A Cross-Sectional Study of Prominent US Mobile Health Applications: Evaluating the Current Landscape

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Abstract

Mobile health (mHealth) could offer unprecedented opportunity to provide medical support closer to the users. We have selected some relevant criteria to describe 100 apps from Google Play store and Apple's App Store's top suggestions in medical category. These characteristics were compared based on the paid or free nature of the apps, the target users: consumers or healthcare professionals, and the platform: Android or iOS. Seventeen provided functionalities and 27 medical subjects covered by these apps were also extracted. Our study shows that even in top rated mHealth apps, a high proportion lacks some basic criteria regarding the quality of the apps including the presence of a privacy policy, describing content sources, participation of the target users in the app development, etc. Paid apps did not ensure better quality compared to free apps. The current mHealth market is not mature enough to be used widely and recommended by healthcare professionals.

Introduction

Mobile health (m-health) is a subdivision of the eHealth phenomenon that is in a perpetual state of active refinement. There is a vast amount of potential for m-health to positively affect health and healthcare processes[1]. Mobile apps offer an unprecedented opportunity to provide medical support at the time /location of the demand[2]. This opportunity can be harnessed by the general public (e.g. patients) or health professionals who are in need of various specialized tools (means of interdisciplinary communication, ready access to health and medical information, simple consultation of medical records, and clinical decision-making support systems)[3].

Although m-health apps are a relatively recent development, their virtual presence is exploding with no indication of slowing any time soon. There are over 259,000 health-related applications (apps) available in app stores (e.g. Google Play and Apple's iOS "app store") for smartphone devices. Approximately 100,000 m-health apps have been added as of the beginning of 2015[4]. Each month, about 1,000 new applications are put on the market[5]. These apps proffer myriad functionalities, ranging from simple text message reminders to platforms designed for sophisticated disease management. Naturally, the growth of the m-health market correlates with the increase in usage these apps are experiencing. In the next several years, upwards of three million free downloads and circa 300,000 purchased downloads are expected to be made of mHealth applications in the United States alone[6]. These values exhibit a swift rise in the prevalence of mobile technology in the medical and wellness fields. Being readily accessible and simple to procure ensures that smart devices (smartphones and tablets) are made very attractive in the eyes of medical professionals. We are reaching a turning point in the use of mobile technology in healthcare. There is therefore a pressing need to ensure that patient safety is not compromised post-maturation of the field[7]. The continually-rising number of mHealth apps and the variety of obtainable functionalities render it burdensome for any kind of user (health professional or patient) to ascertain which apps excel in terms of quality.

There exist a great deal of potential dangers, and the reliability of some mHealth apps was investigated in several works of literature[8–10]. The involvement of a medical professional in the development of a given application[11], the accuracy and reliability of the content as utilized in diagnosis and patient management[12], the potential danger of camera functionalities in mobile devices to judge whether skin lesions are suspicious[13,14], and deficiencies in self-management applications (in both diabetes[15] and asthma[16]) were called into question by various researchers.

While the growing popularity of m-health is well-documented, its impact is not. The reported implications of mHealth interventions are mixed, with studies exhibiting modest benefits for some clinical diagnosis and management support outcomes[1]. Furthermore, the information provided in app stores does not permit users to ascertain the quality of apps. The existing five-star rating system currently in use is not a reliable assessment method[17]. One is faced with a veritable

jungle of health-related apps, including very good apps as well as those that endanger patient/physician safety. In order to address to this deficiency in today's mobile health market, a research study was proposed to assess the current standing of mHealth applications available for download in the United States. We were interested in determining whether or not the current market could be considered a reliable source of medical applications. The main aim of this study was therefore to isolate characteristics of health apps currently available and identify existing gaps.

