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Internet of medical things-based real-time digital health service for precision medicine: Empirical studies using MEDBIZ platform

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Abstract

The aim of this study was to introduce the implemented MEDBIZ platform based on the internet of medical things (IoMT) supporting real-time digital health services for precision medicine. In addition, we demonstrated four empirical studies of the digital health ecosystem that could provide real-time healthcare services based on IoMT using real-world data from in-hospital and out-hospital patients. Implemented MEDBIZ platform based on the IoMT devices and big data to provide digital healthcare services to the enterprise and users. The big data platform is consisting of four main components: IoMT, core, analytics, and services. Among the implemented MEDBIZ platform, we performed four clinical trials that designed monitoring services related to chronic obstructive pulmonary disease, metabolic syndrome, arrhythmia, and diabetes mellitus. Of the four empirical studies on monitoring services, two had been completed and the rest were still in progress. In the metabolic syndrome monitoring service, two studies were reported. One was reported that intervention components, especially wearable devices and mobile apps, made systolic blood pressure, diastolic blood pressure, waist circumference, and glycosylated hemoglobin decrease after 6 months. Another one was presented that increasing high-density lipoprotein cholesterol and triglyceride levels were prevented in participants with the pre-metabolic syndrome. Also, self-care using healthcare devices might help prevent and manage metabolic syndrome. In the arrhythmia monitoring service, during the real-time monitoring of vital signs remotely at the monitoring center, 318 (15.9%) general hikers found abnormal signals, and 296 (93.1%) people were recommended for treatment. We demonstrated the implemented MEDBIZ platform based on IoMT supporting digital healthcare services by acquiring real-world data for getting real-world evidence. And then through this platform, we were developing software as a medical device, digital therapeutics, and digital healthcare services, and contributing to the development of the digital health ecosystem.

Keywords

Digital healthcare, internet of medical things, big data platform, healthcare services, empirical studies

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Introduction

Digital healthcare is regarded as a convergence industry with healthcare and information and communication technology for personal healthcare services.[1] In addition, digital healthcare consists two main parts platform (hardware) and service (software). The platform is used as data collection, data storage, and data processing. The service is based on software as a service for diverse healthcare services using personal health data that stored in platform.[2]

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Initially, descriptive statistical analysis were performed for the healthcare services, then deep learning and artificial intelligence frameworks were applied to the sequence or pattern analysis for more convenience and reliable digital healthcare services.[3]

Internet of medical things (IoMT) are terms of the medical things that have support to data transfer over a network does not require human-to-human or human-to-computer interactions. An IoMT is mainly a smart device that comprises sensors and an integrated circuit to acquire biological signals from the subjects, a processing unit to process the bio-signals, a network module to transmit the data over a network, and a temporary storage unit.[4]

Since 2015, there are several studies which have been proposed various types of the big data platforms based on big data, internet of things (IoT), and cloud computing technology for healthcare and e-health services. These studies proposed a conceptual architecture or data structure for big data platform for digital healthcare applications. Emna et al. proposed a semantic big data platform for integrating the heterogeneous wearable data. In this study, the authors designed a database architecture for heterogeneous data including structured and nonstructured data.[5] George et al. designed a big data architecture for data storage and processing to the cloud computing system. They adopted advanced technology including the IoT and machine-to-machine (M2M) communications that enabled for tele-monitoring and e-health services.[6] Recently, Gunasekaran et al. proposed a new architecture of the big data platform based on IoT data store and process for healthcare applications. It consists of two main track architecture Meta Fog-Redirection (MF-R) for data collection and Group and Choosing (GC) architecture for data integration.[7] Furthermore, there are more studies on the diverse uses of IoT devices in various fields.[8,9] Among them, Sanja Budimir et al.[10] studied using IoT devices about the emotional reactions of subject who faced cybersecurity breach. Peter Ray Chai et al.[11] proposed a conceptual application of IoT-based real-time notifications in-hospital workflow. Ching Lam et al.[12] were systemically reviewed the related studies of IoMT-based systems for weight management.

However, all these previous studies or proposed big data platforms are focused on the architecture and data structure. To the best of our knowledge, they did not deploy in real-time healthcare services and clinical applications. Therefore, in this article, we demonstrated the digital healthcare services based on MEDBIZ platform which is able to connect with various IoMT devices. To do this, there are some descriptions and specifications of IoMT devices for personal health data acquisition and measurement. Also, detailed information on the MEDBIZ platform which is a cloud-based big data platform for digital healthcare services.

The aim of this study was to introduce the implemented MEDBIZ platform based on the IoMT supporting real-time digital health services for precision medicine. In addition, we demonstrated four clinical trials or empirical studies of the digital health ecosystem that could provide real-time healthcare services based on IoMT using real-world data from in-hospital and out-hospital patients. Finally, we discussed pros and cons of the currently providing real-time digital health services thru the MEDBIZ platform and its further clinical or healthcare applications.

