

A Systematic Review of mHealth apps Evaluations for Cardiac Issues [†]

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Abstract: Currently, with the widespread penetration of mobile devices with Internet access, including the smartphones, they can allow specific and/or complementary activities in the health field as well as in other commercial sectors. To verify the impact of the studies about medical scientific publications relatives to cardiac mobile applications (app). This review corresponds to information in scientific journals of high impact. The intention of this review is respond to the follow question: How these research works have evaluated the performance of health mobile applications, with a special interest in cardiac issues? This review of these searches corresponds to an analysis by 4 categories, which are: Assessment of the wearables—Body Care, Use of sensors in the applications, app in health, Health Care—Comparisons of review app and app specialized commercial/clinical use. Only 6% of the app are associated with a medical professional, 15% is published by a professional medical society and 63% according to the opinions of the user. It provides evidence of how some apps have been evaluated, and in some cases the effectiveness of the estimated accuracy is not in line with the real situation. In Panama, a platform has been presented that permit the integration of health applications for patient follow-up. AmI-HEALTH has been developed to provide a mechanism for self-management of hypertensive patient data, by re-cording elements such as blood pressure (systolic, diastolic and pulse). In this point is very important to remember to the near relation between the Cardiac Issues and the hypertension condition. This makes us reflect on the true implications that bring us closer to these technological innovations. Today, our world is so changing and globalized.

Keywords: hypertension solution; cardiac applications; heart rate monitoring; mobile health development; wearables technologies

1. Introduction

M-health (mobile health) is part of the e-health and ICT such as computers, smart phones, mobile health applications, patient monitoring of services. All this information generated is used with the purpose to positively increase access to health information and increase healthier behavior [1].

Many studies have been conducted in the hope of providing a more comfortable life to the patient and allowing the patient to continue carrying out his/her daily activities. It is no longer an

exclusive activity of the medical and health field. Nowadays, it has become a field of multidisciplinary research. New proposals have been initiated to change the way in which health services are provided to patients.

The evolution of the different technological devices has been integrated into the treatment and monitoring of diseases. A broad integration of the mobile devices has emerged that allows a wide range of activities, including greater functionality in comparison with the original purposes for which they were initially developed.

Here, our interest is presented a proposal methodology to verify the impact of studies of medical evaluations in which cardiac applications have been evaluated. When we refer to normal heart rate, the normal heart rate at rest is 60 to 100 beats per minute. It is usually measured by the electrocardiogram (ECG). The ECG measures the electrical activity of the heart [2].

Currently, it is a fact the wide penetration of mobile devices with Internet access, including the smartphones. They can allow specific and/or complementary activities in the health field. On the other hand, advances in sensors, mobile and built-in devices have made it possible to monitor the medical condition of the patient, have provided medical treatments and other healthcare assistance based on a communication platform that allows the safe transmission of medical data [3].

New technological innovations can bring benefits to healthcare professionals. Smartphone applications prove to be powerful tools to improve education in the health sector. However, by deeply analyzing the medical implications of APPs, it is neither easy nor feasible to do so transparently or objectively because of the lack of reliable comparative data. Despite the benefits offered by APPs in health care, the outcome of the patient, end-user and education of beginning professionals, they are not appreciated so easily in some cases of medical specialties. In addition, we raise more disturbing questions about the regulations of these applications and how sensitive patient data are protected [4].

Currently there are wearables, refers to the set of electronic devices that are incorporated in some part of our body interacting continuously with the user and other devices for the purpose of performing specific functions [5]. For example, smart watches, GPS shoes incorporated bracelets that monitor our health and others devices etc. Currently people have access to a mobile device connected to the internet, according to Nielsen [6], the 74% of global respondents appreciate being connected anywhere and anytime. In addition, 70% of the global respondents mention that their mobile devices have made their lives better. The people access from their smartphone to find information and use the app to solve a specific activity [7].

In this sense, many mobile applications or app can give us some information about heart rate. Here, in this point, it is important to know the scope of these applications, how reliable can be their results and in which field moves. For example, we can say that many of these applications range occur from companies that must do with body care or training (for example sports brands: Nike, and others) until to the apps used by medical bodies. Within this range there are some applications verified by studies with certain criteria that allow the user chooses any with references to tests.