Methods

In collaboration with medical doctors from France and Stanford University, we have conducted a cross-sectional descriptive study of the top 100 medical applications available in the Google Play store and Apple's App Store. We selected the top 25 free apps from the App Store followed by 25 of the same from the Google Play Store. When an app appeared in both stores, it was only selected once and passed over in favor of the following app. For the payed apps we employed the opposite strategy, beginning with the Google Play Store and only afterwards the Apple Store. If the reported purpose of the app had no relation to medicine, it was not selected. Other exclusion criteria were that no apps that encapsulated other apps (a mini store of apps) and paid apps more expensive than 70 dollars were not selected.

The order of apps on the top lists are very subject to change. In the beginning of January 2017, we selected our apps in compliance with the aforementioned criteria. We did not alter our choices over the course of the study. The working group was composed of four physicians invested in medical informatics. The apps were installed on a relevant mobile device and analyzed one by one by each group member.

In order to define the criteria used over the course of the study, we hypothesized that we could utilize key elements of the mHealth Quality (mHQ) process[18]. We have isolated from said process the most relevant criteria to assess the American market. The extraction criteria included informative and assessment criteria.

Apart from the characteristics of the app, we have analyzed each app to evaluate the use cases (functionalities) imparted by the app according to a previously published model of use cases for mHealth apps[3]. We have also determined the relevant medical subject/specialty related to each app.

Each member of the working group had an Excel table to fill for each app. We organized a weekly meeting to discuss differing opinions and reach a consensus.

Descriptive data were provided for each criterion. The characteristics of both free and paid apps were compared according to their target demographic (consumers or health professionals) as well as the platform (iOS and Android). Chi-Square test was used to determine whether there was a significant difference between the elements of the information in the categories and $P < 0.05$ was considered statistically significant.

Results

Half of the analyzed apps were installed on Android phones, and the other half were installed on iOS ones. From each platform 25 paid apps and 25 free apps were selected. Whilst performing the selections, three apps were excluded from the study due to their non-medical nature. One app was not selected due to its high price and two others were excluded because they were essentially a mini store of apps.

The selected criteria were divided into informative elements and assessment elements. The informative elements include type of owner (start-up, corporation, patient association, etc.), target user, the topic the app was attempting to address, whether or not it belonged to the appendix A, B or C of the FDA document on Mobile Medical Applications[19], etc. Assessment elements include the existence of general terms and conditions of use, existence of privacy policy, presence of a health professional during app development, citation of content sources, etc. Table 1 provides descriptive explanations of various criteria and distribution of apps.

Most app criteria were evaluated in all 100 of the analyzed apps. However, some criteria were not applicable to all apps. For example, "user consent to personal data collection" and "ability to link to a connected device in order to collect data" were rendered obsolete for apps whose purpose was not to collect personal health data. The aforementioned criteria were only applicable to 58 apps. Another example is "citation of the content sources or bibliographic references" and "medical content is kept up to date" because only 71 of selected apps include medical content.

The pecuniary nature of some apps caused a significant difference ($p<0.001$) between those addressed to consumers and those targeting healthcare professionals. Apps whose target demographic consisted mostly of healthcare professionals were less likely to be free to download. However, 28% of free apps had in-app integrated purchases.

Table 1. Characteristics description of the health apps available on the US market.

