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Readiness Assessment of Mobile Health Applications in Coronary Artery Disease Management: A Systematic Review

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Abstract

Coronary Artery Disease (CAD) management has increasingly integrated digital tools and mobile applications to enhance diagnosis, treatment, and patient care. These technologies offer capabilities such as risk assessment, decision support for healthcare providers, cardiac rehabilitation assistance, remote patient monitoring, and medication adherence facilitation. By utilizing these tools, medical professionals can improve diagnostic accuracy, optimize treatment strategies, and enhance patient engagement. However, assessing the readiness of CAD management applications remains a crucial area of study. This review explores the key components of CAD app readiness, including clinical validity, user experience, data security and privacy, integration with healthcare workflows, demonstrated efficacy, technical considerations, and regulatory compliance. Additionally, the paper discusses existing challenges in implementing CAD-focused mobile applications and identifies critical gaps that require further research. Finally, recommendations for future studies are provided to advance the development and adoption of effective CAD management solutions.

Keywords: CAD, Readiness Assessment, Mobile Health, Management, Applications

Introduction

Coronary Artery Disease (CAD) is a significant global health concern, causing a high burden of morbidity and mortality (Hirsch et al., 2023). In 2019 alone, CAD accounted for approximately 7.8 million deaths worldwide, making up 16% of all deaths (Aune, 2019). The economic impact of CAD is substantial, with healthcare expenditures related to the condition reaching approximately $219 billion in the United States in 2014 (Gonzalvo et al., 2023). To address the challenges posed by CAD, the integration of technology and mobile applications has emerged as a promising approach. Mobile apps offer a range of functionalities that can enhance CAD management, including risk assessment, diagnosis, remote monitoring, and medication adherence support (Ullah et al., 2023). These tools have the potential to improve accessibility, patient engagement, and personalized care. Analyzing an organization's capacity to undergo a significant shift is called "readiness measurement" (Terminanto et al., 2019). A readiness evaluation highlights possible issues that may develop while adopting new procedures, structures, and processes within the present organizational framework (Pirola et al., 2020). Preparation assessment also gives the chance to resolve existing organizational gaps prior to or as part of the implementation plan by identifying any gaps. Institutional quality improvement programs and quality improvement projects have two degrees of assessment readiness (Al-Arkee et al., 2021). The preparedness of an enterprise quality improvement program comprises an evaluation of the organization's general readiness for change, as well as its current infrastructure and support.

An organization's readiness assessment also gives a chance for the organization to decide what is functioning well, what needs improvement, how the company's purpose, and vision connect to its aim of improvement (Bunn et al., 2018). It presents Information Technology (IT) structure, shared income sources, and the way decisions are made inside the firm are all examined as part of a readiness assessment (Radenković et al., 2020). The Quality Improvement (QI) team's readiness for change, motivation, team infrastructure, and leadership support are all assessed as part of the project's preparedness for QI (Omer, 2022). The team is able to evaluate what is functioning well and what needs to be improved by conducting a readiness assessment (Ovretveit, 2017). It is also highly significant for the organization to evaluate the existing state of data gathering, analysis and how it relates to Total Quality Index (TQI) objectives. Even though these processes are critical, readiness assessments will take place at different times and in various parts of the organization. Moreover, the quality improvement team should stay away from identifying whether the company is fully ready to adopt its own quality improvement program by conducting a quality improvement project. Furthermore, quality improvement projects focusing on CAD may go forward with the help of an overall evaluation of the organization's preparedness (van Veghel, 2016).

However, the development and implementation of effective CAD tools are crucial. Robust tools should incorporate advanced imaging technologies, accurate risk assessment algorithms, decision support systems, cardiac rehabilitation programs, remote monitoring solutions, and medication adherence support (Klarin & Natarajan, 2022). In this paper, we aim to review and evaluate the readiness model of mobile apps for managing CAD. The assessment will focus on critical aspects such as clinical validity, user experience, data security, integration with clinical workflows, evidence of efficacy, technical considerations, and regulatory compliance. By comprehensively evaluating these factors, healthcare providers can make informed decisions regarding the adoption and utilization of CAD tools, ultimately improving the quality of care provided to individuals with CAD.

The rest of this paper is organized as follows: Section 2 presents the mobile health; Section 3 gives the readiness assessments; Section 4 presents the organizational readiness; Section 5 describes the wearable technology devices; Section 6 discusses the previous studies on CAD readiness; Section 7 gives the discussion and challenges of CAD readiness. Ultimately, Section 8 presents the conclusion of the current paper.

Mobile Health

Secondary prevention of CAD disease, which is the major cause of illness and mortality in the ageing population, is necessary (Jin et al., 2019). Older people may now employ mobile Health (mHealth) technology to lower their risk of CAD illness and improve their overall cardiovascular health. Because of increasing the number of elderly people who are becoming more educated (Vo et al., 2019), it is more vital than ever to understand how ambulatory health (mHealth) might aid in the secondary prevention of CAD (Murphy et al., 2018). Following an extensive literature search, researchers uncovered 26 studies that employed portable health to increase medication adherence and adjust lifestyle behavior as an additional method of preventing CAD disease (Larson, 2018). Studies have been demonstrated that SMS (i.e., text messaging) may help improve health habits and medication adherence, as illustrated in Figure 1.

