The Recent Advances of Mobile Healthcare in Cardiology Practice

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ABSTRACT

Background: Digitalization of healthcare led to the optimization of monitoring, diagnostics, and treatment of the range of disorders. Taking into account recent situation with COVID-19 pandemics, digital technologies allowed to improve management of viral infections via remote monitoring and diagnostics of infected patients. Up to date, various mobile health applications (apps) have been proposed, including apps for the patients diagnosed with cardiovascular pathologies. Objective: The presented review aimed at the analyses of a range of mHealth solutions used to improve primary cardiac care. In addition, we studied the factors driving and hindering the wide introduction of mHealth services in the clinics. Methods: The work was based on the guidelines of the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement. The publication search was carried out using PubMed, Web of Science, Cochrane Library, Scopus, and Google Scholar databases. Studies published during the period from 2014 until January 2022 were selected for the analysis. The evaluation of risk of bias for the included studies was conducted using the Cochrane Collaboration Risk of Bias tool. Results and Discussion: An overall 5513 studies were assessed for eligibility after which 39 studies were included. The main trend in the mobile health for cardiological applications is the use of different types of wearable devices and Artificial Intelligence-platforms. In fact, mobile technology allows remotely to monitor, interpret, and analyze biomedical data collected from the patient. Conclusion: The results of this literature search demonstrated that patients diagnosed with cardiovascular disorders can potentially benefit from the application of mHealth in cardiology. However, despite the proven advantages of mHealth for cardiology, there are many challenges and concerns regarding effectiveness, safety, reliability and the lack of official regulation and guidelines from official organizations. Such issues require solutions and further work towards a wide implementation of mHealth technologies in cardiac practice.

Keywords: mobile applications, telemedicine, cardiology, mobile app.

1. BACKGROUND

The term ‘Mobile Healthcare’ (mHealth) refers to the use of mobile computers and wireless technologies in healthcare to expand and improve the delivery of healthcare services outside hospitals (1, 2). The introduction of m-health dates back to 1924, when the article “The Radio Doctor–Maybe!” was published in Radio News Magazine, where a doctor assists a patient through a video call.

The recent rapid spread of coronavirus infection (COVID-19) sparked the interest in the use of m-Health platforms in healthcare (3-5). In fact, telemedicine has been proven as an optimal way to provide medical services due to the possibility to avoid a close contact with infected patients and reduce overall mortality (6-11). In addition, mobile health has been shown to lower the cost of health care and improve an access to healthcare in undeveloped nations (12, 13).

In turn, technological progress and the use of mobile phones (e.g. smartphones, tablet computers, etc.) have led to the widespread applications of so-called ‘mobile applications’ (‘apps’). Mobile devices have become commonplace in healthcare settings, leading to a
rapid increase in the development of medical software applications for these platforms (14-19).

Despite the rapid development of the digital healthcare systems and technological progress, this concept of medical care is facing various challenges. The main problems for the widespread implementation of digital health are limited digitalization and financial issues (2). Apart from that, there are concerns regarding the reliability and safety of smart devices, availability and free access to the equipment and health data (2). Another issue is a low digital literacy of some groups of patients and physicians. In addition, many other factors play a pivotal role in the effective implementation of digital platforms in healthcare and cardiology, including ethical, social, mental, political and financial factors (2). Mobile health has also been criticized for the lack of clinical quality and safety of this type of healthcare (20).

Thus, mobile applications are becoming an increasingly important platform for the provision of medical services, and their capabilities can reduce overall mortality. To date, according to the WHO, cardiovascular diseases still occupy the first position in the list of causes of death (21). The use of mobile health in these patients can improve cardiac rehabilitation (22), increase adherence to treatment, exercise tolerance (23), reduce cardiovascular symptoms (24), improve the psychosocial status, and thereby, reduce overall mortality.

The growing interest of professional organizations such as the European Society of Cardiology and the American Heart Association in using mHealth technologies indicates a need in a new systematic analysis with focus on non-invasive mHealth interventions for patients with heart failure is warranted.

2. OBJECTIVE

In this review, we intended to highlight and analyze the available mobile applications used in the primary cardiac care service. In addition, we studied the factors driving and hindering the wide introduction of mHealth services.

3. MATERIAL AND METHODS

The study was performed in compliance with the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions version 5.1.0 (25, 26). The work was based on the guidelines of the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement (26).

3.1. Data Sources and Search Strategy

The following databases were searched: PubMed, Web of Science, Cochrane Library, Scopus and Google Scholar (period covering from 2014 up to January 15, 2022). Search strategies were performed by using a combination of free text and MeSH terms, as well as Boolean operators. Search strategy was presented in Appendix 1. The articles were selected using a two-step approach. First, the titles and abstracts identified by the above searches were screened for relevant studies. Second, the full texts of these shortlisted articles were downloaded and assessed for eligibility based on the inclusion criteria.