Characteristics (n)	Number of apps (%)	Price			Target users			Platform		
		Free apps (%)	Paid apps (%)	P-value	C. (%)	HP. (%)	P-value	Android (%)	iOS (%)	P-value
App provider (100)				0.517 *			0.426 *			0.034 *
Corporate	30 (30)	13 (43)	17 (57)		19 (63)	11 (37)		15 (50)	15 (50)	
Healthcare institution/ enterprise	16 (16)	6 (38)	10 (63)		9 (56)	7 (44)		10 (63)	6 (38)	
Start up	35 (35)	20 (57)	15 (43)		27 (77)	8 (23)		11 (31)	24 (69)	
Patient association / Non-profit	10 (10)	5 (50)	5 (50)		5 (50)	5 (50)		8 (80)	2 (20)	
Individual	9 (9)	6 (67)	3 (33)		6 (67)	3 (33)		6 (67)	3 (33)	
if corporate (30)				.			.			.
Device company	3 (10)	3 (100)	0 (0)		3 (100)	0 (0)		1 (33)	2 (67)	
Electronic Health Record	2 (7)	2 (100)	0 (0)		1 (50)	1 (50)		0 (0)	2 (100)	
Insurance	4 (13)	4 (100)	0 (0)		4 (100)	0 (0)		3 (75)	1 (25)	
Drug	0 (0)	.	.		.	.		.	.	
Services provider	16 (53)	1 (6)	15 (94)		9 (56)	7 (44)		7 (44)	9 (56)	
Other	5 (17)	3 (60)	2 (40)		2 (40)	3 (60)		4 (80)	1 (20)	
Price (100)				.			$<10^{-3}$			.
Free	50 (50)	.	.		43 (86)	7 (14)		.	.	
Paid	50 (50)	.	.		23 (46)	27 (54)		.	.	
If free, in-app purchase (50)				.			.			0.208
No	36 (72)	36 (100)	0		33 (92)	3 (8)		16 (44)	20 (56)	
Yes	14 (28)	14 (100)	0		10 (71)	4 (29)		9 (64)	5 (36)	
Target user (100)				$<10^{-3}$			.			0.206
Consumers	66 (66)	43 (65)	23 (35)		.	.		30 (45)	36 (55)	
Health professionals	34 (34)	7 (21)	27 (79)		.	.		20 (59)	14 (41)	
Existence of a "contact" tab for the users to ask their questions (100)				0.663			0.580			0.383
No	30 (30)	14 (47)	16 (53)		21 (70)	9 (30)		13 (43)	17 (57)	
Yes	70 (70)	36 (51)	34 (49)		45 (64)	25 (36)		37 (53)	33 (47)	
If yes, is there a hotline? (70)				0.009			0.415			0.173
No	52 (74)	22 (42)	30 (58)		32 (62)	20 (38)		25 (48)	27 (52)	
Yes	18 (26)	14 (78)	4 (22)		13 (72)	5 (28)		12 (67)	6 (33)	

Table 1 (continued)

	Total			p			p			p
Description of the general terms and conditions of use (100)				0.016			0.405			0.420
No	56 (56)	22 (39)	34 (61)		35 (63)	21 (38)		26 (46)	30 (54)	
Yes	44 (44)	28 (64)	16 (36)		31 (70)	13 (30)		24 (55)	20 (45)	
Description of personal data privacy policy (100)				$<10^{-3}$			0.003			0.316
No	47 (47)	11 (23)	36 (77)		24 (51)	23 (49)		21 (45)	26 (55)	
Yes	53 (53)	39 (74)	14 (26)		42 (79)	11 (21)		29 (55)	24 (45)	
User consent for the personal data collection (58)				$<10^{-3}$			.			0.346
No	24 (41)	9 (38)	15 (63)		24 (100)	0 (0)		9 (38)	15 (63)	
Yes	34 (59)	28 (82)	6 (18)		33 (97)	1 (3)		17 (50)	17 (50)	
The app can link to a connected device to collect data (58)				0.187			.			0.431
No	44 (76)	26 (59)	18 (41)		43 (98)	1 (2)		21 (48)	23 (52)	
Yes	14 (24)	11 (79)	3 (21)		14 (100)	0 (0)		5 (36)	9 (64)	
FDA category[19] A, B, C (100)				0.109			$<10^{-3}$			1
A	52 (52)	22 (42)	30 (58)		21 (40)	31 (60)		26 (50)	26 (50)	
B	48 (48)	28 (58)	20 (42)		45 (94)	3 (6)		24 (50)	24 (50)	
C	0	.	.		.	.		.	.	
FDA approval for group B (48)				.			.			.
No	47 (98)	27 (57)	20 (43)		44 (94)	3 (6)		23 (49)	24 (51)	
Yes	1 (2)	1 (100)	0 (0)		1 (100)	0 (0)		1 (100)	0 (0)	
Other certification approved? (48)				.			.			.
No	46 (96)	26 (57)	20 (43)		43 (93)	3 (7)		22 (48)	24 (52)	
Yes	2 (4)	2 (100)	0 (0)		2 (100)	0 (0)		2 (100)	0	
The app has passed a usability test process (100)				.			.			.
No	100 (100)	50 (50)	50 (50)		66 (66)	34 (34)		50 (50)	50 (50)	
Yes	0 (0)	0 (0)	0 (0)		0 (0)	0 (0)		0 (0)	0 (0)	
Participation of the target users in the conception or development of the app (100)				0.825			$<10^{-3}$			0.825
No	71 (71)	35 (49)	36 (51)		56 (79)	15 (21)		35 (49)	36 (51)	
Yes	29 (29)	15 (52)	14 (48)		10 (34)	19 (66)		15 (52)	14 (48)	

