Accredited Ranking SINTA 2
Decree of the Director General of Higher Education, Research and Technology, No. 158/E/KPT/2021
Validity period from Volume 5 Number 2 of 2021 to Volume 10 Number 1 of 2026

Published online on: **http://jurnal.iaii.or.id**

JURNAL RESTI
(Rekayasa Sistem dan Teknologi Informasi)
Vol. 7 No. 6 (2023) 1412 - 1421 ISSN Media Electronic: 2580-0760

A Cost-Effective Vital Sign Monitoring System Harnessing Smartwatch for Home Care Patients

Dodon Turianto Nugrahadi[1], Rudy Herteno[2], Mohammad Reza Faisal[3], Nursyifa Azizah[4*], Friska Abadi[5], Irwan Budiman[6], Muhammad Itqan Mazdadi[7]
[1,2,3,4,5,6,7] Computer Science Department, Faculty of Mathematics and Natural Sciences, Universitas Lambung Mangkurat, Banjarmasin, Indonesia
[1]dodonturianto@ulm.ac.id, [2]rudy.herteno@ulm.ac.id, [3]reza.faisal@ulm.ac.id, [4]nursyifaziza@gmail.com, [5]friska.abadi@ulm.ac.id, [6]irwan.budiman@ulm.ac.id, [7]mazdadi@ulm.ac.id

Abstract

Telemedicine applications enable online health consultation services, but they have limitations: there is no vital sign examination as in offline consultation. Furthermore, vital sign examinations for patients treated outside hospitals, such as outpatients and home care patients, are not as routine as for inpatients. Although patient monitors can be used to monitor vital signs in real-time, they are expensive, making it difficult to use them for home care patients. This research aims to develop a vital sign monitoring system for home care patients that integrates a smartwatch as a data acquisition sensor device, a mobile application as a gateway that collects vital sign data and sends it to a web server, and a web application to remotely monitor vital signs and changes in their values. This system also aims to make it easier for patients and their families to communicate with doctors and nurses while viewing vital sign information and the risk of patient deterioration in the form of Early Warning Score (EWS). The smartwatch chosen is based on its features and low price, so a cost-effective vital sign monitoring system can be produced. Testing using the black-box method shows that the system functions well and meets the expected functionality.

Keywords: *home care; national early warning score; vital sign; smartwatch; e-health*

1. Introduction

Telemedicine applications such as KlikDokter, Alodokter, and Halodoc have made it easier for the public to obtain online health consultation services. These applications allow users to consult with doctors through chat or voice calls to receive advice on their symptoms or complaints. However, the drawback of these applications is the lack of vital sign examination that typically takes place during face-to-face consultations. In face-to-face consultations, patients have their vital signs examined, including blood pressure, heart rate, respiratory rate, and body temperature, as part of their condition assessment. The absence of vital sign examinations in telemedicine implementation can result in incomplete patient condition information, affecting the quality of diagnoses or advice given by doctors [1], [2]. If the user's complaint or symptoms are serious, doctors may recommend face-to-face consultations [3]. Therefore, the use of telemedicine in Indonesia is currently limited to non-emergency patients [4].

Vital signs during face-to-face consultations are measured one by one using appropriate tools such as a sphygmomanometer to measure blood pressure, a thermometer to measure body temperature, and a stethoscope to listen to the sound of the heartbeat. Sometimes, the respiratory rate is also examined by observing the patient's chest or belly movements for one minute. However, for the general public or patients using telemedicine services, vital sign examinations can only be done independently by the patient. Patients need to purchase several measurement tools, which can be expensive when added up. These tools are also not directly connected to the telemedicine application. In order for the doctor to know the measurement results, the patient needs to either type it in the chat or manually input it in the application. Meanwhile, for home care patients, doctors or nurses usually make home visits according to the scheduled time. The more routine or frequent the home visits, the more time-consuming it becomes.

Accepted: 30-05-2023 | Received in revised: 21-12-2023 | Published: 27-12-2023

Routine monitoring of vital signs is mandatory for inpatients. It is usually accompanied by tools called the Early Warning Score (EWS), which help the medical team recognize early symptoms of patient deterioration [5], [6]. It is important to pay particular attention to patients who are treated outside the hospital, especially those who are suffering from certain diseases and are susceptible to changes. The application of EWS for patients outside the hospital is highly recommended because it not only helps detect patient condition deterioration [7] but also effectively identifies which patients need hospital admission [8]–[10].

Previous research has developed a remote vital sign monitoring system using self-designed wearable sensors [11]–[15]. These prototypes of wearable sensors generally use microcontroller boards as data collection platforms and use wired transmission between the sensor and processing board [16]. The example is shown in Figure 1. However, as they are still in prototype form, some of them lack packaging or have a relatively large size. In addition, the cost of large-scale development is not yet known.