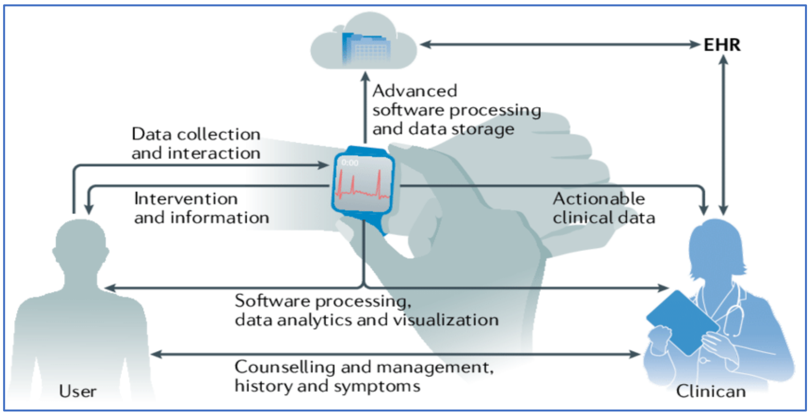

Figure 1. Workflow and integration of wearable data in clinical practice (Bayoumy et al. ,2021)

Nevertheless, it's still a struggle for the elderly to utilize mobile technology because of worries about privacy and security, as well as the cost and convenience of use of the devices. Research on the most effective type of portable health for older individuals with longer study times is crucial as the area of portable health continues to develop (Garcia & Pilueta, 2020). Identifying and applying low-cost generally recognized mobile health remedies for a vulnerable population as the population ages is imperative. Additionally, there are several applications or domains that belong to the area of mHealth technology, which can be explained briefly in the following subsections.

IoT-Enabled Health

The health results can be tracked and enhanced by using technologies named "Digital Health". With the emergence of new technologies like big data analytics (Gordon, 2020, Thomason, 2021), and machine learning (AL-Dhief et al., 2020, Al-Dhief et al., 2021), the phrase "digital health" has been more often used to characterize the use of Information and Communication Technologies (ICTs) in healthcare(Charbonneau et al., 2020). It is worth mentioning that machine learning techniques have been proved their efficiency in detecting and diagnosing various diseases (Mohammed et al., 2020), such as breast cancer detection (Albadr et al., 2023, Albadr et al., 2024), voice pathology identification (Al-Dhief, 2022, Albadr, 2020). COVID-19 detection (Saoudi, 2024), and diabetic detection (Ganapathy, 2020). It's a win-win scenario for patients and healthcare providers when digital health technology based on IoT health is used to enhance treatment quality (Zahid et al., 2019).

Telecommunications Applications

There have only been text-messaging applications on the market for a short period of time, but literature indicates that they are one of the most effective methods to enhance one's digital health (Tagliapietra & Iannacci, 2021). It is worth mentioning that text messaging quickly established itself as a low-cost, frequent, and convenient method of communication that doesn't need Internet connectivity (Zhao et al., 2019). Text messages are becoming popular in the healthcare industry because they can be sent to a large number of people at once with little human involvement, may be purchased in bulk at a lower cost to the provider, and are considered non-intrusive. It is feasible that text message interventions may give healthcare services to persons who would otherwise be unable to obtain them, such as those living in rural or isolated places (Wang et al., 2018). Treatment for CAD patients through text messaging has been demonstrated to enhance both lifestyle and drug adherence (Khandpur, 2017).

Mobile Devices Apps

The usage of mobile devices to provide digital health services has exploded. Newer devices like smartphones and tablets may run apps, which are computer-like applications with a range of capabilities, making them more complicated than text messages (Lai et al., 2019). With the aid of built-in diaries and reminders, applications may supply patients with instructional information in the form of text and visuals, as well as monitor and manage their medical issues automatically (SUWANNAPONG et al ., 2019). A critical factor must be kept in mind when building health apps, despite their great potential. In certain cases, health apps are developed without consulting healthcare professionals (Cheng et al., 2023). In the app stores, there are hundreds of thousands of health apps that have not been tested to see whether they are beneficial or harmful to people.

Medication Adherence

Prevention of cardiovascular disease is made more difficult by individuals who do not adhere to their prescribed treatment plans (Mechta Nielsen et al., 2018). Patients are more likely to adhere to their doctor's instructions as a consequence of employing mHealth technology. There were eight Randomized Controlled Trials (RCTs) in which mobile health treatments were tested for their impact on medication compliance (Fadhil , 2018). App-based intervention, SMS, a supplementing website, and a combination of the three were all used in the program (Haldane et al., 2019). Patients' medication adherence improved with all SMS treatments As a result of forgetfulness or cognitive impairment, patients may benefit from medication adherence reminders through SMS or mobile app (Al-Arkee et al., 2021). Congestive heart failure discharges who got standardized instructional text messages within 10 days of their release from the hospital had reduced readmission rates as well as improved medication adherence than those who did not get the messages. Standardized SMS messages enhanced patients' medication adherence by 30 percent and 16 percent, respectively, in two separate studies after six months. Blood pressure and cholesterol levels did not improve despite the trials being underpowered. Customized SMS scheduling allowed us to send prescription reminders to patients at predefined intervals. If the patient didn't respond or take their medicine, this two-way communication prompted an automatic phone call (Silver et al., 2016). Patients with CAD disease may benefit from SMS-based treatment, according to the literature, it has been found that mHealth approaches may present high assistance for individuals who are suffering from cardiovascular disease in terms of improving medication adherence (Hafid et al., 2021).

Readiness Assessments

Prior to starting or spreading the QI project, a readiness assessment is used to identify any potential roadblocks in the way of success and equip the QI team or organization with the tools necessary to overcome those roadblocks. Thus, completing the readiness assessment gives the team members a chance to get to know one another better and gives them their first taste of collaboration. Prior to joining the QI project, team members should establish a working relationship to help them succeed in their improvement efforts (Kovner et al., 2010). Individuals who take part in the preparedness process have a thorough grasp of the procedures necessary to overcome the hurdles they have identified. An organization's QI project will have a better chance of success if the step of preparedness is done (Waiswa et al., 2017). The effective adoption of new processes or systems into an organization's present infrastructure is connected with certain readiness characteristics. When these traits are present, a company has a better chance of achieving its objectives and avoiding the frequent pitfalls of transformation attempts. In the absence of any of the following critical qualities, the organization is not ready to continue with a QI project or program. Specific measures should be included in the implementation strategy to close these holes.