Methods

Architecture of MEDBIZ platform

The architecture of the implemented MEDBIZ platform is consisting of four main layers including physical, network, presentation, and application layers. The physical layer covers the IoMT devices as home healthcare devices, wearable, and other devices that collect the data from the patients. In addition, health data from Health Insurance Review & Assessment (HIRA) and medical institutions and hospitals as Wonju Severance Christian Hospital. Next is a core or network that we called a bio-health platform which includes main components as one M2M, common and metadata, data identification and encryption, data processing, and big data cloud storage of implemented MEDBIZ platform. The presentation layer compromised a portal and mobile that provide controls task for system admin at the backend and platform users at the frontend. Lastly, application layers support the real services of healthcare, emergency medicine, telemedicine, and medical travel (Figure 1). Detailed explanations and the structure of each component are described in the following sections.

Software components

The MEDBIZ platform consists of four main software components: IoMT, core, analytics, and services. IoMT component is used for out-hospital data acquisition from the IoMT devices. The platform core is the main component and it contains managing the metadata, resources, security, and system log. The analytics component has been implemented with two main environments for data analyzing frameworks and distributed computing. Finally, the service component has several OpenAPI tools to provide digital healthcare services based on the web or mobile apps (Figure 2). A detailed description of the each component is presented in the following section.

1. IoMT component (one M2M)
   It was directly connected to the open healthcare platform without a separate procedure through the standard communication protocol method (one M2M). In addition, a server gateway was provided for

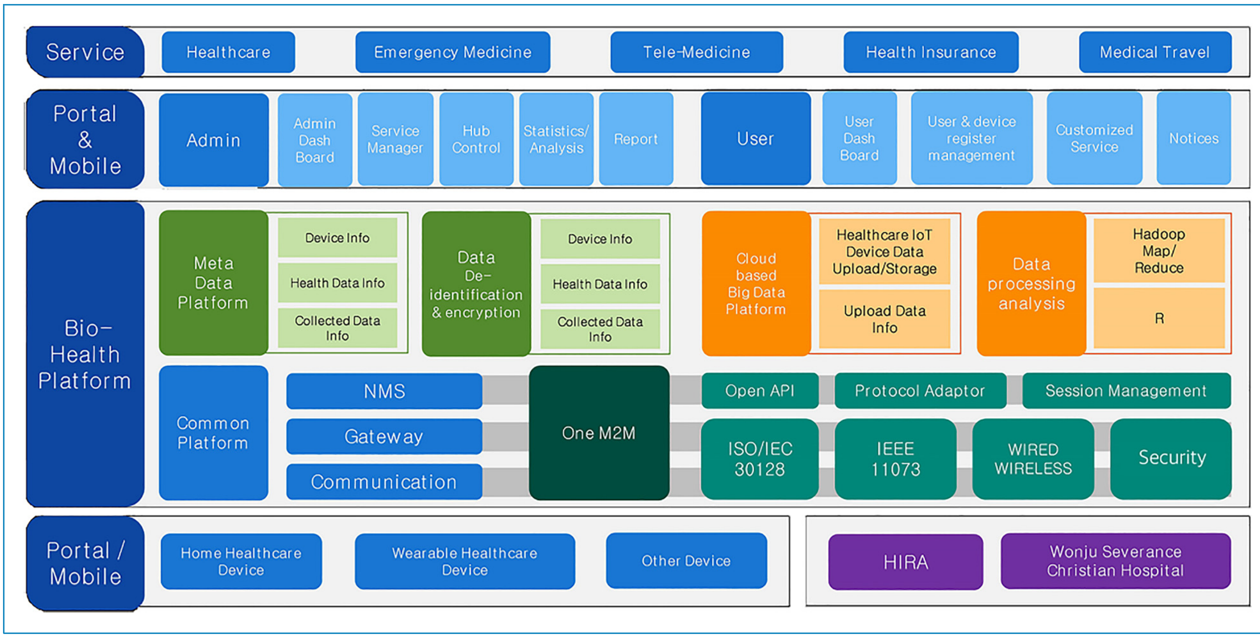

Figure 1. Architecture of MEDBIZ platform for healthcare service.

nonstandard healthcare devices and interworked with the MEDBIZ platform through this.