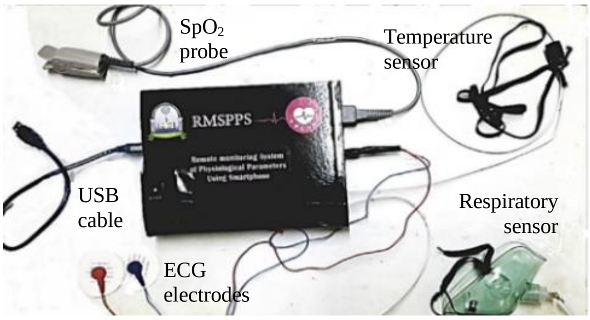

Figure 1. An Example of a Self-Designed Sensor Prototype [12]

Other research focuses on utilizing commercially available wearable sensors. For example, a research has developed a telemedicine system for COVID-19 patients [17]. Their research was continued, and the system was able to reduce the number of nurse visits to patients' rooms, especially for vital sign examinations [18]. Another study developed a COVID-19 patient monitoring system in hospital isolation rooms using two types of commercial wearable sensors (Figure 2) [19]. They developed mobile and web applications equipped with EWS calculations. Research [17]–[19] uses commercial wearable sensors, however, the chosen sensor devices tend to be specific tools for measuring one or several specific vital signs, so patients need to use several sensor devices at once to obtain complete vital sign values.

There are various types of wearable sensors available for monitoring vital signs, such as patches, clothing-based monitors, chest straps, and wristbands [7]. Wrist-worn commercial wearable sensors like smartwatches are the most commonly available on the market [20], [21]. Besides being small and comfortable to wear, they are affordable and capable of measuring multi-parameter vital signs. Smartwatch vendors usually provide mobile applications that can collect vital sign measurement data and display its history. However, data from vendor applications cannot be accessed by third parties, which means that others cannot use it to monitor vital signs. In other words, these applications are typically for personal use.

Figure 2. An Example of Commercial Wearable Sensors [19]

Smartwatches are a suitable and affordable option for monitoring vital signs, especially for patients who receive home care. With just one device, multi-parameter vital signs can be measured without limiting the patient's movement. However, to use smartwatches as a tool in vital sign monitoring, an application is needed that can capture and read smartwatch data, has EWS calculation, and allows data to be monitored remotely. Therefore, this research focuses on developing a telemedicine system integrated with smartwatches for home care patients. The proposed system consists of a mobile application used as a gateway and acts as a patient monitor, and a web application used by patients, patient families, doctors, and nurses. They can use the web application to communicate and view patient vital sign information along with their EWS scores. The purpose of this research is to complete the function of the existing telemedicine application in Indonesia, specifically by providing vital sign data remotely.

2. Research Methods

This research uses Rapid Application Development (RAD) in system development. The phase flow is shown in Figure 3. The requirements planning phase is carried out to identify the system's purpose and requirements. In this phase, a comparative analysis is conducted to understand the information structure, flow, and features commonly used in existing telemedicine applications that have been implemented in the real world. The results are used as a knowledge base, and applicable aspects are taken into account in the system being built. Besides comparative analysis,

DOI: https://doi.org/10.29207/resti.v7i6.5126
Creative Commons Attribution 4.0 International License (CC BY 4.0)

the information structure and layout of the patient monitor device commonly used in hospitals are also considered. The goal is for the developed mobile application to have similarity with the patient monitor in terms of simple layout but can clearly and easily convey vital sign values. After collecting requirements, they are transformed into the Unified Modeling Language (UML), which outlines the features and user interactions.

The output from requirements planning is continued to the design phase, which produces the database structure and interface design. The application development phase is carried out using a local web server that produces a prototype of the mobile and web applications. Finally, internal testing is carried out using the black-box method. Testing is carried out with participants acting as patients and doctors who are instructed to use the application's functionality. The process and results of working on requirements, design, application development, and implementation will be explained further in the Results and Discussions section.

The type of EWS used in this research is the National Early Warning Score (NEWS). Table 1 shows the scoring system for physiological or vital sign parameters based on NEWS [23]. Each vital sign is given a score of 0-3, so the total score determines the risk level [10] and how often vital sign measurements are recommended according to NEWS thresholds and triggers.

The device used to capture vital sign data is a commercial wearable sensor in the form of a smartwatch: the SKMEI E66 than can be seen in Figure 4. This smartwatch is used to measure respiration rate, oxygen saturation, temperature, blood pressure, and heart rate. Meanwhile, supplemental oxygen and the level of consciousness are manually inputted into the mobile application. These two do not change as often as other vital signs.

