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RESEARCH PAPER

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Smart Design of TB MediBox Prototype with Reminder and Monithoring Method for Taking Medicine Based on ESP32 for Pulmonary Tuberculosis Patients

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ABSTRACT

Appropriate and complete TB treatment it is very important to ensure TB bacteria are killed effectively and prevent recurrence disease. If treatment is not followed properly, TB bacteria can become resistant to medication, and difficult to treat. TB sufferers who receive appropriate and complete treatment usually recover completely. As an effort to increase medication compliance in patients TB requires technological innovation, one of which is by making a box prototype design a drug called MediBox TB. Therefore, this study aims to remind TB Patients to take medication regularly with the alarm on the MediBox TB and know the amount of medication consumed. This study contributes to helping patients undergo a more regular therapy schedule, reduce the potential for the emergence of drug resistance, and improve treatment success, thereby supporting efforts to overcome tuberculosis as a whole. The research method uses an experimental approach Laboratory-based research and development consists of two stages, namely the design stage tools and tool testing. This tool is designed using a microcontroller-based method ESP32 as a device controller and RTC alarm as a time reader. The level of accuracy is assessed of the component's ability to work according to its function, this is influenced by time and sign warning. This prototype shows that it can detect when testing is carried out and There is an alarm sign on the LCD panel display which indicates the device is capable of reading and detect tool components according to instructions. Then to assess the quality of the automatic medicine box that we have designed, we distributed questionnaires to 50 respondents. This questionnaire aims to measure their satisfaction with various aspects of the device. The average score shows a good level of satisfaction in the aspects of ease of use and alarm quality with an average value of 4.08 and 4.06, while the lower average score is in the aspect of battery life with an average value obtained of 3.92. The average score for each aspect is calculated from a scale of 1 (very dissatisfied) to 5 (very satisfied). The results of this study show that the MediBox TB automated medication box, offers features that have great potential to improve the user experience in following the medication schedule.

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1. INTRODUCTION

Tuberculosis is an infectious disease that is still a public health problem and is one of the main causes of death, so a sustainable TB control program needs to be implemented [1][2]. Tuberculosis (TB) is an infectious disease caused by the bacteria Mycobacterium tuberculosis, which attacks the lungs [3]. Even though effective treatment is available, the level of patient compliance in carrying out long-term therapy is still a big challenge in treating this disease. According to the World Health Organization (WHO), in 2022, approximately 10 million people fell ill with tuberculosis, and 1.5 million deaths were attributed to this disease worldwide. Indonesia is among the countries with the highest TB burden, making it critical to address not only the medical treatment but also patient adherence to long-term therapy [4]. The TB treatment process takes a long time, around 6 to 12 months, with regular and timely medication

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consumption. Non-compliance with the medication schedule can cause relapse, drug resistance, and an increased number of deaths [1], [2], [5]. The main problem in TB therapy is the low level of patient compliance in following the treatment schedule [6], [7]. Efforts are being made to control the incidence of TB for patients who are not compliant in taking TB medication, WHO recommends various approaches including TB care and control, namely the Stop TB Strategy starting in 2006, related to the Millennium Development Goal's target, namely reducing the prevalence rate and mortality rate by 50 % in 2015 compared to 1990, and eliminate TB as a public health problem. WHO recommends DOTS (Directly Observed Treatment Short-term Chemotherapy) as a strategy for controlling TB and is an effective intervention. The DOTS strategy was developed to improve the quality of services, ease of access, discovery and treatment so as to break the chain of transmission, as well as guarantee the availability of Anti-TB Drugs (OAT) for TB control [2], [8], [9].