Table 1 (continued)

Participation of a Healthcare professional in the core team (100)			0.065			0.023		0.065
No	39 (39)	15 (38)	24 (62)	31 (79)	8 (21)		15 (38)	24 (62)
Yes	61 (61)	35 (57)	26 (43)	35 (57)	26 (43)		35 (57)	26 (43)
Existence of a study/publication approving the efficacy of the app (100)			.			.		.
No	100 (100)	50 (50)	50 (50)	66 (66)	34 (34)		50 (50)	50 (50)
Yes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)		0 (0)	0 (0)
Citation of the content sources or bibliographic references (71)			0.796			0.002		0.040
No	40 (56)	18 (45)	22 (55)	30 (75)	10 (25)		16 (40)	24 (60)
Yes	31(44)	13 (42)	18 (58)	12 (39)	19 (61)		20 (65)	11 (35)
Medical content is kept up to date (71)			0.595			0.002		0.919
No	41 (58)	19 (46)	22 (54)	31 (76)	10 (24)		20 (49)	21 (51)
Yes	30 (42)	12 (40)	18 (60)	12 (40)	18 (60)		15 (50)	15 (50)
Information about the risks of the app usage (100)			0.224			0.014		0.005
No	58 (58)	32 (55)	26 (45)	44 (76)	14 (24)		22 (38)	36 (62)
Yes	42 (42)	18 (43)	24 (57)	22 (52)	20 (48)		28 (67)	14 (33)
Existence of an ethical chart (100)			.			.		.
No	99 (99)	49 (49)	50 (51)	66 (67)	33 (33)		50 (51)	49 (49)
Yes	1 (1)	1 (100)	0 (0)	0 (0)	1 (100)		0 (0)	1 (100)
If iOS, can the app connect with HealthKit? (50)			0.462 *			.		.
No	41 (82)	19 (46)	22 (54)	27 (66)	14 (34)	.	41 (100)	
Yes	9 (18)	6 (67)	3 (33)	9 (100)	0 (0)	.	9 (100)	
In app advertisement (100)			$<10^{-3}$			0.228 *		0.140
No	87 (87)	39 (45)	48 (55)	55 (63)	32 (37)		41 (47)	46 (53)
Yes	13 (13)	11 (85)	2 (15)	11 (85)	2 (15)		9 (69)	4 (31)

* with Yates correction, C: Consumers, HP: Healthcare Professionals

We did not find a significant difference between target users of Android vs. iOS apps, none of the two major markets is oriented more towards consumers or healthcare professionals.

Seventy apps presented a means of contacting the owner via email. There was no significant difference between free and paid apps, between those addressed to consumers vs. healthcare professionals, or between the two platforms. 26% of selected apps provide a hotline to address users' potential queries. There was a significant difference ($p < 0.009$) between free and paid apps: free apps provide more hotline services than paid ones.