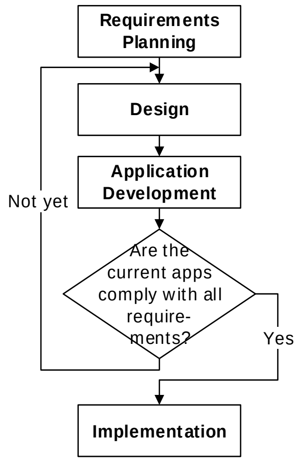

Figure 3. Phases of Research [22]

Table 1. NEWS Score Chart

Physiological Parameters	Score 3	2	1	0	1	2	3
Respiration rate	≤8		9 -11	12 - 20		21 - 24	≥25
Oxygen saturations	≤91	92 - 93	94 - 95	≥96			
Any supplemental oxygen		Yes		No			
Temperature	≤35.0		35.1 - 36.0	36.1 - 38.0	38.1 - 39.0	≥39.1	
Systolic blood pressure	≤90	91 - 100	101 - 110	111 - 219			≥220
Heart rate	≤40		41 - 50	51 - 90	91 - 110	111 - 130	≥131
Level of consciousness				A			V, P, or U

Figure 4. SKMEI E66

The cost of the aforementioned timepiece falls below IDR 400,000, despite bearing crucial functionalities, notably, a patient monitor employed in hospital, valued at no less than IDR 10 million. The patient monitor exhibits superior characteristics and precision compared to the utilized watches.

Furthermore, the patient monitor instrument has undergone rigorous testing and is specifically designed for the purpose of monitoring the patient's critical state. However, in terms of a meticulous domiciliary healthcare framework that is accessible to a multitude of individuals, the selected timepiece is deemed apt for such an undertaking.

3. Results and Discussions

The system proposed in this research is developed with the aim of: 1) enabling routine vital sign monitoring of patients even when they are being treated at home with affordable devices; and 2) facilitating communication between patients, their families, and medical teams through a consultation

DOI: https://doi.org/10.29207/resti.v7i6.5126
Creative Commons Attribution 4.0 International License (CC BY 4.0)

feature while also viewing the patient's vital sign information and the risk category of their health condition in the form of EWS.

3.1 Results

The requirement planning phase began by analyzing similar products or applications in telemedicine applications in Indonesia, such as KlikDokter, Alodokter, and Halodoc. We also analyzed telemedicine applications that are integrated with commercial wearable sensors based in Europe and America, such as VitalConnect, Huma, and Current Health. From the comparative analysis, we took what could be applied to the system that will be developed, so we can define the main functionalities of this system as shown in Table 2 and Table 3.

Table 2. Main Functionalities of the Web Application

Main Functionalities of the Web Application
Register for an account
Register as a home care patient
Send consultation messages
Accept patients as home care patients
View the home care patient monitoring dashboard
View historical vital sign data for home care patients
End the monitoring period of home care patients
View the statistics of home care patients

Table 3. Main Functionalities of the Mobile Application

Main Functionalities of the Mobile Application
Update vital sign data
Send vital sign data to web server

The main functionalities are further processed into system requirements and modeled into a use case diagram. In the following, we present some of the use case diagrams that are related to monitoring vital signs. Figure 5 shows the use case diagram of the web application in the Home Care Patient module, while Figure 6 shows the use case diagram of the mobile application.

Figure 5 depicts the use case diagram of the web application, specifically in the Home Care Patient module. Patients can register as home care patients and communicate with doctors and nurses through consultation messages. Doctors and nurses have the authority to accept patients into the home care program, view and filter patient lists based on monitoring status, search patients by ID or name, access historical vital sign data, respond to consultation messages, and end the monitoring periods.

Figure 6 shows the use case diagram of the mobile application, which serves as a gateway for collecting vital sign data from wearable sensors and transmitting it to the web server. The mobile application system is sending the vital sign data to the web server. Patients can view their latest vital sign data and update vital sign data measurements. In the event of a sudden or emergent situation, the patient's family or caregivers may update the level of consciousness or additional oxygen values.