Measurement of Readiness for Data Collection

Before embarking on a QI project, it seems sense to examine the QI team's competence to collect, measure, and manage data (Kassem et al., 2019). Besides, a QI team takes into account the team's preparation for data collection and measurement, as well as what to do next (Suriyawongpaisal et al., 2020). The following questions are important to take into account while measuring the team's preparedness to handle data:

- Does the organization know what it wants to accomplish and what its top priorities are?
- How would the team know that the goals can be achieved if they don't have a way to track the progress?
- Is there a system in place to keep tabs on how close the project is getting to its goals, including a way to clearly show the data?
- What kind of communication strategy does the team have in place to ensure that everyone involved in achieving the intended outcomes may share and contribute feedback?
- Is a schedule in place for reviewing progress on a regular basis?

Support Readiness Assessment

Understanding an organization's structure and function is the first step in creating a culture of excellence and evaluating current organizational practices (Bonomi et al., 2002). The Assessment of Chronic Illness Care (ACIC) and the Readiness Assessment Check List (RACL) are two popular options. The MaColl Institute for Healthcare Innovation developed the ACIC (Atiehet al., 2023), which is a tool for medical teams to identify areas for improvement in chronic illness care before beginning quality improvement work and to evaluate the level and nature of improvements made in response to quality improvement interventions (Kirchmer, 2017). Moreover, Table 1 provides a selection of other tools that companies have found useful. It is critical to evaluate a company's preparedness before launching an improvement project, even if all tools will not work for every firm.

Table 1
Guidelines for template design

No.	Style	Convention
1	Typical text format	Indicates text that should not be utilized for any particular project and may be used instead as a placeholder.
2	Textual instructions included in brackets	This symbol designates text that the user is free to alter, amend, or remove.
3	Text shown as an example in italics	This symbol denotes text that the user has the ability to change, remove, or replace.

Environmental Readiness Assessment

The environmental readiness assessment should be carried out once the CAD practitioner has gained a thorough understanding of the whole firm and its culture (Brickwood et al., 2019). Furthermore, using the environmental preparation, organizations may assess their preparation for change in four distinct areas related to the environment:

- A person's leadership potential.
- High-level performance by staff is essential.
- Contributing to the infrastructure's state of readiness.
- Priority levels are assigned to environmental regions based on claims of preparation.

Organizational Readiness

At the beginning, a business must be ready to launch an entire quality improvement program (Haffar et al., 2019). Organizational preparation includes:

- Executive commitment from key decision-makers to the quality improvement initiative.
- There must be a grasp of the financial and time commitments that quality improvement entails.
- This quality improvement project has widespread support since it is consistent with the company's values Goals set by the organization.
- Physicians and clinicians who support the project and appreciate its importance.
- Physicians who like to work in a team environment.

Staff Characteristics

Staff characteristics are the second readiness characteristic of organizational QI program preparedness. The provider's acceptance of the QI project is an important staff attribute (Stentoftet al., 2021).

- The provider's belief that it is relatively simple to care for patients at the facility and that the improvement strategy will improve this experience.
- The relationship between the provider and the organization's administration and other clinicians is open and collaborative.
- The provider actively participates in initiatives that promote evidence-based and leading clinical practices.
- The provider is willing to assume responsibility for the improvement strategy.

Resource Readiness

The capacity of the company to support the QI endeavor is a distinguishing feature of resource readiness (Procureur et al., 2023). Quality improvement initiatives involve a variety of organizational resources, and this study examines whether or not healthcare decision makers are aware of these resources' types and locations. The availability of training, supervision and even consulting services are all examples of resource preparedness (Lin et al., 2020).

QI Project Readiness

Preparation for a QI project has certain aspects in common with a QI program's readiness evaluation. To enhance healthcare, a company must be motivated and prepared to make changes in its culture (Fernandez & Shaw, 2020).

Leadership Readiness

A leader's performance may be judged based on whether or not the QI project has been prioritized, regardless of whether it pertains to a clinical condition or a particular procedure. Executives that are actively involved in the transformation process tend to be considered leaders in the company (Malak et al., 2022). When it comes to allocating the necessary time and resources to meet the project's objectives, the senior leader is the appropriate leader. Administrative control over all areas that will be impacted by team changes, and an advocate for effective change implementation across the company are all responsibilities of the leader (Flaherty & Bartels, 2019). The CEO, COO, medical director, nursing director, and business manager are the most important members of the senior leadership team (Flaherty & Bartels, 2019).

The project's success or failure rests solely on the leadership group. Goals are set, impediments are removed and communicated to the health care personnel and governing board, the team is chartered, and resources are made available to achieve success (Iqbal & Ahmad, 2021) . With the help of their "spread of improvement modifications," they integrate them throughout the whole system of healthcare at all levels. It is the main duty of a senior leader to guide the company toward achieving its high-performance objectives. With the help of top management, a team may make major improvements to the quality and affordability of care provided by an organization.

Quality Assurance and Quality Control

An organization's QI team serves as a focal point for enacting change in addition to providing leadership (Ursu et al., 2019). Effective teams are connected with better care, and a quality-oriented micro-system may be created. People who are part of a team have a shared goal and are held responsible to one another for the progress they make towards that goal together. The project's goal is often developed by the QI group. The QI work assigned to a project is usually carried out by a multidisciplinary QI team (Contreras et al., 2020). With the appropriate team in place, it's easier to drive change on the correct path Clinical, managerial, technical, and leadership abilities are all needed to form a strong team. Team members should have a high level of visibility and credibility within the company, as well as appropriate skills and experience that can be applied to the project's goals. For QI, a team may be valuable and productive. However, without leadership promoting the cause, the team's effectiveness might be restricted (Awolusi et al.,2018).