This paper is structured to present general data on the use of smartphone. First, we present the used methodology. Then, the results are showed in 4 categories, which are: Evaluation of wearables—Body Care, Use of sensors in the applications, app in health, Health Care—Comparisons of app and app specialized commercial/clinical use. Finally, the discussion and main conclusions are presented.

2. Methodology

The information search strategy has been structured as follows:

1. The review corresponds to scientific journals of high impact, with the intention of verifying how they have evaluated the performance of mobile applications related to health topics with special interest in cardiac issues. The main scientific databases used are: IEEE Xplore, Web of Science, Science Direct and Scopus.
2. In view of this situation, information has been searched with the keywords like “app” & “Heart” & “rate” where scientific articles have been searched, which have been selected by title and abstract, later organized in the following categories.

3. Multiple information has been found of some professionals, who evaluate their own applications. However, there are little information related to the evaluation and comparisons of apps in the health sector. In our preliminary research, 16 articles have been found, which presented interesting information on diabetes and other diseases. So the analysis of 16 articles selected in this methodology represent our main objective. It is to verify scientific articles about app evaluations to be able to consider them.

The information search strategy, consulted recent scientific studies from the period of 2005 to 2017, where scientific articles will present the apps evaluations related to cardiac issues, in English language. Figure 1 shows the used methodology in the review.

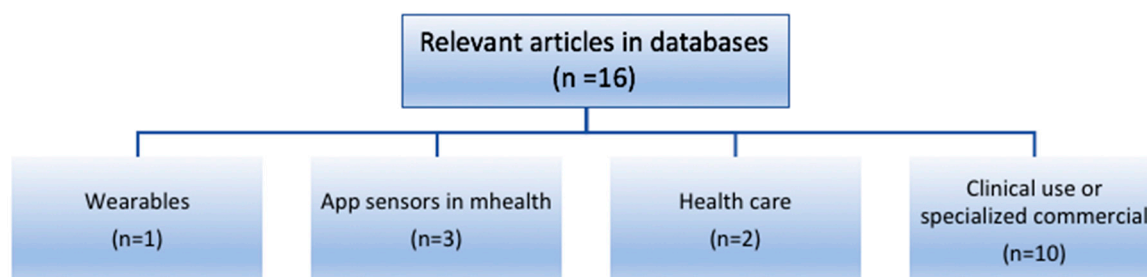


Figure 1. Methodology in the review.

3. Results

In the field of health, innovation and new products are developed that can surprise to the consumer, people with the need to take care or wellness. For example, in some companies sell watches that can measure the pace cardiac or discharge the app that indicates its performance. It is important to mention that personal training is part of this sector. The selected scientific articles have been grouped according to the distribution proposed in the methodology (See Figure 1). The information search strategy has been structured as follows:

1. Category Wearable Assessment—Body Care.

According to the study on the accuracy of measuring heart rate in smart clocks [8], in this research was established a methodology to evaluate the accuracy of smart clocks, where the main result on the top 4 watches brands have a low performance in terms of accuracy estimating the expenditure energetic. However, clocks accurately measure acceptable heart rate [8]. Wallen et al., [8] comment that: Samsung wear uses accelerometers based on an algorithm that predicts during the movement of the person. Meanwhile Apple watch, Fitbit charge HR and Samsung wear has an acceptable accuracy when measuring heart rate between the range of 4% to 6% of error [8]. The methodology used in this study comprised twenty-two (22) healthy volunteers (50% women, 24 ± 5.6 years) completed the protocols of one (1) hour with supine rest and sitting, walking and running on a treadmill and cycling on an ergometer.

Data from the devices collected during the protocol were compared with reference methods as: electrocardiogram (heart rate) and indirect calorimetry (energy expenditure) [8].

2. Category Use of sensors in applications, APP in health.

The Table 1 presents several applications of sensors incorporated into mobile phones recently developed. Some of these applications are already distributed and used for medical purposes, but the others are current research projects. The main reason for using mobile phones in the health domain is to improve the quality and availability of health services that many people in the world already have a mobile phone. Solutions based on mobile phones can reduce the costs of health services and is another reason to use them [9].

Measurement and monitoring of heart rate is used for medical care, physical training and stress management. In these aspects, monitoring of heart measurements in individuals presents challenges. On the one hand, the availability of equipment and on the other, the motivation of the user [10].