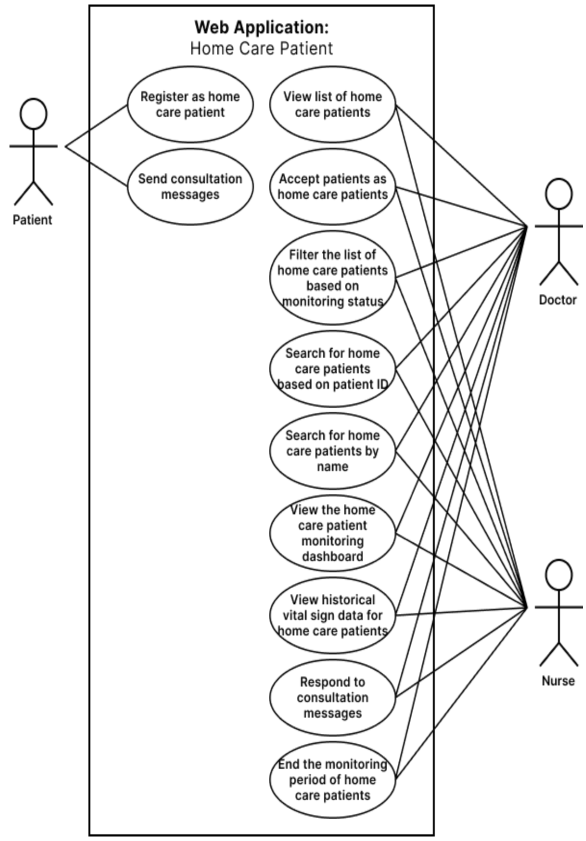

Figure 5. Use Case Diagram of the Web Application

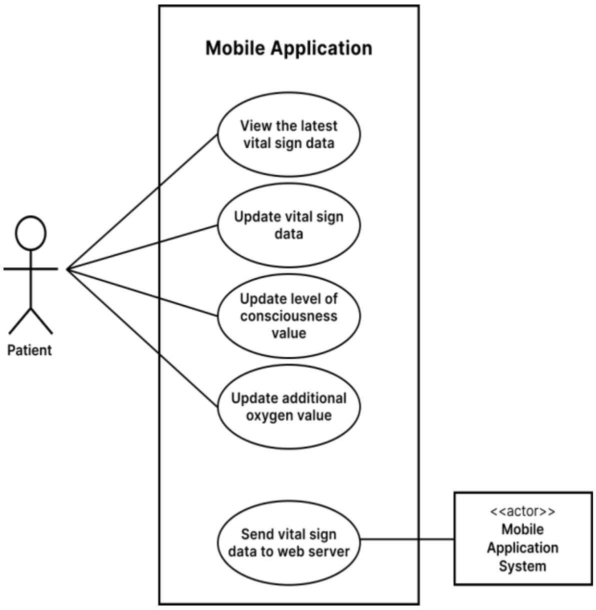

Figure 6. Use Case Diagram of the Mobile Application

Other outputs of the requirement planning phase are activity diagrams that show the overall flow of the system. Some activity diagrams related to the vital sign monitoring of home care patients are shown

DOI: https://doi.org/10.29207/resti.v7i6.5126
Creative Commons Attribution 4.0 International License (CC BY 4.0)

below. Figure 6 shows the flow from the patient wanting to register for home care to being accepted as a home care patient, while Figure 7 shows the flow of vital sign data acquisition.

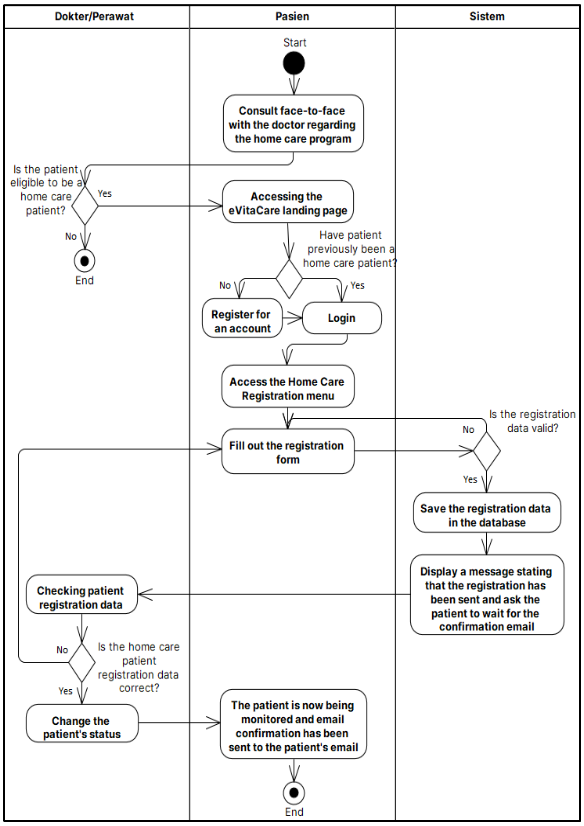

Figure 7. Activity Diagram of Home Care Patient Registration

Figure 7 illustrates the activity diagram depicting the step-by-step process of home care patient registration within the system. The registration procedure begins with a face-to-face consultation between the patient and the doctor to discuss the home care program. If the doctor recommends or states that the patient is eligible, the patient is encouraged to register through the web application. The patient then opens the eVitaCare landing page. If the patient has registered and completed the home care monitoring program before, the patient just needs to log in. If they are new to this program, they will create an account first. After logging in, the patient navigates to the Home Care Registration menu and fills out the form. The system stores the data in the database. Then a confirmation message is displayed, prompting the patient to await an email notification. On the nurses' and doctors' sides, they will review the patient's registration data and approve the registration. Finally, upon successful confirmation, the patient enters the monitoring phase, marked by the dispatch of an email notification.

