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Benefits of Information Technology in Healthcare: Artificial Intelligence, Internet of Things, and Personal Health Records

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Objectives: Systematic evaluations of the benefits of health information technology (HIT) play an essential role in enhancing healthcare quality by improving outcomes. However, there is limited empirical evidence regarding the benefits of IT adoption in healthcare settings. This study aimed to review the benefits of artificial intelligence (AI), the internet of things (IoT), and personal health records (PHR), based on scientific evidence. **Methods:** The literature published in peer-reviewed journals between 2016 and 2022 was searched for systematic reviews and meta-analysis studies using the PubMed, Cochrane, and Embase databases. Manual searches were also performed using the reference lists of systematic reviews and eligible studies from major health informatics journals. The benefits of each HIT were assessed from multiple perspectives across four outcome domains. **Results:** Twenty-four systematic review or meta-analysis studies on AI, IoT, and PHR were identified. The benefits of each HIT were assessed and summarized from a multifaceted perspective, focusing on four outcome domains: clinical, psycho-behavioral, managerial, and socioeconomic. The benefits varied depending on the nature of each type of HIT and the diseases to which they were applied. **Conclusions:** Overall, our review indicates that AI and PHR can positively impact clinical outcomes, while IoT holds potential for improving managerial efficiency. Despite ongoing research into the benefits of health IT in line with advances in healthcare, the existing evidence is limited in both volume and scope. The findings of our study can help identify areas for further investigation.

Keywords: Medical Informatics, Artificial Intelligence, Internet of Things, Personal Health Records, Review

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I. Introduction

The healthcare sector is increasingly recognized as an industry well-suited for the future, particularly in the era of hyperconnectivity where cutting-edge information technologies can be applied. However, there is limited empirical evidence regarding the benefits of these information technologies in healthcare settings. Therefore, it is crucial to systematically evaluate the advantages of health information technology (HIT) to ensure that these efforts will help enhance the quality of healthcare by improving outcomes.

The present study aims to summarize several cases where information technology has been applied in healthcare and to review the published systematic reviews and meta-analyses on the benefits of HIT. The scope of this review focuses on three HITs: artificial intelligence (AI), the Internet of Things (IoT), and personal health records (PHR). These were identified as priority areas of high significance and immediacy within the realm of technology development in a previous Delphi study [1].

1. Areas of Focus in this Study on HIT

1) Artificial intelligence

AI technology is expected not only to contribute to providing personalized healthcare based on patient-centered big data systems, but also to enable the more efficient use of medical resources. With the aging of the global population and the increasing prevalence of chronic diseases, combined with the paradigm shift toward patient-centered care, it is becoming increasingly important to predict diseases based on symptoms and risk factors and effectively manage chronic diseases. In addition, given the shift toward personalized healthcare [2], AI technologies may help predict and prevent diseases using patient-centered big data systems. This would facilitate accurate disease diagnoses and the recommendation of the most effective treatment [3].

Since AI is capable of automating repetitive, daily medical tasks, it has a high potential for applications in a wide range of healthcare settings, including patient and resource management. As such, this technology will be rapidly adopted in the healthcare sector and play an important role in improving managerial efficiency [4].

2) Internet of Things

The use of IoT has been widely promoted in various industries, such as home appliances and automobiles. Medical devices, in particular, have been recognized as an area where IoT can be employed particularly effectively and have a greater impact on our daily lives. Its applications in the medical field are as follows [5].

- Home healthcare: Monitoring using sensors (detecting falls, seizures, or the risk of pressure ulcers).
- m-Health solutions: Monitoring using various types of sensors linked to smartphones.
- e-Health: Medical services connected to the internet to perform various remote medical services (remote monitoring, remote consulting, robot-aided surgery, etc.).
- Hospital management: Logistics supply chain management, remote patient monitoring, and drug identification monitoring.

