

# An Evaluation of Free Medical Applications for Android Smartphones

Roxana-Denisa CAPRAȘ<sup>1,2,3,\*</sup>, Sorana D. BOLBOACĂ<sup>1</sup>

<sup>1</sup>Iuliu Hațieganu University of Medicine and Pharmacy, Department of Medical Informatics and Biostatistics, Louis Pasteur Str., No. 6, 400349 Cluj-Napoca, Romania

<sup>2</sup>Iuliu Hațieganu University of Medicine and Pharmacy, Department of Morphological Sciences, Clinicilor Str., No 3-5, 400004 Cluj-Napoca, Romania

<sup>3</sup>Obstetrics and Gynecology, Gynecology Clinic "Dominic Stanca", Boulevard 21 Decembrie, No. 55-57, 400125 Cluj-Napoca, Romania

E-mails: Capras.Roxana@umfcluj.ro; sbolboaca@umfcluj.ro

\* Author to whom correspondence should be addressed; Tel.: +40740009302

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## Abstract

*Introduction:* The field of healthcare applications (apps) currently holds potential to improve the daily medical practice by implementing evidence-based healthcare tools. The purpose of this study was to describe the main characteristics of Android-based healthcare applications available in Google Play and to identify those applications that are evidence-based. *Methods:* The study was undertaken between the 1<sup>st</sup> of July and the 30<sup>th</sup> of August 2016. An evaluation form was developed to characterize the healthcare apps available in Google Play retrieved for the following keywords: (medical apps) and (evidence based medical apps) respectively. Only the free apps were considered eligible for the purpose of our study. Besides the general characteristics, several criteria with regards to interactivity, functionality, esthetics, contents, benefits, as well as evidence-based aspects were considered. *Results:* A number of 147 healthcare apps were displayed based on the used keywords and were included in the analysis. 42 of them were excluded due to the need for payment, malfunction after installation or games/animations that used medical terms. The remaining 105 apps were then analyzed by the evaluation criteria established in the research protocol. This study shows that until this point, mobile medical applications are mostly designed for consumers or medical students and less for medical professionals. 2 medical application include evidence based medical information and 19 applications were developed in this direction. The majority of the applications were developed in USA. 60% of the analyzed applications have the capacity of improving the quality of medical care. *Conclusions:* We found only 2 "ideal" mobile medical applications that brought together all the requirements that every application designed for medical use should fulfill.

**Keywords:** Mobile applications; Healthcare; Evidence-Based Medicine (EBM); Smartphone; Google Play

## Introduction

The field of medical apps is currently one of the most dynamic in medicine, with real potential to change the way evidence-based healthcare will be delivered in the future [1].

Smartphone applications-so-called "apps" are becoming increasingly popular among medical professionals [2,3,4]. More than 500 million smartphone users (not necessary healthcare

professionals) worldwide use a medical application [5,6,7]. Franko et al. reported that over 85% of health professionals use a smartphone, and 30–50% use medical apps in clinical care [7]. Apps have huge potential to improve patient practice, system efficiency and communication by providing a quick reference tool accessible at the point of care (8). To date, there are 10,000 apps available in the ‘medical section’ of Apple’s ‘App store’ and over 3000 on Google’s ‘Play store’ [9,10]. These platforms facilitate distribution of apps while the developers sustain their utility and the users as healthcare professionals approve their rapid proliferation of the market will likely continue.

However, there has been minimal description of the limits posed by medical apps within medical literature. Studies have addressed the lack of evidence and professional medical involvement in the design and development of the apps, raising concerns regarding the reliability and accuracy of their medical content, and with possible consequences for patient safety [2,3]. It has been proposed that medical apps should be reviewed by clinical experts and that regulatory measures should be increased in order to safeguard quality of care [1]. Regulation and guidance are urgently needed.

As medical apps are increasingly used to support diagnosis and management of diseases (e.g., apps that allow the user to input patient-specific information along with reference material to automatically diagnose a disease or condition), the appropriate use of their reliable and valid medical information becomes crucial. Medical professionals must be aware that some medical apps contain unreliable, non-peer-reviewed content-as such, it is necessary to exercise caution in choosing an app to use in a clinical setting [1].

Most medical apps lack authenticity details (such as author(s), manufacturer, distributors, etc.) while references are unavailable or out-of-date. Two recent studies in the fields of dermatology and microbiology revealed that less than 35% of medical apps had expert medical involvement during their development [3, 4].

Eighty-six percent of 111-reviewed pain-management apps were found to have no medical professional involvement. Moreover, only 12% reported a physician as the app’s author [11].

Recently, a pharmaceutical-sponsored app, designed to assess disease severity, was recalled from app stores because it was giving erroneous scores in comparison with those calculated using the official formula [12].

Several websites have recently been launched by medical professionals to present latest medical apps, providing commentaries and reviews. Although this is a good starting point for reviewing apps, the assessment criteria do not address the scientific evidence for the apps content, but rather matters of usability, design and content control [13,14].

All medical apps should have an assured quality, as be scientifically sound and cost-effective in their use. All stakeholders in the mobile medical market should be involved in the regulation process of medical apps. A shared decision-making approach in the creation of a regulatory guideline would both facilitate its acceptance among all stakeholders and enhance compliance to the guideline [15].

Governmental healthcare authorities should provide guidelines which app-developers and reviewers should follow. Hospitals, healthcare institutions, medical publishing companies and physicians’ accrediting bodies play a pivotal role in selecting and providing apps for healthcare professionals. Since mobile technology has acquired a dominant role in society, further research on the use and implementation of medical apps in clinical practice is necessary. The integration of medical apps could contribute significantly to accessible and evidenced-based healthcare [1].

The aim of this study was to describe the characteristics of Android healthcare applications available on Google Play and to identify those applications that implemented the principles of evidence-based medicine.

## Material and Method

### *Data Sources, Inclusion and Exclusion Criteria*

A mobile application (app) is a software application specifically developed for use on small, wireless computing devices, such as smartphones and tablets. Medical apps are applications that

offer access to useful medical information on the spot. Mobile medical apps provided by Google Play that includes applications that run on Android systems, regardless of the medical field, were searched using (medical app) and respectively (evidence-based medical app) keywords. All English medical apps without any fee for utilization were considered eligible. The study was conducted since July 1<sup>st</sup> until August 30<sup>th</sup> 2016. Medical apps that manifested malfunctions or games/animations that used medical terms were excluded from the study.

