

REVIEW

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An overview of clinically and healthcare related apps in Google and Apple app stores: connecting patients, drugs, and clinicians

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Abstract

Successful clinical outcomes involve both clinician and patient factors such as good decision making, accurate diagnosis, patient compliance, effective monitoring of the condition, and accurate interpretation of clinical results. With a general trend in healthcare towards personalized medicine, the smartphone holds great potential to play a role in personalized care and aid in the above mentioned factors. Through the use of apps, the increasingly powerful smartphone may be a useful aid in the healthcare and clinical industries. This review surveys the currently available apps in Google and Apple app stores that are purposed for aiding healthcare and clinical use, and discusses how they may also help transform the smartphone in a medically relevant device.

Introduction

In ancient times, physicians made house visits to the sick, often administering medical attention within the comforts of the patient's home. Although house-visits do continue to exist today, they are more common in smaller towns or village communities and the very affluent in cities. In the developed world, there is a trend of reversal in the mode of medical care of our forefathers: from doctors attending to patients in their homes, to patients consulting doctors in hospitals.

Such changes have risen out of the necessity for efficiency and improved healthcare. In a hospital/clinic, the concentration of medical expertise, equipment and sanitized environment improves the quality of healthcare over house-visits. Nonetheless, both models of consultation have their own disadvantages. In house visits, the physician's travelling time slows down the immediacy of care and compromises diagnostic accuracy without the necessary medical equipment (e.g. X-Ray machine). On the other hand, we have the very real problem of long

patient waiting hours just for a few minutes of consultation or the collection of test results.

Regardless of the consultation model, today's world offers a solution which overcomes the flaws of each model: the smartphone. With the advancement and incorporation of technology into healthcare, it might be possible to do away with physical visits, especially with video or other imaging technology through smartphones. Patients can get a quick consultation or access their test results with accompanying clinical comments easily. If advanced equipment are required, there might be possibility to leverage on smartphone sensors as simple medical equipment (e.g. microphone as a stethoscope), turning the smartphone into a multi-purpose mobile medical equipment that can be used by both patients and clinicians.

Nonetheless, when dealing with clinical procedures, accuracy and precision outweighs convenience and time. With the growth of technology in medical diagnostics (e.g. electronic ECG, electronic X-Ray), accuracy and efficiency are not necessarily mutually exclusive. Thus, there is potential for the use of apps and wirelessly connected peripheral added sensors to enable the smartphone to change the workings of the healthcare industry.

In spite of this potential and the pockets of activity towards this cause, there is a dearth of literature covering

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Table 1 Clinical apps classified in 'communication' (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|--------------------------------|---------------|---|----------|----------|
| DrBridge | Android | Helps doctors to follow up with patients and deliver care plans through text messaging, email and app-to-app interactions | Hybrid | None |
| Drchrono EHR/EMR | iOS | Allows doctors to communicate with their patients | Hybrid | None |
| GatherPro | Android | Allows doctors to communicate with their patients | Hybrid | None |
| - Patient Portal by ConstantMD | | Allows doctors to communicate with their patients | | |
| HealthJump | iOS | Communicates with doctors to schedule appointments | Hybrid | None |
| Medical & Health Records Caddy | Android & iOS | Manages and share patient list as well as patient tasks, notes, medications, records, images, and messages. | Hybrid | None |
| Message patient management | iOS | Organises patient and treatment sessions | Hybrid | None |
| MedBooking | iOS | Allows patients to book their appointments | Hybrid | None |
| Practo Ray | iOS | Calls Patients for appointments | Hybrid | None |
| SirenMD | iOS | Sends messages, medical records and photos between health professionals | Hybrid | None |

the already available clinical aid apps that both the patient and the clinician can leverage on. To address this, this review discusses the currently available clinically and medically relevant apps and how they might be incorporated into practice for better outcomes.