There are many different ways to measure the person’s heart rate. One of them can be by using mobile phones. All what is necessary for the measurement of the heart rate is the mobile phone with camera equipped with flash.

There are several algorithms available for measuring heart rate using mobile phones [11].

Table 1. Sensors: Types, Environments and Position. Source: Stankevich et al., [9].

Types of sensors	Sensors of Environment		Orientation or Position Sensors
	Microphone	Camera	Accelerometer
Key applications	Healthcare Communication and Training for health workers.	Remote consultations can be applied when the patient cannot attend the qualified specialists for the following reasons: Lack of access Lack of funds	Track a person’s level of physical activity. Detection of human falls.
	Follow-up of outbreaks and diseases. Support for diagnosis and treatment.	Lack of medical resources, especially in difficult or rural areas Other apps.	Provide rehabilitation services.

The main idea of measuring the heart rate using the mobile phone is to detect variations in the color of the skin of the finger and the brightness that occur due to the pulsation of the blood using the camera of the smart phone. Detection is performed by analyzing the mean values of the red component of the frames or part of the frames taken by the camera. Laure et al., [11] proposed an algorithm that has been used by Nike app to measure the heart rate which presents a margin of error of approximately 8%.

Han et al., [10] did another interesting study, which measures heart rate while people play was introduced by LivePulse Games (LPG), a novel technique to measure the heart rate of users in real time through games on mobile phones. The main contribution was demonstrated the feasibility of non-invasive real-time heart rate monitoring during mobile game [10]. This study detected changes in the transparency of the fingers of the users through camera. This was tested experimentally with 12 individuals, resulting that find the game fun and allow measuring the heart rate with precision during their entertainment.

3. Health Care Category – APP Comparisons of Reviews.

As an app, we are interested in the evaluation carried out by Laure et al., [11], where the authors evaluated 34 app using the Expert Rating Scale (MARS), the functionalities of the Health Informatics Institute (IMS) and the American Heart Failure Society Guidelines for Non-Pharmacological Management (HFSA). The app was downloaded and with peer reviewers (2–4) only achieved high performance in 3 out of 34 apps. According the review of Masterson et al., [12], this study allows to visualize the characteristics that can be defined and mapped, giving great importance to the scientific evidence.

The best quality in the monitoring of heart failure, some as self-management can be improved by more rigorous criteria, because health issues, especially those related to the heart, need to be taken seriously. App developments should consider the medical criteria on the subject. The main contribution of this evaluation commercial app was verified the characteristics taken into account in some APP, where we can punctuate their yields in the effectiveness of their results. The most common of the features within all evaluated APPs was the functionality of recording the information by synchronizing data from other sources. In addition, few of the APPs provide some guidance on inbound response, reminders or alerts on medication or symptom tracking, or facilitate communication with providers [12].

In the evaluation performed by Eldin et al., [4], they searched the Apple store and play store with the keywords cardiothoracic, thoracic, cardiac, heart, lung, surgery along with the topic “medical” using those terms. Eldin et al., [4] found 379 app in 2013. According the Table 2 by Eldin et al., [4], the main conclusions are only 6% of the app are associated with a medical professional, 15% is published by a professional society and 63% according to the opinions of the user. An interesting aspect of this study is that it shows the risks of the contribution of technological innovations in the medical profession. In this point is interesting note the very low percentages of medical professional (6%) and professional society (15%) in comparison with the very high percentage about user opinions (63%). This situation demonstrates the lack of studies in the subject.

It is necessary to improve the quality, regulation and security of the medical information in a specific way for the smartphones, so that it can be consolidated as an integral and safe part of the provision of medical care.

The challenge for future healthcare professionals is to be able to rely on mobile applications to help the patient, such as generating alarms for medications, education treatments or procedures to patients during their consultations, among other uses that could be offered with apps. It is important to be able to differentiate between applications for personal use and those for professional medical use.

Table 2. Health care category-Apps Comparison of review [4].