All citations were downloaded and adjusted into EndNote version X6 (Clarivate Analytics, New York, USA). The duplicates were removed using EndNote software, and manually too. We also employed the Rayan online screening tool for searching the articles (27).

3.2. Procedure of the Data Extraction

Two reviewers (co-authors) independently extracted the data on participant characteristics, intervention details and outcomes measures. Disagreements were resolved either by oral discussion or resolved by a third author. Data were collected using a data extraction spreadsheet developed specifically for this study.

3.3. Criteria for considering studies for this review

The inclusion criteria were as the follows: all clinical trials or randomized controlled trails of mobile applications (aimed at improving the primary cardiac care or rehabilitation), reported original data, and research conducted on human participants. The publications written only in English were considered for the analysis.

The interventions were considered only for the cases of the use of medical mobile applications. Such applications (apps) were based on a well-defined function to measure risk factor for cardiovascular diseases (CVD), changes and the intention to change health behavior in outpatients diagnosed with CVD or treated.

3.4. Exclusion criteria

The studies conducted before 2008 were excluded from the analysis (the first Apple smartphones with the iOS operating system was released on June 29, 2007 (28)). From the analysis were excluded the following publications: review articles, systematic reviews, editorials, books and book chapters, conference materials, study design description (or study protocols), pilot studies without indication preliminary data, articles directly related to telemedicine without use of mobile applications (videoconferencing, sending a message, usage only web platforms, computers, phone calls). Apart from that, the usage of additional smart or medical devices in combination with telemedicine tools without smartphone apps was also excluded from the study.

The articles discussing the mobile applications in a different context were also excluded from the analysis: for example, research on the biological effects of radiation from mobile phones.

3.5. Quality assessment

The quality assessment tool is based on the Cochrane Risk Of Bias tool (29). Specifically, this assessed the risk of bias in random sequence generation; allocation concealment; blinding of participants, personnel, and outcome assessors; incomplete outcome data; selective outcome reporting, and overall; Each question is answered as “yes” (low risk of bias), “no” (high risk of bias), or “unknown” (unknown/unclear risk of bias).

The risk of bias assessment was conducted by one reviewer and validated by the second reviewer, and disagreements were resolved by discussion.

4. RESULTS

4.1. Study selection and study characteristics

The characteristics and main features of the analyzed studies are provided in Table 1. Figure 1 illustrates a systematic procedure for searching and selecting articles. The initial query yielded 25258 potentially relevant records. 19745 articles were excluded for duplicate records. An overall 5513
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| Author Year | Name of app | Method | Participants | Interventions | Outcomes |
|-------------|-------------|--------|--------------|---------------|----------|
| 1 Bergland et al. (37), 2018 | Smartphone application system for alerting out-of-hospital cardiac arrest (OHCA). | For reducing SBP levels among adults with stage 1 systolic hypertension | Two-arm, small-scale efficacy RCT (NCT01961909); Follow-up: 12 months; N=166 out of 174 patients were included. | TT group: 46.5% ± 10.2%; SPCTL group: 43.4 ± 9.4; N=66 out of 70; TT group: 49.3% ± 8.7% | TT group showed continuous real-time heart rate (HR) from a user’s finger tip placed over a video camera lens during resuscitation. Users receive immediate feedback graphs after each session, showing their HR changes. SPCTL group: twice-daily dosage schedule for engagement in a waiting or running program using the WearableTM app for 1 month. 2 min sessions: months 4–12; 6 min sessions. |
| 2 Chandler et al. (38), 2020 | Tensio Tower (TT) (Android or iOS) | For checking an accuracy of heart rate monitoring | N=100 randomly selected patients | Information not provided | Information not provided |
| 3 Carugati et al. (44,2017) | For non-contact PPG: “What’s My HeartBeat?” (WMH); “Cardiio” (CAR). (iPhone 5). | To report adherence to treatment and long-term (1 year) clinical outcomes of the mAFA-II trial | N=120 subjects; Follow-up: 12 months; Mean age: 67 years. | Information not provided | Information not provided |
| 4 Guo et al. (37), 2019 | King OPTO-Electronic (version 2.0) | To evaluate the efficacy of mobile app for the management of coronary artery disease | A cluster randomized trial; N=120 subjects; Follow-up: 6 months; 69.35±11.15 Information not provided | Information not provided | Information not provided |
| 5 Guo et al. (42), 2020 | mobile Atrial Fibrillation App (mAFA) | To evaluate the efficacy of mobile app for the management of coronary artery disease | N=36 out of 50; Information not provided | Intervention group: usual care; Control group: usage of mAFA. | N=35 out of 127; Information not provided | Information not provided |
| 6 Johnson et al. (36), 2018 | Web-based smartphone application | To evaluate the efficacy of mobile app for the management of coronary artery disease | N=35 out of 50; Information not provided | Control group: 56.4±6; Active group: 56.8±6; Control group: 63/17; Active group: 71/17; Control group: 81; Active group: 88; | Information not provided | Information not provided |
| 7 Nt et al. (43), 2018 | Two mobile applications were used: WellChat and BB Reminder | To develop a mobile technology (WellChat) to improve medication adherence among patients with coronary artery disease (CAD). | N=35 out of 50; Two phases: Phase 1 lasted for three months; Phase 2 lasted for two months; Follow-up: 1 month; | Control group: 55/12; Control group: 14/4; Control group: 16; Control group: 18; | At 30 days follow-up, the mean of the difference in medication-taking adherence score in the experimental group compared to the control group was 3.35. SD 0.7, n=36. At 30 days follow-up, the mean of the difference in medication-taking adherence score in the experimental group compared to the control group was 2.85. SD 0.73, n=36. Participants’ use of the mobile app was voluntarily and by whom they wanted or if they felt a need to connect with others. In the nine consecutive participants were assigned to the same “Circle of Friends”. |
| 8 Sakoibara et al. (35), 2021 | Healing Circles (HOC) (iPad with at least iOS 7.3) | To explore the use of technology to facilitate peer support in women with CVD. | N=38 out of 12; Follow-up: 18 weeks; Information not provided | Participants’ use of the program was completely voluntary and by whom they wanted or if they felt a need to connect with others. In the nine consecutive participants were assigned to the same “Circle of Friends”. | Information not provided | Information not provided |
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9. Liz et al (40, 2020)

