BP-ExerGuide: Smart Blood Pressure Monitor System for Personalized Exercise Safety Guidelines in Senior Communities

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***Abstract*—Hypertension is highly prevalent among older adults, and its global incidence is increasing primarily due to the aging population. With the development of information and communication technology, smart blood pressure monitors have been developed to offer more personalized guidance to users. A smart blood pressure monitor must provide users with professional guidance, such as monitoring pregnancy-induced hypertension for pregnant women and brain health indicators for older adults. This increases user willingness and engagement. In this study, we developed a smart blood pressure monitor system called "BP-ExerGuide" to provide a personalized exercise safety guideline for older adults in the community's smart gym. In this scenario, all smart gym devices are equipped with RFID sensors, and members can use their personal RFID cards to start a blood pressure measurement. Only when the blood pressure value meets the safety criteria for exercise, can they use the exercise devices. If an individual's blood pressure is too high, BP-ExerGuide acts like a sports coach, advising seniors to take a rest first and then start exercising once they meet the safety guidelines. The system also integrates exercise logs and blood pressure logs into a smart healthcare platform for seniors to track their physiological changes. Overall, the BP-ExerGuide system provides older adults with a safer and more personalized exercise experience while monitoring their blood pressure levels. This system improves the willingness of seniors to exercise regularly and thus promotes better health and well-being.**

Keywords—smart blood pressure monitor system, BP-ExerGuide, older adults, personalized exercise safety guideline, smart gym

I. INTRODUCTION

Rapid population aging is a significant global challenge that countries worldwide are grappling with. According to the United Nations, it is projected that by 2050, the population over the age of 60 will make up approximately 21.3% of the global population[1]. In Taiwan, this issue has become particularly prominent, as the country officially entered the realm of an aging society in 2018, with individuals over 65 years old accounting for 14.56% of the total population. Furthermore, Taiwan is expected to transition into a "super-aged society" by 2025, as the proportion of older individuals surpasses 20% of the overall population [2].

Hypertension is highly prevalent among older adults, and its global incidence is increasing primarily due to the aging population. Projections indicate that by 2025, approximately one-third of the world's population will experience hypertension, amplifying the significant burden it imposes on public health [3]. Since 2012, the World Health Organization (WHO) has progressively introduced resolutions for eHealth, emphasizing the importance of utilizing Information and Communication Technology (ICT) to establish a comprehensive, accessible, and equitable healthcare system as part of long-term developmental strategies [4]. In line with this, the WHO released the "Global Strategy on Digital Health 2020–2025" to advocate the integration of intelligent technologies for enhanced medical diagnosis, treatment decision-making, digital therapy, clinical trials, self-care, and human-centered care [5]. Recently, Tainan City Government has collaborated with telecom operators to promote community blood pressure measurement programs using an Internet of Things (IoT) system to encourage senior citizens in the community to monitor blood pressure regularly. Unfortunately, this system has limitations such as only displaying the current blood pressure value, and the platform lacks user-friendliness. Consequently, residents have discontinued their use of the system, leading community volunteers to revert to the traditional method of recording

blood pressure using pen and paper. With the development of information and communication technology, smart blood pressure monitors have been developed to offer more personalized guidance to users. A smart blood pressure monitor must provide users with professional guidance for monitoring pregnancy-induced hypertension for pregnant women [6] and brain health indicators for older adults [7]. The monitoring can increase user willingness and engagement.

Elevated blood pressure is related to various diseases, including cardiovascular disease, stroke, and kidney disease [8]. Studies have highlighted the positive impact of regular exercise in effectively reducing high blood pressure and promoting beneficial changes in the body. However, there has been limited attention to the safety of exercise for individuals with hypertension. Addressing this concern, this research is focused on developing a smart blood pressure monitoring system specifically designed to ensure the safety of exercise for older adults. The innovative solution named "BP-ExerGuide" is proposed as a smart blood pressure monitor system that offers personalized exercise safety guidelines for older adults within the community's smart gym.

II. Methodology

A. Design of BP-ExerGuide System

The smart blood monitoring system, called BP-ExerGuide integrates a commercially available blood pressure measuring device with IoT technology and a user interface. The system is designed for the health management of individuals who have questionable vital signs and need exercise. The system can send warnings to both the users and their caregivers via the Internet. Figure 1 illustrates the configuration of the BP-ExerGuide system.