Figure 8 shows an activity diagram that outlines the process of acquiring vital sign data. The process begins with the patient installing the mobile application via a link provided in the acceptance email. After logging in using their credentials (the same ones they use to log in to the web application), the patient connects their smartwatch and smartphone through the app. Once connectivity is confirmed, the patient can click a button to update data and trigger the data acquisition process. This action prompts the mobile application system to request vital sign data from the smartwatch. The collected data is then transmitted to the web server through the REST API and stored in the database. Finally, the mobile application system displays the measured values on the user interface.

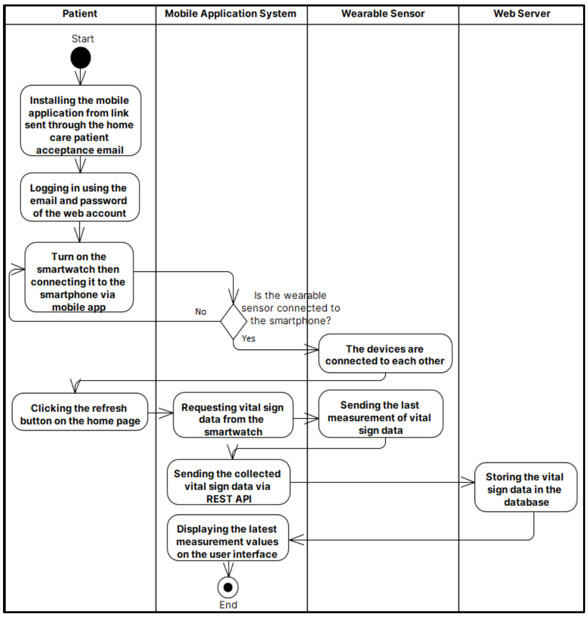

Figure 8. Activity Diagram of Vital Sign Data Acquisition

Next is the design phase. As an overview, the proposed system consists of several components, including: 1) a smartwatch capable of measuring multi-parameter vital signs; 2) a mobile application installed on a smartphone as a gateway; 3) a web server; and 4) a web application. The system architecture can be seen in Figure 8.

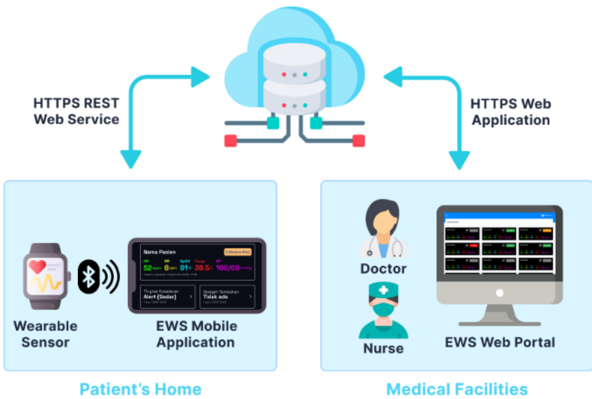

Figure 9. System Architecture

DOI: https://doi.org/10.29207/resti.v7i6.5126
Creative Commons Attribution 4.0 International License (CC BY 4.0)

Figure 9 shows an overview of the system architecture. During the patient's stay at home and during the monitoring period, the patient wears a smartwatch and connects it to the mobile application via Bluetooth. The patient clicks the refresh button as a trigger for the mobile application to request the latest measurement data from the smartwatch and then upload it to the web server. The measurement data that has been stored in the database can finally be accessed remotely by doctors and nurses.

The result of the database structure design used in this system is shown in Figure 10.

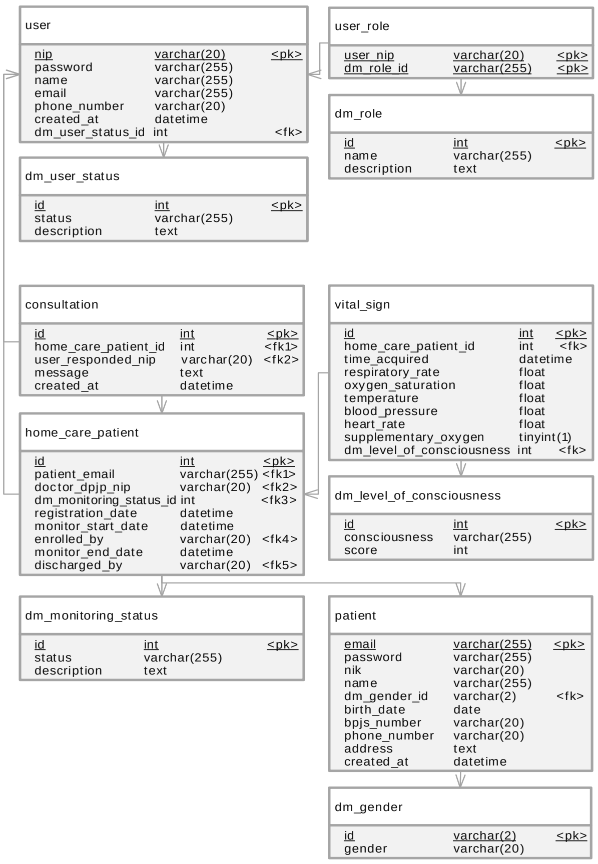

Figure 10. Database Structure

Figure 10 shows the database structure. There are user-related tables for doctors, nurses, and administrators: user, dm_user_status, user_role, and dm_role. Then there are tables related to home care: consultation, home_care_patient, dm_monitoring_status, vital_sign, dm_level_of_consciousness, patient, and dm_gender.

