

## THE INTERVENTION OF IOT (INTERNET OF THINGS)-BASED SMART APPLIANCES IN SUPPORTING DIABETIC ELDERLY'S HEALTHCARE: A LITERATURE REVIEW

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### ABSTRACT

*Ageing is one of the important risk factors for aged people suffering from chronic diseases, such as type 2 diabetes (T2D). The increasing number of diabetic elderly raises the demand for better quality and efficient healthcare services. Meanwhile, technological advance has greatly boosted the development of IoT-based smart appliances. Ageing causes a decline in memory and receptivity among diabetic elders, in turn, it becomes difficult for sufferers to use and accept high-technology IoT smart appliances. The aged with diabetes need special and ageing-oriented design healthcare provided by smart appliances. Therefore, as an appliance with essential function and operation in daily life, smart appliances can assume the responsibility of monitoring the health condition of elderly at home. This paper used literature review method to identify the health problems among diabetic elderly and examine the applications and challenges of IoT-based smart appliances for supporting diabetic elderly's healthcare. This study found that diabetic elderly suffers from various health problems, including complications, hypoglycemia, frailty, disability, depression, and cognitive impairment. A healthy lifestyle can help early-stage diabetic seniors manage their condition. Smart appliances have three main application fields in diabetic elderly healthcare. However, challenges such as unfriendly use, high price, and lack of privacy security hinder their acceptance and need to be addressed. The findings provide insights into the design and development of user-friendly and personalized smart appliances, which can significantly improve the life quality and health outcomes of diabetic elderly and represent a promising direction for the future of elderly healthcare.*

**Keywords:** Diabetic elderly, smart appliances, IoT, healthcare

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### INTRODUCTION

As one of the most rapidly increasing diseases in the world, diabetes affects people of all ages, resulting in a major economic and societal loss worldwide. There is an anticipated global prevalence of 628.6 million population suffering from this disease by 2045. The prevalence of global diabetes varies by age, with the 55–59 and 65–69 age groups experiencing rates of roughly 15% and nearly 20%, respectively (Standl et al., 2019). In Malaysia, diabetes is a significant public health issue, and the prevalence of type 2 diabetes (T2D) affects 2.8 million people (Hussein et al., 2016). Elderly group with type 2 diabetes is exposed to particularly difficult challenges (Ahola, 2016). The global population who are over 65 years old with diabetes mellitus is anticipated to increase from 122 million in 2017 to 253 million in 2045. In tandem with an expected growth from 652 million to 1.42 billion among the aged population from 65 to 99 years old, it means almost 20% of diabetes are the elderly (Bellary et al., 2021). Therefore, an increasing number of diabetic elderly raises the demand for better quality and efficient healthcare services, which matters globally (Finland et al., 2018). The increasing number of diabetic elderly group presents a significant public health issue worldwide. However, this population group demonstrates a larger range of physical and cognitive disability than the younger group, which can make taking care their diabetes particularly challenging (Wang et al., 2021). Current smart appliances designed for diabetes may not be suitable for elderly users, as their complex function design and features hinder their independent use. As a result, diabetic elderly individuals may be unable to benefit from the advanced technological products of healthcare, which can affect their quality of life and health outcomes. A special and personalized healthcare appliance is needed to meet the unique demands of diabetic elderly group (Ahmadi et al., 2019).

Smart healthcare gadgets based on the Internet of Things are currently booming in the healthcare industry. The industry has developed from generation 1.0 to 4.0 during the Internet of things period. Home healthcare service was one of the most prominent IoT healthcare applications, IoT-based smart appliances present promising solutions in the field of diabetic elderly's healthcare (Ahmadi et al., 2019).

Based on the problem mentioned above, by literature review, this paper aims to investigate the problems faced by diabetic elderly, and the development of smart appliances for diabetic elderly as well as the challenges IoT smart appliances will encounter in the future. IoT-based smart appliances present promising solutions for developing healthcare for diabetic elderly.