**“WeChat”**

To reduce the time taken for diagnosis and treatment of ST-elevation myocardial infarction (STEMI)

- N=510 patients;
- Control group: 56.3±15.6; Intervention group: 60.5±18.8;
- Control group: 56/14; Intervention group: 56/12;
- Control group: 70; Intervention group: 70;
- Control group did not transfer pre-hospital ECG; Intervention group had per-hospital ECG transmission through WeChat;
- In the WeChat group versus the control group, the median first medical contact to wire was shorter (25 vs 30 minutes), and the median first medical contact to balloon was shorter (75 vs 90 minutes), p=0.04. No significant differences were observed in elderly patients.

10. Manders et al (48, 2014)

**Smartphone-based application**

To evaluate the effects of a combination of continuous positive airway pressure (CPAP) and telemedicine support on blood pressure (BP) in patients with obstructive sleep apnea (OSA)

A multi-center RCT (NCT18252641);
- N=12 out of 16 patients with high cardiovascular risk;
- Standard care group: 62 ± 8; Telemedicine group: 62 ± 8;
- Standard care group: 75.7±24.5; Telemedicine group: 75.7±24.5;
- Standard care group: 42; Telemedicine group: 42;
- Standard core group: CPAP; Telemedicine group: CPAP and teleconsultation. These BP measurements, CPAP adherence, sleepiness, and quality of life data, in return, received precautions containing health-related messages.

11. Motora et al (56, 2016)

**Medication Pana (AppIoP)**

To assess the mobile app on a tablet aimed at supporting drug intake and vital sign parameter documentation of elderly patients

N=24 patients; Follow-up: 28 days;
- Patients before pandemic:
  - App user group: 48 (43–53);
  - Non-App user group: 65 (53–76);
- Patients after pandemic:
  - App user group: 87 (75–98);
  - Non-App user group: 71.5 (64–75–73);
- Information not provided

12. Nae et al (58, 2020)

**The Tsien-tronio app**

To compare outcomes in patients with STEMI who had percutaneous coronary intervention (PCI) and the use of a telemedicine app

Randomised, controlled cross-over trial;
- Participants who completed baseline and at least one intervention: 43.6±15.28;
- Participants who completed baseline and all 4 interventions: 50.3±4.45;
- Patients before pandemic:
  - App user group: 1272 (1158–1386);
  - Non-App user group: 1050 (950–1150);
- Patients after pandemic:
  - App user group: 53 (71–83);
  - Non-App user group: 32 (20–48);
- Information not provided

13. Shcherbina et al (59, 2019)

**MyHealth Count (iPhone 5)**

To assess the effect of four different physical activity coaching interventions on daily step count via mobile app

Participants who completed baseline and at least one intervention: 4.6±4.6;
- Participants who completed baseline and all 4 interventions: 50.3±4.45;
- Patients who were randomly assigned to receive four combination areas of heart: 2 demonstrated interventions via app, interventions continued: daily 10,000 steps, hourly prompts to stand following 15 s of sitting.