Search Term	App Provider (Number of Apps)	
	Google	Apple
Cardiothoracic	193 (User rating: 64%)	7 (User rating: 14%)
Cardiothoracic surgery	70 (User rating: 94%)	3 (User rating: 33%)
Cardiac surgery	51 (User rating: 59%)	23 (User rating: 9%)
Thoracic surgery	26 (User rating: 65%)	6 (User rating: 0%)
Total	340 (User rating: 70%)	39 (User rating: 8%)

4. Category: APP specialized commercial/clinical use

In this category, we can locate the heart monitor. AliveCor is a rectangular pocket-size device that contains 2 electrodes. It is connected directly through a fixing adhesive plate to a mobile device. It must be within 30 cm of the mobile device during operation. The AliveCor heart monitor can be removed from the card when it is not in use [13]. This electrocardiogram monitor is complemented by a mobile application called Kardia, available on iOS and Android. This product is a commercial example because it can be purchased by Amazon.com and other stores.

People should place two fingers of each hand on the plate to record an electrocardiogram, which is transmitted wirelessly to the mobile application. Its main function is to identify atrial fibrillation (AF) or better known as cardiac arrhythmia and its corresponding analysis by physicians [13]. The most frequent sustained cardiac arrhythmia is described as an irregular heart rhythm.

In addition to having a commercial access, this product is used people who have an abnormal heart rhythm and it allows a possible follow-up with his/her doctor.

Another interesting research did in India, presents the importance of treating cardiovascular diseases, which are one of the main health problems worldwide, causing deaths for almost 17 million people each year. About 80% of all cardiovascular diseases occur in developing countries. It is known that these diseases can be prevented or postponed, if it is detected in their earlier stages and subsequently adapted to the appropriate preventive methods.

The cost and availability of laboratory equipment for early diagnosis are key elements in controlling the spread of cardiovascular disease cases in India, particularly in rural areas. Non-lab-based methods outweigh the available expenditure, while mobile technology provides the availability and opportunity to allow approaches that can detect the risk of disease, even in the remotest part of the country. In Singh et al., [14] evaluate the CVDMagic application, a study based on mobile telephony for the detection of risk of these diseases. The analysis of the initial survey (of 169 people) of a pilot deployment of CVDMagic was carried out. Preliminary analysis suggests that

mobile-based approaches can be used to accurately collect required data, leading to early, accurate, low-cost, and non-laboratory detection of CVD risk in the Indian context [14].

A third study selected for this article, allows us to see how the applications of smart phones allow to measure the heart frequencies during supraventricular tachycardia in pediatric patients and compare them with the heart frequencies measured by standard electrocardiogram [15]. This study was performed with patients <18 years of age ($n = 26$) who underwent an electrophysiology study. During the study, heart rates were measured at the baseline and during supraventricular tachycardia in the use of 2 smartphone applications. The obtained heart rates were compared with a standard simultaneous electrocardiogram. The Pearson correlation coefficient (r) was used to compare the precision of the applications with electrocardiogram. During tachycardia, none of the two applications consistently assessed an accurate heart rate at rates > 200 bpm. The tested applications should not be considered as accurate tools for assessing heart rates during supraventricular tachycardia in pediatric patients. The selected applications may have utility detecting slower supraventricular tachycardia or confirming normal cardiac frequencies with additional validation [15].

On the other hand, hypertension is a public health problem and affects millions of people worldwide. Hypertension is an asymptomatic disease and easy to detect, if it is not treated in time can lead to serious or fatal complications. In 2010, a global disease burden study revealed that nine million people died as a result of hypertension, making this cardiovascular problem the leading global health risk factor [16].

Hypertension is the main cardiovascular risk factor; attributing 80% of the deaths due to cerebrovascular and cardiovascular complications in the group of population of 65 years or more. It affects almost half of the men and in a smaller proportion of 1 in 4 to the women. The President of the Panamanian Heart Foundation, Dr. Bey Mario Lombana, said that out of every three adults, one is hypertensive. "The 33% of the adult panamanian population suffers from the pressure. Of these people, there is a third party who does not know that they are suffering or have not been detected, "he says and warns that is what the world statistics" [17].

In Panama, a platform has been presented that permit the integration of health applications for patient follow-up [18]. AmIHEALTH (Figure 2) has been developed to provide a mechanism for self-management of hypertensive patient data, by recording elements such as blood pressure (systolic, diastolic and pulse) and weight [19]. The patient can control their pressure in the area, thus avoiding cardiovascular problems later. The blood pressure reading is obtained from the biometric devices (blood pressure monitor) and stored in the mobile device or computer [20].