*Data Extraction*

The retrieved medical apps were downloaded, installed and tested by the same physician. Several general characteristics (see Table 1) besides several criteria in regards of interactivity, functionality, esthetics, contents, benefits as well as evidence-based aspects (see Table 2) were collected to characterize the medical apps included in the study. The specific characteristics of the apps were evaluated according to criteria published in scientific literature [16,17,18].

**Table 1.** General characteristic of mobile medical applications

No.	General characteristics	Remarks
1.	Type	possible ...Guidelines   Treatment   Common diseases   Diagnosis   Signs and symptoms of common diseases   Etiology   Prognosis   Educational Medical Application   "Medical news"   Medical dictionaries   Medical calculators   Medical "scoring system"   Medical abbreviations   Surgical techniques   Medical atlas (pictures or video)   Laboratory reference values   Laboratory tests   Medical journals   Answering questions   Rare diseases   Applications used for patient monitoring   Other (homeopathy, acupuncture, etc.) one application can have more than one type
2.	Ranking	0 to 5 where (0 means no ranking for consumers and 5 means maxim score evaluation)
3.	Developer	It was considered the country of the developer
4.	Update	The last update (since 2011)
5.	Downloads	The number of downloads
6.	Users	as: Physicians (resident doctors, specialists, primary care physicians) / Nurses / Medical students / Patients one application can have more than one class of users
7.	Technical details	such as: Need internet connection?   Allow information distribution on the social networks?   Own specific application forums?   Need login?   Offer the possibility of having a password for protecting personal data?

Each of the criterion presented in Table 2 received a score from 0 to 5. Since each criterion evaluated several issues, if for a criterion all issues were present than the score was equal with 5; otherwise the score was calculated by applying the following formula:

$$(5 \times \text{number presented issue}) / (\text{total number of issues associated to the criterion})$$

The sum of all scores associated to the 6<sup>th</sup> evaluation criterion presented in Table 2 was calculated as an overall estimator for each evaluated medical app.

The classification of apps included in the study was done using the overall score as well as TOPSIS (Technique for OrderPreference by Similarity to Ideal Solution) method as described in details in [19]. TOPSIS ranking identified the best solution by maximizing all maximum criteria and minimizing all minimum criteria [19].

*Data Analysis*

Summarization of qualitative data was done using absolute and relative frequencies. 95% confidence intervals using an exact formula were provided for percentages [20,21]. The significances expressed as probabilities of the relative frequencies were calculated by applying the Z test for proportions at a significance level of 5%. Association analysis between overall score and

TOPSIS score and rank attributed for each apps by users was done with Spearman’s correlation coefficient at a significance level of 5%.

**Table 2.** Medical apps evaluation criteria

No.	Criterion	Issue
1.	Interactivity	sends messages?   sends notifications?   sends alarms?   provides feedback?   allows sharing?
2.	Functionality	Allows search for signs or symptoms?   Allows search for drugs?   Allows search for substances?   Allows search for illnesses?   Provides automatic suggestions during search?   Provides results for keywords in the same family?   The number of steps that a user makes to receive the results are less than or equal to 5?   Provides tutorial when we first run the application?   Provides help in any application page?   Provides options to search results in privacy? (the applications do not have history of consumers searching)   Do not store personal information   The response time does not exceed 15 seconds (between the time the user presses the search button and receives the response)?   Provides the functionality for connection and distribution through social networks?
3.	Aesthetics	The app respects the standards imposed by the operating system (menus, buttons and their location)   Uses suggestive icons?   Users can control the text size after display of the results
4.	Content	Is the content of the app in accord with its title?   The application has specific objectives?   The application has achievable goals?   The content of the app is complete (contains the minimum information needed to provide the desired response?)   The content is concise? (short and targeted to the answer)
5.	Benefits	Does the application have the potential to reduce health care costs? (reduces the unnecessary addressability towards health care services and decreases medical resources consumption)   Improves the quality of health care?   Save time of the healthcare professionals? (Literature search becomes faster and more handy?)   Increases patient compliance?   Increases patient independence?
6.	Evidence based medicine	Are there references to sustain the provided information?   Is the grade of the recommendation specified?   Is the level of evidences mentioned?

## Results

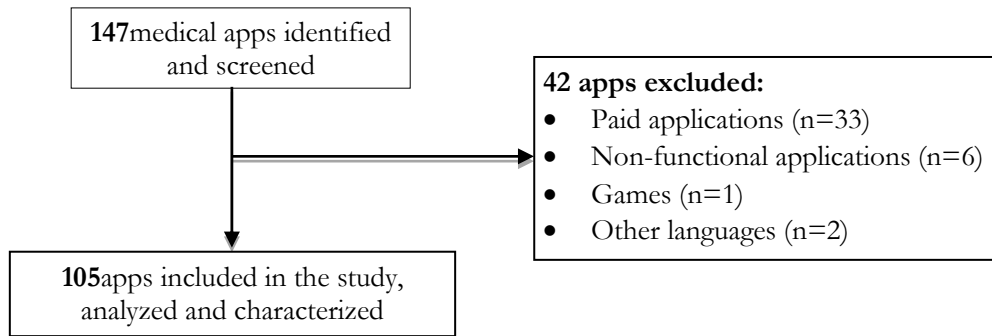
The flow diagram of identifying eligible apps for this study is shown in Figure 1. The Google Play searches resulted in a total of 147 which were initially screened on the titles and description, downloaded and installed. The application of the inclusion and exclusion criteria results in the exclusion of 42 apps that represent almost 29% of the medical apps retrieved initially. Almost twenty nine percent of the retrieved apps were excluded because perceive a fee after downloading, not functioning properly or solely being games/animations that used medical terms. The remaining medical apps were analyzed.

The earliest published or updated apps were from 2011, while almost half of them the last updated in 2016.

### *General Characteristics of Android Medical Apps*

Most of the apps included in the study were design for multi-users (such as physicians – n=89 (84.76%), nurses – n = 84 (80.00%), medical students – n = 89 (84.76%)). Fifty nine (56.19%) of the apps included in the study were design for patients.

The application were grouped into 20 categories based on functional similarities, most of the evaluated apps having an educational component, followed by medical dictionaries, treatment, diagnosis and common diseases(see Table 3).