Wearable Technology Devices

The term "wearable technology" refers to gadgets that use electricity may be worn on the body and gather data, analyze that data, and then provide the user with the appropriate results of their efforts (Al-Dhief et al., 2020). Patients are increasingly requesting wearable electronics since they may be used as real-time tools for monitoring vital signs, activities, and behavioral patterns (Lewy, 2015). Having access to relevant data through wearable technology may aid medical practitioners in making better clinical decisions (bin Sham et al., 2023, Bayoumy et al., 2021). Wearable technologies in CAD treatment and management were the first to focus on physical activity as a crucial lifestyle component (Evensonet al., 2015). Consumer-oriented activity monitors like Fitbits are now available at low prices in retail stores throughout the world. The number of steps taken, the distance walked, the number of calories expended, and even the pulse rate may be tracked by these activity trackers (Salmanet al., 2022). It is possible to motivate people to exercise by using smartphone apps and activity trackers, which may offer virtual rewards when a goal is met, and promote peer support by sharing performance statistics to create a competition-like atmosphere.

As activity trackers become more widely available and popular, researchers have begun looking at whether they might motivate people to be more physically active (Degroote et al., 2020 , Suorsa et al., 2022). Consumer-based activity trackers were compared to no activity tracker usage in new research released in 2019 to see how participation rates in physical activity and sedentary behavior were changed by the use of consumer-based activity trackers (Haffar et al.,2019). There were 3646 participants in the research, which was finished in March of this year. There were 28 RCTs in all. Meta-analysis of 11 studies found that a group wearing an activity tracker increased daily steps by 627 (95 percent confidence range: 417–862 steps) compared to the control group (standardized mean difference (SMD): 0.23, 95 percent confidence interval (CI): 0.15–0.32, p 0.001). Studies have shown that there is a statistically significant difference between those who use an activity tracker and those who do not (SMD 0.28, 95% CI 0.14–0.41, P = 0.001). MVPA was visited an additional 75 minutes per day by those using activity trackers. While sitting time did not correlate with the study's findings (Yun et al., 2021). In contrast to therapies where wearable devices were the primary component, consumer-based activity trackers were merely one component of the many programs reviewed by the researchers. More people become active as a result of these initiatives.

Another systematic review looked at the impact physical activity outcomes in CAD patients who use wearable devices (Mittelstadt, 2017). Thirty-five clinical studies were conducted between January 2000 and May 2018, including a total of 4528 participants. Many of these studies were included in meta-analyses. According to the findings of 17 RCTs, wearing a wearable device increased daily steps by 95% confidence intervals (CIs) of 1688.62–3496.04 (p0.0001) (mean difference: 2592.33 steps per day). Based on meta-reviews of 12 RCTs, an intervention was shown to improve weekly MVPA minutes by an average of 36.31 minutes (95 percent CI 18.33–54.29, p0.0001).

In general, the wearable sensor technology enables recording and analyzing physical, chemical, and electrophysiological parameters in real-time and in a non-invasive way (Arnett et al., 2019). The continuous monitoring of clinically relevant information aims at the prevention, treatment, and management of diseases and the well-being of the users (Flack &

Adekola, 2020). To meet the wearability requirements, the choice of materials used from the substrate/transducer to the recognition and robustness elements should be carefully evaluated to provide a reasonable cost, flexibility, biocompatibility, and superior analytical features. Furthermore, there are many different wearable sensors, some of these important sensors will be provided and explained in the subsequent subsections as follow:

Activity Monitors

Physical activity is one of the AHA's lifestyle recommendations for improving heart health since it has been shown to have an adverse relationship with cardiovascular outcomes and overall mortality (Fan et al., 2019). Patients' levels of physical activity have traditionally been assessed only by the doctors themselves, with just the most essential notes being taken during office visits. Techniques like this one have a number of drawbacks, including the difficulty of reliably evaluating physical activity in a real-world setting. By employing a range of sensors in wearables and smartphones, these devices will render subjective reporting of activity levels unnecessary in the future (Yunardi et al., 2020).

Current wearables employ a triaxial accelerometer, which detects linear acceleration in three separate planes, to track movement (Khouqeer et al., 2023). The gyroscope is a sensor that monitors angular movement (Özdemir, 2016). A seismic mass suspended by a mechanical suspension system powers triaxial accelerometers. Using Newton's second law, mass deflection in the direction of motion in the opposite direction may be quantified. Differential capacitive accelerometers are the most often utilized in wearables because of their superior performance over other types of accelerometers. The acceleration of a seismic mass is directly proportional to the difference in capacitance between the two electrodes in a differential capacitive accelerometer (Slade et al., 2019). Due to the lower power consumption, faster response time, and greater accuracy, these accelerometers are preferred over piezoresistive ones. An accelerometer's measurement accuracy may be greatly affected by where it is placed on the subject's body (Kristoffersson & Lindén, 2022). The most accurate findings may be achieved by placing a sensor in the center of the torso (either implanted in a vest, strapped to the body, or affixed directly to the skin). The best sensors for tracking steps and energy use are those worn on the ankle (Sakpere et al., 2017).