## **METHODOLOGY**

This paper used literature review as the main method. The literature review study follows the unique “Literature Review Synthesis Process” (Ibrahim, 2008). Topics were identified based on Ibrahim’s research question’s construct categorization technique for identifying three different RQ Constructs— “WHO”, WHAT” and “HOW—to formulate research questions and keywords. In this research, WHO refers to diabetic elderly, WHAT is IoT-based smart appliances, and HOW, means to provide healthcare. According to three RQ Constructs, there are three topics that can be defined to collect the articles: a) the problems of diabetic elderly; b) the status of IoT-based appliances for diabetic elderly; c) the status of healthcare for diabetic elderly. This study selected related articles under RQ Constructs. The search for relevant articles was conducted under these keywords: (diabet\*) AND (old\* OR elder\* OR aged OR senior\*) AND ( "intelligent home appliance\*" OR "smart home" OR "smart home appliance\*" OR "home appliance\*" OR "kitchen appliance\*" OR IoT OR "internet of thing\*" ) AND (health\* OR "healthcare" ) through Google Scholar, Scopus and Web of Science databases. After those titles were searched and abstracts screened among the whole research articles from 2010 to 2022, 79 articles were initially identified. The original literature was manually screened. Inclusion criteria were: (1) research with diabetic elderly aged over 60; (2) elderly people using IoT-Based smart appliances; (3) IoT-Based smart appliances as a major tool or intervention. Exclusion criteria were: (1) young diabetic patients, but not type 2 diabetes; (2) Healthcare products out of IoT categories. According to the two kinds of criteria, 47 articles were finally selected for this review through detailed search inquiry. These articles are reviewed according to the identified topics: (a) health problems of diabetic elderly; (b) the application of IoT-Based appliances by diabetic elderly; (c) the challenges of applying IoT-based smart appliances in the field of diabetic elderly healthcare.

## **RESULTS AND DISCUSSION**

The following topics are presented and discussed:

### **A). HEALTH PROBLEMS OF DIABETIC ELDERLY**

As an extensive chronic disease among senior population, diabetes is often neglected by elderly people residing in nursing homes. Diabetic elderly are facing health problems, against which they have special characteristics and needs (Sari & Manungkalit, 2019). According to the review results, four serious and common diabetic-related problems are suffered by diabetic elderly, including complications, hypo glycaemia, frailty and disability, and cognitive impairment.

Firstly, complications are very common among elders with diabetes. They are at higher risk of suffering microvascular and macrovascular diseases (such as ischemic heart disease, peripheral artery disease, stroke, heart failure, and chronic kidney disease) compared to young group (Elliott, 2012). Complications will have a serious influence on diabetic elderly’s living independence, self-care capability and daily life quality. Especially the episodes of cardiovascular and hypoglycemics are at the highest occurrences. According to the 2013 International Diabetes Federation (IDF) worldwide guideline, "all diabetics over the age of 60 are considered to have a high cardiovascular risk (Gambert & Pinkstaff, 2006)."

Another common diabetic-related disease is hypo glycaemia, which is an overlooked medical problem that happens among diabetic elderly. It is reported that a high risk of serious hypo glycaemia episodes has a high connection with a long duration of type 2 diabetic elderly. Frequent hypo glycaemia will increase the possibility of frailty among diabetic elderly (Sinclair et al., 2015). Many diabetic elderly who need to inject insulin can be frail, declined in vision or suffer from cognitive issues. Therefore, it is essential for elder diabetics to arrange insulin dose injections depending on daily and hourly glucose fluctuations, which can benefit the hypo glycaemia prevention for diabetic elderly (Sinclair et al., 2015).

Besides above mentioned, as diabetic elderly age, type 2 diabetes also has an increasing impact on functional autonomy (Pilotto et al., 2020). Long-term diabetes accelerates the loss of skeletal muscle mass and its function, both of which are essential to preventing frailty, sarcopenia, and incapacity from happening. While losing both can result in the decrease of mobility and quickness of movement. Hence, sarcopenia is regarded as a significant indicator to measure the development of limb impairment and frailty in diabetic elderly (Prina et al., 2019).

Finally, one of the crucial health problems for diabetic elderly is that long-term diabetes may be associated with modest cognitive impairment and produce brain cortical abnormalities in the elderly, resulting in difficulties with daily living tasks. It has been linked to mental, motor, and cognitive slowness. Diabetes and dementia, such as incident vascular dementia and Alzheimer’s disease, are very prevalent. These chronic conditions frequently coexist with senior population (Feinkohl et al., 2019).