14. Tian et al (59, 2015)

**Android-powered app**

To compare outcomes in patients with STEMI who had percutaneous coronary intervention (PCI) and the use of a telemedicine app

Randomised, controlled cross-over trial;
- Participants who completed baseline and at least one intervention: 43.6±15.28;
- Participants who completed baseline and all 4 interventions: 50.3±4.45;
- Information not provided

15. Västman et al (60, 2016)

**Mobile app**

To measure heart rate via the neural network in arrhythmic patients

Two apps, Heart Rate Monitor (California) and Heart Beat Rate (France) (iPhone 5);
- Control group: 5.7±0.18; Intervention group: 5.8±0.18;
- Control group: 39/8; Intervention group: 38/8;
- Control group: 18; Intervention group: 18;
- Information not provided

16. Weibel et al (60, 2014)

**Heart Rate Monitor**

To measure heart rate via the neural network in arrhythmic patients

Two apps, Heart Rate Monitor (California) and Heart Beat Rate (France) (iPhone 5);
- Control group: 5.7±0.18; Intervention group: 5.8±0.18;
- Control group: 39/8; Intervention group: 38/8;
- Control group: 18; Intervention group: 18;
- Information not provided

17. Elsby et al (61, 2017)

**SaltSwitch smart phone app**

To determine the effectiveness of an app to support people with cardiovascular disease to make lower salt load choices

Two apps, parallel, randomised controlled trial (NCT1949393206);
- N=510 patients; Follow-up: 6 weeks (2 weeks baseline and 4 weeks intervention);
- Control group: 64/5; Intervention group: 64/5;
- Control group: 33/5; Intervention group: 33/5;
- Information not provided

18. Hamwan et al (62, 2021)

**Hemaw (iOS and Android)**

To assess the effects on heart rate variability (HRV) and cardiovascular risk factors

Heart rate variability:
- Intervention group: 54/2; Information not provided
- Information not provided

**Daily step count, area under the step activity curve, and insurance claims data of the Kencom users were analyzed.**
- The use of the app was significantly associated with enhanced physical activity, which might reduce weight loss and improve health-related quality of life profiles.
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19  Nabil et al. (2020) Mobile app “My Smart Heart” (Android)  To determine the effect of using smartphone applications on self-care behaviors in patients with heart failure Randomized controlled clinical trial; N=120 patients; Follow-up: Each week, the patients were reminded of using the application for 6 months and then every month for about two more months; Control group: 60±7±2.6; Intervention group: 59±7±1.4; Adherence group: 62±8±0.8; Non-adherence group: 53±3±3.2; The main features of the application are: profile, reminder, educational content, educational messages, medication guide, FAQ, registration of physical and mental symptoms and vital signs with the ability to record symptoms and alerts in abnormal cases daily; App improves the condition in patients with heart failure

20  Mung屁股 et al. (2020) Pharmacology-designed app (Android)  To determine the effectiveness of using a smartphone in improving BP and promoting adherence to anti-hypertensive medication regimen in patients with hypertension Pre-service, multicenter, randomized controlled trial (NCT04994010); N=87 patients; Follow-up: during 3 months before, during study, and 3 months after study completion; Information not provided; Control group: 48±5%; Intervention group: 47±3.1%; The control group: usual care; Intervention group: received features of full version of app such as calendar reminder; “Call your pharmacy” button; By log-in to enter BP value, educate patient; App did not result in improved medication adherence on BP control, but may be beneficial in patients with hypertension who want to improve medication adherence.

21  Marquez et al. (2019) “APENMAT” app  To evaluate the effectiveness of app in pharmacological therapy reduction of the mild-moderate arterial hypertension Pre-service, randomized controlled trial; N=158 patients; Follow-up: 12 months; Control group: 51±6%; Intervention group: 51±7%; Follow-up: 12 months; Information not provided; Control group: 100%; Intervention group: 94%; The control group: usual care; Intervention group: received an eHealth diary and symptom tracking tool in combination with PCC compared with traditional care.

22  Wolf et al. (2018) Mobile-based health tool  To investigate the effect of an mHealth app and symptom tracking tool in combination with person-centered care (PCC) for patients with acute coronary syndrome (ACS) Randomized intervention study; Swedish registry; Recruitment n=109 patients; Follow-up: 6 months; 66±1; Information not provided; Control group: 105; Intervention group: 94; During the study period, patients received weekly, individualized monitoring through the app; All patients used the app for preventive activities and found the app both useful and motivating.

23  Lunde et al. (2020) Mobile app (Android or iOS)  To assess feasibility of usage of app for promoting and monitoring patients’ adherence to a heart healthy lifestyle after CR Experimental, pre-post single-arm trial; N=64 participants; Follow-up: 12 weeks; 60±1±5; 10/4; During the study period, patients received weekly, individualized monitoring through the app; All patients used the app for preventive activities and found the app both useful and motivating.

24  Lunde et al. (2020) Mobile app (Android or iOS)  To assess the effect of individualized follow-up with an app for one year plus peak oxygen uptake (VO2peak) in patients completing cardiac rehabilitation (CR) Randomized controlled trial; N=170 patients; Follow-up: 3 months; Control group: 51±7±1; Intervention group: 55±5±1; Control group: 40±6%; Intervention group: 44±6%; Control group: 94; Intervention group: 97; During the study period, patients received weekly, individualized monitoring through the app; All patients used the app for preventive activities and found the app both useful and motivating.