**Figure 1.** Flow diagram of identifying eligible application for this study

None of the investigated apps had any rank between 0 and 2, while a significant higher percentage received from the users a rank higher than 4 (64.76%, 95%CI [55.25–74.28],  $p < 0.0001$ ).

A significantly higher percentage of medical apps could be considered recent apps (last update in 2016, 42.86 [33.34–53.32]) or contemporary apps (last update during 2014–2015, 47.62% [38.10–58.09]) compared with legacy apps (last updated on or before 2013, 9.52% [4.77–17.13]) ( $p < 0.0001$ ).

The information regarding the country of the developer was provided in 62 apps (59.05%). The top five of developers by country are: USA (27.6%), India (8.57%), Poland (8.57%), Canada (2.8%), while Vietnam (0.95%), Austria (0.95%), Bahrain (0.95%), Colombia (0.95%), Switzerland (0.95%), Mauritius (0.95%), New Zealand (0.95%), Pakistan (0.95%), Singapore (0.95%), with UK having one app (0.95%).

The majority of apps included in the study (97.14%) do not require internet access. However, 21.90% allow distribution of information on the social networks, 3.80% own specific application forums, 7.61% require login and 1.90% offer the possibility of having a password for protecting personal data.

Most of the applications included in the study ( $n = 81$ , 77%) were downloaded between more than 10000 to more than 500000 times (see Figure 2).

WebMD had the highest number of downloads (5,000,000+) followed by *Care zone*, *Diseases dictionary medical*, *Medical terminologies*, *Medscape*, and *Organs 3D* with 5,000,000+ downloads. Twelve apps represented by *Anatomy Guide*, *Calculate by QxMD*, *Dorland's Medical Dictionary*, *Drugs Dictionary offline*, *Electrocardiogram ECG Types*, *Figure1-Medical Cases*, *Home Remedies*, *Medical dictionary offline*, *Medical & Medicine Dictionary*, *Omnio*, *Oxford Medical Dictionary TR*, and *Prognosis: Your Diagnosis* (see Appendix) have 500.000+ downloads each.

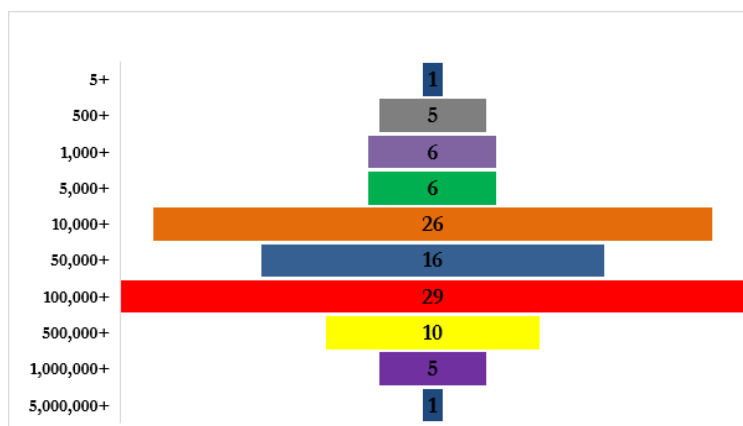
#### Evaluation of Android Medical Apps

The scores received by each of the investigated criteria such as Interactivity, Functionality, Aesthetics, Content, Benefits, and Evidence based medicine registered values from 0 (minimum possible) to 5 (maximum possible). The evaluation criteria were not applicable all the time to all apps included in the analysis. For example, interactivity and functionality were not applicable on the following apps:

- *Skyscape Medical Library*: <https://www.skyscape.com/sml/>
- *Smart Medical-Labs*: <https://play.google.com/store/apps/details?id=com.smart.and&hl=ro>
- *Teach Me Anatomy*:  
<https://play.google.com/store/apps/details?id=com.atomengineapps.teachmeanatomy&hl=ro>
- *Calculate by QxMD*: <http://www.qxmd.com/apps/calculate-by-qxmd>
- *Essential Skeleton*:  
<https://play.google.com/store/apps/details?id=com.medical.EssentialSkeleton&hl=ro>

**Table 3.**Types of investigated medical apps

Type	No. (% [95%CI])
Educational Medical Application	94 (90.38 [81.91–94.28])
Medical Dictionaries	45 (42.85 [33.34–53.32])
Treatment	38 (36.19 [26.68–45.71])
Diagnosis	26 (24.76 [17.15–34.28])
Common Diseases	26 (24.76 [17.15–34.28])
"Medical News"	19 (18.09 [11.44–26.66])
Medical Abbreviations	17 (16.19 [9.53–24.75])
Signs and Symptoms of Common Diseases	15 (14.28 [8.58–22.85])
Guidelines	14 (13.33 [7.63–20.94])
Medical "scoring system"	10 (9.52 [4.77–17.13])
Medical atlas (pictures or video)	10 (9.52 [4.77–17.13])
Etiology	5 (4.76 [1.91–10.47])
Answering Questions	5 (4.76 [1.91–10.47])
Laboratory Tests	4 (3.80 [0.96–9.52])
Surgical Techniques	3 (2.86 [0.96–7.61])
Medical "Scoring System"	2 (1.90 [0.01–6.66])
Laboratory Reference Values	2 (1.90 [0.01–6.66])
Medical Journals	2 (1.90 [0.01–6.66])
Rare Diseases	1 (0.95 [0.01–4.75])
Applications used for Patient Monitoring	1 (0.95 [0.01–4.75])
Other (Homeopathy, Acupuncture, etc.)	7 (6.66 [2.87–13.32])

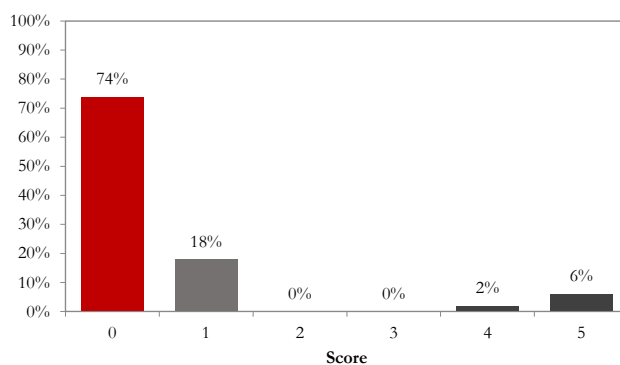


**Figure 2.** Distribution of mobile medical applications based on the number of downloads

*a. Interactivity*

Five criteria were evaluated to assess interactivity as presented in Table 2. In most of the cases, the evaluated apps did not allow any interactivity (74%, see Figure 3) the percentage of apps without interactivity being significantly higher compared with the percentage of apps that allow at least one interactivity ( $p < 0.0001$ ).