The healthcare sector has been progressively incorporating IoT technology. This technology aids patients in managing their health more effectively, enables providers to improve service quality, decreases costs, and boosts the efficiency of hospital resource management. For patients, the implementation of IoT solutions can increase satisfaction and promote adherence to self-care principles, which are intended to facilitate improved self-management. For service providers, systems based on IoT technology can allow the monitoring of patients who require constant care and attention, thereby increasing the overall standard of healthcare [6,7]. Furthermore, this technology can introduce novel strategies for resource management in healthcare organizations, leading to cost reductions [8].

3) Personal health records

The Markle Foundation's Connecting for Health [9] defines PHR as an electronic application through which individuals can access, manage, and share their health information, and that of others for whom they are authorized, in a private, secure, and confidential environment. With the healthcare paradigm shift from diagnosis and treatment to prevention and management, the role of PHR is expected to expand to personalized health maintenance services and chronic disease management. Three general types of PHR exist: standalone PHR, electronic medical record (EMR)-tethered PHR, and interconnected PHR. OF these, the EMR-tethered PHR, which is connected with a hospital's EMR, is most widely used.

For this study, we first summarized HIT use, which is expected to create greater synergy with regard to prediction, diagnosis, health maintenance, and organizational management. We reviewed the benefits reported in previous studies from diverse perspectives across four outcome domains: clinical, psycho-behavioral, managerial, and socioeconomic. For the clinical domain, specific evaluation tools included patient outcomes such as detection of drug-adverse effects, mortality, length of hospital stay, readmission rates, and safety. In the psycho-behavioral domain, user acceptance and satisfaction were used as evaluation tools. The managerial domain was assessed through managerial efficiency, while the socioeconomic domain was evaluated based on cost reduction.

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II. Methods

1. Search Strategy

We searched the PubMed, Cochrane, and Embase databases for systematic review and meta-analysis studies published in peer-reviewed journals between 2016 and 2022. The combination keywords used in searching the databases were as follows: artificial intelligence, Internet of Things, personal health records, patient portals, personal health, and hospitals. Fifty publications in the AI, 10 in the IoT, and 39 in the PHR were initially identified as potentially eligible studies for full-text screening. In addition, we manually searched reference lists from systematic reviews, eligible studies, and publications from major journals. The benefits of each HIT were then assessed, and the results were summarized.

2. Study Selection

Our search found 18 meta-analysis studies on AI, all of which discussed the clinical effectiveness of technologies in the realm of disease prediction and diagnosis. Seven of these studies [10-15] focused on tumor diagnosis, specifically of the stomach, intestine, thyroid, brain, lung, and ovary. Two studies [16,17] were centered on the diagnosis of eye diseases, namely diabetic retinopathy, and retinal vascular disease. Another two studies focused on the diagnosis and prognosis of kidney disease [18,19], while one study examined the diagnosis of coronary artery disease [20]. The remaining six studies investigated heart failure [21], sepsis [22], pneumonia [23], intrapartum fetal heart rate [24], trauma [25], and mood disorders [26]. In addition to these, we found two systematic reviews that analyzed the utility of IoT. One paper explored the application of IoT solutions for health management [27], while the other assessed how IoT has enhanced the quality of services [28]. These studies evaluated the effectiveness of IoT from clinical, managerial, and socioeconomic viewpoints. We identified four systematic reviews on PHR [29-32]. The specific conditions examined in these studies included diabetes mellitus, various chronic diseases, and vaccination. Each of the four papers investigated both clinical and psycho-behavioral effectiveness.

III. Results

In this section, we present findings on the benefits of AI, IoT, and PHR from clinical, psycho-behavioral, managerial, and socioeconomic perspectives. We also summarize the key findings in Table 1.

1. Artificial Intelligence

1) Clinical effects

(1) Accuracy of disease diagnosis

The diagnostic performance of AI, in comparison to healthcare professionals and existing diagnostic methods, is summarized below. In seven out of 12 areas, AI diagnosis demonstrated superior diagnostic accuracy to the existing methods (Table 2). The diagnostic accuracy of AI was compared to that of healthcare professionals in ten areas. In six of these areas—gastric lesions, retinal vessels (STRARE, CHASEDB1 dataset), and thyroid nodules—AI showed higher diagnostic accuracy. For ovarian cancer, the diagnostic accuracy of AI was comparable. However, in the remaining three areas—colon polyps, brain tumors, and retinal vessels (DRIVE dataset)—no significant difference in accuracy was observed. One study that compared the diagnostic accuracy of AI with existing methods for coronary artery diseases found the AI-based method to be more effective in diagnosing the disease [20]. Another study that examined the degree of inter-rater reliability between human and AI interpretation of intrapartum fetal heart rate found a moderate level of agreement [24].