25  Alko-El-Nour et al. (2020) Mobile app  To examine the impact of using a mobile app on the level of adherence to treatment regimen among hypertensive patients Randomized controlled trial; N=172 patients; Follow-up: 3 months; Control group: 52±6%; Intervention group: 55±4±8; Control group: 43±1%; Intervention group: 56±8%; Control group: 49; Intervention group: 56; Control group: received usual care; Intervention group: received medication reminders and cardiac health education; A smartphone-based application supporting secondary prevention among patients with CABG did not lead to a greater adherence to secondary preventive medications.

26  Yu et al. (2020) Heart Health Application  To evaluate the effectiveness and feasibility of using a smartphone-based application to improve medication adherence in patients after coronary artery bypass grafting (CABG) A large scale, multicenter, open-label, randomized controlled trial (NCT02342309); N=1000 patients; Follow-up: 6 months; Control group: 56±6±4; Intervention group: 58±6±6; Control group: 63±7%; Intervention group: 71±5%; Control group: received usual care; Intervention group: received medication reminders and cardiac health education; A smartphone-based application supporting secondary prevention among patients with CABG did not lead to a greater adherence to secondary preventive medications.

27  Basangi et al. (2021) Mobile app  To assess the effect of a self-management application on patient adherence to hypertension treatment Randomized, controlled clinical trial (RCT) (NCT2015111722119); N=118 out of 128 patients; Follow-up: intervention for 8 weeks and follow-up until the 24th week; Control group: 51±6; 5±9; Control group: 36; 24; Control group: 58; Intervention group: 50; Control group: received usual care; Intervention group: received educational-suporative interventions along with the routine treatment; The treatment adherence score increased by an average of 5.9 (95% CI 5.9-6.9) in the intervention group compared to the control group. App can be effective in self-management and better patient adherence.

28  Chen et al. (2016) Cardio-Rhythm app  To assess the diaphragmatic performance of a smartphone’s smartphone photoplethysmographic (PPG) application Prospective screening study; N=193 out of 198 patients; Follow-up: 6 months; 6±6; 4±6; 3; 0±4; FP measurements were performed by using the Cardio-Rhythm smartphone application; App provides a convenient and reliable means to detect AF in patients at low risk of developing AF.

29  Canova-López et al. (2019) Mobile app  To assess the effect of an application that records physical activity on the Mediterranean diet Multicenter, randomized and controlled clinical trial (NCT03801914); N=823 patients; Follow-up: 12 months; Control group: 53±3; a 11; Intervention group: 51±4; a 12; Control group: 160±98; Intervention group: 166±94; Control group: received counseling; Intervention group: received counseling + app; Control group: 41; Control group: received counseling; Intervention group: received counseling + app; The app provided a daily 15-minute program that included video-guided exercises, video sessions to improve information about CAD, and a daily personalized program and heart rate once a day.

30  Eckhardt et al. (2019) Smartphone-guided secondary prevention (S2PP) app  To assess lifestyle changes for patients with CAD after usage of app N=77 out of 93 patients met the criteria for 28-day adherence; Follow-up: 24 weeks; Adherence group: 67±8±4; 8±3; Non-adherence group: 59±7±3; The app provided a daily 15-minute program that included video-guided exercises, video sessions to improve information about CAD, and a daily personalized program and heart rate once a day.

The regular use of a S2PP app supports lifestyle changes in patients with CAD.
By category, the research was focused on the following areas: mobile applications for diagnostic purposes (for example, ECG recording (30), assessment of heart rate (31, 33, 44, 65)). Some studies were carried out to validate the system for urgent care alarm (37), lifestyle changes (43, 45, 53, 62, 65), adherence to treatment (35, 38, 41, 47, 48, 51, 53, 55, 59, 60, 63, 64, 67, 68), and physical activity of the patients (22, 32, 34, 41, 45, 46, 52, 63, 64, 66). Two studies were conducted simultaneously in India (n=2) (67, 68).
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There were prospective (22, 24, 46, 55, 60, 66), retrospective (40, 49, 50, 61), RCTs (22, 24, 32, 35, 39, 40, 42, 51, 53, 56-63, 67, 68). Some mobile applications have been designed for use in pediatric cardiac patients (30, 33).

Apart from that, it should be noted that many mobile applications were employed as an additional tool for medical personnel to monitor the condition of patients (22, 24, 31, 35, 36, 46, 52).

In addition to the analysis of mobile application, we also studies text messages (31, 36, 38, 46, 56, 58), educational materials (38, 51, 55, 58, 59, 64), video instructions for using the application and monitoring the health status (31, 46, 65, 70), reminder functions (35, 36, 41, 46, 48, 51, 55, 63, 68) and as a symptom-tracking tool (39, 41).