## **B). THE APPLICATION OF IOT-BASED APPLIANCES FOR DIABETIC ELDERLY HEALTHCARE**

This part reviewed the specific domains of IoT- Based appliances applications in healthcare, which can be classified into three categories as follows:

### **HOME HEALTHCARE**

Diabetes is a common chronic illness among home care residents who have the elevated rates of comorbidity, disability, frailty, and mortality. There is a demand for home care services that address problems of nutritional deficiencies, weight loss, increased risk of hypoglycemia, high infection, as well as leg and foot ulcers (Nyashanu et al., 2022). In order to prevent unnecessary hospitalizations for diabetes-related complications, home care services should pay attention to the safety, comfort, and maintenance of the life quality of diabetic seniors, as well as preventative treatment to reduce hypoglycemia. Home healthcare services provided by IoT-based appliances are a promising solution to handle the problems associated with diabetic elderly and even the ageing population at large. According to the analysis by research, the majority of applications were utilized for home healthcare monitoring. In the nearer future, the delivery of healthcare services will be shifted from a hospital-home balance manner in 2020 to a home-care service in 2030 (Singh et al., 2017). Advanced technology covers all aspects of aged diabetic patients' daily life, including monitoring, emergency management, rehabilitation strategies in stroke, medication management and tele-medicine. IoT wireless sensor network technology is particularly effective for home monitoring, such as vital sign monitoring and tele-monitoring (Ahmadi et al., 2019).

### **MOBILE HEALTHCARE AND ELECTRONIC HEALTHCARE**

The fast development of smartphones and related electronic devices increases the usage of IoT appliances. Electronic devices like wearable appliances can detect and collect physiological signals of elderly people's body by means of variable and wearable sensors through software applications (mobile or watch). These signals can be delivered to a cloud database platform in healthcare companies, and then they send the data to caregivers or doctors for health monitoring (Singh et al., 2017). For the new coming m-health (mobile-health) era, the IoT-appliance solutions provide a personalized method in healthcare services. In other words, mobile and electronic healthcare not only promise new solutions for patients' and doctors' instant communications but also create a better-personalized treatment strategy to the patients. In the field of e-health (electronic-health), electronic or wearable devices can connect to the Internet to perform various telehealth services such as tele-monitoring, tele-consultations and elderly supervision (Calvaresi et al., 2017). Acceptability and usability of mobile and electronic healthcare for long-term diabetic elderly were identified in this review. Results show many IoT-based appliances focus on providing self-management service for diabetic elderly, such as blood glucose patterns and insulin calculation. Mobile phone applications can provide health habit guidance for diabetic elderly to help them form good habits and enable them to track daily food caloric intake and record physical activities. Those recorded data is available to caregivers and doctors who will in turn provide essential information and support (Al-Adhab et al., 2016). In a world, IoT-based mobile and electronic appliances make a change in lifestyle of diabetic elderly and provide them with positive health outcomes.

### **HOSPITAL MANAGEMENT HEALTHCARE**

Services in hospital management healthcare have been identified in this review, including developing a comprehensive plan for diabetic elderly education and hospital infection prevention. IoT remote technologies such as sensors, ZigBee, and RFID, can bring solutions to meet the challenge of hospital patient management. In addition, it is crucial to plan nursing services after hospital discharge in hospital management. The whole process of patients from admission to discharge rely on careful plan making (Catarinucci et al., 2015). IoT technologies appliances offer acceptable and efficient patient telemonitoring solutions to solve this dilemma. For example, researchers developed a healthcare management system based on an IoT application for daily continuous glucose monitoring and matching medications of diabetic elderly. This model dramatically reduces medication-taking problems, meanwhile, it also provides real-time alerts and health reports to doctors and patients via IoT cloud data transmission (Bhatia & Sood, 2016). To sum up, IoT technology appliances will be used for post-discharge planning for diabetic elderly.