The result of the design phase is then continued to the application development. The following is the result of the web application interface for home care patient registration flow. First, the patient needs to consult with a doctor face-to-face. If the patient is eligible to register for home care, then the patient is directed to register an account through the web application.

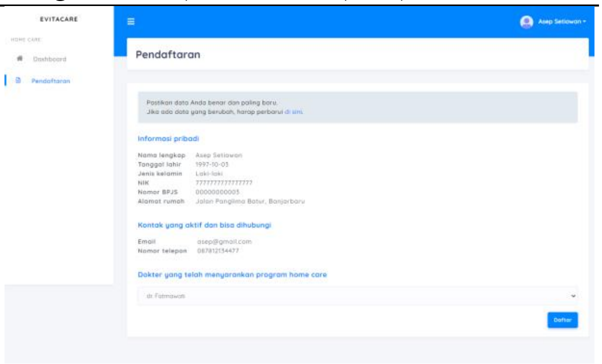

Figure 11. Home Care Patient Registration Page

Figure 11 shows the home care patient registration page after the patient has registered an account and has logged in. In the first section, there is personal information about the patient. In the next section, there is information about the patient contact, and the last is a drop-down to choose the doctor who has advised the patient to take the home care program. The doctor who suggested the patient register for the home care program will be identified as the patient-responsible doctor.

The next step is for the doctor or nurse to review the registration data on the Home Care Patient menu (Figure 12).

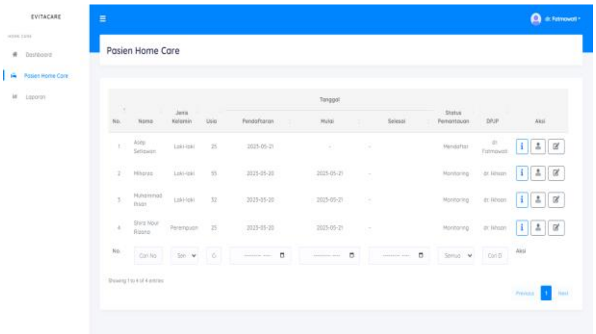

Figure 12. Home Care Patient Menu

Figure 12 shows all patients that have registered for the home care program in all monitoring statuses. On this page, doctors and nurses can edit the patient-responsible doctor, view the registration data and patient details, and change the monitoring status. If the registration data is valid, the patient's status will be changed to "Monitoring" by doctors or nurses, which means the patient is in the monitoring period. An acceptance email will be sent to the patient's email, and each patient will be lent a smartwatch. Patients are encouraged to connect the smartwatch to the mobile application and measure their vital signs every day at home.

This section will explain the interface for the flow during the monitoring period. Doctors and nurses monitor by observing the dashboard page (Figure 13).

DOI: https://doi.org/10.29207/resti.v7i6.5126
Creative Commons Attribution 4.0 International License (CC BY 4.0)

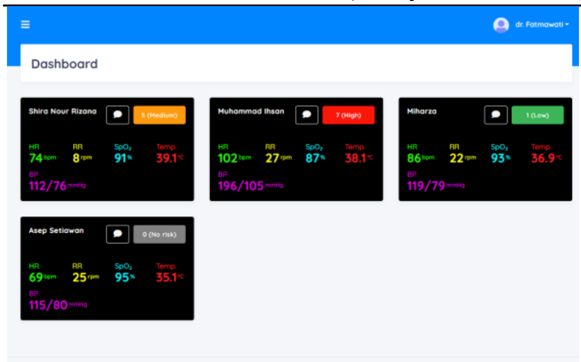

Figure 13. Dashboard Page (Doctor and Nurse Roles)

Figure 13 shows the dashboard page, which displays patients filtered by patients who are in "Monitoring" status, with one home care patient represented as one card. All patients that are currently monitored can be easily seen along with the risk of their condition.