The future of mobile apps

Efficiency is one of pursuits of excellent healthcare especially in today's growing demands of ageing populations in many developed societies. Incorporating mobile apps with internet connectivity into routine medical processes (e.g. consultations) enhances the convenience for both

doctors and patients alike. In the common problem of long waiting times, registration and appointments can be booked using mobile apps without long queues for the receptionist. Similarly, medical results or clinically relevant pictures taken by patients can be sent through secured apps to physicians and specialists for consultations without the physical transfer of document between hospital departments. With increased efficiency in consultations and diagnosis, patients can be treated earlier, thereby improving prognosis. It might even be possible to do away with face to face outpatient consultations or routine follow-up through the use of apps. Patients can

Table 2 Clinical apps classified in 'patient data management' (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|---------------------------------|---------|---|----------|----------|
| Clinic On Go - My Patients | Android | Manages patient information and appointments | Hybrid | None |
| Doctors Aid - OPD Management | Android | Manages and stores patients' health and medical records | Native | None |
| - Doctor Assist | | | | |
| - Doctor Assistant | | | | |
| - My patients | | | | |
| - Patient Doctor Records | | | | |
| Doctor Buddy – Patients Manager | iOS | Manages and stores patient info for Doctors | Native | None |
| HouseOfficer | | Manages and store patient info for Doctors | | |
| Lybrate For Doctors | | Manages and store patient info for Doctors | | |
| Hospital Rounds Management | iOS | Stores patient details, diagnosis and billing codes | Native | None |
| iGrade for psych | iOS | Manages patient info for psychotherapists | Native | None |
| MDclick for Physicians | iOS | Shares patient info with other health professionals | Hybrid | None |
| MedicoSA | Android | Enables Physicians to access patient appointments, patient history, and write e-prescriptions | Hybrid | None |
| OPD MANAGEMENT | Android | Stores information such as Patient History, Patient Diagnosis, and Prescription | Native | None |
| Patient History Taker | Android | Database app for medical history for patients | Native | None |
| Practice Management | Android | An application that helps record data of patient | Hybrid | None |
| Patient Management System | Android | Manages the patient's medical record and able to standardize diagnosis and action. | Native | None |
| Patient List | iOS | Keeps track on patients' info | Hybrid | None |
| Prescapp - Doctors | iOS | Manages and stores patient info | Native | None |

receive professional consultation through apps in the comfort of their homes, a scenario that is especially beneficial for elderly patients or those with high dependency to getting around.

Displacing medical equipment for lower healthcare costs

The rising costs of healthcare, contributed by the increasing costs of skilled personnel, medical equipment and infrastructure, poses a challenge to accessible healthcare to the less privileged in society. On this problem, the smartphone might help to reduce costs by displacing expensive medical equipment with clinical mobile apps that leverage on the many sensors in smartphones. One such example is the displacement of a heart rate monitor (costing between USD\$70 - \$150) with a free heart rate monitor app that functions via the in-built microphone or camera. Coupled with internet connectivity, one can even easily send results to clinicians, a feature that most current medical equipment lack. Should artificial intelligence be incorporated, these apps may further aid in diagnosis by detecting abnormalities.

Patient compliance

Patient compliance to clinical advice and care is essential for successful clinical outcomes (Martin et al. 2005). The most effective treatment regimens would be rendered ineffective if patients failed to comply. This is particularly true for chronic diseases where patient compliance directly affects disease control. On this aspect, mobile apps that monitor patient conditions and sends reminders of treatment would certainly be a boon for chronic disease management. This is especially so if clinicians can use such apps to monitor disease/symptoms for diagnosis and adjustment of treatment methods.

Clinical mobile apps

In view of the potential for mobile apps in the above-mentioned areas, we did a survey of apps in the Google and Apple app stores using key words: “patient info management”, “patient health monitor”, “eye diagnosis”, “skin diagnosis”, “blood pressure”, “heart beat rate”, “medical calculator” and “patient compliance”. As of early 2016, we found over 1121 and 536 apps in Google Play Store and Apple App Store, respectively. Only about 139 apps of these were directly relevant to practical uses for healthcare. Of these, 30 apps were for patient data management and communication; 44 apps for patient health monitoring; 36 apps for clinical diagnosis; 21 apps for medical calculations; and 7 apps for patient compliance. Within these, we further classified them into nine categories based on their functions.