TB patients often forget to take their medication, especially when they feel their physical condition is starting to improve. Medication adherence refers to patients following medication instructions. Because medication adherence varies between individuals, this can have an important influence on treatment outcomes [10]. Compliance with taking medication is a key factor in the success of TB treatment. A number of patients in many countries stop treatment before completion for various reasons. The extent of treatment non-adherence is difficult to assess, but it is estimated that more than a quarter of TB patients fail to complete 6 months of treatment [9], [11]. Non-compliance with treatment increases the risk of treatment failure and is considered one of the causes of the emergence of drug-resistant TB [12]. In 2010, the Indonesian Health Research and Development Agency explained that one of the factors in the low recovery rate was non-compliance with the treatment of pulmonary TB sufferers. Anti-Tuberculosis Drugs (OAT) are provided free of charge to patients with a treatment duration of 6-8 months [13], [14]. This leads to lack of patient attention and irregular use of medications. Irregular treatment causes varying resistance of TB germs to anti-TB drugs. In TB treatment, there are many cases of patients who do not recover after treatment [15] [12].

The level of patient compliance with pulmonary TB treatment is often low due to various factors, such as the long duration of treatment, side effects of drugs, and lack of understanding or support from the health system [16]–[18]. This requires a solution that can help patients be more disciplined in undergoing consistent drug therapy and facilitate monitoring by medical personnel [19]. To increase medication adherence in pulmonary TB patients, a medication reminder tool can be an effective solution. This tool is designed to help patients follow their regular medication schedule, remind them when it is time to take their medication, and provide additional motivation to adhere to treatment [20][15]. Compliance with treatment is very important. If the treatment process is followed and completed, it is very effective in preventing drug-resistant tuberculosis, thereby curing the disease and preventing its spread to other people [21].

In 2018, Ekbal Rosli et al. developed a robotic device that can help patients to take medicine by implementing an IOT system. This research uses four sensors namely PIR, IR, ultrasonic and LM35 sensors. In addition, it uses, servo motors, Arduino Mega microcontrollers and bluetooth modules. However, this research has no shortcomings, namely the absence of a display on the tool, not being able to know the amount of medicine contained in the tool and the physical form of the tool that still needs to be tidied up again [22].

In 2018, Muhammad Abdul Kader developed a smart medicine box using ATmega328P, Character LCD, DS1307 and speaker. This research provides 21 small compartments to put medicine accompanied by color leds with different colors. However, this research has not used a TFT LCD for its display and cannot count the amount of medicine in it [23]. In 2018, Hiba Zeidan et al. developed an advanced medicine box that has a locking system so that it is not easily reached by children, integrated with IoT, calculates the weight of each pill, informs the number of pills remaining, alarms if the patient does not take the medicine. However, this medicine box does not have a display on the device, so to find out information you need to open an application on a smartphone [24].

In 2018, M. Srinivas et al. designed an IoT-based medicine box with SMS notifications given to guardians using ultrasonic sensors, IR sensors and sensors, stepper motors and Arduino microcontrollers. However, this research does not have a display on the device, so to find out information you need to open an application on a smartphone. In addition, the alarm system used still uses a buzzer, has not used a human voice system and has not used a battery[25]. In 2019, Ben-bin Chen at al., Developed an intelligent medicine box control system with 3D printing technology for the elderly using serri STM32407ZGT6 single-chip microcontroller, A4988 stepper motor, OLED LCD, buzzer, DHT 11, ESP8266. However, in this study the alarm system used still uses a buzzer, not yet using a human voice system [26]. The development of health technology (e-health) provides opportunities to increase the effectiveness of treatment through tools such as reminder and monitoring systems [20].

Based on the identification of previous research, many medicine boxes still do not have a display on the device using a TFT LCD, then the reminder alarms used still use buzzers, not using human voice recordings, with a human voice system that can provide clearer instructions and can increase compliance with drug use. Furthermore, the medicine box made still uses an adapter, not yet using a battery that can complicate the mobility of using the tool. In addition, there are still few medicine boxes designed that can calculate the amount of medicine inside.