In order to better monitor one's physical activity, wearables include GPS and barometers (Stone & Grundy, 2019). The precise time and position of the 24 or more GPS satellites, which are continually sending signals, are determined using an atomic clock. Relativistic ideas from Albert Einstein's work are taken into account while calculating the GPS receiver's distance. Trilateration may then be used to pinpoint the receiver's position on the globe to within 4.9 meters (Gilgen-Ammann et al., 2019). The GPS is a valuable tool for finding and tracking items, despite these limitations. There are two types of pressure sensors: thermometers and barometers. The thermometer uses a thermometer to measure temperature, while the barometer measures pressure. Diaphragm deformation may be converted into electrical signals using capacitive or piezoresistive strain models, where plates move closer together or diaphragm resistors change their electrical resistance (Lee et al., 2018). Because air pressure reduces as height increases, a barometer can monitor changes in elevation, count the number of steps walked, and detect falls. Due to its susceptibility to temperature and pressure variations, barometer readings may be subject to error. Using multiple sensors puts additional strain on batteries, even if it yields more accurate readings of physical activity and energy use.

Sensors for Monitor Heart Rate and Rhythm

It is possible to forecast cardiovascular illness based on HR values during rest and exercise. A high resting heart rate in healthy people is a predictor of cardiovascular disease and death from any cause, and this is equally true in those with heart failure (HF). Increased cardiovascular events have been associated with a slower recovery of heart rate after exercise. HRV has also been shown to be a strong predictor cardiovascular events in healthy people and those with a lower ejection fraction of heart failure (Natarajan et al., 2020). To identify cardiac rhythm and calculate beat-to-beat intervals, commercial wearables use algorithms based on electrocardiograms or photoplethysmography (PPGs). Measurements of heart rate and rhythm are possible using ECG instruments. Bulky ECG patches and chest strap monitors are less attractive to the ordinary consumer because of their restricted functionality and long-term discomfort. The single-lead ECG may be recorded on certain smartwatches by putting a hand finger on the crown in the opposite direction of the negative electrode on the watch's side, with the back of the watch acting as the positive electrode. Atrial fibrillation is one of the most frequent and basic arrhythmias, and single-lead ECGs are an essential diagnostic tool for early identification (AF). Myocardial infarction and other complicated arrhythmias may be missed by a single-lead ECG, even if special measures are taken (MI) (Torres-Soto & Ashley, 2020). PPG technology is used to capture pulse waves and tachograms to measure changes in microvascular blood volume. Photodetector monitors the change in intensity of photons reflected off tissue while a continuous pulse of photons from an emitter is used. Photodetector. Battery life may be saved by activating the PPG during activity, but only intermittently during sleep and relaxation. Arrhythmias may also be detected with the use of PPG and ECG tachograms. PPG technology, despite these disadvantages, is still valuable. A sensor that works best while in close proximity to the skin may not achieve the real purpose. However, a single piece of research indicated that the PPG operated equally across a broad range of skin tones, regardless of skin color, wetness, or even tattoos (O'Brien et al., 2018).

Because of the broad range of HR accuracy, several studies have looked directly at the performance of PPG sensors on a variety of wearable devices. chores or cleaning one's teeth, for example. The average difference between the Fitbit Charge and the Apple Watch 3 was – 1.80 beats per minute over the course of 24 hours, according to the gold standard electrocardiogram, with a 95% agreement rate. Another piece of research when it comes to heart rate monitoring shows that the Fitbit Blaze and Apple Watch were shown to be accurate when compared to an ECG in patients with established heart disease who underwent phase II or phase III cardiac rehabilitation. There were no significant differences in accuracy between wrist-worn devices and the chest strap (Lin's concordance coefficient rc = 99%), although there were significant differences between wrist-worn devices and the chest strap in terms of heart rate (HR) accuracy (Padwal et al., 2019). When it comes to accurate PPG HR measures when exercising, chest-strap monitors are more dependable than wrist-worn devices. More studies into newer devices and their usefulness in various populations are needed to better understand the limits of PPG technology and improve its performance.

Sensors for Measuring Blood Pressure

In many areas of the world, high blood pressure is a primary cause of mortality and disability. Consumer-grade wearables that offer precise blood pressure (BP) readings, which have been related to lower outcomes, may enhance hypertension screening. The Omron Heart Guide wristwatch (Japan) was compared to an ambulatory blood pressure cuff in both office and ambulatory environments. During office BP measures, a patient's non-dominant arm was coupled to both the Heart Guide wristwatch and a typical BP measuring equipment (Sadek et al., 2019), which obtained readings twice every 30–60 seconds. After each ambulatory BP measurement, patients were asked to utilize the Heart Guide device ten more times. This was done every 24 hours. The mean difference (s.d.) between the two groups was 0.8 percent in the office and 3.2 percent in the outpatient environment. Our results highlight the limitations of wrist-based cuff BP measurements. People's lives have been made simpler by not having to wear a cuff all day long to check their blood pressure. PPG and ECG measurements are used to compute the pulse transit time, or the time it takes for an arterial pressure wave to travel from the heart to a distant artery. Modest research was conducted without the use of cuffs or monitors to measure blood pressure (BP). Diastolic BP bias rose from 0.5 mmHg (–10.1 mmHg to 11.1 mmHg) to 2.24 mmHg (–17.6 mmHg to 13.1 mmHg) during the course of seven days between the wearable and ambulatory devices. Cuff-less BP monitoring uses pulse wave velocity and propagation, although most research is limited by small sample numbers and lack of external validation (Maurya et al., 2021). Deep learning approaches were also examined. In the early stages of development, blood pressure monitoring without the use of a cuff needs more investigation.

Other Sensors

Electrochemical transducers may be used to measure electrolytes in human fluids, which can provide valuable information on plasma volume status and analyte concentrations through biochemical sensors. Skin temperature, skin infection, hair density, and other variables all influence these sensors (Alivar et al., 2019). Biochemical sensors include continuous glucose monitors that have been clinically proved but are challenging to incorporate into consumer-grade wearable devices. Figure 2 shows the popular wearable sensors. It may be more convenient to use wearable sweat and saliva sensors, but additional study is required. For example, ballistocardiograms and dielectric sensors may be used to monitor cardiac output and lung fluid volume in order to better understand and treat conditions such as HF (Handayani et al., 2021). Noninvasive, hemodynamic, and continuous blood pressure monitoring may be possible using flexible, tattoo-like sensors based on microfluidics (Samadbeik et al., 2018). Before these novel sensors can be placed on the market, they must be properly evaluated in the clinic.