(2) Diagnostic efficacy

The efficacy of a diagnostic test can be assessed using receiver operating characteristic curves and the area under the curve (AUC), which are based on the test's sensitivity and specificity. In 18 meta-analysis studies on AI, the diagnostic efficacy was evaluated across 25 areas using the AUC. The results indicated that the diagnostic efficacy was good, with scores ranging from 0.83 to 0.99 [10-12,14-16,18-21,23,25].

(3) Treatment prediction and reduction of side effects and medical errors

The application of AI to clinical practice can help identify appropriate treatment options, reduce side effects, medical errors, and costs, and support the further integration of research and practice [33]. AI allows us to explore and identify new genotypes and phenotypes of existing diseases, thus helping to improve the quality of patient care [34]. One study reported that AI was capable of predicting the onset of acute kidney injury in a hospitalized patient 48 hours before it actually occurred, thereby enabling early treatment [35].

2) Managerial and socioeconomic effects

According to a 2020 report by the McKinsey Global Institute [36], AI helps improve operational efficiency in healthcare by reducing the time providers spend on routine and administrative tasks by up to 70%. Additionally, AI usage can help decrease medical costs, as it has been shown to improve the treatment prognosis by approximately 50% at half the cost

Table 1. Summary of the utility of each information technology based on an analysis of the literature

Information technology	Literature type	Utility areas	Utility assessment results
Artificial intelligence (AI)	SR	Clinical	Diagnostic accuracy (compared with health-care professional): gastric lesion (●), retinal vessels (STRARE, CHASEDB1) (●), thyroid nodules (●), ovarian cancer (◎), colon polyps (○), brain tumors (○), retinal vessels (DRIVE) (○) Diagnostic accuracy (compared with existing methods): coronary artery disease (●) Consistency in diagnosis: intrapartum fetal heart rate (◎) Diagnostic efficacy: a good test with AUC of 0.83–0.99 in 25 areas
	Respective literature	Clinical	Prediction of suitable treatment, side effects reduction, medical errors and costs reduction, and integration of research and practice
		Managerial	Reducing time required for healthcare providers to manage their repeated, daily tasks by up to 70% or minimizing time to greatest possible extent
		Socioeconomic	Improving the prognosis of treatment at only half the normal cost Reducing medical costs by 150 billion dollars every year until 2026 with use of AI applications
Internet of Things (IoT)	SR	Clinical	Improving overall performance of treatment by enabling patient monitoring and detection of abnormal patient behavior
		Managerial	Improving workflow management of medical institutions User preferences for IoT-based health management solutions: Response time (●), cost (●), energy consumption (◎), availability (○), security (○), and throughput (○)
	Respective literature	Clinical	Helping medical professionals better understand and interpret patient data
		Psycho-behavioral	The level of satisfaction for smart healthcare applications (3.73 points) was higher than average (3.67 points) in a survey on utility of IoT services. Smart healthcare applications with high satisfaction rating: Infant sleep monitoring, healthcare services for pregnant women, blood sugar meter, blood pressure meter, and oxygen saturation meter
		Managerial	Reducing patient waiting time using short-range wireless IoT-based solutions (3.5 ± 5.8 minutes or more) Improving sales revenue and internal process (reducing operational costs and working hours and increasing productive capacity)
		Socioeconomic	Reducing medical costs and hospitalization of the elderly Expected to have a potential economic effect amounting to 170 billion to 1 trillion and 590 billion dollars in health management and disease monitoring and management
Personal health record (PHR)	SR	Clinical	Expected to have potential effects on management of chronic disease (diabetes, hypertension, asthma, human immunodeficiency virus, childbirth management, glaucoma, hyperlipidemia, etc.) Chronic disease management: weight loss (●), blood glucose control (◎), blood pressure management (○), cholesterol control (○)
		Psycho-behavioral	Promoting changes in preventive management behavior: increasing patient knowledge, reducing decision-making conflicts, improving compliance with medication and checkups, etc.