2. Metadata
   It loads metadata using Kafka, an open source message broker, and processes metadata for creating and delivering heterogeneous database queries using Java API. Next, is MongoDB to store or back up metadata, and use elastic search API to analyze metadata.
3. Resource broker
   The resource broker is responsible for operating the healthcare daemon-centered platform including virtual file systems, storage elements, and computing elements. It manages and controls resources for servers and platforms, manages and controls input/output of file systems, manages and controls keys according to data encryption, and accesses file data through in-memory.
4. Computing element (CE)
   CE applies the cluster to available servers and creates a highly efficient analysis environment through dynamic allocation of resources. These include JDL verification and analysis work control, preprocessing of analysis task, analytical task monitoring, and analytics activity logging.
5. Virtual file system (VFS)
   VFS can perform tasks in the cloud space when processing large amounts of data, and provides an API based on Linux file system commands. Simultaneous multi-use support is possible, and the number of simultaneous users can be expanded according to the hardware specifications. With distributed computing technology, storage elements (SEs) with different spaces and regions can be used. Additionally, it performs roles such as cloud storage index, storage data access control, storage usage control, and data redundancy policy management.
6. Analytics component
   The analytics platform consists of a distributed computing environment and an analysis working environment. Distributed computing environment includes distributed system kernel, file sharing, duplication, and in-memory clustering. Analysis working environment includes analytics language, machine learning, deep learning, and the artificial intelligence (AI) framework, which is called as 'Bee AI'.[13]
7. Security
   A data encryption key distribution technology and system applying Shamir's Secret Sharing Scheme (SSSS) was built. Secured security and reliability for data encryption/decryption with multikey and distributed technology.[14]
8. System log
   The System log module provides a variety of logs that you can use to troubleshoot and debug transactions and events that take place within the platform. It also provides archived logs in the log history with the certification, authorization, and visualization.
9. Service components
   Service components can support the web-based or app-based digital healthcare services through the Open API to the end-users such as respiratory disease monitoring service, endocrine disease monitoring service, and

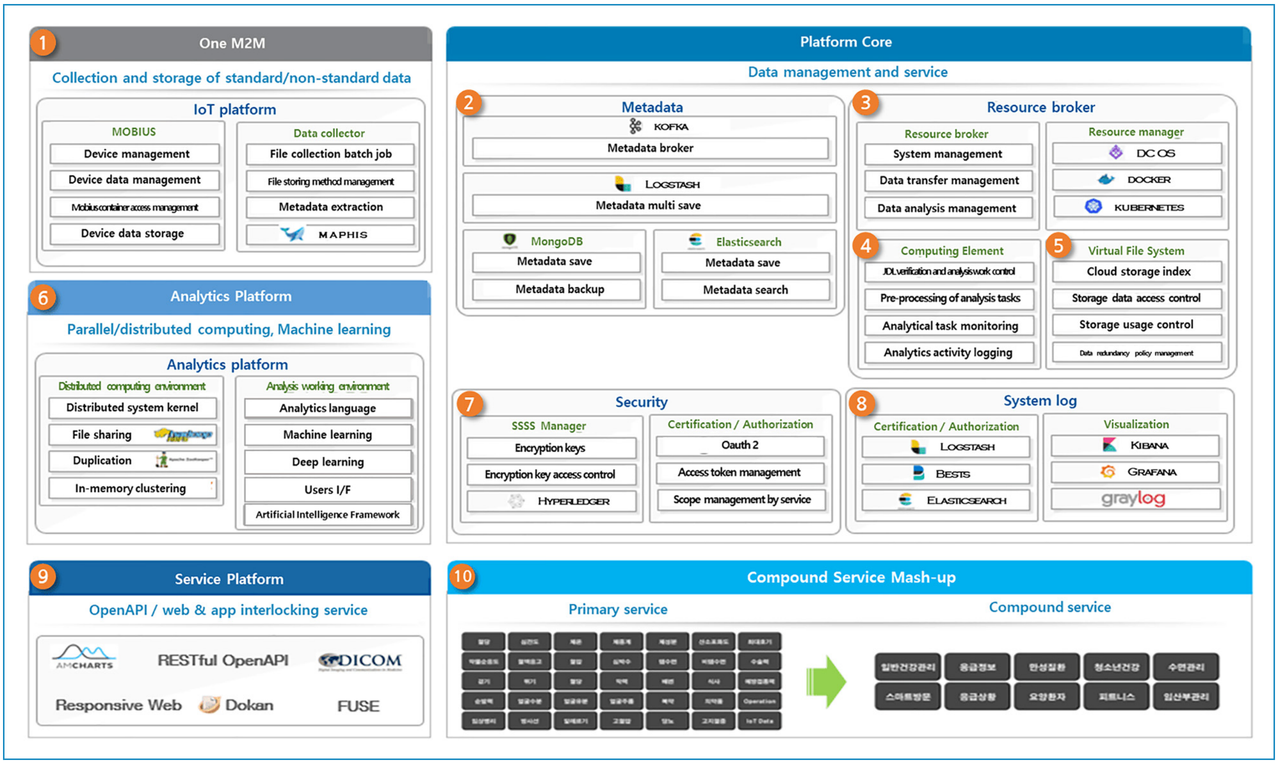

Figure 2. Software components in MEDBIZ platform.

cardiovascular disease monitoring service. Respiratory disease monitoring service is a healthcare service for patients with respiratory diseases. It analyzes the health of the respiratory system and monitors air condition in real-time, a threat to the prevention and management of respiratory diseases. Endocrine disease monitoring services such as diabetes and metabolic syndrome provide the optimal management service for each individual by analyzing age, type of diabetes, type period of diabetes, growth habits, health status, and level of blood sugar control. Cardiovascular disease monitoring service provides information for cardiovascular disease prevention by synthesizing patient's vital signs (SpO_2, blood pressure, heart rate, electrocardiogram, and so on), motion level, air condition data, and weather data.