Despite the progress in the use of mobile applications, there is a range of challenges caused by various factors, including the lack of RCTs and a small sample size (31, 33, 36, 46, 49, 67, 70). A relatively heterogeneous ratio of different age categories of patients (47) and a short follow-up period (22, 64) dictate the research in this direction and optimization of the study design. Moreover, statistically significant effectiveness of mobile applications was not found out and requires further intensive studies (50, 56).

4.2. Risk of Bias Assessment

The evaluation of risk of bias for all 39 studies was conducted using the Cochrane Collaboration Risk of Bias tool (Figure 2)

As for random sequence generation, only 2 studies identified the unclear risk of bias (53, 64), and 15 studies identified the low risk of bias (24, 32, 35, 42, 44, 48, 49, 51, 56, 58, 59, 61, 62, 67, 68). Results of allocation concealment bias (selection bias) showed that only 9 studies revealed low risk of bias (24, 32, 44, 47, 49, 58, 62, 67, 68) and 4 studies was assessed as having a unclear risk of bias (46, 48, 60, 64). According to the binding of participants and personnel, in general, high risk of bias was detected in many studies, and only 4 studies revealed low risk of bias (31, 49, 67, 58) and 4 studies demonstrated unclear risk of bias (44, 47, 50, 60). In terms of blinding of outcome assessment, in total, in the 19 papers included in this review was identified with low risk of bias (31, 32, 34, 36, 37, 44, 47, 49, 50, 58, 70) and in 10 studies was determined unclear risk of bias (24, 33, 36, 37, 46, 47, 48, 50, 58, 70).

According to the indicator of selective reporting, 10 studies...
were with the characteristics of the unclear risk of bias (24, 37, 38, 39, 46, 57, 58, 66, 67, 70) and only 9 works had low risk of bias (32, 34, 35, 40, 45, 47, 52, 58, 63).

In general, it should be noted that most of the studies included in the analysis (37 out of 39 studies) on many points of assessment were found to be of poor quality, and only 2 studies (58, 67) were assessed as satisfactory.

5. DISCUSSION

It has been shown that health digital platforms can help to improve physical activity, healthy eating, and socialization (71-74). Moreover, mHealth applications demonstrated an effectiveness to treat various behavioral outcomes such as an adherence to the treatment (75-79). However, health apps were not able to effectively reduce harmful behavioral factors, including smoking, alcohol consumption, unhealthy diet, and improve clinical indicators (BMI, level of triglycerides, diastolic and systolic blood pressure, and HbA1c).

The main trend in the mobile health for cardiological applications is the use of different types of wearable devices and Artificial Intelligence-platforms (AI) (80-86). In fact, mobile technology allows remotely to monitor, interpret, and analyze biomedical data collected from the patient (87). Up to date, the classical approach for the diagnostics and prevention of heart pathology is based on the thorough analysis of patient’s medical history, physical examination, laboratory and imaging data (87). The recent advances in digital health provides an opportunity to fasten and optimize heart diagnostics via effective analysis of massive data obtained from electrocardiography, echocardiography, patients‘ electronic health record data, and laboratory tests. It encompasses the use of AI-platforms to monitor and analyze cardiac activity in real-time manner (88).

Apart from AI technologies, there is a number of studies on the application of different wearable devices and smart clothes in cardiology. Such technologies allow to monitor the vital parameters of cardiovascular system such as blood pressure, heart rate and ECG (89-91). In this regard, mobile applications can be classified into several categories, such as daily applications for improving public health, applications for improving patient care, and applications for communication and counseling (Figure 3).

Daily apps for improving public health can be divided into health and fitness apps, apps for chronic patients, apps for monitoring medication intake, and apps for women’s health. Applications for improving patient care include: applications for storing and recording personal medical data and documents, applications for health insurance, and reference applications. Communicating and consulting apps consist on apps for online consultation, apps for appointment booking, apps for ab tests and apps for drugs delivery.

Over the past decade, several studies have been published on mHealth treatment for heart failure (83, 92-97). Most of published systematic reviews have mainly been focused on the effects of telephone support and traditional telehealth interventions using fixed-line technologies such as home tele-monitoring and video conferencing. Other systematic reviews highlighted findings of studies on the mHealth based on other types of remote patient monitoring interventions or invasive technologies to distort the true impact of digital platforms.

One of main public concerns and barriers for a wide implementation of mHealth in monitoring patients is the safety and data protection (87). In fact, many medical apps possess some security vulnerabilities or a weak encryption (98-101). In this regard, the employing of block-chain technology can help to protect the sensitive information via decentralized storage of patients’ data (102-104). This problem has been aggravated by the absence of universal and standard ethical regulations of health data protection (2).