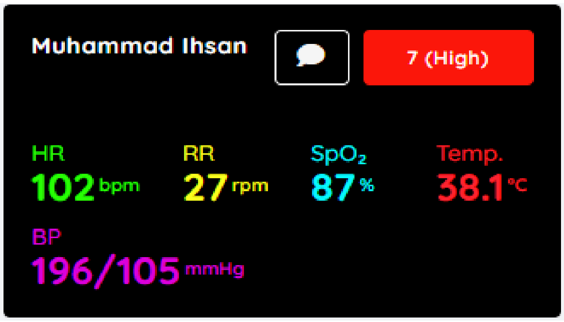

Figure 14. Home Care Patient Card Component

Figure 14 shows the details of the home care patient card component. Each card contains the name of the patient, an indicator icon for consultation messages, the NEWS score and risk category, and the five main vital sign values. When one of the home care patient names is clicked, the web application will direct to the patient's detail page.

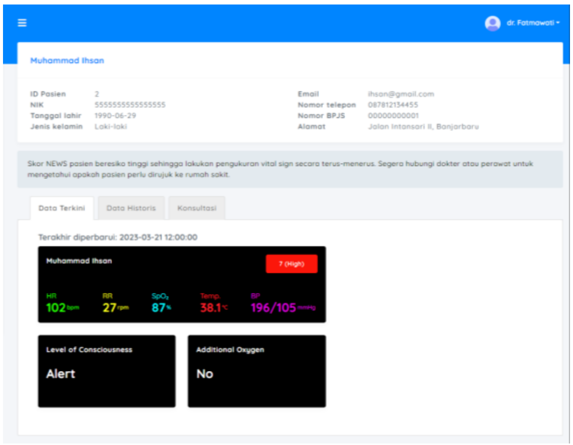

Figure 15. Home Care Patient Detail Page (Latest Data)

Figure 15 shows the home care patient detail page. It contains the patient's personal information, recommended vital sign measurement frequency information according to NEWS regulations, and the latest vital sign data.

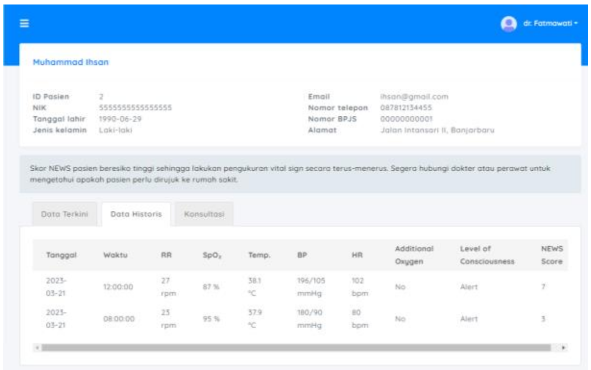

Figure 16. Home Care Patient Detail Page (Historical Data)

Figure 16 shows the home care patient detail page too, but now in the tab Historical Data. It contains historical vital sign data in the form of records by time and date.

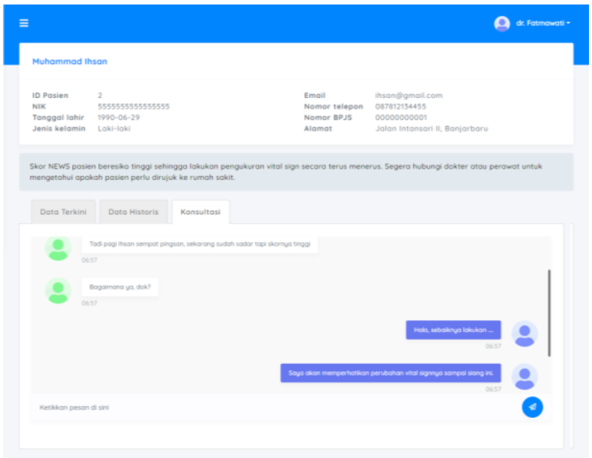

Figure 17. Home Care Patient Detail Page (Consultation)

Figure 17 is the home care patient detail page on the tab Consultation that allows patients or their families to communicate with nurses or doctors.

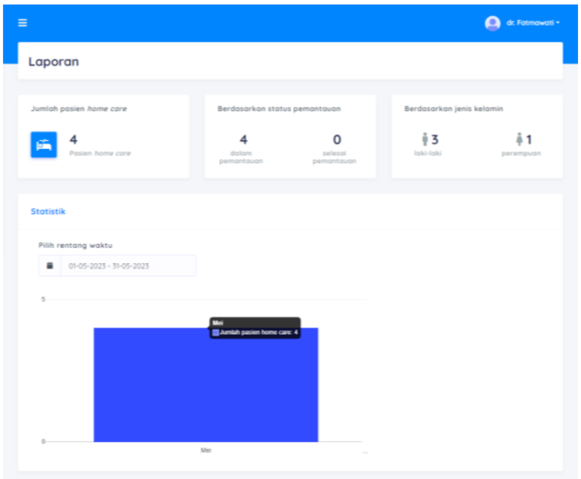

Figure 18. Report Page

Creative Commons Attribution 4.0 International License (CC BY 4.0)

The next part is the interface for functionality to view the statistics of the number of home care patients.

Figure 18 shows the Report page, which provides information on the number of home care patients in that month and statistics on the number of home care patients in chart form based on the selected time range.