10. Compound service
 As an open API for IoMT application service development, it provides various APIs for use in WEB, CS programs, and mobile platforms. It also provides APIs for search, statistics, analysis, operation/management, data service, and healthcare IoMT device management. By providing mesh-up, new services and contents can be produced through a combination of services and contents that already exist.

IoMT-based real-time data communication

The implemented MEDBIZ platform has contained an IoMT platform for data transmission between the digital health devices and platform in real-time.[15] To do this, an IoMT platform support for managing the digital health devices that used for healthcare services. In addition, it can provide the data managing of the each connectable device and services.[16] Currently, IoMT platform have the number of devices and apps for real-time data transmission for several different digital health services. The IoMT platform has some functions to control the data storage, metadata, batch processing, and metadata.[17,18] All these functions can be applied to the listed connectable devices and apps thru the gateway. Finally, real-time data transferred to the core, analytics, and service platforms.

MEDBIZ platform stores the collected data from IoMT devices in its own database, and then delivers it to the message queue Kafka for final database construction and persistence of data. Kafka sends the received data to the implementation module and the module stores it in the database MongoDB. Data stored in MongoDB provides open APIs to various monitoring applications such as web services through MEDBIZ platform.[19]

IoMT-based real-time service design

An implemented MEDBIZ platform can provide various clinical trials for the in-hospital and out-hospital patients based on various IoMT devices, as below.

Chronic obstructive pulmonary disease (COPD): COPD is regarded as an obstructive lung disease characterized by long-term breathing problems and poor airflow. The main symptoms are shortness of breath, cough, and sputum production. In 2013, the prevalence of COPD in adults over 40 was 13.5%, and the prevalence rate increased with age. In particular, men showed a high increase after their 60s. It would be estimated as a major cause of death that is predicted as top 4 in 2030.[20] COPD is a representative ambulatory care sensitive disease that, if properly managed in primary care, can reduce the worsening of symptoms and hospitalization.

Metabolic syndrome (MetS): MetS is a disease characterized by more than three of the following five factors: abdominal obesity, high blood pressure, high blood sugar, high triglycerides (TGs), and high high-density lipoprotein (HDL) cholesterol.[21] It has a high prevalence in the United States, 32.8% for men and 36.6% for women in 2012. In Korea, it was reported in 28.1% of men and 18.7% of women in 2017, and it was considered as an important socio-economic problem.[22] Metabolic syndrome is known to be associated with increased risk of diabetes, chronic renal failure, hypertension, and cardiovascular disease.

Arrhythmia: Cardiac arrhythmia is an irregular heartbeat that is regarded as tachycardia or bradycardia, also one of the most common cardiovascular diseases. Many types of arrhythmia are not serious, but they are a precursor to certain diseases such as stroke, heart failure, and cardiac arrest. In addition, arrhythmias can be a risk factor of dizziness, fainting, rapid heartbeat, shortness of breath and anxiety, chest pain, and collapse, and sudden cardiac arrest in extreme cases. According to the report of World Healt Organization (WHO), more than 20% of deaths were attributed to heart disease in 2012, continuous monitoring of cardiac disease like arrhythmia is important.

Diabetes mellitus (DM): Skeletal muscle occupies the largest part of the human body and is a tissue that plays a major role in glucose uptake in response to insulin. Decreased skeletal muscle mass can affect insulin sensitivity and promote metabolic disorders such as type 2 diabetes. Therefore, interventions such as resistance exercise that help to increase or maintain skeletal muscle mass are considered very important in preventing metabolic diseases. In addition, since the thigh circumference accounts for 30% to 40% of the total skeletal muscle mass in our body, the establishment of an exercise intervention method for increasing the mass of the thigh circumference and improving muscle strength is considered to be effective in reducing metabolic and cardiovascular disease risk factors. As a result of a study of about 320,000 men and women aged 30 to 79 years who had undergone a medical examination at the Korea Medical Institute from 2009 to 2011, a correlation was reported that people with thin thighs had a high risk of developing diabetes. This study suggests that each 1 cm decrease in thigh circumference increases the risk of diabetes by 8.3% for men and 9.6% for women.[23]

Results

IoMT-based digital health clinical trials

Currently, this platform used to provide four healthcare monitoring services through IoMT devices and smartphone apps. These were the COPD, metabolic syndrome, arrhythmia, and DM monitoring services (Table 1).

COPD monitoring service

This service was a healthcare service study using IoMT equipment for patients with COPD (IRB approval number CR319136; trial registration number KCT0005784). It was divided into a test group using an IoMT device and a control group not using the IoMT device, and is intended to measure lung capacity including FEV_1 between the two groups, and to collect lifelog data. In addition, we would like to investigate whether monitoring using IoMT equipment and active intervention based on individual values were effective in preventing acute exacerbation in patients with COPD. The experimental group and the control group consisted of 50 people each, and the IoMT equipment provided an environmental information meter, a blood pressure monitor, and a smart watch. A smart portable spirometer was assigned to only the experimental group (Figure 3).

