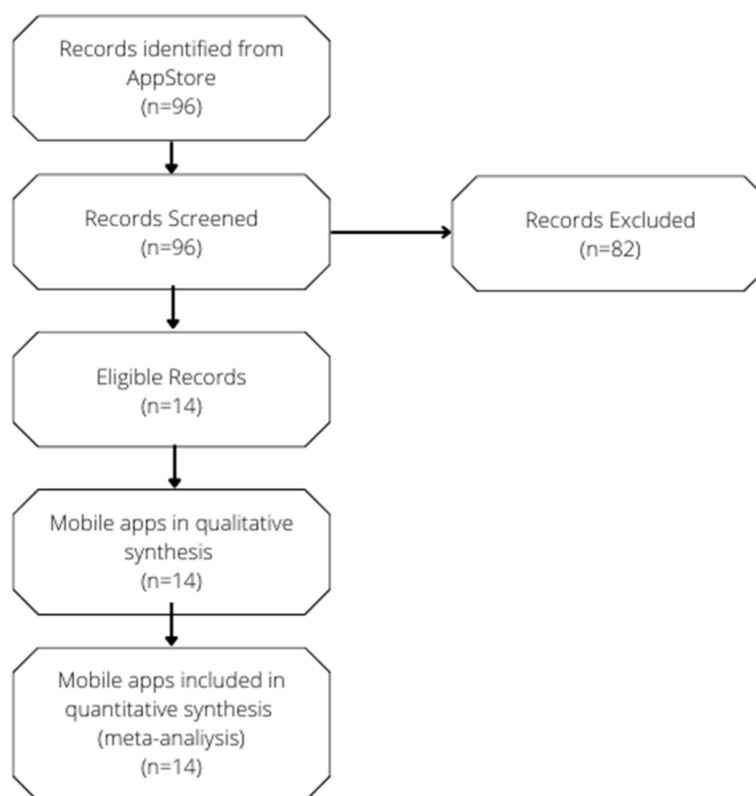

Figure 1. Identification of mobile applications via Google Play Store.

Regarding the health and fitness applications, "National Cardiac Center" [24] showed where it is possible to learn about several diseases related to cardiac problems. This allows persons to understand what type of problem they have and even their solutions. Apart from that, there is a section where persons can talk to doctors, making it easier to talk about their problems.

"Wave: health & Symptom tracker" [27] allows for recording activities such as sleep, meals, exercise, vitals, and more, discovering patterns and trends that impact their health, helping doctors by preparing their appointments with health reports, tracking symptoms and managing their treatment journey, and teaching individuals what is better or worse for their health. This application can still learn what affects the mood, symptoms, and overall health. It is not just an application directed to the CVD, but it is a very complex application in terms of content and is very easy to handle.

"Health-Pie Digital Nurse" [31] shows where persons can learn about diseases and obtain health tips, tracking blood pressure and blood sugar. It is still possible to secure all medical records, meaning you can download the record on any device with the application installed. Another feature is that who uses the application allows for monitoring the health of their loved ones.

Table 2. Mobile applications analysis.

Name	Purpose	Parameters Monitoring					Events Report	Associated Devices	Medical Feedback
		Blood Pressure	Heart Rate	Blood Oxygen	Blood Sugar	Temperature			
Blood Pressure Diary [18]	Health Monitoring	X					X		
Blood pressure record diary [19]	Health Monitoring	X	X				X		
BloodPressureTracker BP Info [20]	Educational/Informative + Health Monitoring	X					X		
MDCalc Medical Calculator [22]	Educational/Informative								X
Medocity Home Health: Patient Virtual Care [23]	Educational/Informative + Health Monitoring	X	X	X	X	X	X	X	X
National Cardiac Center [24]	Educational/Informative								X
Wave:health & Symptom tracker [27]	Educational/Informative + Health Monitoring		X			X	X		X
Da linha cardíaca e diário [29]	Educational/Informative + Health Monitoring	X	X				X		
Health-Pie Digital Nurse [31]	Educational/Informative + Health Monitoring	X	X		X		X		X
Cardiograph [28]	Health Monitoring		X				X		
CardioSmart Heart Explorer [30]	Educational/Informative								X
TruMonitor [25]	Educational/Informative + Health Monitoring	X	X	X	X	X	X		X
Unique Heart Rate Monitor [26]	Health Monitoring		X				X		
HRV Camera ECG BLE [21]	Health Monitoring		X				X	X	

Regarding the medical care applications, "Medocity Home Health: Patient Virtual Care" [23] allows for tracking how individuals feel and reporting symptoms, following vital signs, including blood pressure and blood sugar and also temperature, weight, heart rate, and oxygen level. The application allows the users to track the medication taken, obtain reminders when it is time to take them, and allows the users to track the drug taken and obtain reminders when it is time to take them and has a small section for nutrition to achieve a perception of the meals that individuals eat and what they drink. This application is available on smartphones, tablets, and computers.