## **C). THE CHALLENGES OF IOT-BASED APPLICATIONS FOR DIABETIC ELDERLY HEALTHCARE**

### **PRIVACY SECURITY**

Privacy security is one of the most crucial factors that influence diabetic elderly's willingness to accept and use IoT smart appliances. There are two main factors of privacy: physical and information. Physical privacy means to respect patients' personal space, any data collection that infringes on their privacy will reduce the acceptance. The informational privacy is the security to limit the disclosure of personal information to third parties, otherwise it might infringe on users' informational privacy (Astell et al., 2020). Many diabetic elderly, their families, and healthcare professionals have concerns about the rules of data collection, the sorts of data gathered, the use of the data and access levels, because home monitoring systems may retain and communicate intimate personal data (Chan et al., 2022). This demonstrates the importance of comminating views of users and designers together and considering privacy in a broader sense. Designers need to consider protecting diabetic elderly patients' data from hacking or being stolen, which is a challenging issue.

## USER ACCEPTABILITY AND USABILITY

Technology enthusiasm is an important factor that influences user acceptability, put it aside other factors like appearance, interface, usability, functions and so on (Sohn, n.d.). While diabetic elderly who feel negatively and connect ageing with "sickness," "loneliness," or "dependence" are more prone to reject IoT smart appliances technology than those who possess a positive view to accept and use IoT devices. Therefore, diabetic elderly is more likely to reject to accept new technology if their values are ignored. In turn, it would be easier to be accepted by diabetic elderly if their values are respected (Arar et al., 2021). Thus, to put good use to IoT technology's value, all the above-mentioned factors must be considered to improve the acceptability and usability of IoT smart appliances among diabetic elderly. In addition, appliances designers should take the demands of diabetic elderly into consideration. It is significant for designers making adjustment in their attitude and practice to change from "doing for" users to "doing with" users.

## COST

It may be expensive for individuals or families to buy advanced IoT smart appliances equipped with sensors, security protocols, network infrastructure and compatible devices. Manufacturers and enterprises should promote the concept of IoT and expand the supply chain capacity to reduce sales prices so as to stimulate the acceptance and purchase of IoT-based smart appliances (AlShorman et al., 2021). Technological advance recently brings down the cost of smart appliances design process, for example, smart appliances which adopted the micro-controller controlled system with external appliance switching circuit enable consumers to afford smart appliances with cheaper budget (Hasan et al., 2019). Although it's expensive to buy home care smart products for individuals, to own one personal smart product is much more effective and cheaper than to hire a house caregiver for those families who need private healthcare service. The multi-function of smart products provides a great convenient for elderly's daily life (Zhang et al., 2020).

## CONCLUSION

Nowadays, diabetic elderly and the ageing population are increasing globally amid the IoT era. This review paper aims to investigate the main healthy problems among diabetic elderly, the applications, and future challenges of IoT-based smart appliances. Results showed that the complex healthcare needs special and personalized healthcare appliances to cope with series of conditions that diabetic elderly come across, including complications, hypoglycemia, frailty and disability, and cognitive impairment. Internet of Things (IoT)-based smart appliances show great advantage in the healthcare of diabetic elderly as they can provide personalized and convenient health monitoring and management services. IoT smart appliances in healthcare are mainly applied in three fields, that is, home care, mobile and electronic care, as well as hospital management. However, the development of IoT-based smart appliances also meets significant challenges, which involve security and privacy concerns, standardization absence, and usability limitations for elderly users. On the one hand, this review paper's results can help appliance companies better understand demands to occupy new markets and improve product competitiveness in the market. On the other hand, this research will improve the diabetic elderly's life quality standard by designing aging-oriented smart appliance so that diabetic elderly can better control their daily habit to keep good glycemic condition. However, the intervention of smart applications is limited for elderly group, future study may be applied in all-age diabetic groups including children, teenagers, and adults. Further research on IoT-based smart appliances designed for the diabetic elderly could investigate even more extensive aspects, such as healthcare impact, privacy security protection, cost-effectiveness, infrastructure, acceptability, and usability. Overall, IoT-based smart appliances have the potential to significantly improve the quality of life and health outcomes for diabetic elderly, and they represent a promising direction for the future of elderly healthcare.

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