MetS monitoring service

This service was a self-health management study using digital health for patients with metabolic syndrome among cohort study participants (IRB approval number CR319089; trial registration number KCT0005783). People who met two or more of the five criteria for diagnosing metabolic syndrome were selected. Of the 1519 participants in the cohort study, 867 (57.1%) had metabolic syndrome. In total 355 out of 867 (40.9%) people were recruited to the clinical trial over the phone and then confirmed their participation with the detailed explanation during a hospital visit. IoMT equipment provided a blood glucose meter, weight scale, blood pressure monitor, smart watch, and smart tape measure. The solution for diet management was to take pictures of food and record the calorie information of the food. In addition, an application (Yonsei Health) that collected data measured by IoMT and transmits it to the MEDBIZ server was developed and used (Figure 4).

Using this service, there were reported two articles with each different results. One study was hypothesized that intervention components, especially wearable devices and mobile apps, for the prevention of metabolic syndrome would have a positive effect on physical activities in the middle-aged population. A total of 267 out of 355 (75.2%) people participated, excluding 88 people who

Table 1. Outlines of IoMT-based digital health clinical trials.

	Name	Subjects (persons)	Number of IoMT devices (expeimental/control)	Application	Status
1	COPD monitoring service	100	4/3	SOOM Health	Doing
2	MetS monitoring service	355	5	Yonsei Health	Done
3	Arrhythmia monitoring service	2000	1	HiCardi	Done
4	DM monitoring service	68	1	BagelFitness	Doing

COPD: chronic obstructive pulmonary disease; DM: diabetes mellitus; IoMT: internet of medical things; MetS: metabolic syndrome.

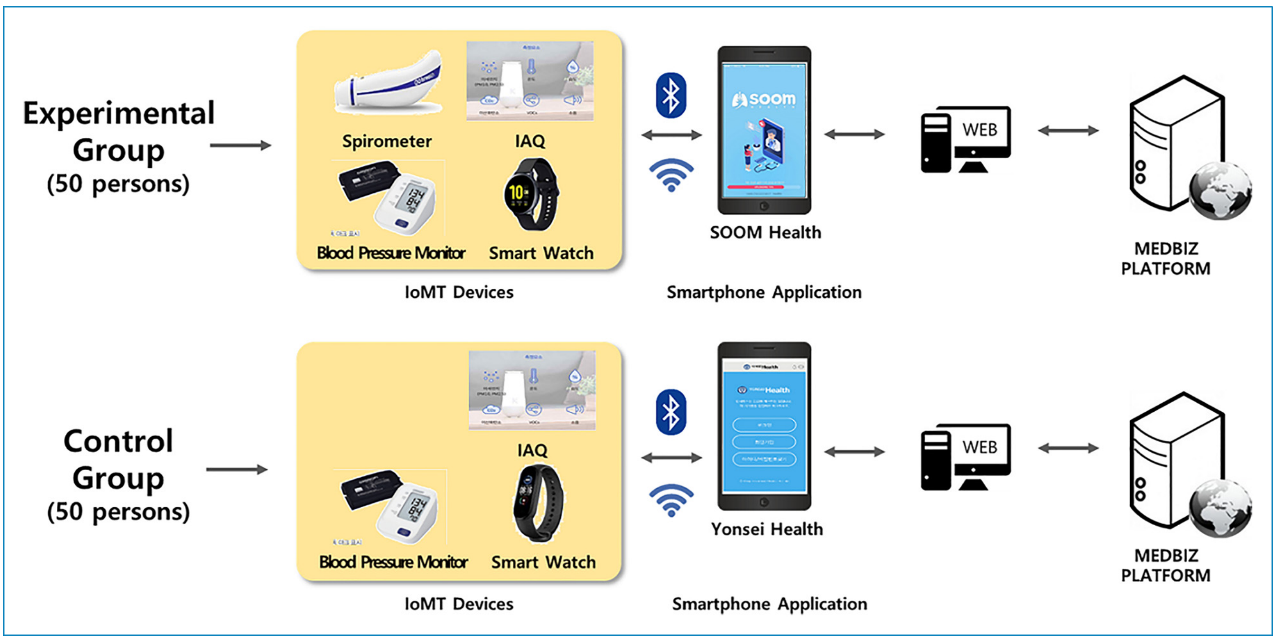

Figure 3. COPD monitoring service. COPD: chronic obstructive pulmonary disease.

had difficulty using IoMT equipment. Also, it was purposed to compare the changes in clinical values and physical activities between an enhanced intervention group and standard intervention group that had not received the intervention for 6 months. A total of 267 participants were randomly selected, of which 221 (82.8%) completed the 6-month study. As many as 113 out of 221 (51.1%) subjects were assigned to the enchanced intervention group and 108 to the standard intervention group. After 6 months, body weight and body mass index decreased in the enchanced intervention group. In both groups, systolic blood pressure, diastolic blood pressure, waist circumference, and glycosylated hemoglobin (HbA1c) decreased.[24] Another study was aimed to confirm the utility of self-care prevention and management tools using healthcare devices. In this study, 106 of 136 (77.9%) people were enrolled, excluding 30 people who withdrawn of consent or had pharmacological treatments. The participants were evaluated at two time points. The first assessment examined risk factors for MetS. At a point of 6 weeks after the first assessment examining risk factors for MetS, a lifestyle intervention was introduced to induce lifestyle change and to induce continued participation in the medical device. Follow-up assessments of risk factors for MetS were performed at 26 weeks. The participants with pre-MetS/MetS were divided into two groups, according to the baseline and follow-up (26 weeks) assessment findings. It was presented that increasing HDL-C and TG levels were prevented in participants with pre-MetS. Also, self-care using healthcare devices might help prevent and manage the MetS.[25]