Table 3 Clinical apps classified in ‘patient health monitors and trackers’ (general health) (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|-------------------------|---------|--|----------|----------|
| Cure companion | Android | Keeps track of patients’ health records | Hybrid | None |
| Data Manager for Fitbit | iOS | Track health related data such as weight, sleep and body fat | Native | None |
| HealthTouch | iOS | Records and tracks key health stats | Native | None |
| iThermonitor | iOS | Monitors the body temperature | Native | None |

The various categories of apps relevant to healthcare and medical purposes

Clinical care communication [Table 1]

In healthcare, timely communication between a patient and doctor enables the former to get medical advice and the latter to keep track of the patient condition and intervene when necessary. A range of clinical communication apps have been developed to facilitate better communication between patients and clinicians. One notable example of such apps is ‘Health-Jump’ (Healthjump Inc 2015) which not only allows patients to schedule their appointments with their doctors, but also provides medical records securely.

Patient data management [Table 2]

Patient data management is tantamount for accurate diagnosis/disease management and has to be secured to ensure patient confidentiality. Incomplete or missing reports can result in the loss of crucial information that could have serious clinical consequences (e.g. drug allergies). Apps in this area facilitate the viewing, storage and management of patient data without the spatial constraints of desk-bound medical computer systems. ‘My Patients’ (Evgeny 2015) and ‘Patient Reports Doctor ON GO-T’ (Siyami Apps 2015) are example apps that allow the clinicians to view patients’ medical history, diagnosis and prescription on the go. Such apps make clinical rounds in the ward or house visits much more convenient, doing away with bulky files and folders.

Table 4 Clinical apps classified in ‘patient health monitors and trackers’ (heart rate) (as of Jan 2016)

| App Name | OS | Description | App type | Hardware |
|--------------------|---------|---|----------|----------|
| Cardiograph pro | Android | Saves patient’s daily Blood Pressure and Heart Rate | Native | None |
| Heart Rate monitor | iOS | Tracks and records heart rate | Native | None |
| PulsePRO | iOS | Monitors patient heart rate | Hybrid | None |

Table 5 Clinical apps classified in ‘patient health monitors and tracker’ (blood pressure) (as of Jan 2016)

| App Name | OS | Description | App type | Hardware |
|-------------------------------------|---------------|--|----------|-----------|
| Acc. Blood pressure | Android | Keeps track on blood pressure measurements | Native | None |
| Best Blood Pressure Monitor | iOS | Tracks and automatically collect blood pressure measurements via bluetooth | Native | Tonometer |
| Blood Pressure | iOS | Manages and track blood pressure progress | Native | None |
| Blood Pressure (BP) Watch | Android | Collect, track, analyze and share your blood pressure record | Native | None |
| Blood Pressure Companion | iOS | Tracks Blood pressure, weight and heart health | Native | None |
| Blood pressure diary | Android | Keeps track on blood pressure records | Native | None |
| Blood pressure monitor pro | Android & iOS | Keeps track on blood pressure records | Native | None |
| Blood Pressure log diary | Android | Keeps track on blood pressure records | Native | None |
| Blood Pressure Tracker | Android | Tracker of Patients’ blood pressure records | Hybrid | None |
| Blood Pressure PRO | Android | Collect and analyze blood pressure measurements | Native | None |
| Blood Pressure lite | Android & iOS | helps keep track of blood pressure and weight | Native | None |
| Blood Pressure + Pulse Grapher lite | iOS | Records blood pressure and pulse rate measurements | Native | None |
| Bloody Pressure | iOS | Record, track and share blood pressure measurements. | Native | None |
| HeartStar Blood Pressure Monitor | iOS | Monitors blood pressure and automatically records via bluetooth | Native | none |
| My Blood Pressure | Android | Records blood pressure measurements taken | Native | None |

Besides secured data transmission and data encryption necessary for patient confidentiality, there are other limitations for such apps. One such limitation is the accessibility of file formats where certain medical equipment may store data (e.g. X-Ray, ECG print-outs etc.) in specific file formats not easily accessed on the apps. It is also questionable if the small screen of these mobile devices would allow sufficient analysis of important test results (e.g. small abnormalities in X-Rays). Although difficult viewing conditions may increase human errors, this can be mitigated with image processing algorithms that perform automated diagnostic parameters to detect anomalies.