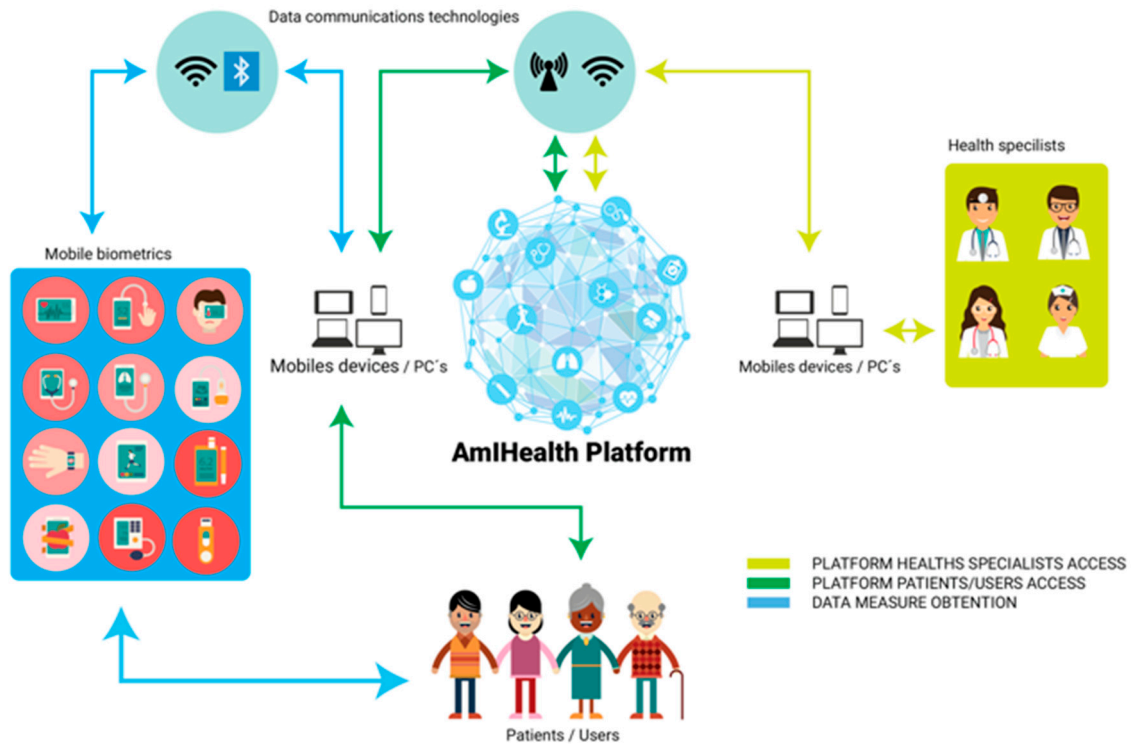


Figure 2. AmIHEALTH platform for blood pressure control [20].

Hypertension is the main element that must be considered as a risk factor for patients with a probability of having cardiac affections. In this sense, Di Rienzo et al., [21] presented a textile-based wearable system, named MagIC, with the objective of unobtrusive recording of cardiorespiratory and motion signals during spontaneous behavior in daily life and in a hospital environment. In Deepu et al., [22] presented an ECG-on-Chip for Wearable Cardiac Monitoring Devices. This ECG-on-Chip consisted in a small size and low power consumption, which make it design suitable for usage in wearable heart monitoring devices. Martinez-Tabares et al., [23] presented a methodology to optimize the design of wearable sensor systems oriented to cardiac monitoring. In Martinez-Tabares et al., [23] was proposed this methodology based on the selection of a subset of 5 design variables. They were sensor contact, location, rotation, signal correlation, and patient comfort. This method had two objective functions that were functionality and wearability.

These variables were optimized using linear and nonlinear models with the purpose of maximize those objective functions simultaneously. In Kutuyifa et al., [24] presented a prospective registry of patients using the Wearable Defibrillator, called WEARIT-II. This registry was designed to provide real world data on the wearable cardioverter defibrillator (WCD) as a strategy during a period of risk stratification. WEARIT-II registry enrolled 2000 patients with ischemic condition ($n = 805$, 40%), or non-ischemic cardiomyopathy ($n = 927$, 46%), or congenital/inherited heart disease ($n = 268$). This WCD was prescribed between the period of August 2011 and February 2014.