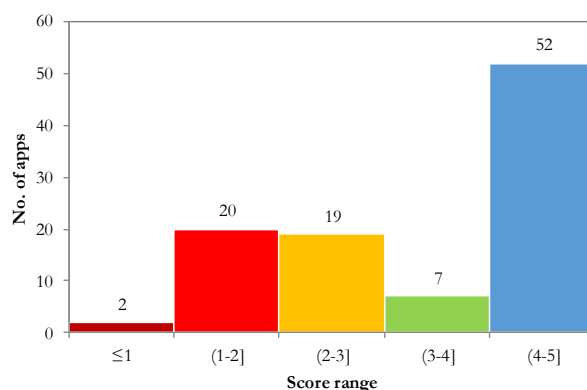
The applications that allows highest interactivity defined by possibility to send messages, notifications, alarms, feedback and that allow sharing are as follow: *Alternative Medicine*, *Anatomy Guide*, *Ayurvedic Herbs&Medicine Book*, *Beats Medical*, *Calculate by QxMD*, and *Care zone* (see Appendix).



**Figure 3.** Distribution of scores for interactivity (0 = no interactivity, 5 = highest interactivity)

*b. Functionality*

Twelve criteria were evaluated in functionality and a significantly higher percentage of investigated apps accomplished at least seven out of twelve possible (a score higher than 2.92, 59.00% vs. 41.00%,  $p = 0.0003$ ). In the majority of the cases, the apps received a score higher than or equal with 4 for functionality (see Figure 4).



**Figure 4.** Functionality of apps by scores (0 = no functionality, 5 = 12 criteria of functionality accomplished)

Three apps received the highest possible score for functionality: *Alternative Medicine*, *Anatomy Guide*, and *Ayurvedic Herbs&Medicine Book*(see Appendix).

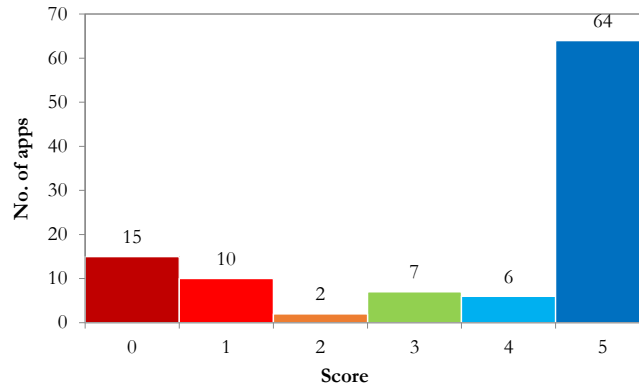
*c. Aesthetics*

The aesthetics evaluated three items (see Table 2) and had scores from 1.67 (one item accomplished) to 5 (three items accomplished). Seventy nine of the apps included in this study accomplished just one item, the percentage being statistically significant ( $p < 0.0001$ ). Nineteen apps had a score of five for this criterion: *Alternative Medicine*, *Anatomy Guide*, *Ayurvedic Herbs&Medicine Book*, *Beats Medical*, *Calculate by QxMD*, *Care zone*, *DailyRounds-Doctor s App*, *Diagnose*, *DIMS*, *Diseases dictionary*, *Diseases dictionary medical*, *Drug Dictionary offline*, *Drugs Dictionary offline*, *Drugs Medical Dictionary A-Z*, *Electrocardiogram ECG Types*, *Essential Skeleton 3*, *Explain Medicine*, *Figure1-Medical Cases*, and *Pharmacology* (see Appendix).

*d. Content*

Five items were evaluated as criterion for content. In most of the cases the content was in accord with its title (80.95%,  $p < 0.0001$ ). Specific objectives were seen in 74.29% of the investigated apps ( $p < 0.0001$ ), while achievable goals were present in 72.38% ( $p < 0.0001$ ). The

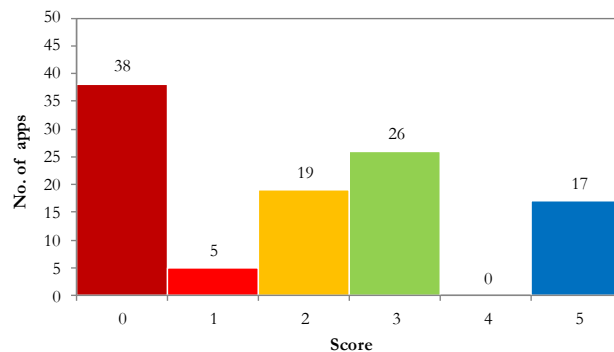
content of apps containing the minimum information needed to provide the desired response in 63.81% ( $p < 0.0001$ ) and the content is short and targeted to the answer in 69.52% of cases ( $p < 0.0001$ ). The maximum score for content criterion was obtained by the majority of application (see Figure 5, ~61%, to one application this criterion was not appropriate).



**Figure 5.** Distributions of scores for content criterion (0 = the worst content possible, 5 = the best content possible)

*e. Benefits*

Five items were evaluated in this criterion as presented in Table 2. 16.19% of apps included in the study accomplished all benefit items (see Figure 6).



**Figure 6.** Distributions of scores for benefits criterion (0 = no benefits, 5 = the best benefits as possible)

*f. Evidence-Based Medicine*

Twenty one applications were retrieved when the evidence-based medical apps keywords was used. Three items were evaluated on those apps: presence of the references to sustain the provided information, the presence of the grade for recommendation and the presence of the level of evidences as specified in methods section. Two of the retrieved apps accomplished all defined criterion and two of them accomplished two criterion (references and grade of recommendation, see Table 4).

*g. Overall Assessment*

An overall score that sums the individual scores for interactivity, functionality, aesthetics, content and benefits has been calculated for the apps included in the analysis and ranges from 8.33 to 24.58. Twelve apps had the overall score closest to the highest possible: *Calculate by QxMD*, *Care zone*, *DailyRounds-Doctor's App*, *DIMS*, *Diseases dictionary*, *Diseases dictionary medical*, *Drug Dictionary offline*, *Drugs Dictionary offline*, *Drugs Medical Dictionary A-Z*, *Electrocardiogram ECG Types*, *Essential*



*Skeleton 3*, and *Explain Medicine* (see Appendix). Half of the investigated apps had an overall score lower or equal to 15.17 (maximum possible score is 25) and 19% of apps had an overall score higher than the values of third quartile (19.25).