Patient health monitors and trackers [Tables 3, 4, 5, 6, 7, 8, 9, 10 and 11]

Apps in this category facilitate the recording and monitoring of disease conditions after diagnosis. In the example of hypertension, ambulatory monitoring may enable better diagnosis (Gan et al. 2003) as compared to readings taken at clinics that may be confounded by psychosomatic fear. Some apps in this category can do more to make a comparison analysis with previous data and

alert the user of significant fluctuations in the condition. ‘Blood Pressure Diary’ (FRUCT 2016) and ‘PulsePRO’ (Cocoalena Software 2015) are examples of such apps that record, analyse and send the clinical measurements to attending physicians without the need of an ambulatory machine (typically costing up to hundreds of dollars). With a wide range of types and functions, other apps are also made to track patient’s general health, skin problems, eye problems, blood parameters, menstrual cycles and the presence of diseases. With such monitors and trackers, behavioural changes that improve eating habits and physical activity levels have been observed in young adults. Thus such monitoring apps do encourage patients to be more aware of their daily condition (Higgins 2015).

Heart rate measurement [Table 12]

As a subgroup of the health monitoring apps, heart rate measurement apps form a significant bulk of the group in the mega app stores. Basic heart rate information can be an indicator of general health and aid in both monitoring and detection of cardiac problems. Apps in this category often function like a stethoscope by using the microphone or camera in the smartphones.

Table 6 Clinical apps classified in ‘patient health monitors and trackers’ (skin conditions) (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|-------------|---------------|--|----------|----------|
| FotoSkin | Android & iOS | Tracks photos of patient’s skin for easy diagnosis of skin cancer for dermatologist. | Hybrid | Camera |
| Skin Tagger | iOS | Tracks photos of skin pictures | Hybrid | Camera |

Table 7 Clinical apps classified in ‘patient health monitors and trackers’ (eye conditions) (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|---------------|-----|--|----------|----------|
| Paxos checkup | iOS | Allows patients to monitor their vision and physicians to keep track | Hybrid | None |

Table 8 Clinical apps classified in ‘patient health monitors and trackers’ (blood constituent levels) (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|--------------------------------|---------|---|----------|----------|
| Calcium Pro | Android | Tracks and monitors the blood calcium, vitamin D levels of Patient for osteoporosis | Native | None |
| Glucose Buddy : Diabetes Log | Android | Manages Diabetes by tracking glucose levels | Native | None |
| Glucose Monitor | iOS | Tracks glucose level and weight | Native | None |
| Iron Tracker – Hemochromatosis | Android | Allows patients to track and monitor their iron levels | Native | None |
| One Drop | iOS | Manages Diabetes by tracking glucose levels | Native | None |

One example, the ‘Cardiograph Heart Rate Monitor’ (BIG DREAMS Lab 2014) app measures the user’s heart rate via the placement of the index finger on the camera. Through the inbuilt camera flash, the app would then track the colour changes on the finger. There is also a significant move in this area towards peripheral devices, where there has been an increase in smart watches (built by major smartphone makers e.g. Apple, Samsung, etc., and other technology companies e.g. Fitbit) that monitors heart rate and send data to the smartphone.

Blood pressure measurement [Table 13]

Similar to measuring heart rate, measuring blood pressure is also another indicator of health status and condition. However unlike heart rate apps, the typical measurement of blood pressure would require the use of peripheral cuff devices connected to the smartphone. Nonetheless one app seems to be able to measure the parameter indirectly without the use of external devices. The ‘Instant Blood Pressure’ (Auralife 2014) relies on in-built camera and flash to provide blood pressure readings. As the technology is protected, it is likely that the dominant apps in this type would be more dependent on peripheral devices.