The combining of all information about the patient’s health condition from smart and wearable devices, hospital equipment (radiography, ECG, etc.) and laboratory data can help to optimize the analysis of health status and treatment strategies (Figure 4). For example, collecting information via smart and wearable devices is a way for daily monitoring of life style, diet, physical activity and cardio parameters which can facili-
tate control of patient’s health condition. In terms of hospital equipment, as it known that, there is a possibility to gather a data such as ECG, blood pressure measurement, MRI, ultrasound, CT, laboratory data, and physical examination. As for precision medicine, it is a way to obtain the information about genetics, gut microbiota, psychological monitoring and treatment. Finally, the application of artificial intelligence, machine learning and neuro net for the analysis of health data will provide an opportunity for improving the life quality, diagnostics and treatment of various disorders.

Despite the recent progress, there are still many unresolved issues for the wide implementation of health mobile applications. One of the main problems is the age of the patients. It includes the difficulty of using a smartphone by elderly people (105). It should be noted that the age-related disparities are a temporary barrier. In fact, young cohort of patients will also become elderly after a certain period of time. So, some of youngsters will join the group of patients with chronic diseases. Aside from that, there is a problem related to the privacy and security of mHealth data (106). The situation can be improved by employing a protection system used for Internet banking, such as two-factor authentication or biometric platforms (107). Other problems related to digital health technologies include, but are not limited to, reliability, safety, productivity, and ethical issues.

At present, there is a range of mobile health applications recommended by WHO (108). For example, there are applications for detecting hearing loss “hearWHO” (109), quit the smoking app (111), and fitness/yoga instructions (112). However, the absence of official guidelines for mobile apps given by official state institutions and WHO (for therapy adherence improvement and cardiac rehabilitation) hinders their wide implementation in the clinical environment.

6. CONCLUSION

The application of mobile technologies for health practice led to the significant improvement of early diagnostic and timely treatment of life-threatening conditions such as cardiac arrest (113-118). In fact, early cardiopulmonary resuscitation and defibrillation using digital technologies could help save many lives. Mobile health apps can fasten and optimize the medical assistance for the patients with cardiac arrest in pre-hospitalization stages (114, 119-122).

In addition, it has been shown that digital health platforms can be effectively employed to assist the patients with other cardiologic pathologies such as arrhythmias and atrial fibrillation (123-126). The results of a number of the studies demonstrated that patients diagnosed with cardiovascular disorders can potentially benefit from the application of mHealth in cardiology. It encompasses the improvement of clinical outcomes such as decreased infarct size, smaller reductions in ejection fractions, lower peak troponin and creatine-phosphokinase, and reduced mortality (127).

However, despite the proven advantages of mHealth for cardiology, there are many challenges and concerns regarding effectiveness, safety, reliability and ethical issues. Another big issue is the lack of official regulation and guidelines from official organizations. It concerns data privacy, standardization and unification of digital protocols. Such issues require solutions and further work towards a wide implementation of mHealth technologies in cardiology practice.

- **Author’s contribution:** S.K. and K.T. conceived the original draft preparation. L.S., I.S., and A.M. were responsible for conception and design of the review. S.R., S.T., and I.F. were responsible for the data acquisition. S.K., K.T., L.S. and I.F. were responsible for the collection and assembly of the articles/published data, and their inclusion and interpretation in this review. All authors contributed to the critical revision of the manuscript for valuable intellectual content. All authors have read and agreed with the final version of the manuscript.

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Supplementary file
Appendix 1. Search strategies

For PubMed

| Search Strategy | Result |
|-----------------|--------|
| #1 "mobile application" OR "mHealth" OR "m-health" OR "mobile health" OR "mobile device" OR "mobile app" OR "mobile apps" OR "smartphone" OR "mobile phone" OR "tablet" | 108,714 |
| #2 cardiovascular disease OR "heart failure" OR "ischemic heart disease" OR "acute coronary syndrome" OR "myocardial infarction" OR "cardiac rehabilitation" OR "hypertension" | 1,237,030 |
| #3 (#1) AND (#2) Filters: Clinical Study | 5,030 |
| #4 (#1) AND (#2) Filters: Clinical Study, Clinical Trial | 1,442 |
| #5 (#1) AND (#2) Filters: Clinical Study, Clinical Trial, Randomized Controlled Trial | 1,442 |
| #6 (#1) AND (#2) Filters: Clinical Study, Clinical Trial, Randomized Controlled Trial, English | 1,283 |
| #7 (#1) AND (#2) Filters: Clinical Study, Clinical Trial, Randomized Controlled Trial, English, Humans | 1,274 |
| #8 (#1) AND (#2) Filters: Clinical Study, Clinical Trial, Randomized Controlled Trial, Humans, English, from 2008 - 2022 | 725 |