More than half of the apps did not provide general terms and conditions of use. We found no substantial difference in availability between Android/iOS apps or between consumer-targeted/healthcare-professional-targeted ones. However, a larger amount of free applications offer general terms and conditions in juxtaposition with paid apps ($p<0.016$). This phenomenon occurs once again with the availability of privacy policies. Free apps include privacy policies more frequently than paid apps ($p<0.001$).

Only 59% of the apps collecting user health data require the explicit consent of their users pre-collection, and free apps were once again superior ($p<0.001$). No difference was found when we compared the two major platforms and target users.

There was only one app that boasted an ethical chart. This app was free, meant for healthcare professionals, and available in the Top 25 of both the Google Play and App stores (in compliance with the aforementioned selection criteria we studied the iOS version).

Seventeen disparate use cases were discovered in the 100 analyzed apps according to the Yasini and Marchand Model[3]. Six use cases were related to health professionals and eleven to consumers. We discovered 226 use cases in these apps, meaning that the average number of use cases provided by each app is 2.26. Table 2 illustrates the various uses cases and their frequency in the selected apps.

Table 2. Frequency of various uses cases in the top apps of the two major US stores.

Use Cases	number	%
C. Calculate and/or interpret data	30	13,3
C. Communicate/share information, social network	7	3,1
C. Database (drug, image, nutrition...)	21	9,3
C. Diagnostic/measurement tool	12	5,3
C. Health news	4	1,8
C. Information/Scientific popularization/Therapeutic patient education	19	8,4
C. Interaction with a health institution (Scheduling an appointment, Drug ordering...)	17	7,5
C. Locating a health service	18	8,0
C. Looking for information on health professionals/institutions	10	4,4
C. Tracking a physiopathological state	29	12,8
C. Treatment reminder/Managing the drug stock	6	2,7
HP. Clinical cases/serious gaming/Reviewing previously given exams	8	3,5
HP. Database (drug, image, bibliography...)	22	9,7
HP. Decision support system, calculate and/or interpret data	3	1,3
HP. Diagnostic/measurement tool	1	0,4
HP. Managing professional activities (searching for job offers, calculating the fees...)	1	0,4
HP. Text book, journal, guidelines and synthesis of medical knowledge	18	8,0
Total	226	100

C: Consumers, HP: Healthcare Professionals

We were able to classify the chosen apps in 27 subject groups, of which 15 were consumer-oriented and 12 targeted health professionals. For consumer-targeted applications the most well-covered subject was general health status (29%), most often exhibited by apps attempting to centralize all patient data in order to provide a comprehensive synthesis of such. We also noted that an integral portion of consumer apps (18%) focused upon women's health issues such as menstrual cycles and pregnancy concerns. The subject of eight apps (12%) was managing the use and cost optimization of medications.