**Table 4.** Results of assessment the evidence-based medical apps

Name of EBM app	References	Level of evidence	Grade of recommendation	Score
<i>Alternative medicine</i>	☑	☒	☒	1.67
<i>DailyRounds-Doctor'App</i>	☑	☒	☒	1.67
<i>Diagnose</i>	☑	☒	☒	1.67
<i>Diseases Dictionary</i>	☑	☒	☒	1.67
<i>Diseases dictionary medical</i>	☑	☒	☒	1.67
<i>Explain Medicine</i>	☑	☒	☒	1.67
<i>Intensive Care Medicine</i>	☑	☒	☒	1.67
<i>Internal Medicine in review</i>	☑	☒	☒	1.67
<i>Medical Dictionary</i>	☑	☒	☒	1.67
<i>Medical Drug Dictionary</i>	☑	☒	☒	1.67
<i>Medical Journal</i>	☑	☒	☒	1.67
<i>Medical News</i>	☑	☒	☒	1.67
<i>Medical News online</i>	☑	☒	☒	1.67
<i>Medical Terms Online</i>	☑	☒	☒	1.67
<i>Medical Wikipedia</i>	☑	☒	☒	1.67
<i>Medical Xpress</i>	☑	☒	☒	1.67
<i>Medical Journal</i>	☑	☒	☒	1.67
<i>Medscape</i>	☑	☑	☑	5.00
<i>Pubmed online</i>	☑	☒	☒	1.67
<i>Skyscape Medical Library</i>	☑	☒	☒	1.67
<i>Dynamed</i>	☑	☑	☑	5.00

A significant monotone relation has been identified between the overall score computed on clear criterion and the average rank received by the apps from its users ( $\rho = 0.3119$ ,  $p = 0.0016$ ).

#### b. TOPSIS Classification

The highest rank according with TOPSIS classification was obtained by 12 apps (11.43%, 955CI [5.72–19.04]) represented by *Calculate by QxMD*, *Care zone*, *DailyRounds-Doctor's App*, *DIMS*, *Diseases dictionary*, *Diseases dictionary medical*, *Drug Dictionary offline*, *Drugs Dictionary offline*, *Drugs Medical Dictionary A-Z*, *Electrocardiogram ECG Types*, *Essential Skeleton 3*, and *Explain Medicine*. Identical result was obtained by our proposed overall score (see *Overall Assessment*). The next classified apps according with TOPSIS classification was *Beats Medical* (class 2), followed at distance by *Anatomy Guide* (class 3), and *Diagnose*, and *Figure1-Medical Cases* (both as class 4).

A significant monotone relation has been identified between the TOPSIS rank computed on clear criterion and the average rank received by the apps from its users ( $\rho = 0.3087$ ,  $p = 0.0014$ ). An almost perfect correlation was obtained between our proposed overall score and the TOPSIS rank ( $\rho = 0.9909$ ,  $p < 0.0001$ ).

## Discussions

### General Characteristic of Mobile Medical Applications

The use of smartphones to access clinical applications (such as information management – hospital information system, medical records, clinical decision support system, picture archiving

and communication system, and laboratory information system), informational resources (such as guidelines, medical literature, drug references, evidence-based resources) and clinical software applications (such as disease diagnosis aids, medical calculators) at the point of care is becoming common practice [22]. This study presents the characteristics of the Android medical apps available on Google Play.

It is retainable that from all the considered applications, 94 may be used for medical education and 38 of them are made for drug treatment orientation. Significantly smaller percentages (13.33%) of the investigated apps are designed as medical guidelines (see Table 3). Most of medical apps available today are as support of telemedicine, disease awareness, appointment making, and record keeping, followed by medical education and scholarly information [23]. A similar study noticed that the three most frequent (intended) functions of the medical apps developed for patients are: provide users with information/education (52.6%, 61/116), assisting users with their therapy adherence (37.1%, 43/116), and helping users monitor the effect and possible side effects of their medication (37.1%, 43/116) [24]. Less common (intended) functions included helping users choose a medication or dose (19.8%, 23/116), drug interaction monitoring (11.2%, 13/116), and providing users with news (7.7%, 9/116) [24].

Almost a quarter of medical apps included in the analysis are developed in the USA while the medical apps developed in India tend to represent one tenth of the total. It could be noted that for a significant percentage of application (43%) the developer is not provided, leading to the question in regards of quality of information provided. A study conducted in 2015 developed a centralized resource that provides detailed information for more than 60,000 health-related apps from the Apple App Store and the Google Play Store, but unfortunately this tool is available strictly upon request [25]. More than 98.19% (47,883/48,764) of the medical apps taken into consideration were available in the United States [25]. There is no doubt that the development of mHealth apps is continuously increasing while the target groups are becoming more clearly specified and focused (chronic diseases continuing to be the most promising in terms of business potential) [26]. It could be said that the mHealth market is becoming crowded and clear characteristic and criteria needed to be applied when a user decides which medical apps to use. The number of downloads could be one criterion but it is very subjective and does not necessary sustain the validity and reliability of the contents especially for apps developed for health care professionals. In healthcare, it is extremely important that the information is up to date, so one recommendation is to find a medical app that has been recently updated. However, our study showed that a significantly lower percentage (42.5%,  $p=0.0019$ ) of the apps included in the study have information updated in the year when the study was conducted.

The majority of the investigated mobile medical apps (94/105, see Table 3) can be used with benefit by medical students during their practice hours, showing that the interest in education of health care professionals is high. The use of medical apps has become a daily activity; 70% of medical school HCPs (healthcare professionals) and students reported using at least one medical app regularly, with 50% using their favorite app daily. The advantages offered by these applications to doctors are questionable [27,28].

A high percentage of the evaluated Android medical apps do not require Internet access (97.14%) and thus assure their usefulness in healthcare setting without Internet connection. However, an Internet connection is mandatory for several features such as communication (sending emails) [29].

#### *Evaluated Characteristic of Mobile Medical Applications*

Interactivity, functionality, aesthetics, content and benefits had been evaluated on the medical apps included in the study.

