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Evaluation of Mobile Health Applications Developed by a Tertiary Hospital as a Tool for Quality Improvement Breakthrough

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Objectives: To evaluate the mobile health applications (apps) developed by a single tertiary hospital in Korea with a particular focus on quality and patient safety. **Methods:** Twenty-three mobile health apps developed by Asan Medical Center were selected for analysis after exclusion of the apps without any relationship with healthcare or clinical workflow, the apps for individual usage, and the mobile Web apps. Two clinical informaticians independently evaluated the apps with respect to the six aims for quality improvement suggested by the United States Institute of Medicine. All discrepancies were resolved after discussion by the two reviewers. The six aims observed in the apps were reviewed and compared by target users. **Results:** Eleven apps targeted patients, the other 12 were designed for healthcare providers. Among the apps for patients, one app also had functions for healthcare providers. 'My cancer diary' and 'My chart in my hand' apps matched all the six aims. Of the six aims, *Timeliness* was the most frequently observed (20 apps), and *Equity* was the least observed (6 apps). *Timeliness* (10/11 vs. 10/12) and *Patient safety* (10/11 vs. 9/12) were frequently observed in both groups. In the apps for patients, *Patient-centeredness* (10/11 vs. 2/12) and *Equity* (6/11 vs. 0/12) were more frequent but *Efficiency* (5/11 vs. 10/12) was less frequent. **Conclusions:** Most of the six aims were observed in the apps, but the extent of coverage varied. Further studies, evaluating the extent to which they improve quality are needed.

Keywords: Mobile Health, Telemedicine, Quality Improvement, Patient Safety, Patient-Centered Care

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I. Introduction

Ubiquitous health (u-health) aims to provide innovative healthcare services that are consumer-oriented, customized, and accessible anytime, anywhere by ubiquitous computing [1]. More than 10 years have passed since the concept of u-health was proposed in Korea [1]. Despite very high expectations, u-health still is in its very early stages, in part because its clinical effectiveness has not been clearly demonstrated [1,2]. It is also struggling in Korea in part because of the complex debates about telemedicine. However, electronic health (e-health), a concept that is similar to u-health, which utilizes information systems by applying them to existing healthcare practices to improve the productivity of the work of the health service provider [1], has been growing in Europe and the United States even though issues regarding its clinical effectiveness have not yet been resolved [3-7]. The e-health market has grown rapidly, especially after the emergence of mobile health (m-health) in 2009 [3-5,7-10]. m-Health services using both wearable devices and smartphones are also expanding [11-13].

m-Health provides innovative healthcare services by using the unique characteristics of the smartphone such as mobility, connectivity, accessibility, and the capacity to gather and transmit data [9-14], so it is considered a subtype of u-health in Korea [1,2]. Diverse u-health devices, including wearable devices, can be connected to smartphones, and sometimes the smartphone itself can be used as a u-health device [15,16]. m-Health services and trials using smartphone sensors, such as cameras, accelerometers, and pedometers, are frequent now [13,17,18].

Despite this rapid growth, challenges remain which must be addressed if m-health is to result in the hoped-for changes [3,8,12]. According to Dr. Joseph Kvedar, Director of the Center for Connected Health of Partners Healthcare, one in ten U.S. patients has used a health tracker, but the majority stop using it within six weeks, and for m-health applications (apps), 80% are abandoned after only two weeks [19]. Several studies have suggested key features that encourage users to be more likely to continuously use such apps, but most trackers and apps have little impact, and more research is needed [19-21]. m-Health must also be connected to personal health records or Electronic Health Records to provide a continuous care model and to improve patient outcomes [8], but such connectivity and interoperability remain major issues. The Apple HealthKit and ResearchKit have the potential to be breakthrough technologies in this area [22]. Another big challenge is determining the clinical effectiveness of m-health. Whether the use of m-health can improve patient outcomes must be determined [2,3,5,6,8,23]. Like telemedicine cases, not all m-health services can achieve this goal [3,24]. The common features of m-health that impact its outcomes must be researched [8]. Therefore, well-designed clinical trials and meta-analyses are required to definitively determine the effectiveness of m-health [3,6,8]. Healthcare organizations in Korea have also developed many m-health apps and have provided m-health services [9,25]. However, few outcomes research studies have been done in this area. The six aims for quality improvement of the Institute of Medicine (IOM) in the United States can be applied to evaluating the benefits of m-health apps [26]. In 2001 the IOM recommended that "health care should be supported by systems that are carefully and consciously designed to produce care that is safe, effective, patient-centered, timely, efficient, and equitable" and "health information technology (HIT) must play a critical role to achieve the six aims [26]." Some studies reviewed HIT applications with respect to the six aims to evaluate their benefits and impacts [27,28].