"MDCalc Medical Calculator" [22] is a free and fast medical calculator based on evidence and clinical decision support. This application helps make better decisions and be more efficient in the workflow. It gives an in-depth appraisal and validation of evidence and clinical relevance.

"Da Linha cardíaca e diário" [29] is an application that allows adding blood pressure records where it is possible to make a graphic with added data. This graphic helps the patient and the doctor see if there is any health problem related to blood pressure. It has a history section to indicate where all the data are saved. Besides all of this, it also contains information about cardiac diseases, diagnosis, prevention, and treatment. Lastly, it presents a tip section related to blood pressure to help users with this problem.

"Blood pressure record diary" [19] is a blood pressure history that helps patients with blood pressure information manage their accounts. It is possible to keep monthly and daily logs. It also has an information section to educate and teach the users about problems related to blood pressure.

"Blood Pressure Diary" [18] is a personal tool for tracking and analyzing blood pressure. This application helps persons suffering from several cardiac and blood diseases. It is possible to keep monthly and daily logs. The app also teaches much information about this kind of disease.

"BloodPressureTracker BPInfo" [20] allows users to track their blood pressure by adding blood pressure records. It also gives many tips and information about blood pressure and several diseases. It is also possible to build a graphic with all the data inserted in the application.

"Cardiograph" [28] is improved and redesigned to provide a fast and reliable heart rate measure, obtaining accurate results almost instantly with a measurement algorithm. It is perfectly tailored to allow multiple individuals to use the application on a shared device.

"CardioSmart Heart Explorer" [30] is designed to enhance the clinician/patient relationship at the point of care. It could review and discuss common heart problems and treatment options with the patients and their caregivers. The app provides high-resolution cardiac graphics and animation, exploring the structure of an animated 3-D beating heart by swiping up or down through nine primary layers of rotatable cardiac anatomy.

"TruMonitor" [25] is a learning tool for doctors, medical students, nurses, and paramedics/EMS, undertaking realistic medical simulation training without the need for expensive/high-fidelity mannequins. It also aids in life support courses, OSCE exam preparation, or ad hoc teaching. It verbally creates a scenario as straightforward or as complex as the teacher wishes. If the student has a second device, connecting via Bluetooth or Wi-Fi, the second device becomes a monitor.

"Unique Heart Rate Monitor" [26] allows measuring the heart rate with great accuracy anytime and anywhere with only a mobile phone. It offers unlimited measurements and records—free of charge. It analyzes resting and active heart rate and presents the heart rate zone.

"HRV Camera ECG BLE" [21] captures Heart rate (Pulse), Heart Rate Variability (HRV), Fitness and Stress level, Cardio progress, and more using a camera, ECG, or BLE device. The application provides summarized analysis results (as classes starting from Poor to Athlete) using HR and HRV (Heart Rate Variability) analysis, as well as data for sharing and crowdsourcing on the ECG for Everybody.

5. Discussion

From the following table about the number of downloads presented (Table 3), it is possible to see that there is one application with between 100 and 1000 downloads (7.14%); three applications have between 1000 and 10,000 downloads (21.43%); four applications have between 10,000 and 100,000 downloads (28.57%); four applications have between 100,000 and 1,000,000 downloads (28.57%); one application has between 1,000,000 and 10,000,000 downloads (7.14%); and one application has more than 10,000,000 downloads (7.14%).

Table 3. Number of downloads.

Number of Downloads	Mobile Applications
(100, 1000)	[20]
(1000, 10,000)	[18,23,29]
(10,000, 100,000)	[19,24,25,27]
(100,000, 1,000,000)	[21,22,30,31]
(1,000,000, 10,000,000)	[26]
(10,000,000, +)	[28]

Regarding the last update of the mobile applications analyzed, it is possible to verify that most applications were updated in 2022 (64.29%), three applications in 2021 (21.43%), and two in 2020 (14.29%).