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Table 1. Continued

Information technology	Literature type	Utility areas	Utility assessment results
	Respective literature	Clinical	Reduced readmission rates reported in some studies
		Psycho-behavioral	Helping patients better memorize their doctors' names and recognize their roles, increasing patient participation in seeking health information, and improving patient compliance with treatment/medication
		Managerial	Reducing patient no-show rates by 53% with the adoption of a mandatory electronic record-centered patient portal
		Socioeconomic	48% of the respondents said that they used medical services less frequently since adoption of mandatory electronic record-centered patient portal.
			Patient portal users visited doctors' offices outside of working hours and used telephone consultation more frequently than control group.

SR: systematic review or meta-analysis, ●: strong evidence, ◎: moderate evidence, ○: weak or pointless evidence.

Table 2. Clinical effects of AI technology compared to existing diagnostic methods (based on a review of meta-analysis studies)

Study, year	Target disease	Diagnostic accuracy	Consistency in diagnosis	Compared to
Lui et al. [10], 2020	Gastric lesions	●		Medical staff
	Barrett's esophagus	●		
	Presence of *Helicobacter pylori*	●		
Lui et al. [11], 2020	Colon polyps	○		Medical staff
Zhao et al. [12], 2009	Thyroid nodules	●		Medical staff
Nguyen et al. [13], 2018	Brain lesions	○		Medical staff
Xu et al. [15], 2022	Ovarian cancer	◎		Medical staff
Islam et al. [16], 2020	Retinal vessels (DRIVE dataset)	○		Medical staff
	Retinal vessels (STARE dataset)	●		
	Retinal vessels (CHASEDB1 dataset)	●		
Tang et al. [20], 2019	Coronary artery disease (per patient and per blood vessel)	●		Existing methods
Balayla and Shrem [24], 2019	Intrapartum fetal heart rate		◎	Medical staff

●: high, ◎: intermediate, ○: no difference.

[33]. Another report suggests that the use of AI applications in healthcare could result in annual savings of $150 billion in the United States by 2026 [37].

2. Internet of Things

1) Clinical effects

(1) Real-time patient monitoring

IoT-based medical technology can be used anywhere in the world to implement real-time patient monitoring and to detect any abnormal or potentially harmful patient behavior. This has the potential to improve the overall effectiveness of patient treatment [38]. Furthermore, physical activity data gathered from patients via a range of sensors can be transformed into visual representations such as abstract art displays, charts, and graphs using IoT solutions. This allows healthcare professionals to comprehend and interpret patient data in a more rapid and intuitive manner [39]. For instance, IoT solutions can be used to visually represent the severity of tremors in patients with Parkinson's disease.

2) Psycho-behavioral, managerial, and socioeconomic effects

(1) Perceived usefulness of smart healthcare applications

Out of 12 smart healthcare applications, users rated the following solutions as particularly beneficial: the integration of smart health technology with smart-care technology, smart healthcare for disease prevention and management, smart healthcare for health management, the combination of smart home and smart healthcare systems, and remote monitoring through smart healthcare (3.73 points, compared to an average of 3.67 points) [40].

(2) Improved workflow and cost reduction

The healthcare sector primarily utilizes IoT for managing lifestyle diseases, monitoring patients with chronic conditions at home, and providing home monitoring and security through remote mobile medical services. Numerous studies have highlighted the benefits of IoT, including rapid response times, cost reduction, and low energy consumption. However, some studies have indicated that it is somewhat less effective in terms of availability, throughput, and security [41] (Table 3). The IoT facilitates more efficient and effective communication between different sectors, enabling the exchange of information between objects, smart authentication, location identification, and efficient monitoring and tracking. This results in a variety of benefits, such as reducing healthcare expenditures and hospitalizations for elderly patients [42].