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Based on the problems above, researchers are interested in carrying out technological innovations in the form of designing a prototype for reminders and monitoring of medication taking in TB patients on a basis ESP32 and an alarm called MediBox TB, MediBox is a smart device designed to help remind patients to take medication regularly and on schedule. This study aims to design a prototype of MediBox TB that functions as a reminder and monitoring tool for taking medication, especially for pulmonary tuberculosis patients. The use of MediBox TB is very important for patients which requires long-term treatment, especially in patients who are prone to forgetting to remember medication taking schedule. MediBox TB was designed with the hope of increasing TB patient compliance in taking medication regularly because it will be easier for patients to remember the schedule and dosage their medicine as well as providing real-time information to medical personnel regarding the patient's drug consumption, so that the treatment process can run more effectively and efficiently. In this case , MediBox can be an innovative solution.

2. MATERIALS AND METHOD

A. Data Acquisition

Tuberculosis remains a major public health challenge, requiring innovative approaches to improve treatment adherence[10]. Previous research identified shortcomings in existing medication reminder systems, including a less user-friendly interface and limited features. This MediBox is designed by using RTC, load cell sensor, HX710, speaker, ESP32, 2.4 Inch TFT LCD and using a 3D printer to design the medicine box. In assessing the quality of the automatic medicine box that we have designed, we distributed questionnaires to 50 respondents. This questionnaire aimed to measure their satisfaction with various aspects of the device. Data was collected through a structured questionnaire to assess user satisfaction with MediBox TB features, including ease of use, alarm quality, and design.

B. Data Processing

Fig. 1 is the system diagram in this study is structured into three primary segments: input, process, and output. Setting consists of the amount of drugs, drug mode, sound and volume, the weight of the drug entered will be weighed, when all has been determined for the setting will be processed by the microcontroller, the microcontroller will display the display according to the setting, if the reminder is in accordance with the setting will be processed by the microcontroller commands the DFplayer to play the sound playlist, the sound is amplified by the power amp, resulting in sound output in accordance with the sound and volume settings, in addition it will also give commands to the display, with the display of notifications and buttons to stop the alarm. The alarm will turn on influenced by RTC, RTC in the process adjusts by giving the same time as the actual time, if the time is the same as the setting then it will be processed by the microcontroller. For the weight of the medicine, it will be read by the loadcell sensor then converted to digital by HX710, the value will be sent to the microcontroller for processing.

Respondents' feedback was calculated using a Likert scale (1 = very dissatisfied, 5 = very satisfied). The scores are averaged to provide insight into the performance of the device, the scores include Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A), dan Strongly Agree (SA)[27].

C. Data Analysis

Descriptive statistics, including mean values, were used to analyze satisfaction scores. Comparative analysis with previous solutions highlighted the advantages of MediBox TB. Data analysis and interpretation using Likert scales is highly dependent on their variation. The symmetrical Likert scale includes a neutral option (neutral/don't know) that lies directly between the two extremes of strongly disagree (SD) and strongly agree (SA). This allows participants to make balanced and independent choices in either direction[28]–[30]. The following is a block diagram and explanation of the device, to provide a clearer understanding of the functions and workflow of MediBox TB.

