Mobile apps for blood pressure monitoring: Systematic search in app stores and content analysis.

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Abstract

The study's objective was to assess the efficacy, accessibility, and usability of mobile applications designed for blood pressure monitoring. A systematic search was conducted using certain keywords on the official Dutch app shops for iOS and Android. In total, 184 apps that target blood pressure were included in the analysis. The Mobile App Rating Scale (MARS), which has mean overall ratings of 2.63 for the Android and 2.64 for the iOS platforms, was used to evaluate the apps' quality. As per the survey, a mere minority of applications claimed the involvement of medical specialists in their development, and not a single app had passed formal evaluations, the results of which were published in peer-reviewed journals. For both iOS and Android, the top-rated apps were In settings with limited health care resources, smartphones may offer a highly accessible method of simplified hypertension screening. The majority of research on blood pressure (BP) apps for smartphones has concentrated on validation under static conditions, ignoring intraindividual BP variability.

Keywords: mobile phone, mobile application, mobile app, self-management, hypertension, blood pressure

Introduction

The development of mobile technology has completely changed the healthcare industry by providing cutting-edge methods for tracking and controlling a wide range of medical disorders. Blood pressure monitoring is one area where mobile applications have demonstrated a great deal of promise. Smartphone apps have become popular tools for people to conveniently and effectively measure their blood pressure levels due to the rising prevalence of hypertension and the significance of routine blood pressure monitoring for optimal management.

With the help of these smartphone apps, users may keep track of trends over time, record and monitor blood pressure readings, set reminders for measurements or medication consumption, and even share data with healthcare experts for improved treatment and direction. These apps are useful resources for people with hypertension or those aiming to maintain a healthy blood pressure level because of their accessibility and ease.

accessibility, usability, and caliber of smartphone apps made for blood pressure monitoring to guarantee their efficacy and dependability in assisting with self-care and medical actions. This introduction lays the groundwork for discussing the function of smartphone apps for blood pressure monitoring and emphasizes the need to evaluate their features and quality for the best possible use in medical settings.

The essay underscores the noteworthy influence of hypertension on worldwide health, stressing its correlation with diverse ailments and death rates. It emphasizes how crucial it is to provide ongoing care and management of blood pressure, with self- measured monitoring playing a major role in enhancing control and drug adherence. Globally, as more people acquire mobile phones, the market for health apps—which concentrate on chronic conditions like hypertension—is expanding. Using mobile apps for self-management of hypertension may have advantages such as the ability to enter blood pressure readings, set up reminders for medication and monitoring, access instructional materials, and share data with healthcare

practitioners. Notwithstanding the possible advantages, little is known about the features, quality, and accessibility of mobile apps for blood pressure monitoring.

For self-management, patients with hypertension may find it simpler to monitor and manage their blood pressure when they use a smartphone app. These apps might contain a number of helpful features. For

example, logbook or diary features make it easier to record blood pressure readings in an orderly manner, and reminder tools might help with medication adherence and monitoring. Furthermore, health applications can give patients important background knowledge about the condition, its care, proper blood pressure measurement techniques, and lifestyle management. Analysis techniques (such as graphs and trend analysis) can give a general picture of how blood pressure has changed over time. Additionally, several applications provide the ability to export user data, including blood pressure measurements, for emailing.

Methods

App Search and Selection

Search and Selection of Apps Following the guidelines for systematic reviews, we conducted a systematic app search. While we adhered to the norms for systematic evaluations of scientific literature, app reviews are not entirely covered by these standards. All blood pressure monitoring applications that were accessible on the Google Play store for Android and the iOS App Store and allowed users to manually enter their blood pressure readings may be included. The following search phrases, together with their Dutch counterparts (bloeddruk, diastole, hypertension, hypotension, heart rate, blood pressure, diastolic, pressure, systolic), were used to search the Dutch app shops on March 1, 2016.

systole, hypertension, hypotension, hartslag, and gezondheid). Apps that were not in English or Dutch, duplicates, or unrelated apps—like games—were not allowed. There were free and paid versions of several apps. Only the free version of the program was reviewed in situations where there was no discernible difference between the two versions' functioning or important features. The suitable apps were chosen by two impartial assessors (FRdG and HJ) using the app store description, screenshots, and app titles. Differences were deliberated about until an ultimate resolution was obtained.