Arrhythmia monitoring service

This service was an empirical study that monitors electrocardiography (ECG) signals for 2000 general hikers (IRB

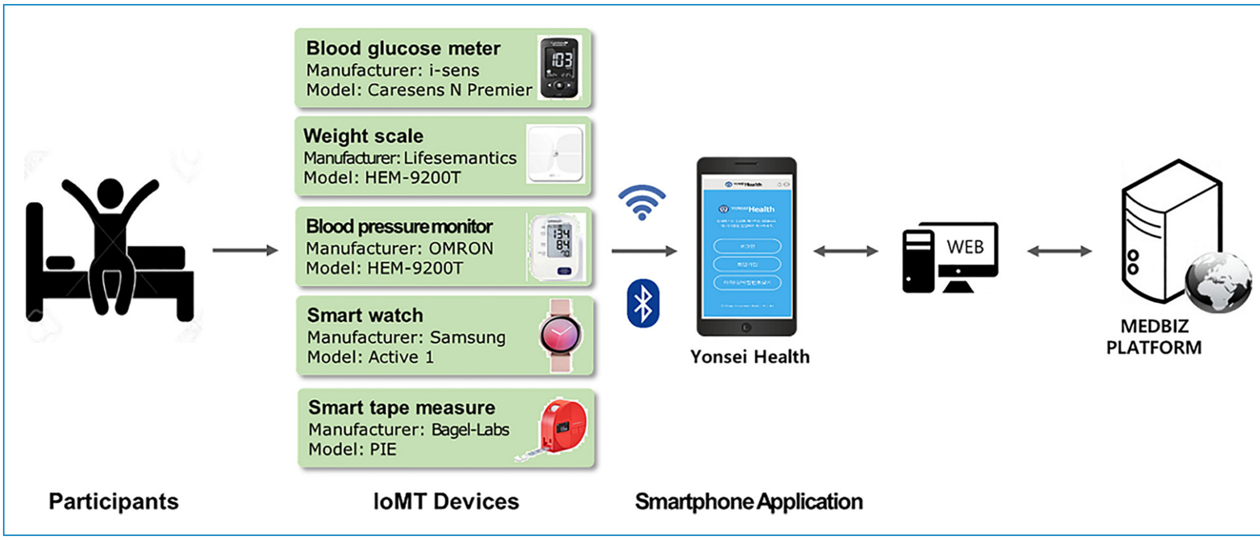

Figure 4. Metabolic syndrome monitoring service.

approval number CR319186; trial registration number KCT0005795). We intended to develop a guideline for medical guidance so that changes in ECG could be monitored as exercise load occurs in a short time, and when abnormal signals or emergencies occur, medical staff at the monitoring center can visit the hospital (Figure 5).

All participants were Korean and aged between 19 and 80 years, consisted of 811 (40.5%) males and 1189 (59.5%) females. In total, 318 (15.9%) subjects found abnormal signals through the health management bio-signal monitoring demonstration service. During the real-time monitoring of vital signs remotely at the monitoring center, 296 (93.1%) people were recommended for treatment, but fortunately, there was no emergency. Of those who received a recommendation for treatment, 139 (46.9%) people were contacted by phone, and 30 (21.6%) of them visited the hospital within 1 month of participating in the study and performed an examination. In fact, 7 out of 30 (23.3%) patients were diagnosed and treated for heart disease, including arrhythmia diagnosis, atrial fibrillation diagnosis, stenting, and medication. Through this, it was confirmed that this service is effective in terms of safety and effectiveness.

DM monitoring service related to thigh circumference

This service applied an augmented reality (AR) motion recognition lower body exercise induction application and IoMT device solution for strengthening thigh muscle strength to increase the muscle circumference and monitor exercise effects (IRB approval number CR320148). As many as 68 participants in the test group (34 DM patients, 34 normal people) collected lifelog data and exercise-related data of subjects by applying a smart phone application to which IoMT devices can be linked and a smart phone application for AR-based lower body exercise. All 68 people in the control groups (34 DM patients, 34 normal people) provided the same smart phone application that IoMT devices could link with, but did not apply a smart phone application for AR-based lower body exercise.