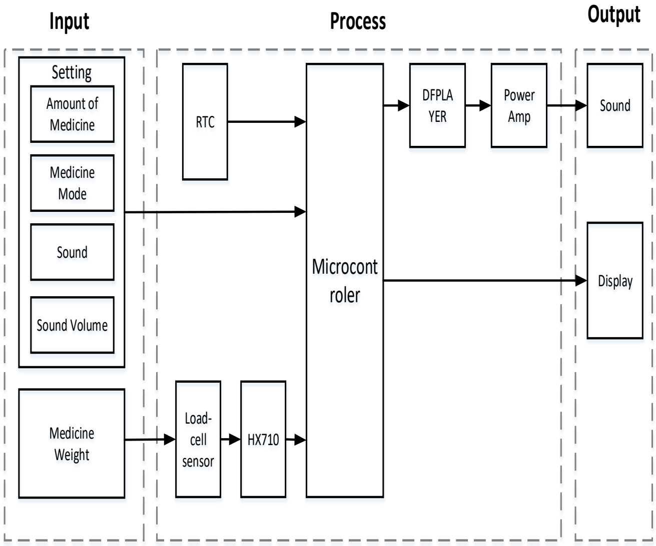

Fig. 1. The System Block Diagram

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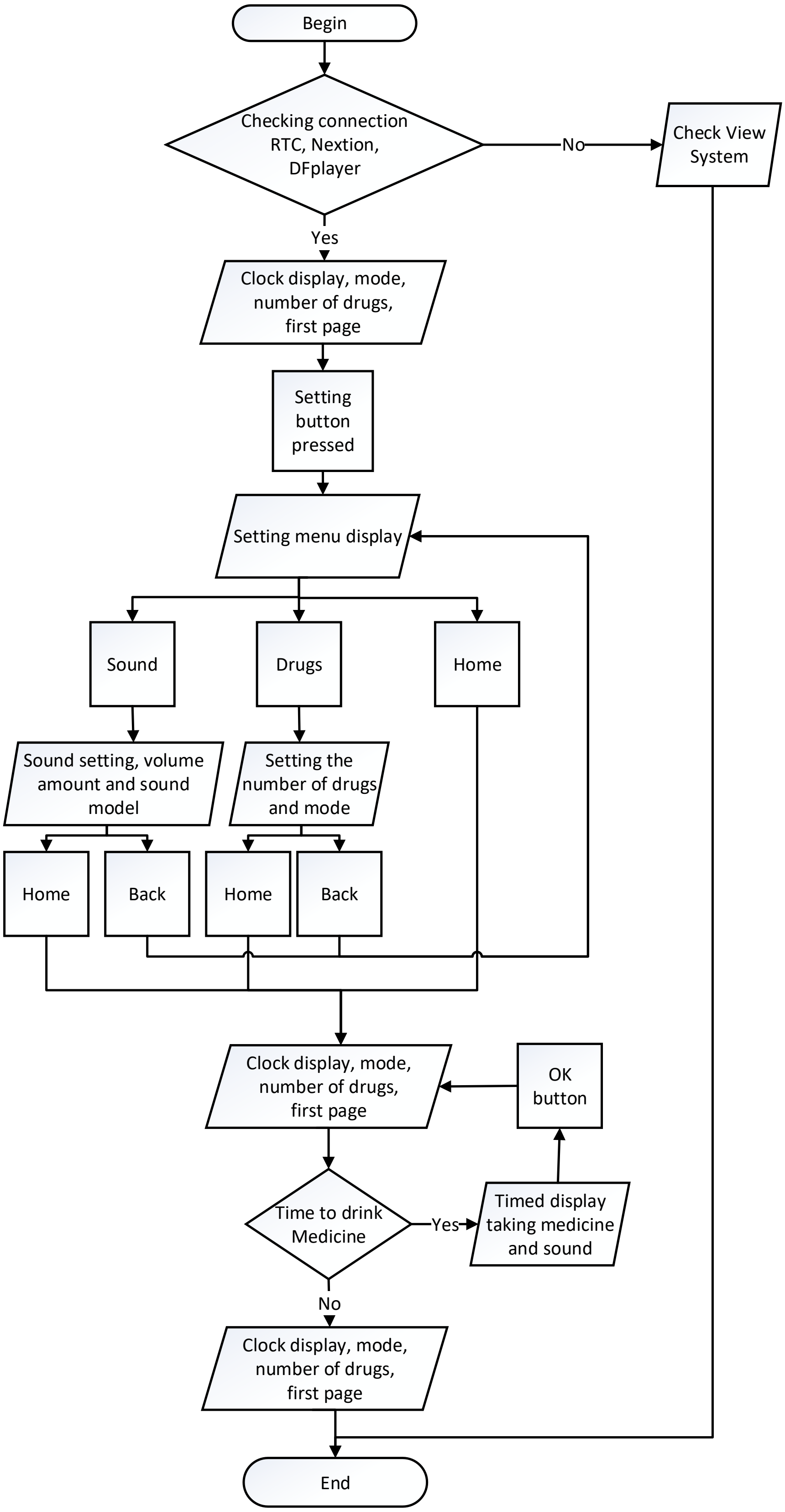