Data Extraction

With over one-third of customers expected to own a mobile phone by the end of 2022, the frequency of concealed hypertension is concerning in light of the global trend toward increased mobile phone ownership. With dozens of new health apps created each year, the market for health apps is growing quickly. There were almost 100,000 new health-related applications released in 2016 alone, increasing the total to 259,000 health apps that are accessible through major app stores. In 2016, there were 3.2 billion downloads of health applications, a 7% rise from the year before. The main focus of app developers is on chronic conditions like diabetes and hypertension. According to an Accenture survey, consumer use of wearables and health apps increased by about 50% in 2016 over 2014. suggesting that both patients and doctors are becoming more interested in and accepting of new technologies. Patients with hypertension may be better equipped to effectively monitor and control their blood pressure by using a mobile app for self-management. These apps provide a number of helpful features, including reminder tools to help with medication adherence and monitoring, logbook or diary functions for organized blood pressure recording, and educational materials on managing diseases, taking proper blood pressure, and making lifestyle changes. Analytical tools that show trends in blood pressure over time include graphs and trend analysis. Additionally, some apps allow users to email their blood pressure readingsand other data.

Encouraging family members and healthcare professionals to communicate. Although there are potential advantages to using mobile apps to treat hypertension, little is known about the features, quality, and accessibility of blood pressure-related apps. Therefore, the purpose of this study was to perform a systematic assessment of applications in order to evaluate their quality, usability, and availability for taking blood pressure readings for monitoring purposes.

Systematic review criteria were adhered to during the app search and selection process, however these principles do not apply only to app reviews. Applications for blood pressure monitoring that allowed users to manually enter their blood pressure readings were taken into consideration for inclusion from the iOS App Store and Google Play store for Android. Specific search phrases were used to search the Dutch app shops, and apps that weren't in English or Dutch, duplicates, or unrelated apps were removed. Based on app descriptions, screenshots, and titles, two impartial assessors chose the appropriate apps; disagreements were settled through debate. On Samsung Galaxy S6 and iPhone 5c smartphones, the chosen apps were downloaded for a comprehensive assessment, with assessors documenting app features and technical details.

Data Sources and Search Methods

The Cochrane Central Register of Controlled Trials (CENTRAL, The Cochrane Library), CINAH, ASSIAN, IEEE Xplore, EMBASE (OVID), MEDLINE (OVID), PsycINFO (OVID),
and Google Scholar were searched. To locate other relevant papers, a manual search of the reference lists of the included studies and systematic reviews was also done. The terms "hypertension," "mobile apps," "telemonitoring," and "self-management" were used to search these databases (for the MEDLINE search technique, see Multimedia Appendix 2). The search approach was restricted to English-language studies released between June 25, 2017, and 2008, the year the first app store opened.

Data Extraction and Quality Assessment

Independently, TA and SA, two reviewers, gathered data and evaluated the caliber of the included research. Until a consensus was formed, disagreements were settled through debate with fellow scholars LdW and MSH.

The reviewers piloted a standardized form that was used to extract data. To evaluate randomized controlled trials (RCTs), the Risk of Bias Tool developed by the Cochrane Collaboration was employed. Three tools—one for observational research, one for controlled studies, and one for pre-post studies without a control group—provided by the US National Institute of Health (NIH), March 2014 edition were used to evaluate nonrandomized quantitative studies. Study quality was evaluated using the Critical Appraisal Skills Programme (CASP) for qualitative

Data Synthesis and Analysis

A table provided a summary of the fundamental features of the research, such as the population, intervention, and result. Due to variations in the study designs, data were not merged. Instead, a narrative synthesis was carried out. Review objectives were used to categorize all research findings.

App Quality Rating

The Mobile App Rating Scale (MARS), a standardized questionnaire of 23 questions divided into 4 objective areas (engagement,

functionality, aesthetics, and information quality) and 1 subjective category, was used to evaluate the quality of apps. A 5-point rating system was used for each question: 1-inadequate, 2-poor, 3-acceptable, 4-good, and 5-excellent. By averaging the means of the four objective categories, the MARS overall score was calculated. Assessors were trained by watching a MARS training video on YouTube and having discussions about the scale using ten randomly chosen apps in order to guarantee rating consistency. During training, a consensus on scoring was obtained. The remaining apps were then evaluated by assessors on their own, without additional discussion, in order to preserve objectivity and standardize the rating procedure.