Subjects performed thigh training exercises such as squats, lunges, and raises through an AR-based motion recognition app. The application provided accurate exercise guidelines and increased the success rate of exercise because it was considered to have been exercised only when the subject's exercise movements were correct. Through many studies on the correlation between thigh circumference and diabetes risk, in this clinical trial, body fat percentage, muscle mass, and musculoskeletal mass were evaluated. The reason for evaluating this indicator was to check whether the thigh exercise through the AR-based motion recognition app actually had an effect on increasing muscle mass. The HbA1c was used as a lab test index for diabetes. HbA1c was a form of hemoglobin that was normally present in red blood cells combined with sugar. When blood sugar was maintained high, the HbA1c level rises and reflects the average blood sugar level for 2 to 4 months, so it was useful for determining the degree of long-term blood sugar control. Subjects measured pre-meal blood glucose levels through a glucometer at least 3 times a week, and in particular, used clinically effective PP1 (postprandial 1 h) or PP2 (postprandial 2 h) after meals. In this clinical trial, PP2 was selected as the postprandial blood glucose level and applied.[26] In addition, by measuring the number of steps through a smart watch and the circumference of the thigh and waist through a smart tape measure, the effect of thigh strength training through an AR-based

Figure 5. ECG and vital sign monitoring service. ECG: electrocardiography.

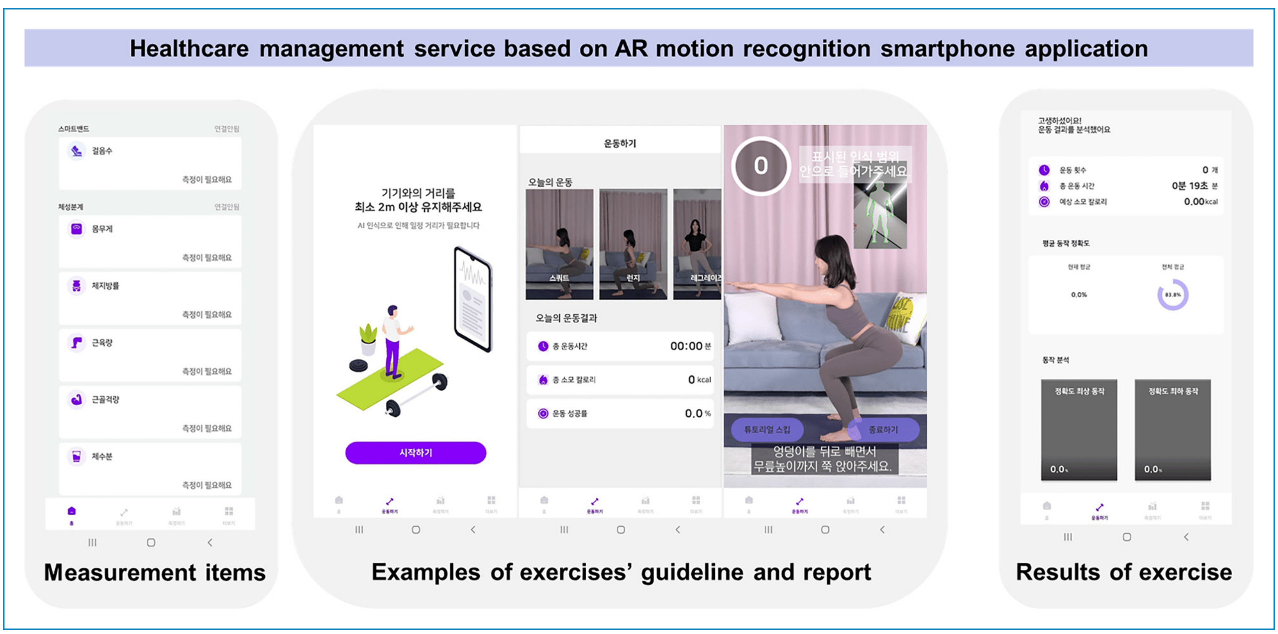

Figure 6. Diabetes mellitus monitoring service related to thigh circumference.

motion recognition app on reducing the risk of diabetic patients was investigated.

These indicators showed that thigh muscle strengthening exercise had a positive effect on reducing the risk of diabetes for DM patients, and AR-based motion recognition application was able to derive positive clinical results as a digital treatment (Figure 6).

Discussion

Findings and summaries

We have introduced the implemented big data platform based on the IoMT to support the digital healthcare services for precision medicine. In addition, we demonstrated the establishment of the digital health ecosystem that can provide real-time healthcare services based on IoMT using real-world data from in-hospital and out-hospital patients. The proposed MEDBIZ big data platform there are several healthcare services are provided to the patients in-hospital and out-hospital environments.

Advantages of the implemented MEDBIZ platform

There are some advantages of the implemented MEDBIZ platform for digital healthcare services. First, the platform is implemented by using advanced technologies including the big data, cloud storage, and IoMT. Second, the platform can provide the stable and reliable services for the users. Third, thru this platform we can support real-time healthcare service from anywhere to anyone.