Majority of the investigated apps did not allow any interactivity (73.3%, 77/105) and obtained a score equal with 0 points on this criterion. Therefore, 77 mobile medical apps do not allow distribution of information on social networks, sending messages, notifications or feedback. Opposite, a very low percentage of the investigated medical apps achieved all interactivity items and obtained on this criterion a score of 5 (see Figure 3). A similar evaluation of 23 medical diet apps

found that most apps offered notifications (82%, 18/23), needed web access to function (68%, 15 apps), worked in background, and had a community (64%, 14 apps,) [30].

Almost half of the investigated apps obtained the highest score possible in the functionality (see Figure 4). 95% of these applications have a download time and a search result less than 15 seconds, 68% of them offer suggestions during the searching process and only 2.8% offer a presentation tutorial. The functionality is an important issue taken into account when you must decide which medical apps to use and it is expected that people to choose well-designed apps that are functional and easy to use [31].

The aesthetics proved not to be a strength of the evaluated medical apps since most of the applications included in the study accomplished just one out of five possible items in this criterion. Only 18% of the apps give the possibility of controlling the text size after displaying the result and only 20% offer pictograms that suggest the following content. Solutions for these weaknesses could be found by the developers to assure a proper usability of the tools.

The analysis obtained by the content criterion showed that in most of the cases four to five items of this criterion are achieved by the majority of the apps included in the study (see Figure 5). This result is opposite with the results of previously published studies that identified lower scores for information quality [32-39].

Regarding the benefit brought by the mobile medical applications, almost half of the investigated apps had a score from 0 to 2 (see Figure 6). Nearly 43% of the investigated apps sustain the possibility of reducing the medical care costs by decreasing the unnecessary addressability towards medical services, 60% can improve the quality of medical assistance, 65% of the applications may be used for a quick search of useful and quick information and 17% are applications that are addressed exclusively to patients. Evidence has shown that mobile devices allow HCPs to be more efficient in their work practices [40,41]. The Deloitte Center for Health Solutions 2013 Survey of U.S. Physicians found that most doctors believe that meaningful adoption of health information technology (EHRs, e-prescribing, health information exchange, analytics/decision support, patient support tools - websites, mobile apps, tools to track and manage health and wellness-, and mobile health technologies - tablets, smartphones) can improve the efficiency of clinical practice [42].

The use of mobile devices has been shown to provide HCPs with enhanced efficiency, including: increased quality of patient documentation through fewer errors and more complete records, more rapid access to new information, and improved workflow patterns[43]. Physicians have reported that the use of a mobile device for retrieving information from a drug database led to more efficient decision-making and patient care [43]. Physicians working in health care organizations have cited improved care coordination, as well as quicker and more efficient access to clinical support resources (guidelines, lab tests, and reports) as principal benefits associated with mobile device use [43]. Physicians who used mobile devices during patient rounds reported spending less time accessing, retrieving, and recording data and said that the increased efficiency freed up more time for direct patient care [43]. In contrast, another study found that the increased efficiency in median doctor-patient encounter time (227 vs. 301 seconds) provided by the use of mobile devices, rather than paper resources, resulted in less time spent with the patient [43].

Twenty one application retrieved when EBM apps was used as search key were included in analysis. The majority of the apps obtained a score from 0 to 2 (maximum possible equal with 5), the item for this criterion accomplished by all included apps being availability of the reference that sustain the information (see Table 4). Two medical apps, represented by Medscape and Dynamed answered all items defined in the research protocol for evidence based medical app (see Table 2). Both apps provide medical news and are used for diagnostic, treatment and prognosis and were exclusively designated for physicians.

A systematic review showed that expert involvement in the development of medical apps is between 9% and 67% [44]. Adherence to medical evidence was found in 10-87% of the assessed apps in 13 studies, and in none of the assessed apps in 17 studies [44]. Medical professionals and patients should be aware of this, as mobile phones play an increasing role in medical education [45] and clinical decision making [42].

For the common user, it may be practically impossible to assess whether or not an app adheres to current evidence and guidelines. In some cases, the app descriptions include references to publications from which the content is based. Levels of evidence as defined by the Oxford Centre for Evidence-Based Medicine state that systematic reviews and individual studies rank higher than opinions of an expert, but an expert opinion ranks better than nothing [43].

The classification of the medical apps proposed in this article has similar performances with the classification retrieved by applying the TOPSIS method with the same 12 application classified as the best apps. The correlation analysis showed a monotone significant relationship between the overall score as well as TOPSIS score obtained by the medical apps included in the study on one hand and the rank given by the users on the other hand ( $p < 0.002$ ). This result may suggest that users ranking may be in fact based on unconsciously targeting criteria. Moreover, the TOPSIS score correlates very well with the proposed overall score, leading to the conclusion that the proposed score is a reliable one since the TOPSIS already proved its validity [46,47].

### *Limitations*

More new medical apps are available daily on online application stores (e.g. Apple's App Store, Android Apps on Google Play, Windows Apps on Microsoft Store, etc.). These medical apps are developed for different platforms and not all the time the same medical app will be available on all smartphone platforms. Hence, just the medical apps on Android platform were the subject of our study and the exclusion of those on other platforms is the main limitation of our study. The second limitation of this study is related to our inclusion criteria and inclusion of those medical apps available free of charge, limitation related with the financial support. Furthermore, the evaluation of the apps by a single physician could be seen as a positive as well as a negative point in the design of the study. The same researcher as the evaluator of all medical apps means that the bias induced by the researcher is constant. However, for a more reliable analysis, the assessment of medical apps for different platforms completed by more than one researcher is needed.

### **Conclusions**

Several conclusions are supported by our results obtained on assessment of free medical apps on Android platform. The majority of the free medical apps on Android platform are developed for educational purposes and were developed in the USA. A very small number of medical apps allow the distribution of information through social media or the increase of the text size after displaying the information. Opposite, the majority of the investigated medical apps do not require an Internet connection. Two freely available medical apps out of 21 investigated provide all requirements to classify them as evidence-based apps.

### **Conflict of Interest**

The authors declare that they have no conflict of interest.