Fig. 2. Flow Diagram on Microcontroller

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Illustrates a comprehensive flow diagram outlining the program executed on a microcontroller Fig. 2 When the device is turned on, the system will correct all components (RTC, Dfplayer, Nextion), if there is an error the display becomes "check system", if correct it will display the first page containing the clock, the number of drugs, and the mode and there is a Setting button, the Setting button on the menu switches to the Setting page, there is Drug, Sound, and home, if Drug is pressed it will go to the Drug Setting page which contains to enter how many drugs and modes, choice 1 for intensive mode and choice 2 for advanced, there are home and back buttons, back will go to the Setting page, home will go to the main page. If Sound is selected, the Sound page is active and can make gender sound selection, and volume size, there is a back button to return to the previous page and a home button to return to the main page, on the Settings page there is a home button, if selected it will return to the main menu. When the alarm is the same as the settings that have been set, it will show a sound indicator and display "time to take medicine", press ok to return to the main menu.

3. RESULTS

The designed medicine box has advanced features such as medication time reminders, customizable sound models, as well as intensive mode and standard mode that can be selected according to user needs. Hardware design involves key components such as microcontrollers, sound modules, display screens, and speakers, all of which are connected in an integrated system to ensure optimal functionality.

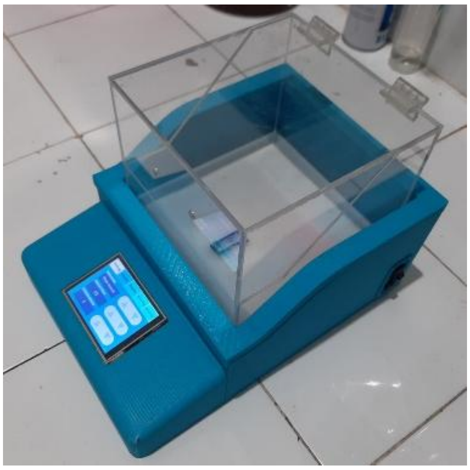

Fig. 3. MediBox TB Design

Fig. 3 showed the TB MediBox prototype designed as a smart solution to support the treatment of tuberculosis (TB) patients with a reminder and monitoring method based on ESP32 technology. This prototype has a modern design with a combination of 3D printing with a dominant blue color and a transparent acrylic top, which functions as a medicine storage container. On the front of the device, there is a touchscreen that displays an interactive interface for setting up the medication schedule and monitoring patient compliance in taking medication.

Fig. 4. MediBox TB Display

Fig. 4 is the MediBox display. On the initial display, the user will set the mode on the device, the amount of medication taken along with the rules for drinking. Users will also adjust the volume and sound that will be displayed. After that, a reminder is displayed on the screen and accompanied by a sound, so users can receive notifications clearly. The device testing process includes evaluating the functionality of each feature, as well as user testing to ensure that the device is easy to use and effective in reminding users to take medication according to a predetermined schedule.

The quality of this automatic medicine box was assessed by providing a questionnaire to 50 respondents. This questionnaire is to measure their satisfaction with various aspects of the device, such as ease of use, reminder accuracy, battery life, alarm quality, and design and size. The assessment is based on the Likert scale method which is a common assessment method in surveys to measure the level of satisfaction, perception, or attitude of respondents towards an item or product. Fig. 5 is the respondent's data to assess the quality of the automatic medicine box.