Asan Medical Center in Seoul, Korea, has developed more than 20 m-health apps since 2010. Because no other hospital in Korea has developed as many m-health apps as our hospital has, we evaluated the m-health apps developed by our hospital with a particular focus on the IOM's six aims with the intention of sharing our findings.

II. Methods

The information about the launch date, the date of the final update, and installed data for the apps was collected from the mobile apps server or hospital information system server with cooperation of the Ubiquitous Health Center in the hospital. We collected the information about the apps from the day of distribution of the app until December 31, 2014. The Institutional Review Board approved our study protocol.

1. App Selection and Categorization

Mobile apps developed by Asan Medical Center or in which there was a leading role of the hospital in the initial request were reviewed retrospectively. After excluding the apps with no relationship to healthcare or clinical workflow and the apps designed for individual usage, 23 apps were chosen for the final analysis. These 23 apps were categorized based on their target users (i.e., healthcare providers or patients) and their range of distribution (i.e., open to public or closed for in-hospital use) (Figure 1). We divided the apps into two groups, according to the target user of the apps. In addition, the functions of the apps and the implementations of the six aims of the apps in each group were evaluated and compared.

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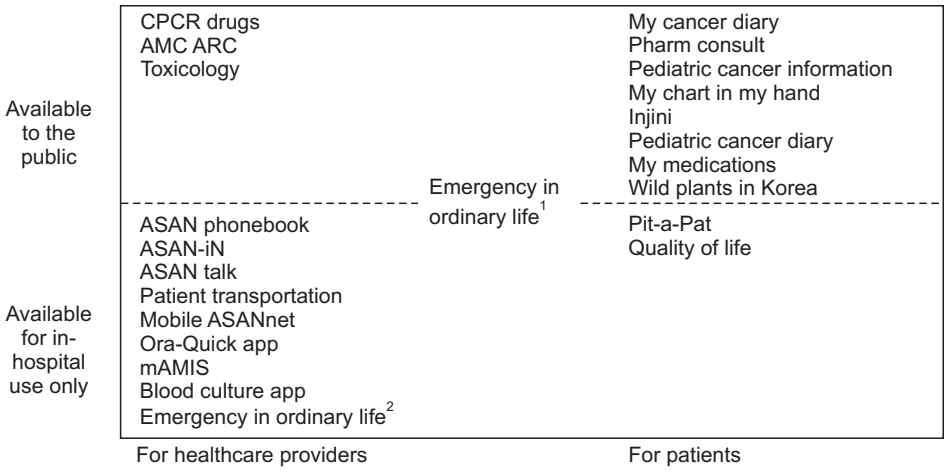

Figure 1. Categorization of the 23 apps selected for analysis. The x-axis represents the target users, and the y-axis represents the range of distribution (Emergency in ordinary life[1]: emergency in ordinary life for patients, emergency in ordinary life[2]: emergency in ordinary life for clinicians).