Recently there are some studies about IoMT-based big data platform in healthcare and tele-health services. Among them, PremaLatha et al., are introduced IoT in healthcare named as IoMT of devices in medical are equipped with WiFi.[27] The authors were elaborated impact of IoMT in healthcare in terms of enhancement of operational efficiency, the ability of digital innovation, and the extension of industry ecosystems. Similar to what these authors mentioned, we built the MEDBIZ platform composed of IoMT, core, analytics, and services components, and demonstrated the empirical studies that could be provided real-time healthcare services within the digital health ecosystem by using it. The study by Rashed et al. demonstrated IoMT-based integrated medical platform for remote health monitoring and assisted living.[28] The authors proposed multilayer architecture to sense and collects information about not only the vital signs of patients but also the surrounding environment. We also introduced an IoMT platform composed of a multilayered architecture in this study. Specifically, we presented that it was consisting of four main layers including physical, network, presentation, and application layers. Firouzi et al. summarized a concept of IoT and big data for smarter healthcare from device to architecture, applications, and analytics.[29] They analyzed the top concerns in IoT technologies that pertain to smart sensors for healthcare applications; particularly applications targeted at personalized tele-health interventions aimed to enable healthier ways of life. We thought we were more detailed about the concepts of big data for IoMT and digital health than they did. We actually designed and conducted four empirical studies in this article and reported some of the results. Radanliev and David presented a concept healthcare system supported by autonomous artificial intelligence that could use edge health devices with real-time data. The authors suggested a practical application of a new research methodology for forecasting cyber risks in health systems through real-time algorithmic analytics.[30] We explained that the analytic platform consisted of a distributed computing environment and an analytic work environment, and included an AI framework. In addition, it was similar in that it prepared for data security by building a data encryption key distribution technology and system. Rubí et al. proposed IoMT big data platform for open electronic health record (EHR) based on the pervasive healthcare data.[31] The authors studied on the healthcare data aggregation, processing, and sharing based on OneM2M. They were used the IoMT domain to extend and integrate the OpenEHR for simplifying the collection and dissemination of data. Similar to their research, we also proposed a OneM2M-based platform. We explained the concept related to the network layer called the bio-health platform among the four main layers constituting the platform. However, they did not provide real-time healthcare services based on the introduced IoMT-based big data platforms. Therefore, in this study, we already implemented and providing various healthcare services using IoMT devices for in-hospital and out-hospital patients. Also, we have developed many smartphone apps which are connected the implemented MEDBIZ platform to provide healthcare monitoring services. In further, the proposed MEDBIZ platform can provide the infrastructure and environment to extended and integrated by the healthcare solution industries and start-ups that lunches the diverse healthcare services.

Conclusions

In summary, we had implemented MEDBIZ big data platform based on IoMT supporting digital healthcare services. The platform consisted of four main software component: IoMT, core, analytics, and services. In addition, we performed the four clinical trials through IoMT devices and smartphone apps by using the MEDBIZ platform. These were monitoring services that were related to COPD, metabolic syndrome, arrhythmia, and DM. We designed monitoring services related to COPD, metabolic syndrome, arrhythmias, and diabetes, and obtained meaningful results with empirical studies while applying these services to the subjects.

However, there were some shortcomings in this study, currently platform can supporting the services only healthcare field. In further, some researches and development should be needed for the business models to provide the services in other fields such as emergency medicine, telemedicine, and medical travel. Forward to the next studies, we suggest that the platform can be used not only for collecting real-world data for getting real-world evidence, but also for developing software as a medical device (SaMD) for digital therapeutics, and digital healthcare services, through this platform. It could be contributing to the development of the digital health ecosystem to support the start-ups and business that can easily enter into the healthcare domain.

Abbreviations

AR:	augmented reality
CE:	computing element
COPD:	chronic obstructive pulmonary disease
DM:	diabetes mellitus
EHR:	electronic health record
GC:	Group and Choosing
HbA1c:	glycated hemoglobin
HDL:	high-density lipoprotein
HIRA:	Health Insurance Review & Assessment
IoMT:	internet of medical things
IoT:	internet of things
MetS:	metabolic syndrome

MF-R: Meta Fog-Redirection
M2M: machine-to-machine
PP1: postprandial 1 h
PP2: postprandial 2 h
SaaS: software as a service
SaMD: software as a medical device
SSSS: Shamir's Secret Sharing Scheme
SE: storage element
VFS: virtual file system

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Contributorship: HY was involved in conceptualization, formative analysis, and writing—original draft, and review and editing. KH was involved in conceptualization, project administration, andfunding acquisition. KH, UE, and SW were involved in investigation (software) and writing—original draft. EY, JH, and HJ were involved in data collection and formal analysis. SB and JW were involved in investigation (hardware); TY and TH in visualization; H in conceptualization, methodology, supervision, and writing—review and editing.

Declaration of conflicting interests: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approvals: Among the implemented MEDBIZ platform, we focused on detailed empirical studies about COPD, MetS, arrhythmia, and diabetes monitoring services. All studies were approved after deliberation by the Research Ethics Review Committee; COPD monitoring service (IRB approval number CR319136; trial registration number KCT0005784), MetS monitoring service (IRB approval number CR319089; trial registration number KCT0005783), arrhythmia monitoring service (IRB approval number CR319186; trial registration number KCT0005795), and diabetes monitoring service (IRB approval number CR320148).

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