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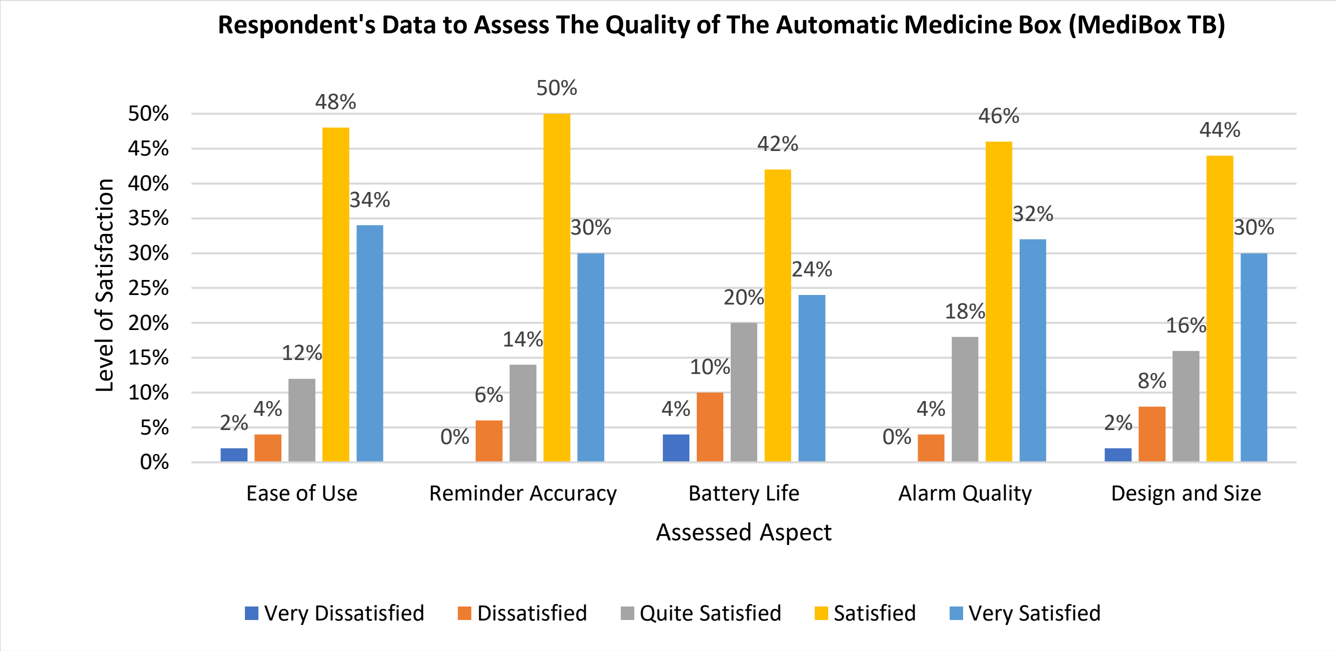

FIG. 5. Respondent's Data to Assess The Quality of The Automatic Medicine Box (MediBox TB)