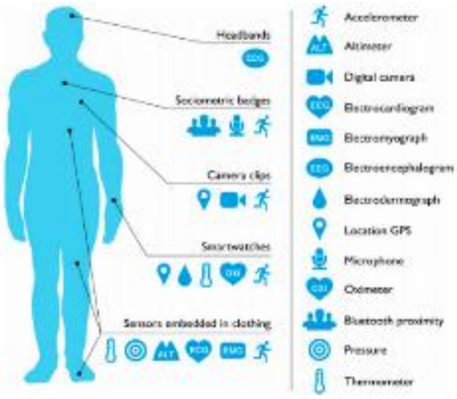

Figure 2. Popular wearable smart devices, embedded sensors, and cardiovascular care applications

Previous Studies on CAD Readiness

In the last decades, there have been many researchers and developers who have gained high attention in terms of CAD disease readiness. Here, we will review some of the recent works that have proposed different methods and approaches in such a field. A group of authors have investigated the m-health readiness factors in Indonesia (Al-Anezi, 2021). They aimed to analyze the readiness factors and dimensions affecting the use of m-health applications in Indonesia from the users' perspective. A large group (624) of m-health app users were participated. They demonstrate that the most influential dimensions in m-health readiness are technological readiness (i.e., ease of use and affordability) and motivational readiness (i.e., trust, attitude, and perceived usefulness). This study has given an important factor that affects m-health readiness. However, it does not perfectly fit the community with few m-health app users.

In addition, a group of researchers were also focusing in their study on readiness of chronic diseases patients to use m-health in developing countries (Hussein et al., 2021). In their cross-sectional study, there were 475 patients with chronic diseases, they found that 24.4% of the participants had the experience of using computers. The readiness of patients with chronic diseases and the experience of computer application was at a medium level. The highest and lowest scores of readiness were related to the relationship with doctors and computer anxiety factors respectively. Hence, they concluded that any plans to use computers and improve the readiness of patients with chronic diseases to use health information technology can eliminate the challenges of accepting IT by the patients. These can also change patients' lifestyle and improve self-care management of chronic diseases. This study had an advantage to use in developing country as a base for further research. Nevertheless, this wok was not specific to a single disease.

Another study was conducted to evaluate the readiness of m-health in Saudi Arabia (Khan et al., 2022). This study was a general investigation of m-health. In other words, it is not proposed to specific illness. However, most of the surveyed patients suffered from cardiovascular diseases and diabetes. They found that almost all the participants (99.0%) had their personal mobile phone and used the Internet on these devices. Moreover, most of the participants did not trust or believe in online health services or online medical consultations and did not spend money on contracting health services through mobile phones. They suggested that the lack of motivation to adopt the e-health system may be due to fear of privacy violations, fear of loss of personal data and information, lack of technical support, and mistrust in doctors who frequently use their cell phones to distract themselves during workhours. The results of this study show the importance of awareness in communities similar to Saudi Arabia and give an idea about what diseases have to focus on.

Another study has been investigated the mobile health readiness of people receiving in-center hemodialysis and home dialysis in California, Texas, and Tennessee (Hsieh et al., 2021). They aimed to examine the status and correlates of mobile health readiness among individuals on dialysis. They found that 81% of participant in survey owned smartphones or other internet-capable devices, and 72% reported using the internet. The majority (70%) reported intermediate or advanced mobile health proficiency. The main reasons for using mobile health were appointments (56%), communication with health care personnel (56%), and laboratory results (55%). The main reported concerns with mobile health were privacy and security (18%). Mobile health proficiency was lower in older patients. They concluded that the majority of patients on dialysis surveyed were ready for proficient mobile health. This study shows the effect of been familiar with mobile app to connect with health system in a readiness to advance mHealth use. However, this study was done in community which is based on advanced health care system only.

Furthermore, a group of authors have investigated the Pakistan elderly community to assess the determinants of technology adoption readiness for m-health (Lu et al., 2020). In their study, they have used the UTAUT theoretical framework, extended to Perceived Ubiquity (PU), Perceived Trust (PT), and Technology Anxiety (TA), to investigate the elderly's intention to adopt mobile phone technology for healthcare (i.e., mHealth) in the socioeconomic environment of Pakistan. Their results show that performance expectancy (PE), effort expectancy, social influence (SI), facilitating conditions, PU, and PT have a positive significant relationship with mHealth adoption intention (AI). However, the results do not indicate the negative relation of TA with m-health AI. It is important to know about readiness among elderly people when design a study for chronic disease such as CAD. However, the authors have not taken the differences in terms of culture and community into account in their study. All previous studies have been used a questionnaire to collect the data. Nonetheless, some studies used a printed form and others used electronic devices. In addition, Table 2 gives and summarizes other works that are relevant to CAD readiness.