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### **Appendix**

**Alternative Medicine:** <https://play.google.com/store/apps/details?id=com.appsbar.AltMedicine296466>

**Anatomy Guide:** <https://play.google.com/store/apps/details?id=af.anatomy.guide>

**Ayurvedic Herbs&Medicine book:**

<https://play.google.com/store/apps/details?id=com.atomic.apps.ayurvedic.herbs.book>

**Beats Medical:** <https://play.google.com/store/search?q=Beats%20Medical&c=apps>

**Calculate by QxMD:** <http://www.qxmd.com/apps/calculate-by-qxmd>

**Care zone:** <https://play.google.com/store/apps/details?id=com.carezone.caredroid.careapp.medications>  
**DailyRounds-Doctor's App:** <https://play.google.com/store/apps/details?id=com.medengage.clinical&hl=ro>  
**Diagnose:** <https://play.google.com/store/apps/details?id=com.DiagnoseSoftware.diagnose>  
**DIMS:** <https://play.google.com/store/apps/details?id=com.twgbd.dims>  
**Diseases dictionary:** <https://play.google.com/store/apps/details?id=com.medicalgroupsoft.medical.refdiseases.eng.free>  
**Diseases dictionary medical:**  
<https://play.google.com/store/apps/details?id=com.atomic.apps.medical.disease.condition.dictionary&hl=ro>  
**Dynamed Plus:** <http://www.dynamed.com/home/>  
**Drug Dictionary offline:** <http://www.androidmedical.com/download-drug-dictionary--free.html>  
**Drugs Dictionary offline:** <https://play.google.com/store/apps/details?id=com.quatkhoi.drug.dictionary&hl=ro>  
**Drugs Medical Dictionary A-Z:**  
<https://play.google.com/store/apps/details?id=com.drugdictionaryparmaterra.apps&hl=ro>  
**Electrocardiogram ECG Types:** <https://play.google.com/store/apps/details?id=DOCECG2.doctor&hl=ro>  
**Essential Skeleton 3:** <https://play.google.com/store/apps/details?id=com.medical.EssentialSkeleton&hl=ro>  
**Explain Medicine:** <https://play.google.com/store/apps/details?id=medicaljoyworks.com.explainmedicine&hl=ro>  
**Figure1-Medical Cases:** <https://figure1.com/>  
**Pharmacology:** <https://play.google.com/store/apps/details?id=com.applemedical.pharmacology>  
**General Medicine:** <http://www.generalmedicine.com/limited-ability-improve-patient-care-apps/medical-app/>  
**Global Medical Education:** <https://play.google.com/store/apps/details?id=com.augment.gmeded>  
**Handbook of Natural Medicine:**  
<https://play.google.com/store/apps/details?id=com.mobisystems.msdict.embedded.wireless.elsevier.naturalmedicine>  
**Herbs Guide:** <https://play.google.com/store/apps/details?id=com.ceardannan.classes.herbs.demo>  
**Herbal Medicine:**  
<https://play.google.com/store/apps/details?id=com.ChauCorp.HerbalMedicineandHomeRemedies.AOVLZUUAWHX LKRN>  
**Home Remedies:** <https://play.google.com/store/apps/details?id=com.si.homeremedies>  
**Intensive Care Medicine:** <http://icmjournal.esicm.org/index.html>  
**Internal Medicine In-review:** <https://play.google.com/store/apps/details?id=com.imir>  
**iTreat-Medical Dictionary:** <https://play.google.com/store/apps/details?id=free.itreat.me&hl=ro>  
**Lab Value+Medical References:**  
<https://play.google.com/store/apps/details?id=com.halcyonmobile.medicalthreeinone&hl=ro>  
**Learn medical terminology:** [https://play.google.com/store/apps/details?id=appinventor.ai\\_dot\\_dox.InterActiveMT](https://play.google.com/store/apps/details?id=appinventor.ai_dot_dox.InterActiveMT)  
**Mafinila s Medical Dictionary:** [http://download.cnet.com/Mafinila-s-Medical-Dictionary/3000-2129\\_4-76461069.html](http://download.cnet.com/Mafinila-s-Medical-Dictionary/3000-2129_4-76461069.html)  
**Medical Abbreviations free:**  
[https://play.google.com/store/apps/details?id=com.mr.complete\\_medical\\_abbreviations\\_dictionary\\_free](https://play.google.com/store/apps/details?id=com.mr.complete_medical_abbreviations_dictionary_free)  
**Medical Abbreviations:**  
<https://play.google.com/store/apps/details?id=com.dictionary.arjunastudiomedicalabbreviations>  
**Medical Abbreviation DE:** <https://play.google.com/store/apps/details?id=eu.ipix.NativeMedAbbrevDE>  
**Medical abbreviation Dict:** <https://play.google.com/store/apps/details?id=megaup.MedicalAbbreviationDict>  
**Medical abbreviation RU:** <https://play.google.com/store/apps/details?id=eu.ipix.NativeMedAbbrevRU>  
**Medical Abbreviations:** <https://play.google.com/store/apps/details?id=com.webmely.medical.abbreviations>  
**Medical Abbreviations:** <https://play.google.com/store/apps/details?id=pl.legacysoftware.medicalabbreviation>  
**Abbreviations:** <https://play.google.com/store/apps/details?id=com.jass.refapp12>  
**Medical Abbreviations ES:** <https://play.google.com/store/apps/details?id=eu.ipix.NativeMedAbbrevES>  
**Medical Abbreviations FR:** <https://play.google.com/store/apps/details?id=eu.ipix.NativeMedAbbrevFR>  
**Medical Abbreviations PL:** <https://play.google.com/store/apps/details?id=pl.net.ipix.NativeMedAbbrev>  
**Medical Abbreviations Search:** <https://play.google.com/store/apps/details?id=tw.com.stnl.imeab>  
**Medical Abbreviations:** <https://play.google.com/store/apps/details?id=yep.com.abbreviations>  
**My Medical Books:** <https://play.google.com/store/apps/details?id=qbase.mymedicalbooks>  
**Medical Calculator:** <https://play.google.com/store/apps/details?id=com.everythingisfour.nursecalculator>  
**Medical Calculator&Equations:** <https://play.google.com/store/apps/details?id=com.medicalcalculator>  
**Medical Calculators:** <https://play.google.com/store/apps/details?id=Pedcall.Calculator>  
**Medical Calculator:** <https://play.google.com/store/apps/details?id=com.stefanroobol.verpleegkundigrekenen>  
**Medical Diagnostics:** <https://play.google.com/store/apps/details?id=wwk.wikikids.com.medicaldiagnostics>  
**Medical Dictionary:** <https://play.google.com/store/apps/details?id=net.medicopedia.english>  
**Medical Dictionary:** <https://play.google.com/store/apps/details?id=zeeshan.com.androiddictionaryapplication>  
**Medical Dictionary:** <https://play.google.com/store/apps/details?id=qlx.sample.advancedmedication>  
**Medical Dictionary:** <https://play.google.com/store/apps/details?id=com.innovapps.diccionariomedico>  
**Medical Dictionary:** <https://play.google.com/store/apps/details?id=com.Medical.Dictionary.JuliaDictionaryInc>  
**Medical Dictionary:** <https://play.google.com/store/apps/details?id=com.medicaldictionary>  
**Medical Dictionary:** <https://play.google.com/store/apps/details?id=buraq.medical.dictionary.full>  
**Medical Dictionary:** <https://play.google.com/store/apps/details?id=com.mci.medicaldictionary>  
**Medical Dictionary:** <https://play.google.com/store/apps/details?id=com.onlineeducare.medicalterms>  
**Medical Dictionary by Farlex:** <https://play.google.com/store/apps/details?id=com.farlex.dictionary.medical>  
**Medical dictionary diseases:** <https://play.google.com/store/apps/details?id=com.bestmedical.apps.disease.dictionary>