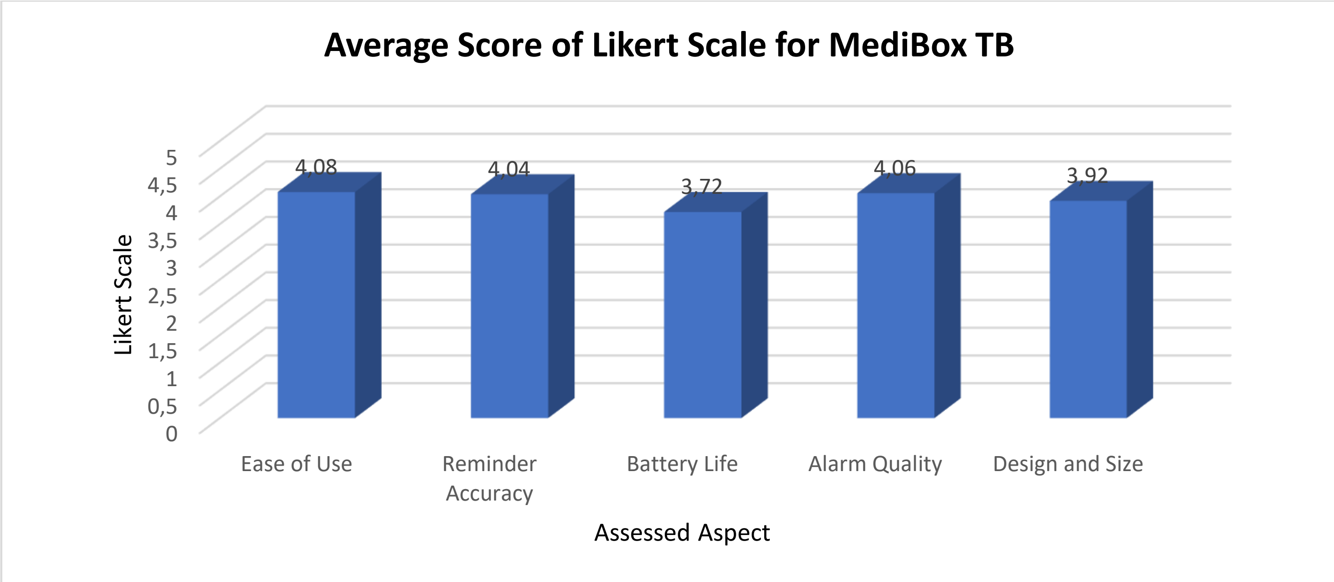

Fig. 6. Average Score of Likert Scale for MediBox TB

Each aspect measured in the questionnaire covers the main features of the automatic medicine box that will affect the user experience, namely whether the medicine box is easy to use, how accurate and quality the alarm is in reminding, battery life, how aesthetic and ergonomic aspects of the automatic medicine box design are. Respondents can choose each level of satisfaction from very dissatisfied to very satisfied. On the ease of use aspect, 2% of respondents were very dissatisfied, 4% were dissatisfied, 12% were moderately satisfied, 48% were satisfied, and 34% were very satisfied. In the aspect of reminder accuracy, 0% of respondents were very dissatisfied, 6% were dissatisfied, 14% were moderately satisfied, 50% were satisfied, and 30% were very satisfied. On the aspect of battery life 4% of respondents felt very dissatisfied, 10% felt dissatisfied, 20% felt moderately satisfied, 42% felt satisfied, and 24% felt very satisfied. On the aspect of alarm quality 0% of respondents were very dissatisfied, 4% were dissatisfied, 18% were moderately satisfied, 46% were satisfied, and

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32% were very satisfied. On the aspect of design and size 2% of respondents were very dissatisfied, 8% were dissatisfied, 16% were moderately satisfied, 44% were satisfied, and 30% were very satisfied. Fig. 6 is average score of Likert Scale for MediBox TB, the average score for each aspect is calculated from a scale of 1 (very dissatisfied) to 5 (very satisfied). The average score shows a good level of satisfaction on the aspects of ease of use and alarm quality, while the lower average score is on the aspect of battery life, because the battery can only last for 12 hours.

4. DISCUSSION

In this study, MediBox TB was designed as an innovative solution that aims to improve user convenience and compliance in taking medication regularly and on time. MediBox TB offers several key advantages that differentiate it from conventional medicine boxes and similar existing devices. With an attractive design and a TFT LCD display screen that facilitates user interface, MediBox TB fulfills not only functional but also aesthetic aspects, making it more user-friendly and easier for users to read the information displayed on the screen. This visual display is important for elderly users or those with visual impairments, as information regarding medication timing and instructions becomes more accessible. Another key advantage of MediBox TB is the use of batteries as a power source, which allows the device to have high mobility. Users can easily move MediBox TB as needed without being limited to the availability of power plugs. This provides more flexibility for users who may need this device in various places, such as home, office, or even while traveling. The reminder system on the MediBox TB also offers a different and better approach compared to standard alarms. In addition to the buzzer alarm, MediBox TB is equipped with a human voice feature, which allows users to choose between a male or female voice. This feature allows MediBox TB to provide softer and kinder reminders, while being able to convey instructions more clearly. This can improve user compliance with medication consumption, especially for elderly or anxious patients. Research shows that the human voice approach is more effective in providing reminders compared to conventional buzzer alarms, as the friendly tone of the human voice can reduce anxiety, provide a sense of comfort, and create a more pleasant experience for users.