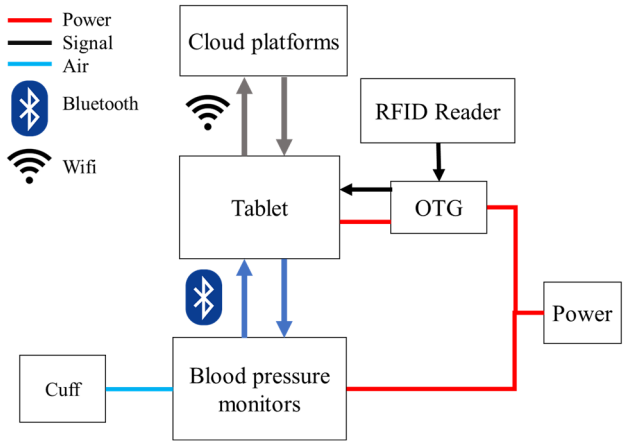

Fig. 1. Schematic diagram of the configuration of BP-ExerGuide system.

The blood pressure measuring device used in the BP-ExerGuide system is the FORA P30 Plus, a medical-grade arm blood pressure monitor manufactured in Taiwan. Its main advantage is the ability to transmit readings via Bluetooth and to initiate and stop measurements with a command. To ensure secure access to the BP-ExerGuide system, an RFID reader (USB RFID IC Card Reader Mifare 13.56MHz) is incorporated into the system so that users can log in to an application interface and proceed with the blood pressure measurement with their ID cards. The BP-ExerGuide system is specifically designed to aid physical training instructors, senior gyms, and community healthcare centers in delivering their services without the need for additional manual operation. As such, the system is designed to be portable and compact in a form of a medium-sized suitcase with dimensions of approximately 396 × 296 × 157 mm. The prototype of this system was made using laser cutting and 3D printing to ensure ease of use.

B. Instruction of Use and User Interface

The procedure for the BP-ExerGuide system involves stretching the left arm in front of the body with the palm facing up. Next, the user sits comfortably with the cuff wrapped around the arm and tightened. To begin the measurement, users must log into the system using their RFID card and start the measurement immediately.

The user interface for the BP-ExerGuide system is an application (APP) installed on a tablet or mobile device. This APP is connected to the smart healthcare platform [9] via the Internet and receives blood pressure readings and identification information via Bluetooth. As shown in Fig. 2, the APP displays a message on the screen for the blood pressure measurement and the associated result to inform the users directly. A notification function is integrated into the system to alert physical training instructors and caregivers via the social media platform LINE. All settings can be modified from the APP with manager authorization, as demonstrated in Fig. 3.

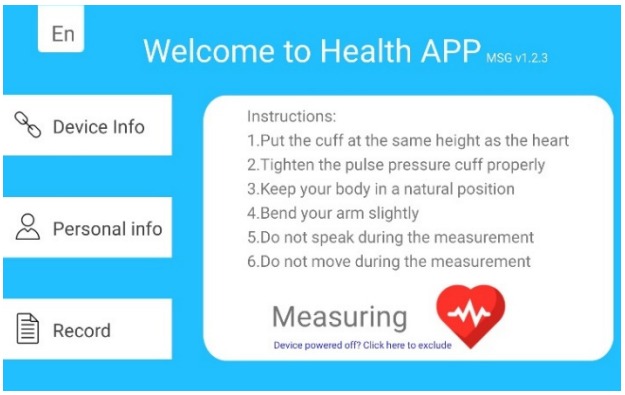

Fig. 2. User interface of BP-ExerGuide system.

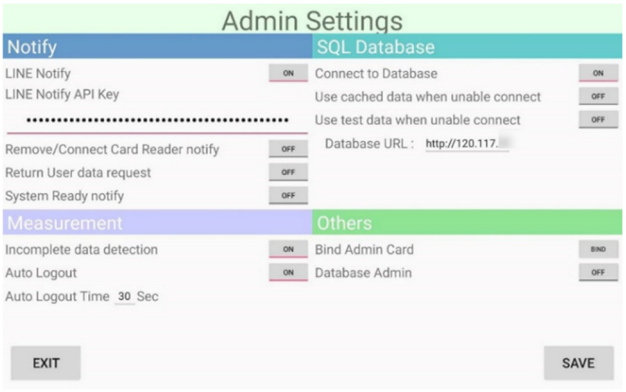

Fig. 3. Function of real-time alarm using LINE notify shown in settings.