**Medical dictionary offline:** <https://play.google.com/store/apps/details?id=com.medicaltermsdictionary>  
**Medical Dictionary offline:** <https://play.google.com/store/apps/details?id=medical.offline.Dictionary>  
**Medical dictionary&Guide:** <https://play.google.com/store/apps/details?id=com.semantic.medical>  
**Medical Drug Dictionary:** <https://play.google.com/store/apps/details?id=com.webmely.medical.drugs>  
**Medical Drugs Guide Dictionary:** <https://play.google.com/store/apps/details?id=com.appguru.apps.drug.dictionary>  
**Medical formulas:** <https://play.google.com/store/apps/details?id=com.sanapps.formulasmedicas>  
**Medicine Handbook:** <https://play.google.com/store/apps/details?id=com.jankari.apps.medihand>  
**Medical Journal:** <https://play.google.com/store/apps/details?id=com.elsevier.stmj.jat.newsstand.medicine>  
**Medical Mnemonics:** <https://play.google.com/store/search?q=Medical%20Mnemonics&c=apps>  
**Medical News:** <https://play.google.com/store/search?q=Medical%20News&c=apps>  
**Medical News Online:** <https://play.google.com/store/apps/details?id=com.medical.news.online>  
**Medical Pearls:** <https://play.google.com/store/apps/details?id=com.trisoftdevelpers.medicalpearls>  
**Medical Psychiatric Dictionary:** <https://play.google.com/store/apps/details?id=com.atomic.apps.psychiatry.dictionary>  
**Medical Study Terms:** <https://play.google.com/store/apps/details?id=com.onlineeducare.medicalstudyterms>  
**Medical terminologies:**  
<https://play.google.com/store/apps/details?id=com.medicalgroupsoft.medical.directory.medtermsmultilang.free>  
**Medical Terminology:** [https://play.google.com/store/apps/details?id=com.qkstudio.medical\\_terminologies](https://play.google.com/store/apps/details?id=com.qkstudio.medical_terminologies)  
**Medical Terminology:** [https://play.google.com/store/apps/details?id=mobmedics.medical\\_terminology.dictionary](https://play.google.com/store/apps/details?id=mobmedics.medical_terminology.dictionary)  
**Medical Terms:** <https://play.google.com/store/apps/details?id=sunita.android.medicalterms>  
**Medical Terms:** <https://play.google.com/store/apps/details?id=com.ablet.medterms>  
**Medical Terms and Definition:** <https://play.google.com/store/apps/details?id=com.defntn.medictermndefinitiapp>  
**Medical Terms EN:** <https://play.google.com/store/apps/details?id=eu.ipix.LexMedEN>  
**normal Lab Value References:** <https://play.google.com/store/apps/details?id=com.normal.labvalues.simple>  
**Medical tools:** <https://play.google.com/store/apps/details?id=com.irtza.pulmtools>  
**Medical Topics:** <https://play.google.com/store/apps/details?id=com.bim.medlinetopic>  
**Medical Wikipedia offline:** <https://play.google.com/store/apps/details?id=org.kiwix.kiwixcustomwikimed>  
**Medical Words:** <https://play.google.com/store/apps/details?id=com.ablet.medicalwords>  
**Medical Xpress:** <https://play.google.com/store/apps/details?id=com.PhysOrg.healthFree>  
**Medical&Medicine Dictionary:** <https://play.google.com/store/apps/details?id=com.medical.dictionary>  
**Medical&Surgical Procedure:**  
<https://play.google.com/store/apps/details?id=com.kmcpesh.medicalskillsproceduresfree>  
**Medical-Surgical Nursing:** <https://play.google.com/store/apps/details?id=com.shah.medicalsurgical>  
**Medicine Dictionary:** <https://play.google.com/store/apps/details?id=com.Medicine.Dictionary.JuliaDictionaryInc>  
**Medicine Journal:** <https://play.google.com/store/apps/details?id=com.elsevier.stmj.jat.newsstand.medicine>  
**Medscape:** <https://play.google.com/store/apps/details?id=com.medscape.android>  
**Normal Lab Value References:** <https://play.google.com/store/apps/details?id=com.normal.labvalues.simple>  
**Omniio:** <https://play.google.com/store/apps/details?id=com.skyscape.android.ui>  
**Organs 3D:** <https://play.google.com/store/apps/details?id=com.androiddeveloper.mx.blogspot.organos3d>  
**Pharmacology:** <https://play.google.com/store/apps/details?id=com.applemedical.pharmacology>  
**Pubmed mobile:** <https://play.google.com/store/apps/details?id=com.bim.pubmed>  
**Skin Diseases and treatment:** <https://play.google.com/store/apps/details?id=com.jdsk.discj>  
**Skyscape Medical Library:** <https://play.google.com/store/apps/details?id=com.medpresso.android.ui>  
**Smart Medical-Labs, Drug, Calc:** <https://play.google.com/store/apps/details?id=com.smart.and>  
**Teach me Anatomy:** <https://play.google.com/store/apps/details?id=com.atomengineapps.teachmeanatomy>  
**WebMD for Android:** <https://play.google.com/store/apps/details?id=com.webmd.android>

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