In the future, MediBox TB has the potential to be enhanced with the addition of a temperature sensor feature, which will serve to maintain the quality of the medicine. Temperatures that are too high or too low can change the chemical properties of the medicine and reduce its efficacy, so the addition of a temperature sensor can assist users in maintaining the stability of the medicine in the device. In addition, a feature that provides instructions for drug consumption before or after meals will provide added value for users who need to comply with certain requirements in drug consumption. Thus, this development is expected to pay more attention to the health and comfort aspects of users. The IoT feature that will be applied to MediBox TB is also one of the significant developments. With this technology, MediBox TB can provide notifications to caregivers or family members if medication is not taken according to a predetermined time. This notification will be very useful, especially for elderly users or patients with physical limitations who require assistance in managing their daily medication. This IoT feature allows for remote monitoring, giving family members and caregivers peace of mind in ensuring that users are taking their medication on the recommended schedule. However, MediBox TB also has some drawbacks that need to be improved in the future. One of the main drawbacks is its large physical size and limited capacity to store only one type of medication. This poses a challenge, especially for users who have multiple types of medication that need to be taken regularly. In addition, the current medication timing still requires adjustments in the coding, which may be difficult for users without a technical background to do. Simplifying this process, such as through an app or a more accessible interface, would be an ideal solution to expand the use of MediBox TB by the general public. When compared to the 2018 study by M. Srinivas et al, MediBox TB shows some further advantages in its design and functionality features. In that study, the designed medicine box was IoT-based with a notification system via SMS, using ultrasonic sensors, IR, stepper motors, and an Arduino microcontroller. However, the device does not have a direct display on the device so users need to open a smartphone application to monitor information related to drug consumption. The alarm system on the device is also buzzer-based, which may be less effective in providing personalized reminders to users. In addition, the device does not use batteries, which may limit the user's mobility and flexibility in using the device in various places. MediBox TB, with its LCD display and the use of a human voice as an alarm, shows superior innovation in terms of user convenience. The battery feature also provides convenience in daily use, which was not the case with the previous device. With these superior features, MediBox TB is able to overcome some of the limitations of previous studies, providing a more practical, efficient, and user-friendly solution in daily medication management.

Overall, MediBox TB has great potential in supporting users to adhere to medication schedules in a more convenient, informative, and easy-to-use way. This

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innovation is expected to not only assist users in timely medication consumption, but also reduce the burden for caregivers or families in remotely monitoring medication adherence. Through further development and improvement of existing weaknesses, MediBox TB can continue to evolve into a more sophisticated and useful device in supporting public health.

5. CONCLUSION

This study aims to MediBox TB, a medication box designed to assist patients in remembering to take their medication regularly. The results of this study show that the automated medicine box, MediBox TB, offers features that have great potential to improve the user experience in following medication schedules. Ratings from 50 respondents on various aspects showed good levels of satisfaction, particularly on ease of use and alarm quality, with most respondents reporting that they were satisfied or very satisfied with mean scores of 4.08 and 4.06, respectively. However, there was room for improvement, particularly on the aspect of battery life which received a lower mean score of 3.92, indicating that users expected improvement in this regard.

The MediBox TB innovation is expected to not only assist users in taking medication on time but also ease the burden on caregivers and families in monitoring medication compliance remotely. Further development that can be done is to design the medicine box to be smaller and increase the number of boxes for storing drugs so that it can not only be used to store one type of drug. Make setting the time to take medicine easier through the display on the device or integrated with IoT without having to set the code again. With further development and improvement of existing weaknesses, MediBox TB has the potential to continue to evolve into a more sophisticated and useful device in supporting public health, especially Tuberculosis patients.

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