C. Rule-based Health Management

The BP-ExerGuide system includes a personalized exercise safety guideline for older adults based on a study of the clinical value of exaggerated exercise blood pressure (EEBP) and supporting best-practice measurement of exercise blood pressure in clinical exercise settings [10]. However, the threshold is arbitrary and does not account for exercise workload, and lacks justification via empirical evidence. In this study, a modified threshold of under 180/110 mmHg and

100 bpm is established for people with chronic diseases. If the user is undergoing hypertension treatment, the threshold is lowered to 140/90 mmHg and 100 bpm. This rule is written into the protocol and alerts users when it is safe for them to join the exercise (Fig. 4).

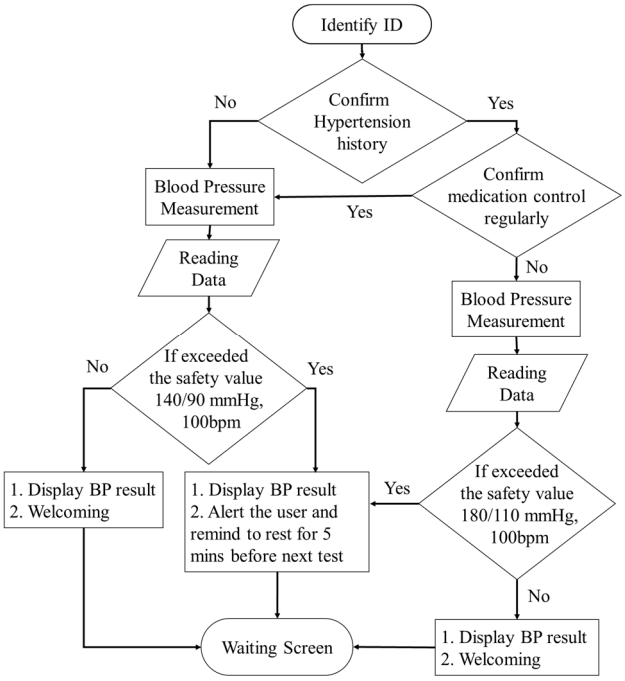

Fig. 4. Rule of blood pressure guideline for safe exercise.

D. Data Collection and Smart Healthcare Platform

After the user measures blood pressure, the information is uploaded to the database. We also developed a mobile platform for caregivers to use. Caregivers can query the blood pressure records of each user through the mobile platform to monitor whether the user has signs of abnormal blood pressure (Fig. 5).

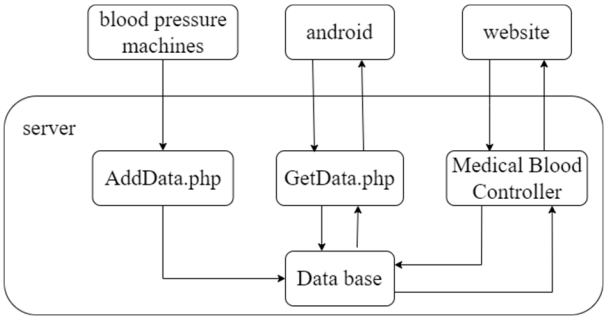

Fig. 5. Structure of each subsystem uploading data to the database.

E. System Architecture and Components

The smart healthcare platform is created on the Nginx web server for database searches and requests on blood pressure data. The system architecture is depicted in Fig. 6.

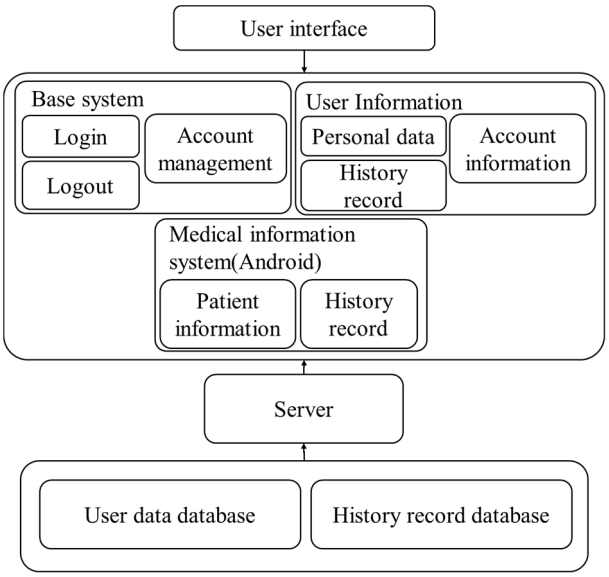

Fig. 6. System architecture.