2. The Six Aims for Quality Improvement

The functions and purposes of the apps were reviewed based on the six aims. The six aims selected by the IOM include the following:

1) Patient-centeredness: Providing care that is respectful of and responsive to individuals (i.e., apps for providing medical/health information to patients themselves, providing patients' authority to decide),

2) Effectiveness: Providing services based on scientific knowledge to all who could benefit, and refraining from providing services to those not likely to benefit (i.e., apps for verifying clinical guidelines and clinical information with evidence, apps for practice based on evidence, apps for clinical trials to make evidence),

3) Patient safety: Avoiding injuries to patients from the care that is intended to help them (i.e. apps for prevention, monitoring, and early detection of harmful events in the field of healthcare),

4) Timeliness: Reducing waits and sometimes harmful delays for both those who receive and those who give care (i.e., apps for providing information without limitations of place and/or time, bedside access to health information),

5) Efficiency: Avoiding waste, including waste of equipment, supplies, ideas, and energy (i.e., apps for fast and precise transmission of health information in clinical workflow to achieve good decision-making, apps for reducing cost, unnecessary processes and manpower),

6) Equity: Providing care that does not vary in quality because of personal characteristics, such as gender, ethnicity, geographic location, and socioeconomic status (i.e., apps for vulnerable population; the disabled, patients with chronic diseases, patients with mental diseases, pediatric patients, maternity patients, and the elderly).

3. Evaluation Questionnaires for the Apps

Using questionnaires, the 23 apps were reviewed to assess their operating system, target user, necessity of log-in, and user supporting method. These questionnaires, and the categories they included, were prepared by two clinicians who specialize in clinical informatics. Both clinicians designed the questionnaires and independently reviewed them. After the forms were filled out, the two reviewers discussed the results of each app and resolved all discrepancies.

III. Results

Table 1 presents the overall characteristics of the selected 23 apps. Eleven of the 23 apps were designed for use by patients and the general population, 12 targeted healthcare providers as users. Among the apps for patients, one app also had functions for healthcare providers. Figure 2 lists the number of users of each app. As expected, the public apps had more users.

The frequency that the 23 apps involved the six aims is described in Table 2. 'My chart in my hand' and 'My cancer diary' were matched for all the six aims. The specific functions or purposes of the apps correlate with the six aims as follows:

1) Patient-centeredness: 'My chart in my hand' and 'Pediatric cancer diary' provide medical data to patients and promote self-management by recording and analyzing personal health data (i.e., body weight, blood sugar level, and blood pressure level). 'Pharm consult' provides e-mail-based consultation for proper drug use and management of drug side effects. 'mAMIS' can help physicians show and explain the patient's information at the patient's bedside.

2) Effectiveness: Apps such as 'ASAN-in', 'Toxicology', and 'Emergency in ordinary life' provide evidence-based information to clinicians and/or patients. 'Pit-a-Pat', 'Quality of life', and 'Injini' are apps for clinical studies to build evidence.

Table 1. Characteristics of the 23 mobile apps analyzed, which were developed or released by Asan Medical Center (AMC)