For apps directed towards healthcare professionals, atlases of anatomy dominated (26%). Second place was held by applications that could be harnessed by professionals of all medical specialties (20%) (e.g. drug databases). 17% of apps specifically for healthcare workers dealt with emergency medicine, and 11% of apps were created to aid students' exam preparation. Figure 1 portrays the various subjects and their relative frequency.
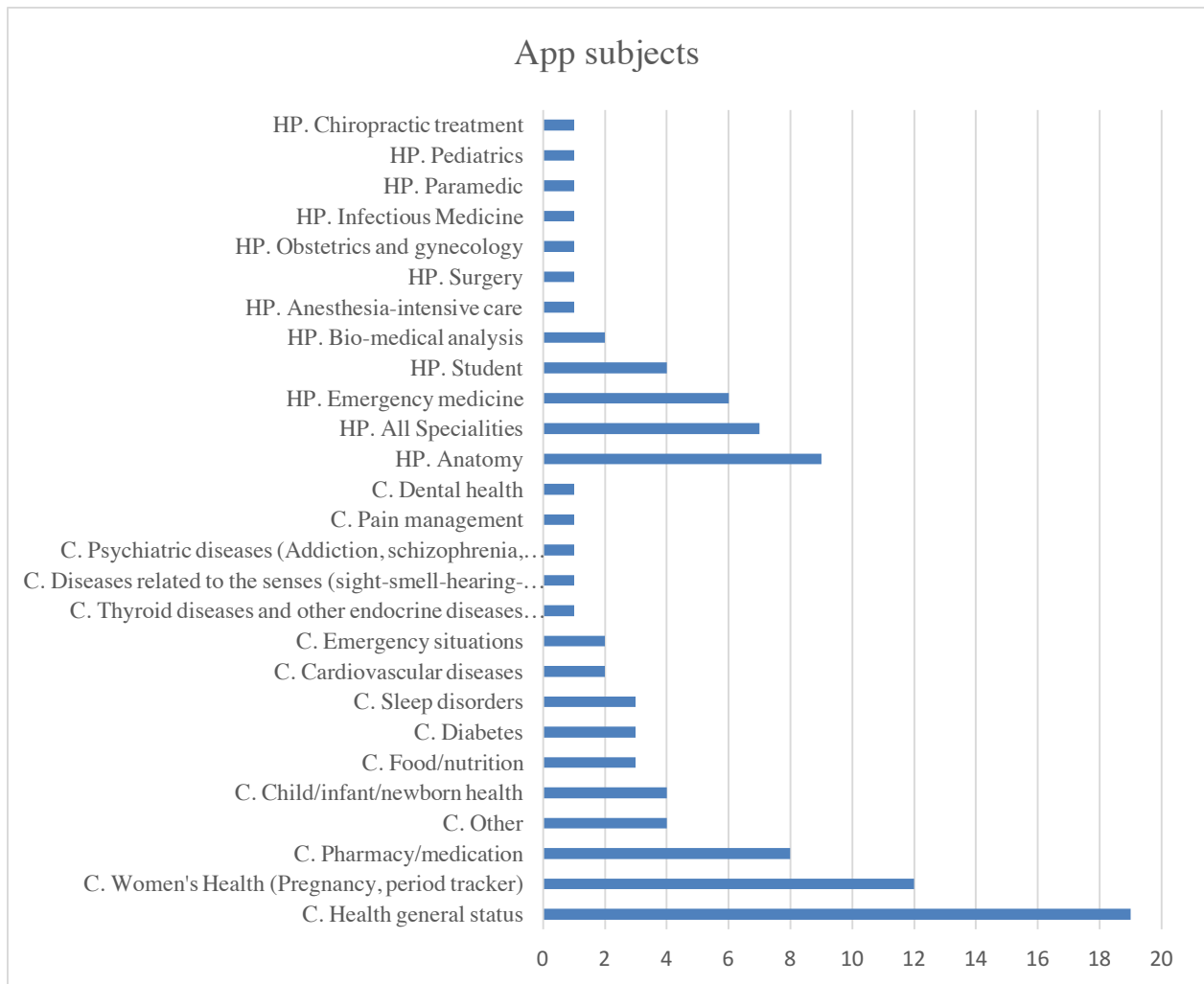
Figure 1. Distributions of applications in different subjects. (HP: Healthcare Professionals, C: Consumers)

Discussion

In this study, we analyzed 100 US mHealth applications available in the medical category of the Google Play store and Apple's iOS App Store. We described some of the characteristics of these apps including the app's target user, the app provider, presence of a physician in the core team of the company owning the app, providing the content sources when relevant, and providing terms and conditions of use and privacy policy. We also extracted the subjects they dealt with and their various use cases.

Although we have only analyzed the apps in the medical category, we have excluded three apps because of non-relevant topic to medicine. One of these apps was a music app and two others were games (that were not considered as serious medical related games). This shows that even in the top-rated apps in the market stores, some apps are not well categorized.