Table 9 Clinical apps classified in ‘patient health monitors and trackers’ (female menstrual cycle) (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|-----------------|---------|---|----------|----------|
| Eva Diary | iOS | Tracks patients’ period cycles and ovulation | Native | None |
| Period Tracker | Android | Helps keep track on menstrual cycle | Native | None |
| iObstetrics Pro | Android | A tool to allow specialists to monitor and synchronise the progress of every patient’s pregnancy from their Pc, SmartPhone or Tablet. | Hybrid | None |

Table 10 Clinical apps classified in ‘patient health monitors and trackers’ (versatile health management) (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|--|---------------|---|----------|----------|
| BloodPressureDB | Android & iOS | Track, monitor and store your blood pressure along with your pulse, blood sugar and BMI | Hybrid | None |
| BP Wiz | iOS | Tracks Blood pressure, weight and heart health. It also tracks medication | Native | None |
| Diabetes Manager | iOS | Tracks Blood glucose, blood pressure, weight and etc. | Native | None |
| Health Tracker & Manager | iOS | Tracks blood glucose and pressure levels | Native | None |
| Heart Wise Blood Pressure Tracker | iOS | Tracks Blood pressure, weight and heart rate | Native | None |
| Qardio Heart Health, Weight and Blood Pressure Monitor | iOS | Tracks Blood pressure, weight and heart health | Native | None |

Eye diagnosis [Table 14]

Apps in this category leverage on the camera/screen to allow for convenient and quick analysis and storage of eye images and tests. The ‘Colour Blindness Test’ (DaDo 2014) app tests for colour blindness and provides category of colour blindness in the result analysis. Another app such as ‘Pain Eye’ (Medina 2014) helps to investigate eye pain using captured images of the pupil using the smartphone’s camera. Using clip-on peripheral camera adaptors, ‘Peek Retina’ (Peek 2015) was created by a team of eye specialists, software developers, designers and engineers for remote diagnosis. Many apps in this category leverage on the inbuilt

Table 11 Clinical apps classified in ‘patient health monitors and trackers’ (disease, pain and injury) (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|-------------------------|---------------|---|----------|----------|
| FIND TB | Android | Supports clinicians in making decisions on the diagnosis and treatment of TB. | Native | Camera |
| Managing My Hepatitis C | iOS | Monitors patients’ health condition on Hepatitis | Native | None |
| Mobile REMM | Android & iOS | For clinical diagnosis and treatment of radiation injury during radiological and nuclear emergencies. | Native | None |
| Pain Stethoscope | Android | Assess and graph patient-reported outcomes of chronic pain management over time. | Native | None |

Table 12 Clinical apps classified in ‘heart rate measurement’ (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|--------------------------------|---------------|---|----------|-------------------------|
| Cardiometer ANT+ Heart Rate | Android | Measures and monitors heart rate | Native | Heart rate Chest Straps |
| Cardiograph Heart Rate Monitor | Android & iOS | Measures and monitors heart rate | Native | Camera with Flash |
| Heart Beat Rate | Android | An application to measure heart rate | Native | Camera with Flash |
| Heart Rate Plus LITE | iOS | Measures and monitors patients’ heart rate | Native | Camera with Flash |
| Heart Rate Monitor | Android | Measures heart rate via placing your index finger on the phone’s camera len | Native | Camera with Flash |
| Heart Rate Monitor Ant+ | Android | Measures and monitors heart rate | Native | Heart rate Chest Straps |
| Medtimer | iOS | Measure the time for each heart beat or breath to calculate heart rate | Native | None |
| iStethoscope Pro | iOS | Records heart beat and showing heart waveform for practioners. | Native | Camera with Flash |
| Instant Heart Rate | Android & iOS | Measures heart rate via placing your index finger on the phone’s camera len | Native | Camera with Flash |
| Runtastic Heart Rate Monitor | Android & iOS | Measures heart rate via placing your index finger on the phone’s camera len | Native | Camera with Flash |
| What’s My Heart Rate | Android & iOS | Measures the heart rate and breath rate through the lens of the camera | Native | Camera |

cameras in smartphones, and there is potential for these apps to even aid in detecting abnormalities when coupled with advanced image processing and artificial intelligent algorithms.