(3) Reduced waiting time by improving the hospital's internal process

IoT will help improve the workflow in hospitals [27]. In general hospitals, the average waiting time is approximately 32.3 ± 27.7 minutes. A simulation study demonstrated that implementing a short-range wireless IoT-based medical reception system could decrease this waiting time by 3.5 ± 5.8 minutes in a typical hospital environment [28].

(4) Potential socioeconomic effects

A report from the McKinsey Global Institute suggests that by 2025, the IoT could generate an annual economic benefit ranging from US $3.9 to $11 trillion. Within this, the impact on health management, as well as disease monitoring and management, could range from US $170 billion to $1.59 trillion per year [43].

3. Personal Health Records

1) Clinical effects

(1) Prevention and management of chronic diseases

A study that reviewed 23 previous studies, including seven randomized controlled trials (RCTs), examined the effects of the PHR. The study concluded that the PHR could potentially be effective in managing and preventing chronic diseases such as diabetes, hypertension, asthma, HIV, glaucoma, and hyperlipidemia, as well as managing childbirth [29]. All these diseases and conditions share a common characteristic—namely, they are chronic conditions where self-management through behavior change is crucial. PHR technology allows healthcare providers to record, monitor, and track their patients' vital signs, such as blood pressure, body temperature, and blood glucose levels. This technology also enables providers to give timely feedback, creating a virtuous cycle in chronic disease management. Han et al. [30] reviewed 24 studies, including 10 RCTs, which examined the effects of patient portal interventions on clinical outcomes. The study concluded that while the patient portal was effective for weight loss and blood glucose management, it was less effective for blood pressure and cholesterol control (Table 4).

Although some research suggests that PHR can improve diabetes management and boost vaccination rates, the evidence supporting these claims is either inconsistent or weak. Coughlin et al. [31] carried out a systematic review of 12 prior studies, five of which were RCTs, to investigate the impact of a patient web portal on diabetes treatment. The study concluded that secure messaging between healthcare providers and patients contributed to better blood glucose control. Some research indicated that PHR increased vaccination rates for influenza and pneumonia, as well as mandatory infant vaccinations. However, the strength of this evidence was questionable, as many of the studies included in the review were retrospective observational studies and the effect size was only moderate [32].

Table 3. Utility of Internet of Things solutions in organizational management (based on the results of systematic reviews)

Availability	Response time	Energy consumption	Cost	Security	Throughput
○	●	◎	●	○	○

●: 2/3 or more of the studied papers, ◎: 1/3–2/3 of the studied papers, ○: 1/3 or less of the studied papers.

Table 4. Utility of personal health record technology for chronic disease management (based on the results of systematic reviews)

Blood pressure management	Blood glucose control	Cholesterol control	Weight loss
○	◎	○	●

●: 2/3 or more of the studied papers, ◎: 1/3–2/3 of the studied papers, ○: 1/3 or less of the studied papers.

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(2) Reduced mortality and readmission rates

Studies examining the effect of PHRs on patients' mortality and readmission rates have reported mixed findings. A three-arm RCT conducted at a teaching hospital investigated the effect of an inpatient portal intervention. The study found that the inpatient portal group showed a lower 30-day readmission rate than both the control group and the tablet PC group [44]. Another retrospective observational study, however, found no significant difference in the 30-day readmission rate, in-hospital mortality, or 30-day mortality between the inpatient portal group and the control group [45].

2) Psycho-behavioral, managerial, and socioeconomic effects

(1) Psycho-behavioral changes of users

Systematic reviews have reported relatively strong evidence that the use of patient portals was effective in improving patients' health knowledge, decision-making, medication adherence, and use of preventive services [30].