Contrary to our impression, paid apps did not provide a more qualified profile compared to free apps based on the evaluated criteria. This may be explained by the fact that mobile apps are often used by providers as another marketing tool to create loyal users. mHealth market is still in the phase that the app providers want to build their brand image and get their name out. Therefore, most of the providers select free apps to increase the download rate and potentially provide more qualified apps to keep their users continually.

Various mHealth apps collect and offer critical and private patient data. The data may be entered directly by the user, collected with the built-in features of the smart device (e.g., camera, microphone), an external sensor, or a connected device (e.g., connected thermometer). These data need a special focus on information security and privacy of mHealth

apps. Potential damage to users through information security and privacy infringements have been discussed in various studies[20–22]. Our study shows that still about half of the analyzed apps do not provide terms and conditions of use or privacy policy. The situation becomes more dramatic when we consider that the analyzed apps come from the top of the App Stores.

The involvement of healthcare professionals in mHealth apps development processes is another important criterion that ensures the reliability of health information[17,23,24]. This study showed that 61% of the studied apps were produced with the participation of a health professional in the core team of the app owner. Other studies in the literature reported the rate of this involvement between 12.8 % to 48% of analyzed apps[20,24]. Although in our sample of apps we found a higher rate of professional involvement in the development of the apps, this is not yet satisfying particularly for the top listed apps of the App Stores.

It is critical that medical applications provide content that are accurate and reliable[25] because patients and healthcare professionals can make critical decisions based on information provided by an app. We did not find the content source for 44% of apps that provide medical information to their target users. When mHealth apps disseminate medical information, which was the case for 71% of the analyzed apps, the information must be developed on the basis of reliable information resources and references. This study showed that 44% of these apps did not mention their sources. This lack of transparency of the apps about the sources is in line with other studies in the literature who call in to question the adherence of the apps to established guidelines[20,24,25].

None of the studied apps could be considered as a medical device according to FDA classification[19]. However, half of these apps were considered as borderline apps (group B). The need for regulating the apps is a real challenge of today's mHealth market. The percentage of apps that resort to FDA authorization or other existing certifications (like European CE for medical devices) is too low. This shows that the market is not yet enough mature to the assessment and certification processes.

Various apps were multifunctional and provided various use cases in different medical fields. This indicates that the iOS and Android App Stores offer a wide selection of mHealth apps with a real diversity of usages that makes mobile devices ready to do almost everything in every medical specialty. However, this diversity prevents a "one size fits all" approach to ensuring the quality of these apps and information security[18,21].

One of the limitations of our study was the number of studied apps. The top-rated apps in the App Stores are based on the five-star rating that the users provide, number of downloads and some other criteria. However, the number of downloads may differ according to the target users of the apps (an app for diabetic patients may be downloaded more than an app that is addressed to the patients affected with a rare disease) and the five-star rating is not a reliable assessment system[17,26]. In this study, we have selected all the studied apps from US App Stores. Further research with a multi country design and a more important number of apps to analyze is the real solution to validate these results.

Conclusion

mHealth apps could provide seamless access to adapted and context oriented health information and have the potential to decrease global health burdens. However, despite these promising potentials, there are some barriers and risks that prevent the users to trust mHealth apps. Recognizing these elements by all the stakeholders including app providers, app stores and users may lead to removal of these risks step by step. We are faced with a plethora and diversity of available mHealth apps. Therefore, implications for assuring the quality, security and privacy seem to be unclear and complex. Our study shows that the current situation of mHealth apps in general is not yet enough mature to be used widely and recommended by health professionals in the US market. Further research and development efforts are required to facilitate the wide range integration of mHealth apps in the real clinical pathways. These efforts could be designed in various axes including disseminating related guidelines for the users or app developers, implementing regulatory certification programs, designing adapted studies to reveal clinical evidence of mHealth apps considering the fast-paced nature of technology, and educating and encouraging app providers to protect their apps from information security and privacy and to test the usability and ergonomic aspects of their apps. Taking the right strategies in the future will help to benefit from the potential of mHealth apps to transform and improve the health care ecosystem and limit the barriers and risks.

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