Statistical analysis

Our study's primary objective was to evaluate BP changes, or trending abilities, as opposed to determining absolute BP values. Thus, no calibration was required because BP changes between every feasible pair of recordings was estimated for every patient (Fig. 2). After calculating the BP change between two recordings, i and j, using the formula $\Delta BP(i,j) = BP(j) - BP(i)$, a list of {ΔBPinv, ΔBPPPG} data pairs was produced for analysis for both BPinv and BPPPG.

We employed the four-quadrant (4Q) plot method in conjunction with polar plots, as suggested by Critchley et al. [33, 34], to evaluate OptiBP's blood pressure trending capabilities. All of the {ΔBPinv, ΔBPPPG} pairs in the 4Q-method's upper-right and lower-left quadrants exhibit a concordant direction of change. As a result, the percentage of data points in which ΔBPPPG and ΔBPinv change in the same direction is represented by the computed concordance rate (CR). The 4Q-method does not allow one to realize the magnitude of changes between {ΔBPinv, ΔBPPPG} pairs, despite being a solid mean for assessing trending ability. In order to achieve this, Critchley proposed to convert the 4Q plots' Cartesian coordinates to polar coordinates, creating what are known as "polar plots," which allow for quantitative evaluations of trending ability.

Literature Survey

After two participants were excluded and 565 recordings were rejected because the app did not generate the BP estimate, 109 subjects' recordings were kept for analysis (equivalent to a worldwide acceptance rate of 51.1%; see CONSORT). With a mean age of 58.5 (SD 14.2),

58/51 male to female ratio. The vasopressors that were utilized to support hemodynamics during the 20-minute research intervals are compiled in A summary of the biometric and demographic data distribution may be found in. The cohort's average per-patient blood pressure and mi-max range are compiled in. The app's estimation of blood pressure as well as the normal temporal evolution of blood pressure in a patient during the anesthesia induction phase are shown.

Study Characteristics

This review contained twenty-one studies. The research were published between 2012 and 2017 (refer to Multimedia Appendix 1). The majority of studies (11/21, 52%) were carried out in the United States and Canada, whilst seven (33.3%) were done in Europe,notably France.,

Italy, Spain, and Sweden. Three (14.3%) of the remaining investigations were carried out in South Korea and China.Of the 21 research, 2 (10%) were qualitative studies,

10 (48%) were nonrandomized studies, and

9 (43%) were randomized controlled trials (RCTs).Fourteen trials (14/21, 67%) reported on how well the apps worked to regulate blood pressure. Four of these studies (or 27%) also evaluated the apps' user experience and satisfaction.

The remaining 7 (33%) studies that did not find any efficacy concentrated on user

attitudes and satisfaction with the usability and apps. The trial lasted anywhere from one to twelve months. The research comprised a spectrum of 19 to 1012 people took part, making a total of 3112 people.The age range of the participants' means was 42.4 to 69.5 years old. The studies' target populations were people with high blood pressure, metabolic syndrome risk factors, high cardiovascular risk obstructive sleep apnea, and obesity. Out of the 21 selected studies, 5 (24%) stated that they based their intervention approaches and technological development on behavioral theories, including theory of planned behavior, motivational interviewing, and self-determination theory.

App characteristics

the 184 apps that were featured, most of them were free, with Android apps often having lower prices than iOS apps. Nonetheless, compared to Android apps, iOS apps were typically free of ads. Less than half of the applications monitored user backgroundinformation.

except for Android applications that track weight. Only a tiny portion of apps provided instructions on how blood pressure was measured; Android apps were more likely than iOS apps to record the measurement side and location. There were just two apps that failed to record the measurement's date and time. A few apps included a reminder feature and supported data export; iOS apps are more likely to provide data export. Of the 184 apps, 26 had predetermined functions that were essential; none of them had informational or educational features.

Just two apps were made by academic institutions or non-governmental groups; the majority were made by commercial or unknown developers. Only a small portion of apps indicated that medical professionals were involved in their creation, and not a single app was tested or assessed with findings shared in a peer-reviewed publication.

The examination of the features and development information of the blood pressure monitoring app research offers important insights into the app market:

App Quality

Both the subscale and overall MARS scores followed a normal distribution. Overall MARS interrater reliability for iOS apps was deemed to be fair (ICC=0.42, 95% CI 0.21-0.59), and the Cronbach's

The alpha was 0.59. The Cronbach's alpha was 0.70 and the interrater reliability was marginally higher for Android apps (ICC= 0.53, 95% CI 0.38-0.66). Table 2 displays the MARS total score for each platform as well as the ICCs and MARS scores for the five categories.