Rios-Aguilar et al., [25] presented a wearable with principal purpose was use the pulsations measurements in conjunction with the physical body activity for the detection of driver drowsiness/sleepiness in order to prevent car accidents derived from fatigue. In other words, Rios-Aguilar et al., [25] presented a application designed for Samsung Gear S smart watch recognizing and alerting drowsy state of a driver at the wheel of a vehicle. In this application, an algorithm was designed using FFT, filters, scatter of points and statistic power in order to detect that the driver is entering a state of sleepiness.

Surrel et al., [26] presented a wearable sensor device for physical and emotional health monitoring, called INYU. INYU obtains key vital signs of the user continuously. INYU use a real-time algorithm for on-line heart-beat classification and correction that relies on a probabilistic model

to determine whether a heartbeat is likely to happen under certain timing conditions. This algorithm was integrated in the processing pipeline of automated Heart-Rate Variability (HRV) analysis, both for time-domain (RMSSD, SDNN) and frequency domain (LF/HF) algorithms.

A recent work of Lazarev [27] presents a study of eHealth sector with smart wearable design supported by Internet of Things (IOT) for personal healthcare in Finland. This study analyzed market situation. This author made an audience research in Finland and he prepared a whitepaper with basic rules, which can help to develop and design a valuable, secure product for personal use. Lazarev [27] covered aspects like: needs and requirements of healthcare IoT, regulations, adoption, IoT user experience, security. Finally, this author applied collected theoretical knowledge in his study and then he designed a smart insulin pump. This Lazarev's invention is now an innovative and new product on today's market.

We are implementing an application called AmiHEALTH developed in Panama. This application allows the management of patient data, through the evaluation of risk factors that are elements that end in heart problems.

The importance of incorporating this application is to present that there are previous and rigorous studies that validate the need to complement hypertension data with cardiac issues [28].

4. Discussion and Conclusions

In health issues, especially those related to the detection of cardiovascular diseases, heart rate measurement turns out to be a good start and mobile applications on smart phones are an available means that can save costs and shorten distance. However, it is important to verify the accuracy of the results of different APPs that are available on iOS and Android. The confidence generated by these applications can benefit users who use it, either by improving their health monitoring or simply to verify their body condition in a workout in the gym. The motivations are many, both for those who develop APPs and for those who use them.

This work provides scientific evidence of how some APPs have been evaluated, and in some cases the effectiveness of the estimated accuracy is not correspond the real one. This makes us reflect on the real implications that approach us in technological innovations, with a world so changing and globalized, information and communication technologies allow us to use mobile applications that by placing fingers on the smartphone we can measure many characteristics of the environment and the position by means of the sensors. There are many ways to measure the person's heart rate. One of them can be by using mobile phones. All that is necessary for heart rate measurement is the mobile phone with camera equipped with flash, for example.

The main conclusions by category are:

- Category Assessment of Body Weights Both Apple watch, Fitbit charge HR and Samsung wear have acceptable accuracy when measuring heart rate between the 4% to 6% margin of error [8].
- Category Use of sensors in applications, apps in health: The main reason for using mobile phones in the health domain is to improve the quality and availability of health services, that many people in the world already have a mobile phone. Solutions based on mobile phones can reduce the costs of health services and is another reason to use them [9].
- Health Care Category—APP Comparisons of review: The main conclusions according to Table 2, only 6% of the app are associated with a medical professional, 15% is published by a professional medical society and 63% according to the opinions of the user [4]. The interesting thing of this study is that it shows the risks of the contribution of technological innovations in the medical profession.
- Category: APP Specialized commercial/clinical use: Tested applications should not be considered as accurate and accurate tools for assessing heart rates during supra-ventricular tachycardia in pediatric patients. The selected applications may have utility detecting slower supraventricular tachycardia or confirming normal cardiac frequencies with additional validation [15]. Some applications have been developed to decrease the cardiovascular effect in people. The care of blood pressure is one of the most relevant elements when presenting

solutions. Patients with cardiovascular problems use applications for the monitoring of vital signs that affect the behavior of the patient.

In this field, future health professionals should rely on mobile applications to help the patient. Mobile apps can generate alarms for medications, education treatments or procedures to patients during their consultations, among other uses that can be offered with apps. It is important to be able to differentiate between applications for personal use and those for professional medical use. Both need the specific education for the integration of mobile technologies in the patient solution.

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