Target user	Application name	OS	Date of distribution	Final update[a]	Range of distribution	Log-in	User count[b] (no.)	User supporting function	Brief introduction or purpose
Patients	My medications	iOS	Jan 2010	Feb 2011	Public	No	79,391	None	Information about medications
	My chart in my hand	Android	Dec 2010	Jun 2015	Public	Yes	13,017	In-app support	Mobile PHR/OPD reservation
	Pharm consult	iOS	Jan 2011	Jun 2011	Public	No	17,824	E-mail	E-mail consultation for medications and side-effects
	Wild plants in Korea	iOS	Feb 2011	Aug 2011	Public	No	20,737	None	Information about wild plants in Korea
	Pediatric cancer diary	Both	Jun 2011	Nov 2012	Public	Yes	-	None	Mobile PHR for pediatric cancer patients
	Injini	iOS	Nov 2011	Jun 2014	Public	No	-	None	To improve cognitive function using a game, for toddlers
	Quality of life	Both	Feb 2012	Sep 2014	In-hospital	No	-	None	Survey of quality of life in cancer patients
	My cancer diary	Both	May 2012	Apr 2013	Public	Yes	9,436	E-mail	Mobile PHR for cancer patients
	Pediatric cancer information	iOS	Jun 2012	-	Public	Yes	-	None	Information about pediatric cancer
	Pit-a-Pat	Both	Aug 2012	Sep 2014	In-hospital	Yes	90	E-mail	Management of breast cancer patients
Both	Emergency in ordinary life[1]	Both	Jan 2012	Apr 2013	Public	No	2,595	In-app support	Information for patients to visit an emergency room
Healthcare providers	ASAN phonebook	iOS	Jan 2010	End of service	In-hospital	Yes	1,784	None	Contact information for staff/direct messaging
	CPCR drugs	iOS	May 2010	-	Public	No	3,610	None	Information about drugs for advanced cardiac life support
	Toxicology	iOS	Aug 2010	Jan 2011	Public	No	9,368	None	Information about toxins, toxidromes, antidotes
	mAMIS	Both	Dec 2010	Sep 2014	In-hospital	Yes	5,087	In-app support	Mobile EMR
	ASAN-in	iOS	Dec 2010	End of service	In-hospital	Yes	1,720	In-app support	Knowledge sharing: policies, guidelines, and education
	Emergency in ordinary life[2]	Both	Jan 2012	-	In-hospital	Yes	-	In-app support	Management of patients in the emergency room
	Blood culture app	Android	Mar 2012	Feb 201	In-hospital	Yes	407	In-app support	To assist in performing the correct method of blood culture
	Mobile ASANnet	iOS	Jun 2012	Sep 2014	In-hospital	Yes	-	None	Mobile groupware service
	ASAN talk	Both	Sep 2012	End of service	In-hospital	Yes	-	None	Communication tool for staff at the AMC
	Ora-Quick app	Android	Sep 2013	-	In-hospital	Yes	-	None	Point-of-care HIV screening units with a barcode reader
	AMC ARC	Both	Jul 2014	-	Public	Yes	1,235	None	Communication tool for the AMC referral center
	Patient transportation	Both	Jul 2014	-	In-hospital	Yes	142	None	To assign and to check the state of patient transportation

OS: operating system, PHR: personal health record, OPD: outpatient department, EMR: Electronic Medical Record, HIV: human immunodeficiency virus.

[a]Final update: the date of latest version, checked on June 28, 2015. [b]User count: accumulated count of users, assembled from the day of distribution to December 31, 2014. [c]Emergency in ordinary life[1]: emergency in ordinary life for patients. Emergency in ordinary life[2]: emergency in ordinary life for clinicians.

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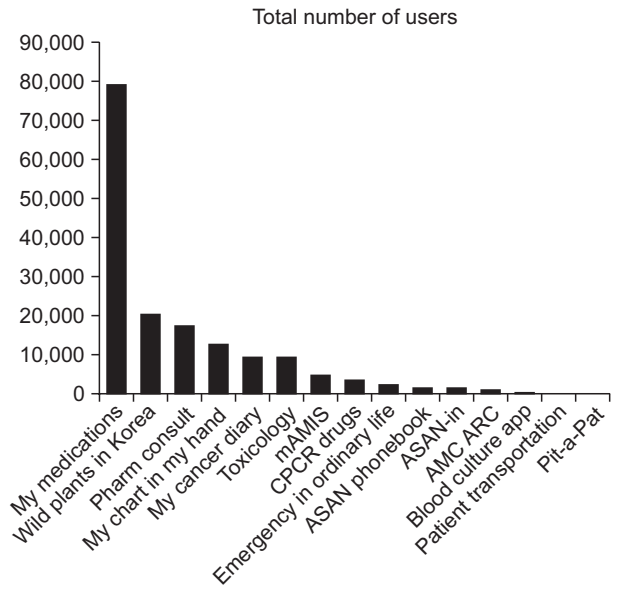

Figure 2. Accumulated count of users from the day of distribution to December 31, 2014.