The mean MARS score for the four objective categories on both platforms was

2.6 on a scale of 1 to 5. For Android and iOS 1.6, the MARS scores for the other categories were likewise quite comparable. The entire list can be found in

Appendix 1: Multimedia.

Seven of the eighty iOS apps had ten or more user ratings in the app store, but there was no association (r=0.29; P=.53) between the star ratings and the MARS overall score. 78 Android apps had at least ten user evaluations; these again had no correlation (r=0.17; P=.15) with the MARS scores. The comparison of quality scores for apps with and without each feature is displayed inTable 2

Table 1. Summary of characteristics of included apps, stratified by platform.

Characteristics	All apps (n=184), n (%)	Android (n=104), n (%)	iOS (n=80), n (%)	*P* values
Pricing				
Free	143 (77.7)	92 (89.4)	50 (62.5)	<.001
No advertisements[a]	95 (66.4)	55 (59.1)	40 (80.0)	.01
Personal data				
Age	75 (40.8)	42 (40.4)	33 (41.3)	.91
Gender	75 (40.8)	41 (39.4)	34 (42.5)	.67
Height	71 (38.6)	44 (42.3)	27 (33.7)	.24
Weight[b]	99 (53.8)	62 (59.6)	37 (46.2)	.07
Blood pressure measurements				
Side (left or right arm)	28 (15.2)	21 (20.2)	7 (8.8)	.03
Position (eg, sitting, lying)	26 (14.1)	20 (19.2)	6 (7.5)	.02
Date and time[b]	182 (98.9)	103 (99.0)	79 (98.8)	.85
Other features				
Reminder function[b]	53 (28.8)	30 (28.8)	23 (28.7)	.99
Analysis tool[b]	158 (85.9)	92 (88.5)	66 (82.5)	.25
Data export[b]	120 (65.2)	60 (57.7)	60 (75.0)	.02
Data upload from blood pressure meter	27 (14.7)	12 (11.5)	15 (18.7)	.17
Needs Web access to function	10 (5.4)	8 (7.7)	2 (2.5)	.12
Password protection	43 (23.4)	20 (19.2)	23 (28.7)	.13
Data storage (local)	181 (98.4)	102 (98.1)	79 (98.8)	.72
Data storage (cloud)	19 (10.3)	15 (14.4)	4 (5.0)	.04

Table 2. Mobile App Rating Scale scores.

MARS[a] subscale	Android			iOS		
	Mean (95% CI)	ICC[b] (95% CI)	Alpha[c]	Mean (95% CI)	ICC (95% CI)	Alpha
Engagement	2.28 (2.17-2.39)	.62 (.48-.72)	.76	2.26 (2.16-2.36)	.47 (.28-.63)	.64
Functionality	3.54 (3.46-3.62)	.23 (.03-.41)	.37	3.55 (3.46-3.65)	.35 (.13-.53)	.51
Aesthetics	3.06 (2.96-3.17)	.51 (.35-.64)	.68	3.16 (3.07-3.25)	.20 (.03-.40)	.33
Information	1.63 (.52-1.73)	.57 (.42-.69)	.73	1.57 (1.46-1.68)	.54 (.35-.68)	.70
Subjective quality	2.54 (2.35-2.74)	.56 (.41-.68)	.72	2.63 (2.42-2.84)	.49 (.29-.64)	.65
MARS overall score[d]	2.63 (2.55-2.71)	.53 (.38-.66)	.70	2.64 (2.56-2.71)	.42 (.21-.59)	.59

Discussion Principal

Findings

Pricing and Ads: Of the apps that were included, 77.7% were free of charge. With 89.4% of Android applications and 62.5% of iOS apps being free, Android apps were more likely to be available for free than iOS apps.

Compared to Android apps (59.1%), iOS apps (80.0%) have less adverts than Android apps.

Tracking Personal Background Data: With the exception of Android apps that track weight, less than half of the apps tracked personal background data.

Recording Blood Pressure Measurements: Only a minor percentage of applications documented the process of taking blood pressure readings, with information on the measuring side (15.2%) and position (14.1%) being particularly scant. Compared to iOS apps, Android apps were more likely to record measurement side and position. Reminder feature and Data Export: Of the apps, 28.8% had a reminderfeature.