Table 2
Related works summary of CAD readiness

TABLE I. **Ref.**	TABLE II. **Sample Size**	TABLE III. **Sample Details**	TABLE IV. **mHealth Software**	TABLE V. **Self-Review**	TABLE VI. **Results**
TABLE VII. Kaso & Annex, 2019	TABLE VIII. N = 25	TABLE IX. 4% female TABLE X. 63% mean	TABLE XI. MyCor telemonitoring app.	TABLE XII. Patients tracked their blood pressure, weight, and steps using pedometers and their medicine usage and subjective well-being with cellphones. Individual goal setting, education, feedback, and clinic visits were provided.	TABLE XIII. Percentage of days with measurements taken every day. TABLE XIV. Phase one: 86%. TABLE XV. Phase two: 77%.
TABLE XVI. Dubois et al., 2021	TABLE XVII. N = 190	TABLE XVIII. female 31.6% TABLE XIX. Mean 67% TABLE XX.	TABLE XXI. SMS/app TABLE XXII. App Takemeds	TABLE XXIII. Patients received one-way SMS instructions. Nonsmokers received four weekday messages on medication adherence, food, exercise, and heart health. Another message helped smokers stop.	TABLE XXIV. Number of people who take their medicine as prescribed: 8.0 percent. Approximately 8% of patients had poor drug adherence (odds ratio, 1.80; 95% confidence interval, 1.14–2.85).
TABLE XXV. Dolmaci et al., 2021	TABLE XXVI. N = 25	TABLE XXVII. emale 24% TABLE XXVIII. ean 59.9% TABLE XXIX.	TABLE XXX. PA-tracking app	TABLE XXXI. The intervention group utilized Fitbits to measure their step count and self-reported their physical activity and medication compliance.	TABLE XXXII. r Health's peak oxygen consumption (VO2) was 4.7% to 13.8%, whereas controls were 8.5% to 11.5%.
TABLE XXXIII. ale et al., 2019	TABLE XXXIV. = 171	TABLE XXXV. emale 19% TABLE XXXVI. ean 60.2% TABLE XXXVII.	TABLE XXXVIII. EART SMS and webpage	TABLE XXXIX. Intervention group participants received an exercise prescription, SMS messages, and a website with behavior modification measures to enhance self-efficacy.	TABLE XL. At 24 weeks: TABLE XLI. 27.8 mL kg min Experimental and control groups differed by 0.21 mL/kg/min (1.15–0.7) (P=0.65).
TABLE XLII. Thakker et al., 2022	TABLE XLIII. N = 24	TABLE XLIV. female 50% TABLE XLV. Mean 73.8%	TABLE XLVI. iPadStudy app	TABLE XLVII. Intervention group members received app-based reminders and blood pressure monitoring.	TABLE XLVIII. Subjective medication adherence was 52.60 (2.49; P 0.001) following both regimens. Apps enhance

					medication adherence (F=27.404; df=1; P=0.001). App BP recording was considerably higher than paper diary (F=361.349; df=1; P=0.033).
TABLE XLIX. World Health Organization, 2019	TABLE L. N =171SMS	TABLE LI. female 19% TABLE LII. Mean 61.38%	TABLE LIII. SMS/website HEART initiative	TABLE LIV. Text messages and a website with behavior modification techniques were delivered to the intervention group; participants reported their step count and physical activity.	TABLE LV. Reports from the participants: TABLE LVI. Text messages: 70% of the time, or 93%. Content approval: 55/75, 73% of the time.
TABLE LVII. Chow et al., 2010	TABLE LVIII. N =123	TABLE LIX. female 19% TABLE LX. Mean 59.5%	TABLE LXI. SMS/website TABLE LXII. Text4Heart SMS application	TABLE LXIII. The intervention group received text messages and a website with behavioral modification approaches; participants self-reported step count and physical activity.	TABLE LXIV. patients' lifestyle modification adherence. TABLE LXV. 3-month: +26% SMS, +10% control. TABLE LXVI. SMS: 20%, control:12% in 6 months.
TABLE LXVII. Peters & Keeley, 2017	TABLE LXVIII. =76	TABLE LXIX. female 18% TABLE LXX. Mean 63% TABLE LXXI.	TABLE LXXII. CR +PHA app	TABLE LXXIII. Health status, tasks and goals, email reminders, and a social reinforcement network were offered to the intervention group.	TABLE LXXIV. Weight: CR+PHA: 5.1 to 6.5 kg. There was an 8.1% increase in readmissions and emergency department visits when the CR+PHA was implemented. TABLE LXXV. 26.6% (risk ratio, 0.30; 95% CI, 0.08–1.10; P=0.054).

Discussion

CAD holds the top position as the leading cause of global mortality (Chowet al., 2010). Previous studies have convincingly demonstrated the critical role of lifestyle adjustments within the realm of secondary prevention strategies. Despite this evidence, a substantial 70% of individuals diagnosed with CAD diverge from the current recommendations for secondary prevention (Peters& Keeley, 2017). This non-compliance could potentially be attributed to a lack of understanding of the benefits associated with recommended changes and the constrained accessibility to traditional rehabilitation programs. Consequently, it becomes evident that the currently available secondary prevention initiatives fall short in effectively integrating successful preventive measures into the daily lives of patients. The rise in smartphone adoption among the elderly demographic presents a unique opportunity to initiate and guide comprehensive lifestyle changes through the implementation of a smartphone application (Gallagher et al., 2017).

The objective behind creating an educational application for CAD patients was to develop instructional materials accessible via smartphones. This educational strategy aimed to furnish patients with comprehensive treatment knowledge and nursing-related information, intending to bolster their ability to implement self-care practices post-discharge. The most important part of developing a smartphone app for CAD patients is taking into account significant factors or aspects on a readiness model for CAD management apps. Examples of these insights such as clinical validity, user experience, data security and privacy, integration with clinical workflow, evidence of efficacy, technical considerations, and regulatory compliance. Consequently, the app will be effective, user-friendly, and aligned with established medical guidelines. In general, there are some challenges and open key issues in the field of the readiness model using mobile apps for managing CAD illness. These challenges and key issues can be summarized as follows:

- Sample Size: The number of samples should be enough in the system with respect to the number of samples for females and men.
- Technical Issues: The mobile app must include an option to contact a health technician to solve technical problems for the participants in case they face difficulties or technical problems.
- Reliability: Mobile apps may rely on self-reported data, which can be subjective and prone to errors or biases. Objective measures, such as medical tests and physical examinations, are crucial for accurate readiness assessment.
- Clinical Validation: Many mobile apps lack rigorous clinical validation. Validating the accuracy and reliability of the algorithms used in these apps is highly essential.
- Data Security: Health-related data is very sensitive, and mobile apps must comply with strict privacy regulations. Ensuring the security of user data and implementing robust privacy measures are crucial to gaining user trust and complying with healthcare data protection standards.
- User Adherence: Sustained user engagement is essential for the effectiveness of readiness assessment through mobile apps. In other words, it is challenging to maintain user interest, ensure regular usage, and promote adherence to recommended monitoring practices.
- Incorporation with Healthcare Systems: The integration with existing healthcare systems is vital for effective communication and coordination of care. Lack of interoperability between mobile apps and healthcare systems can restrict the flow of information and continuity of patient care.
- Misinterpretation: Readiness assessments provided by mobile apps should be easily understandable for users. However, there is a risk of misinterpretation of results. Consequently, the proper instruction and interpretation guidelines are necessary.
- Dynamic Risk Factors of CAD: The risk factors for CAD illness are dynamic and can change over time. Mobile apps need to adapt and update their algorithms to reflect changes in an individual's health status and lifestyle.
- Awareness and Education in Developing Countries: The developing countries have low mHealth awareness and Education, where it was found that the use of portable health is infrequent in developing countries such as Iraq and almost non-existent for several

reasons, including the lack of experience in using technology among CAD patients, language barriers in mHealth adoption, and the lack of support and promotion of mHealth apps by health organisation in Iraq.

Addressing these challenges requires a collaborative effort among healthcare professionals, app developers, regulatory bodies, and users to ensure that mobile apps for readiness assessment in CAD illness are accurate, secure, and contribute positively to healthcare outcomes. In summary, those investigations in the literature collectively enrich our knowledge of mobile health (i.e., m-health) preparedness across various settings, elucidating the influence of technological, motivational, and societal factors on the utilization of mobile apps for managing CAD. The results emphasize the necessity for tailored interventions that consider the distinct challenges and opportunities specific to varied regions and patient demographics.

Conclusion

As a consequence of chronic heart disease's rising prevalence, several studies have shown that mobile health has the ability to enhance and tailor treatment to each patient's unique needs, as well as to help alleviate some of the healthcare concerns that arise from this trend. The majority of evidence was found to support the use of mobile health in the treatment of cardiac arrest, arrhythmias, coronary artery disease, and heart failure. Mobile health services need to be organized and structured in a way that maximizes the benefits of the technology, not just the technology itself. Studies have indicated that health services are more effective and efficient and that health spending is more efficient. In addition, there has been a decrease in the time it takes for a diagnosis to be made, a reduction in the time it takes for a treatment plan to be put into place, and a drop in the Length of Stay (LOS) and rehospitalization rates. Reduced use of emergency departments, referrals, and hospitalizations may all be attributed to the use of RM-enabled mobile technology and the early care actions that follow. It has been shown that the use of mobile health in cardiology may improve outcomes including reduced infarct size, smaller declines in ejection fractions, lower peak troponin and creatine phosphokinase, enhanced QoL and self-care, and decreased all-cause and cardiac mortality. Furthermore, mobile health empowers patients to better understand and control their health in the context of their own lives by providing them with a wide variety of possibilities. In order to reap the benefits of mobile health applications, regulatory and governance procedures must be included in the service delivery paradigm. When it comes to selecting and using mobile applications, healthcare providers and patients alike must exercise caution while new statutory regulatory frameworks are developed and put into place.

Based on this review paper, we can summarize some significant directions that can be considered in future works of CAD readiness based on mobile apps which are as follows:

- Combining data from mobile apps with wearable devices can provide a more comprehensive view of a person's health. Wearables can capture real-time physiological data, such as heart rate, activity levels, and sleep patterns, enhancing the accuracy of readiness assessments.
- Implementing the algorithms of machine learning and deep learning can improve the predictive capabilities of mobile apps. By analyzing large datasets, these algorithms can

identify subtle patterns and risk factors that may contribute to CAD, enabling more accurate risk assessments.

- Designing the readiness assessments based on individual characteristics, genetics, and lifestyle factors can lead to more personalized risk stratification. Personalized recommendations for lifestyle modifications, medication adherence, and monitoring can improve the effectiveness of preventive interventions.
- Developing mobile apps that support continuous monitoring and provide real-time feedback can empower individuals to actively manage their cardiovascular health. This includes features such as instant notifications for critical changes in health metrics and continued guidance.
- Integrating biomarker data and imaging examinations, such as blood tests and CAD imaging, can contribute valuable information to readiness assessments. Mobile apps could facilitate remote monitoring and analysis of such data for early detection of CAD-related abnormalities.
- Expanding the role of mobile apps to include behavioral intervention strategies and coaching can motivate users to adopt healthier lifestyles. This may involve integrating features like virtual health coaches, gamification elements, and social support networks.
- Enhancing connectivity with healthcare providers through telemedicine features can facilitate remote consultations and follow-ups. This integration can improve the coordination of care and allow for timely adjustments to treatment plans based on readiness assessments.
- Designing mobile apps with a global perspective, considering diverse populations, cultural differences, and healthcare infrastructures, can contribute to addressing global cardiovascular health challenges.
- Developing effective strategies for educating users about CAD risk factors, interpretation of readiness assessments, and the importance of preventive measures is crucial. Engaging and user-friendly interfaces, as well as continuous communication, can enhance user understanding and compliance.
- The investigation of the readiness of CAD patients in developing countries such as Iraq is imperative to provide the basic knowledge to apply mHealth systems and develop applications required to manage CAD and achieve the future goal of continuing to use these applications.

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Conflict Of Interest Statement

Authors state no conflict of interest.

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