Skin diagnosis [Table 15]

Like the ophthalmology apps, skin diagnosis apps leverage on the smartphone inbuilt camera and image processing algorithms. Captured images of the skin are compared against a database of disease images. Apps such as ‘Mole Doctor Skin Cancer App Dermatologist’ (Teodorescu 2014) and ‘Skin Analytics’ (Skin Analytics Development 2014) enable the comparison of mole pictures against skin cancer images. These images can then be sent to dermatologists, making diagnosis more convenient. One limitation of such image based apps is that they are sensitive to the lighting and environmental factors during image capture. Such factors may severely affect the quality of the images and lead to poor diagnostic accuracies.

Medical calculators [Tables 16 and 17]

One frequent clinical mistake that can be fatal in medical treatment is the calculation of dosage. To prevent these mistakes, there are apps available to provide necessary medical calculations, conversions and chemical formulae checks. One such app, ‘Calculate by QxMD’ (QxMD Medical Software Inc 2015) app provides a number of unique calculators specific to various medical specialities and decision support tools including risk analysis. Another example, the Thyroid-SPOT (Sim et al. 2016) apps (Doctor and Patient versions) compute the homeostatic euthyroid set point, guiding the optimization of personalized treatment plans as well as to monitor the patient’s condition. With these apps, more informed patients can also do their part and check their prescription or treatment regimen thus reducing clinical errors.

Patient compliance [Table 18]

As discussed earlier, patient compliance is a key factor in the success of treatment regimens. Considering also that most patients are willing to receive medication

Table 13 Clinical apps classified in ‘blood pressure measurement’ (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|---------------------------------|---------------|---|----------|----------------------|
| BP Calculator | Android | Measures the blood pressure and keep record of blood pressure at regular intervals. | Native | None |
| iBP Blood Pressure | Android & iOS | Blood pressure tracking and analysis tool. | Native | Blood Pressure scrap |
| iHealth BPM | iOS | Measures blood pressure using a blood pressure dock. | Native | Blood Pressure Dock |
| Perf.Blood Pressure (BP)Monitor | Android | Calculates and measures your blood pressure via touching thumb on the screen | Native | None |

Table 14 Clinical apps classified in 'eye diagnosis' (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|-------------------------------|---------|---|----------|----------|
| Anomaloscope | iOS | Tests for colour vision of patients | Native | None |
| AmslerPro | iOS | Tests for abnormality in the foveal vision | Native | None |
| Color Blindness Test | Android | Tests for colour blindness | Native | None |
| Eye Care Plus - Eye Exercises | Android | Contains eye test to check visual acuity and information on eye health | Native | None |
| Eye Diagnosis | Android | Supports the visualization of eye photographs to help practitioners diagnose eye diseases. | Native | Camera |
| Eye test | Android | Contains many eye tests including Visual acuity test | Native | None |
| Eye Test Charts | Android | Tests for visual acuity | | |
| Full Visual Test | Android | Tests for visual acuity | | |
| Vision Test 2.0 | Android | Tests for visual acuity | | |
| Morphision | iOS | Qualifies the symptom of distortion in their patient's eyes | Native | None |
| Pain Eye | iOS | Takes pictures of eyes to diagnose eye pains | Native | Camera |
| TeleMed | Android | An application that connects to healthcare services and allows sending photos of eye as part of medical teleconsultation. | Hybrid | None |
| Visual Acuity Test | Android | Monitor acuteness and clearness of vision in person's eyes | Native | None |
| Vision Test | Android | Includes visual acuity test | Native | None |

reminders (Kebede, et al. 2015) and likely to possess smartphones, medication reminder apps can improve compliance. One such example, 'Medisafe Meds & Pill Reminder' (MediSafe™ 2016) monitors and has reminders for scheduled medication times. Such apps are particularly useful for the elderly and those with multiple treatment regimens concurrently.