Of the apps, 65.2% had data export functionality; iOS apps were more likely to have this feature than Android apps. As has also been previously reported, there were no variations in quality scores between premium and free apps [35]. Notably, the top 5 apps—determined by the MARS totalscores with the highest scores—

were all provided without charge. On the other hand, developers may profit from their apps by charging for the data that users contribute or by endorsing additional goods that work in tandem with them, such blood pressure monitors. Of these, PatientsLikeMe is a classic. Although this platform is highly helpful and free, user data is sold [43]. That could help to explain why the app makers are giving these apps away for free in the app stores.

In this study, we found a lot of low-quality apps that could potentially be harmful to users. Examples of these types of apps include those that give patients false information or don't work as intended. At the 2016 American Medical Association interim meeting, Executive Vice President James Madara mentioned a blood pressure app that failed at a high rate of detecting elevated blood pressure but was one of the most downloaded health apps for two years [45]. It's critical to distinguish between good and bad apps and to encourage the development of high-quality apps.

Strengths and Limitations

A substantial number of apps for review were found after the study conducted a thorough search of the two major app storesusing 15 search phrases in both English and Dutch. The search included both paid and apps.

To guarantee uniformity and dependability

in the assessment procedure, each of the identified apps was evaluated by two separate reviewers.
The Mobile App Rating Scale (MARS), a validated instrument frequently used in app evaluations, was utilized to objectively evaluate the apps' quality. Only Dutch app shops were considered for this assessment, and only English or Dutch apps were included. Other national app shops might have a different, bigger, or more varied selection.of applications. While searching every national app store from one country is not possible, the majority of apps are released globally and are not country- specific. Additionally, we restricted our search to the two most popular app stores, iOS and Android. On the other hand, in 2015, these platforms held almost 98% of the market share for mobile phones [49]. Furthermore, we did not include apps that require a prescription from a medical professional or developer consent to be used.

Limitations: Because the research was restricted to Dutch app shops and only included apps in English or Dutch, it's possible that the conclusions won't apply to other national app stores that offer a diverseselection of apps. Some apps that would have been useful were left off because they required a prescription or special permission to be downloaded, even if these apps aren't usually accessible to the general public.The study may have overlooked apps on other platforms because it concentrated on the two main app stores, iOS and Android, which together held a sizable market share in 2015.Not all apps may have been compatible with the devices used in the study, therefore compatibility problems with different mobile phone models and software versions may have had an impact on app performance and user experience.

Perspectives

Smartphone apps could be a helpful resource for hypertension patients who want to manage their own care. Additionally, mobile apps could be utilized to raise awareness and give patients information.

significant health problems associated with blood pressure in patients. Additionally, a lot of mobile apps allow users to export blood pressure data, which medical professionals may utilize to make better treatment decisions [50, 51]. Furthermore, by using specialized, high-quality mobile apps, patients will take a more active role in their own care. As a result, medical professionals ought to encourage hypertension patients to use smartphone apps. In such instance, though, they must ensure that their patients' apps are free of hazardous or deceptive content.
Patients with high blood pressure who wish to oversee their own treatment may find smartphone apps to be a useful tool. Mobile applications could also be used to inform patients and spread awareness.

substantial health issues linked to patients' blood pressure. Furthermore, several smartphone apps let users export blood pressure data, which doctors can use to decide on the best course of treatment [50, 51]. Furthermore, patients will participate more actively in their own care by using specialized, high-quality mobile apps. Therefore, doctors should advise patients with hypertension to use smartphone apps. In this case, however, they have to make sure that the applications their patients use don't include any harmful or misleadingmaterial.

Conclusion

The paragraph emphasizes how the review found that there were very few apps that were good enough for blood pressure self- management. It recommends encouraging patients to use these excellent apps in order to improve patient care. In order to help healthcare professionals and people with hypertension choose appropriate apps for blood pressure monitoring, the study provides a summary of the top apps that are currently accessible in app stores, along with important features for self- management. Nevertheless, the majority of blood pressure applications were of low quality, and it was not determined whether the blood pressure readings in these apps were accurate. In order to improve the caliber and efficacy of mobile apps related to health, the text emphasizes how crucial it is to include medical professionals in the creation process. Only a few excellent apps for blood pressure self-management were found in the review. Promoting these apps' use can improve patient care. The survey helps patients and healthcare professionals choose appropriate monitoring applicationsby highlighting the top apps and essential featuresfor self-management. Unfortunately, the majority of blood pressure applications had unreliable measurement accuracy and were of low quality. To increase the quality of apps, medical specialists must be included in their develop ment.