Regarding the countries with developed applications, presented in Figure 2, the higher ratio of four applications (28.57%) was performed in the United States of America; two applications (14.29%) were developed in the Republic of China; and the remaining countries have only one application.

Table 4 shows how many related works with scientific articles are with the applications analyzed, and it is possible to see their primary goal. The study [32] aimed to provide a "guide that allows developers to use best practices for future development of medical apps". This study identified UIDPs (User Interface Design Patterns) to help the users interact with them and the application.
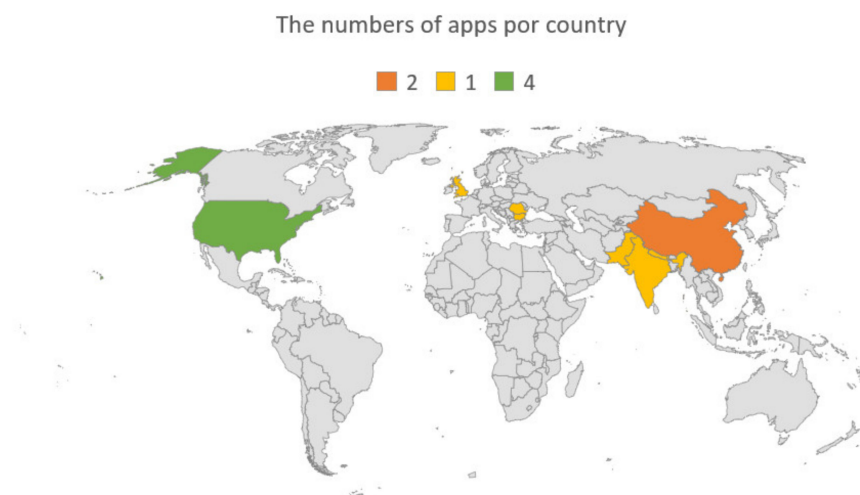
The numbers of apps por country

Figure 2. Relation between the number of applications and countries.

Table 4. Related work comparison.

Scientific Articles	Goal
[32]	Identification of UIDPs for Developing Medical Apps
[33]	Analyze the Classification and Applicability of the Mobile Health Applications
[34]	Monitoring people's activity app for anomalies detection

The authors of [33] present a study of the mobile health applications used by healthcare professionals and patients. The main goal of this study was to provide an "analysis of the usability and user-perceived quality of mobile applications and the challenges related to scientific validation of these mobile applications".

Another study [34] approached people's activity monitoring to help with anomaly detection. This study was made after the beginning of COVID-19 since it made personal treatment access to medical services difficult. The main goal was to create an application that could monitor individuals' activity, mainly older adults, let them know their status, and act in case of anomalies.

6. Conclusions

This review led to an identification and description of mobile applications related to self-reported CVD. We examined nine mobile applications, and the main findings are summarized as follows:

- (RQ1) Which mobile applications for health track are related to CVD? Even though not all mobile applications were fully complete to help the users in every aspect, the applications were related to tracking, cardiac, and reporting. Specific applications did not focus precisely on CVD patients, having just a section about that, for example, "Wave: health & Symptom tracker", "MDCalc Medical Calculator", "Medocity Home Health: Patient Virtual Care", "CardioSmart Heart Explorer", and "TruMonitor".
- (RQ2) How can these mobile applications help the users in self-report? Every application here has the function to allow the user to keep track of their health condition, and some warn the user about possible problems. This may conduct the user to self-report his condition to obtain further help.
- (RQ3) Are any of these applications available in scientific studies? Four applications are available in scientific studies: "Wave: health & Symptom tracker", "MDCalc Medical Calculator", "CardioSmart Heart Explorer", and "TruMonitor".

Few applications had a direct relation to self-report in CVD. For new applications to be developed in the future, they should implement a more specific section to track cardiac

diseases, helping the users be more aware of their problems and probably even helping more knowledgeable people such as doctors to make the diagnostic faster and easier. The direct report to a doctor in this application is still not developed even though it would be a great help. Most of these application types with direct contact with the doctor are only available in a few countries such as the USA and India. It would be a great advantage to be available in several other countries.

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