Discussion

With the smartphone becoming increasingly versatile in different fields of work, there is great promise for its role in the future of personalized medicine. In the current survey of the available apps in the largest apps stores: Google and Apple, we surveyed relevant apps that benefit both clinicians and patients. While there are many apps within the various medical specialities that may exist, they were not covered as focus is given to areas

where patients can play a role, such as taking pictures (skin/eye) for better monitoring and diagnosis. Obviously, certain levels of technical savviness and acceptance from the users (both patient and clinicians) are necessary for the desired benefits of using these apps. The apps surveyed in this review focus on the many clinical aspects with the end-goal of improving the efficiency, cost, simplicity and effectiveness of healthcare. While a horde of apps exist, the majority found in Google and Apple app stores are either glossaries of clinical information apps for health professionals, or basic health knowledge apps for the layman. Even amongst the numerous apps designed for clinical data management and monitoring health, only a minority were found to be of direct practical use. In fact, focusing on the directly practical apps, there is a paucity of evidence-based or professional-informed apps (Majeed-

Table 15 Clinical apps classified in 'skin diagnosis' (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|--------------------------------|----------------|---|----------|----------|
| Doctor Mole – Skin Cancer App | Android iOS | Automatic analysis of mole images to diagnose skin cancer. | Native | Camera |
| Mole Checker | iOS | Takes pictures of skin moles and keep track of changes | Native | Camera |
| Skin Analytics | Android | Takes photos of skin moles and compares for diagnosis of skin cancer | Native | Camera |
| Skin Cancer App – MySkinPal | Android | Takes photos of skin moles and compares for diagnosis of skin cancer | | |
| SkinVision - Melanoma app | Android | Takes photos of skin moles and compares for diagnosis of skin cancer | | |
| Skin MD Now - Expert Skin Help | Android | Send skin photos to Dermatologists for quick diagnosis. | Hybrid | Camera |
| Skin Scanner | Android | Takes photos of skin moles for analysis for skin cancer | Hybrid | Camera |
| SpotMole | Android | Scans photos of skin moles to detect for melanoma | Native | Camera |
| iDoc24 - Dermatologist Online | Android & iOS | Sends on-demand dermatologist skin photos for diagnosis and monitoring. | Hybrid | Camera |

Table 16 Clinical apps classified in 'medical calculators' (calculations) (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|--|-----------------|--|----------|----------|
| ACC Guideline Clinical App | Android | Contains interactive tools such as risk scores, dosing calculators, and algorithms. | Native | None |
| BODE Calculator | Android | Calculates the COPD levels to treat lung diseases. | Native | None |
| Calculate by QxMD | Android | Includes tools for calculations used in clinical practice. | Native | None |
| CuidApp - Nurses and Doctors | Android | Includes calculators and unit conversions. | Native | None |
| CKD Risk Calc Pro | iOS | Evaluates Chronic Kidney Disease via calculations | Native | None |
| Digoxin Calculator | Android | Estimates a patient's digoxin requirements for the treatment of heart failure. | Native | None |
| Ezabx | Android | Contains a metric converter and references for common microbes and antibiotics. | Native | None |
| GRACE 2.0 ACS Risk Calculator | Android | Calculates the probability of fatality after an acute coronary syndrome. | Native | None |
| GFR & BSA Calculator | Android | Estimates the expected Glomerular filtration rate of patients | Native | None |
| Haemoscore | Android | Includes score calculators & algorithms to facilitate decision making in both diagnosis and treatment of thrombotic and bleeding problems. | Native | None |
| MedCalc 3000 Cardiac | Android | Provides medical equations, clinical calculator and dose/unit converters used by Cardiovascular specialists | Native | None |
| Medical Calculators & Equation | Android | Contains a wide range of calculators/convertors for medical purposes. | Native | None |
| Medical Formulas | Android & iOS | Medical Calculator that access to main equations, formula and scores used in clinical practice. | Native | None |
| Medical Tools | Android | Medical calculators, interpretation and scoring systems. | Native | None |
| Melanoma Visual Risk Calculator | iOS | Calculates the possibility of a mole being a malignant melanoma | Native | Camera |
| Opioid Converter | Android | Application designed to aid with opioid dose conversions. | Native | None |
| Ovulation calculator & fertility tracker | iOS | Calculates ovulation cycle and tracks fertility rate | Native | None |
| Pedia BP | iOS | Blood pressure calculator | Native | None |
| Pregnancy Calculator | Android | Estimates the expected due date for the born of a baby. | Native | None |
| Throid-SPOT (Dr and Patient versions) | Android and iOS | Calculates homeostatic euthyroid set points in thyroid diseases | Native | None |