III. Results and Discussion

A. Prototyping of BP-ExerGuide System

Figures 7 and 8 show the BP-ExerGuide System prototype and a maneuver scenario, respectively. By tapping their RFID card on the reader, the user can access blood pressure measurements. The screen displays a user-friendly interface and provides instructions. This prototype comes in two types: portable with a suitcase and bench type . Caregivers can easily transport it to users or place it next to exercise machines. Being lightweight, both types require an internet connection to send the LINE notification and save the readings to the cloud platform.

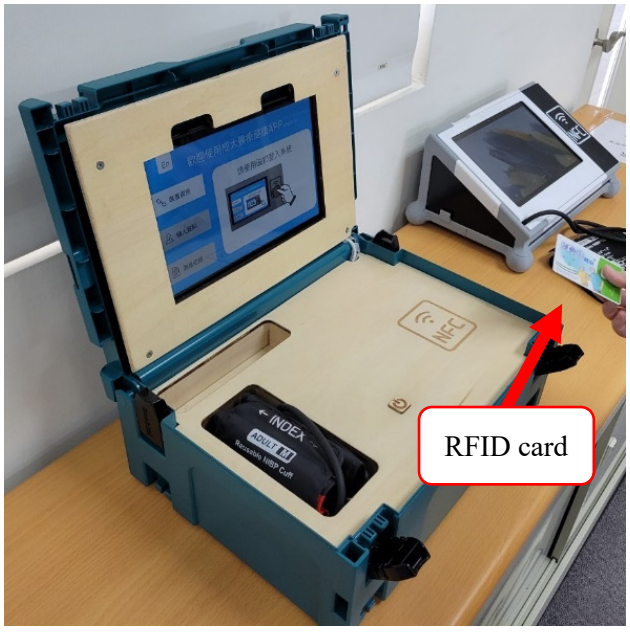

Fig. 7. Accessing BP-ExerGuide with a RFID card.

Fig. 8. Demonstration of measuring blood pressure.

B. Health Management and Alarm Message

To minimize the risk of accidents during exercise and ensure the safety of users with chronic complications, the rule-based management system can quickly identify and exclude suspicious users. As shown in Fig. 9, if a reading exceeds the threshold and poses a risk, the system recommends that the user take a 5-minute break before taking another measurement.

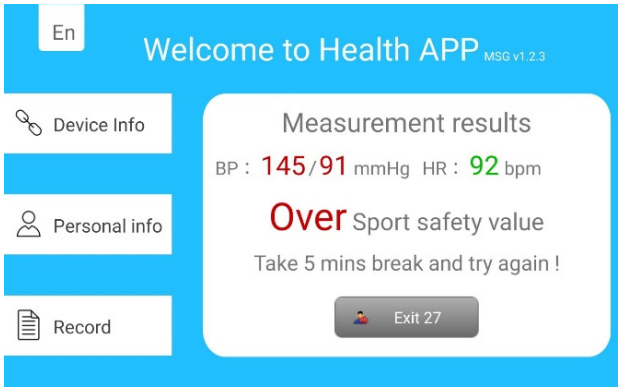

Fig. 9. Demonstration of measuring blood pressure.

C. Performance Evaluation and Testing Results

We built a web page with a fluid layout to show the record. When the window size changes, the page layout adjusts to the current window size. The upper part of the web page converts the blood pressure records into a graphical display, and the lower part shows the records and the detailed time of each measurement. The schematic diagram is shown in Fig. 10.

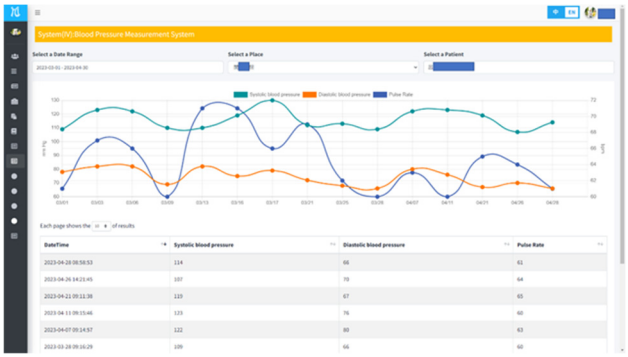

Fig. 10. Website schematic diagram.

IV. Conclusion

The BP-ExerGuide system offers older adults a safer and more personalized exercise experience by monitoring their blood pressure levels. The system enhances the motivation and willingness of seniors to engage in regular exercise. As a result, seniors can enjoy improved health and well-being, reaping the benefits of an active lifestyle.

Acknowledgment

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