(2) Patient perceptions of medical personnel and compliance with treatment

Studies have investigated the effects of patient portals on patients' perceptions of healthcare professionals and health information, with mixed results. A controlled study examined the effect of tablet PCs equipped with a hospitalized patient portal application on patient engagement and health knowledge. The study found that the tablet PC intervention was more effective in helping patients remember their doctors' names and understand their roles compared to the control group. However, there were no significant differences between the groups in terms of patient engagement, awareness of their nurse's name, understanding of planned tests and treatments, or recognition of medication changes [46]. A three-arm RCT was conducted at a training hospital in New York to assess the impact of an inpatient portal intervention [44]. Although there was no difference in patient engagement between the intervention group and both the control and tablet PC groups, the level of patient interaction with health information was higher in the intervention group than in the other two groups.

Numerous studies have reported that patient portals were highly effective in enhancing patient adherence to treatment. One RCT conducted in a specialty clinic for heart failure patients found that the group using the patient portal showed superior treatment compliance compared to the control group, although they also had more visits to the emergency department [47]. Another RCT, which evaluated the impact of a patient portal on antidepressant treatment for depression, found that the intervention group demonstrated higher rates of adherence to antidepressant medication than the control group [48].

(3) Improved managerial efficiency

A survey conducted in Canada involving 957 patient portal users revealed that 48% of respondents avoided visiting doctors' offices, while 2.7% avoided emergency department visits [49]. Furthermore, an analysis of healthcare utilization demonstrated a 53% decrease in no-show rates among patient portal users. However, a retrospective cohort study by Kaiser Permanente on patient portal users indicated an increase in clinic visits, after-hour clinic visits, telephone encounters, emergency department encounters, and hospitalizations [50]. In a separate RCT assessing the impact of a patient portal on patients with depression, there was no discernible difference in outpatient visits and telephone encounters between the patient portal group and the control group [48].

IV. Discussion

The present study reviewed the benefits of AI, IoT, and PHR from clinical, psycho-behavioral, managerial, and socioeconomic perspectives, summarizing the key findings. The benefits observed varied based on the type of information technology utilized and the specific disease in question. Our review indicates that AI and PHRs can enhance clinical outcomes, while IoT holds promise for boosting managerial efficiency. However, given the limited scope and scale of prior studies, further research is warranted.

The data models, having been trained and verified on public datasets, should be continually trained, verified, and improved using actual data gathered from a variety of patients in real hospital environments [51,52]. Further investigation is warranted into the organizational and socioeconomic benefits of PHR. For instance, one could argue that PHR use will yield socioeconomic benefits, as they could potentially improve the efficiency of organizational management through the enhancement of patient treatment processes.

The financial stability of health insurance can also be strengthened by managing chronic diseases more effectively and efficiently [53], as well as by reducing redundant tests and prescriptions. Theories lacking sufficient evidence cannot adequately facilitate widespread PHR adoption, indicating a need for further research on these topics. The application of IoT in the health and medical industry is not as prevalent as in other industrial sectors. Therefore, additional research is necessary to accurately assess the impact of IoT. In the future, smart healthcare services are anticipated to become more affordable [54], which will enhance customer access to these services and significantly foster the growth of the IoT-based healthcare industry.

The findings from this review should be interpreted with caution due to several limitations. First, it is possible that we may have missed relevant articles in the current review that were not found through our search strategy. In addition, since we did not include gray literature, publication bias may exist. We included only articles written in Korean and English; hence, the findings cannot be generalized to studies published in non-English and non-Korean languages. Finally, most of the studies included in this review were conducted in North America, which limits the generalizability of the results.

This review has several implications for future research. As information technology advances and is increasingly used in healthcare, more research on the benefits of HIT has been conducted. However, these studies have been limited to specific diseases and datasets, and thus there is a need to further expand the scope of research. For example, the scope of AI research is primarily limited to specific diseases, and most studies have been conducted using images from specific public datasets. With the increase in chronic and infectious diseases, it is necessary to continue research on developing algorithms for the prediction and diagnosis of these diseases. The findings of the present study will help identify areas of research that warrant further investigation.

Conflict of Interest

Hyejung Chang and Mona Choi are editorial members of Healthcare Informatics Research; however, they did not involve in the peer reviewer selection, evaluation, and decision process of this article. Otherwise, no potential conflict of interest relevant to this article was reported.

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