Ariss, et al. 2015; Krebs and Duncan 2015; Subhi et al. 2015). One contributing factor for the dearth of apps in certain medical specialties is that certain diagnostic or monitoring procedures may be dependent on peripheral devices (see example of blood pressure and Peek Retina above). Such demands of peripheral devices thus limit the exploitation of smartphones. Other factors include the administration and certification required of medical devices which would vary between countries, and also for the device type. As there are a large number of smartphone models and makers, the in-built sensors in these phones would vary. This results in significant

inter-equipment errors that may prevent any standardized guidelines or procedures required for professional clinical use. These make certification and use of smartphone as medical devices more challenging and unlikely to be approved by various authorities (scope of this is beyond this article due to the varying requirements). In the event they are approved for use, it is likely that many of these smartphone-dependent devices will require skilled personnel. As a result, clinical apps will mostly play a supportive role rather than as direct medical equipment replacements. Such limitations may be slightly mitigated by standardised peripheral devices, but

Table 17 Clinical apps classified in 'medical calculators' (checkers) (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|----------------------------|---------|--|----------|----------|
| Drugs.com Medication Guide | Android | Provides drug information, identify pills, check interactions and set up personal medication records for Health professionals. | Native | None |
| WebMD | Android | Includes decision-support tools such as WebMD's Symptom Checker. | Native | None |

Table 18 Clinical apps classified in 'patient compliance' (as of Jan 2016)

| App name | OS | Description | App type | Hardware |
|-------------------------------|---------|---|----------|----------|
| Medisafe Meds & Pill Reminder | Android | Add medications, get reminders for taking pills and receive constant tracking of your health progress. | Native | None |
| Medica Reminders | iOS | Adds medications, get reminders for taking pills and receive constant tracking of your health progress. | Native | None |
| Pill Alert | iOS | | | |
| MyPill | iOS | Birth control pill reminder | Native | None |
| Pill Reminder | iOS | Reminds patients to take medicine, contraceptive and other medication | Native | None |
| Pill Monitor Free | iOS | Medication reminder | Native | None |

these peripheral devices have their own limitations in accessibility to the general public.

Nonetheless in societies with less stringent medical regulation and where specialized medical equipment may not be readily available, the smartphone certainly has a role not only as a patient companion, but also as a screening tool for health problems. The smartphone has already been shown to aid in numerous areas: patient monitoring, transmission of clinical data between patients and clinicians, encouraging patient compliance, and helping with clinical calculations and decision making. Certainly the patient now has the resources to take better ownership of their own health with such apps (regulatory board approved or not) at their disposal.

Conclusion

With an obvious role in personalized healthcare, the smartphone promises to be a portable medical toolkit/clinical gathering device for both clinicians and patients. Much remains to be done with much more apps and peripheral devices that can be made, but with the collaborative effort between medical specialists, software developers and hardware engineers, the future of the smartphone medical toolkit can be materialized. The days of convenient house-visits might return in the form of app consultations.

Competing interests

The authors declare no competing interests.

Authors' contributions

CK and YX drafted the manuscript. PV made the tables. SKEG directed and edited the writing of the manuscript. All authors have read and approve of the final manuscript.

Received: 18 February 2016 Accepted: 6 June 2016

Published online: 19 July 2016

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