3) Patient safety: 'Wild plants in Korea' and 'My medications' are apps to prevent hazards encountered in daily life, and 'Ora-Quick' and 'Blood culture' prevent hazards in the clinical field. 'mAMIS', 'CPCR drugs', and 'Pediatric cancer diary' assist in the early detection and/or rapid management of hazardous events.

4) Timeliness: 'm-AMIS' and 'My chart in my hand' provide access to patients' information independent of space and time. 'My medication' and 'My cancer diary' provide health information or support at the patient's bedside.

5) Efficiency: Apps such as 'AMC ARC', 'ASANnet', and 'ASAN talk' promote efficient networking and communication between healthcare providers. 'Emergency in ordinary life' and 'Patient transportation' help to create an efficient clinical workflow.

6) Equity: 'Pediatric cancer diary', 'My chart in my hand', and 'Injini' provide care for vulnerable populations, such as cancer patients, pediatric patients, children with cognitive disorder or patients with chronic diseases.

The frequency of overlap with the functions of apps and the six aims present different dispositions according to the target user (Table 3) and the range of distribution (Figure 3). *Timeliness* (10 apps out of 11 patients-targeted apps vs. 10 out of 12 healthcare provider-targeted apps) and *Patient safety* (10/11 vs. 9/12) were frequently observed in both groups and evenly distributed. The remaining aims showed differences between patient-targeted apps and healthcare provider-targeted apps. In the apps for patients, *Patient-centeredness* (10/11 vs. 2/12) and *Equity* (6/11 vs. 0/12) were more frequent, but *Efficiency* (5/11 vs. 10/12) was less frequent. All the apps matched with *Equity*, and all the apps except two that matched with *Patient-centeredness* were for patients. In contrast, the apps corresponding to *Efficiency* were predominantly those for healthcare providers. There was no *Equity*-matched app for healthcare providers.

IV. Discussion

It was clear that many apps for healthcare address a number of the key quality aims. For example, *Timeless* was predominant due to the nature of smartphones, which offer accessibility and mobility. Desktop-based programs has a lot of limitations in terms of *timeless*. *Patient safety* was well implemented in both groups. This implies that m-health can be beneficial in the quality aims. Most patient-targeted apps covered *Equity* and *Patient-centeredness*. Most apps for healthcare providers satisfied *Efficiency*. Interestingly, there was no app for healthcare providers that satisfies all of the six aims, in contrast with the apps for patients, such as 'My cancer diary' and 'My chart in my hand.' In addition, *Equity* was not matched for any app for healthcare providers. This reminds us to be aware of vulnerable populations when developing an app, even for healthcare providers [29].

There were some limitations of this study. First, the questionnaires used to assess the apps were evaluated by two clinicians. Since one of the clinicians participated in the development of the apps, any matches between the apps and the six aims might be biased. Also, the other clinician had limited ability to evaluate some apps which ended their services. Therefore, further evaluation of apps is necessary, focusing on currently in-service apps. For more objective and precise evaluation of healthcare-related apps in the future, the assessment of the six aims should be performed by experts uninvolved in their development and should encompass patients who are currently using the apps. Second, we found a disparity in the number of users in accordance with the range of distribution and/or the date of launch. In addition, the number of users who installed an app does not necessarily correlate with the level of usage. Since the extent of usage or the activity of apps is difficult to evaluate precisely, more advanced measures should be developed.