For Scopus

| Search Strategy | Result |
|-----------------|--------|
| TITLE-ABS-KEY ( "mobile application" OR "mhealth" OR "m-health" OR "mobile health" OR "mobile device" OR "mobile app" OR "mobile apps" OR "smartphone" OR "mobile phone" OR "tablet" ) AND TITLE-ABS-KEY ( cardiovascular disease OR "heart failure" OR "ischemic heart disease" OR "acute coronary syndrome" OR "myocardial infarction" OR "cardiac rehabilitation" OR "hypertension" ) AND ( LIMIT-TO ( SRCTYPE, "j" ) ) AND ( LIMIT-TO ( DOCTYPE, "ar" ) ) AND ( LIMIT-TO ( SUBJAREA, "MEDI" ) ) AND ( LIMIT-TO ( PUBYEAR, 2022 ) OR LIMIT-TO ( PUBYEAR, 2021 ) OR LIMIT-TO ( PUBYEAR, 2020 ) OR LIMIT-TO ( PUBYEAR, 2019 ) OR LIMIT-TO ( PUBYEAR, 2018 ) OR LIMIT-TO ( PUBYEAR, 2017 ) OR LIMIT-TO ( PUBYEAR, 2016 ) OR LIMIT-TO ( PUBYEAR, 2015 ) OR LIMIT-TO ( PUBYEAR, 2014 ) OR LIMIT-TO ( PUBYEAR, 2013 ) OR LIMIT-TO ( PUBYEAR, 2012 ) OR LIMIT-TO ( PUBYEAR, 2011 ) OR LIMIT-TO ( PUBYEAR, 2010 ) OR LIMIT-TO ( PUBYEAR, 2009 ) OR LIMIT-TO ( PUBYEAR, 2008 ) ) AND ( LIMIT-TO ( LANGUAGE, "English" ) ) | 3,062 |
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### For Web of Science

| Expression | Count |
|------------|-------|
| #1 TS="("Mobile application*" OR mHealth OR m-health OR "mobile health" OR "mobile device*" OR "mobile app" OR "mobile apps" OR smartphone OR "mobile phone" OR "tablet")" | 214 383 |
| #2 TS=(Cardiology* OR "cardiovascular disease*" OR "heart failure*" OR "ischemic heart disease*" OR "acute coronary syndrome*" OR "myocardial infarction" OR "cardiac rehabilitation" OR "hypertension") | 1 218 510 |
| #3 #1 AND #2 | 4 808 |
| #4 #1 AND #2 and 2022 or 2021 or 2020 or 2019 or 2018 or 2016 or 2017 or 2015 or 2014 or 2013 or 2012 or 2011 or 2010 or 2009 or 2008 (Publication Years) | 3 958 |
| #5 #1 AND #2 and 2022 or 2021 or 2020 or 2019 or 2018 or 2016 or 2017 or 2015 or 2014 or 2013 or 2012 or 2011 or 2010 or 2009 or 2008 (Publication Years) and Articles (Document Types) | 2 927 |
| #6 #1 AND #2 and 2022 or 2021 or 2020 or 2019 or 2018 or 2016 or 2017 or 2015 or 2014 or 2013 or 2012 or 2011 or 2010 or 2009 or 2008 (Publication Years) and Articles (Document Types) and English (Languages) | 2 857 |

### For Cochrane Library

| Expression | Count |
|------------|-------|
| #1 MeSH descriptor: [Mobile Applications] this term only | 977 |
| #2 "mHealth" | 1944 |
| #3 "m-health" | 6853 |
| #4 "mobile health" | 1607 |
| #5 "mobile device" | 396 |
| #6 "mobile app" | 1032 |
| #7 "mobile apps" | 211 |
| #8 "smartphone" | 5005 |
| #9 "mobile phone" | 3206 |
| #10 #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 | 15631 |
| #11 MeSH descriptor: [Cardiology] explode all trees | 128 |
| #12 "cardiovascular disease" | 24833 |
| #13 "heart failure" | 33237 |
| #14 "ischemic heart disease" | 6936 |
| #15 "acute coronary syndrome" | 6954 |
| #16 "myocardial infarction" | 33549 |
| #17 "cardiac rehabilitation" | 2730 |
| #18 "hypertension" | 69145 |
| #19 #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 | 146587 |
| #20 #10 AND #19 | 2726 |
| #21 #10 AND #19 (Filter: custom data range) | 1559 |
| #22 #10 AND #19 (Filter: custom data range; only clinical trials) | 1014 |

### For Google Scholar

"mobile application*" OR "mHealth*" OR "m-health*" OR "mobile health*" OR "mobile device*" OR "mobile app*" OR "mobile apps*" OR "smartphone*" OR "mobile phone*" OR "tablet*" AND "cardiology*" OR "cardiovascular disease*" OR "heart failure*" OR "ischemic heart disease*" OR "acute coronary syndrome*" OR "myocardial infarction*" OR "cardiac rehabilitation*" OR "hypertension*"