In this study, most of the apps designed for patients provide health information or patient medical information and satisfy *Patient-centeredness*. These apps are also a good tool for gathering health information from patients. Unfortunately, the user data collected in this way have not been actively applied to clinical use until now. However, the patients' generated data in clinical apps, with the merits of *Timeliness* and *Effectiveness*, would promote user interaction. In addition,

Table 2. Compatibility of the mobile apps developed at Asan Medical Center with the six aims for quality improvement

Target user	Application name	Patient-centeredness	Effectiveness	Patient safety	Timeliness	Efficiency	Equity
Patients	Injini		●			●	●
	My cancer diary	●	●	●	●	●	●
	My chart in my hand	●	●	●	●	●	●
	My medications	●		●	●		
	Pediatric cancer diary	●		●	●	●	●
	Pediatric cancer information	●		●	●		●
	Pharm consult	●	●	●	●		
	Pit-a-Pat	●	●	●	●		●
	Quality of life	●	●		●	●	
	Wild plants in Korea	●		●	●		
Both	Emergency in ordinary life[1]	●	●	●	●		
Healthcare providers	AMC ARC			●		●	
	ASAN phonebook				●	●	
	ASAN talk				●	●	
	ASAN-in		●	●	●	●	
	Blood culture			●	●	●	
	CPCR drugs		●	●	●		
	Emergency in ordinary life[2]	●	●	●	●	●	
	m-AMIS	●	●	●	●	●	
	Mobile ASANnet					●	
	Ora-Quick			●	●	●	
	Patient transportation			●	●	●	
	Toxicology		●	●	●		
Count		12	12	18	20	15	6

Emergency in ordinary life[1]: emergency in ordinary life for patients, Emergency in ordinary life[2]: emergency in ordinary life for clinicians

Table 3. Apps that have functions or purposes that are compatible with the six aims according to the target user

Aims	For patients (n = 11)	For healthcare providers (n = 12)	Total (n = 23)
Patient-centeredness	10 (90.9)	2 (16.7)	12 (52.2)
Effectiveness	7 (63.6)	5 (41.7)	12 (52.2)
Patient safety	9 (81.8)	9 (75.0)	18 (78.3)
Timeliness	10 (90.9)	10 (83.3)	20 (87.0)
Efficiency	5 (45.5)	10 (83.3)	15 (65.2)
Equity	6 (54.5)	0 (0)	6 (26.1)
Total	47 (71.2)	36 (50.0)	83 (60.1)

Values are presented as number (%).

tailored treatments acquired through user interactions with these healthcare apps would contribute to better *Patient-centeredness* and *Patient safety*. Therefore, the evaluation of an individual app is essential for efficient management and continual improvement of the app.

In conclusion, although this study was performed using the apps developed by a single tertiary hospital in Korea, the evaluation results demonstrate the enormous potential of m-health apps as important tools to achieve breakthrough of quality improvement. To achieve this breakthrough, there should be much more study to improve m-health apps.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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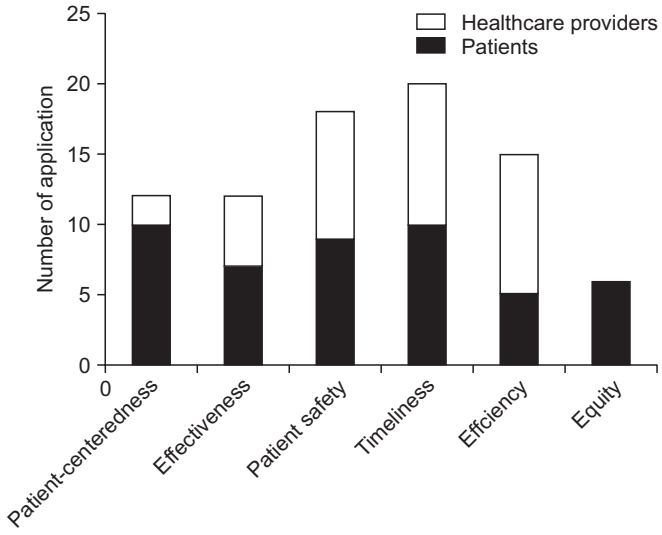

Figure 3. Numbers of applications that have functions or purposes that are compatible with the six aims according to the target user.

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