The following are some of the results of the mobile application interface.

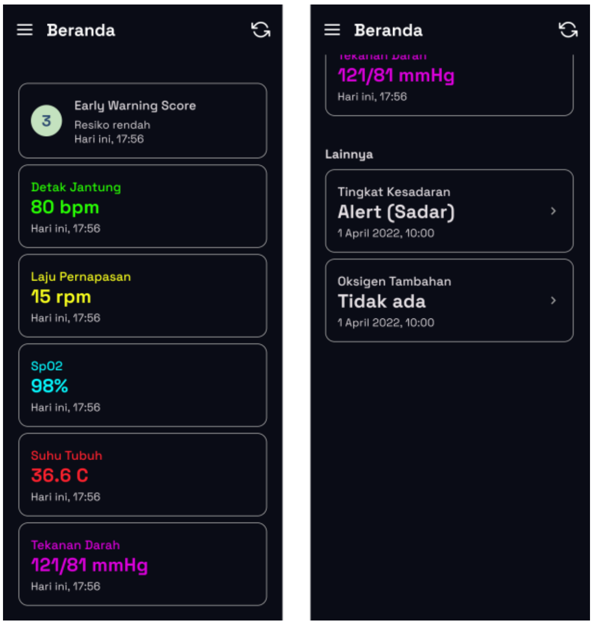

Figure 19. Mobile Application Home Page (Portrait)

Figure 19 shows the home page that appears when the application is connected to the smartwatch. It contains the last updated data on the patient's vital sign data. The button on the top right is the button to trigger data acquisition to ask for and collect data from the smartwatch.

Figure 20. Mobile Application Home Page (Landscape)

Figure 20 is the home page interface in the landscape version. The layout is designed to resemble a patient monitor layout.

The final phase is implementation. In this phase, we test the application. The individuals comprising the testing team are not directly engaged in the development of the application program code, as their primary focus is centered on the systematic design and analysis of the system at hand. The results of testing the functionalities of both applications are shown in Table 4 and Table 5.

Table 4. Functional Test of Web Application

Functional Test of Web Application	Results
Register for an account	Passed
Register as a home care patient	Passed
Send consultation messages	Passed
Accept patients as home care patients	Passed
View the home care patient monitoring dashboard	Passed
View historical vital sign data for home care patients	Passed
End the monitoring period of home care patients	Passed
View the statistics of home care patients	Passed

Table 5. Functional Test of Mobile Application

Functional Test of Mobile Application	Results
View the latest vital sign data	Passed
Update vital sign data	Passed
Update level of consciousness value	Passed
Update additional oxygen value	Passed
Send vital sign data to web server	Passed

At the stage of implementation, numerous hindrances are encountered. The initial hurdle arises during the implementation of mobile applications, specifically when deploying them on certain categories of smartphones. This issue arises due to the lack of compatibility between the mobile application being built and the operating system environment on said smartphones. Another challenge arises when extracting vital sign data from the watch using the mobile application. In order to accomplish this, the user must first activate the specific vital sign they wish to measure on the watch, following which the new value of the vital sign can be updated. Obstacles pertaining to monitoring patients' vital signs at home have not been identified, as testing is currently being conducted under ideal conditions where the watch and mobile app are always in close proximity.

3.2 Discussions

Based on the test results, the vital sign monitoring system has functioned according to its expected functionality. The advantage of this system is that it uses an affordable commercial smartwatch. Patients only need to use one small device that does not interfere with their daily activities. In addition, the mobile application interface and the web application dashboard page are designed to resemble the color, layout, and information structure of the bedside patient monitor to facilitate users easier observation and monitoring of vital sign values.

The outcomes presented in the segment on results and testing interface are discernments that can be applied by a developer in the creation of a home care patient monitoring system that merges interlinked mobile applications with vital sign sensors in the shape of a

DOI: https://doi.org/10.29207/resti.v7i6.5126
Creative Commons Attribution 4.0 International License (CC BY 4.0)

reasonably priced wristwatch. This represents a novel concept in contrast to other healthcare systems that solely rely on mobile or web applications for registering patient vital signs.

However, this vital sign monitoring system still has limitations, namely that it is not fully real-time. First, the consultation feature in the application is still simple and does not use a chat framework, so the consultation activity is not real-time. The part that displays the chat bubble is only refreshed every few seconds. Second, the smartwatch only takes measurements when the patient presses a button to measure one vital sign parameter and waits for the value to appear. Third, patients need to click refresh on the mobile application so that the application requests data from the smartwatch to update the values on the interface and send the data to the server. The difficulty we faced in the data request process is that the smartwatch does not have documentation and Software Development Kit (SDK), so reverse engineering is needed to be able to read and retrieve data from the smartwatch. The mobile application we made is also only compatible with smartphones with the Android operating system.

Based on the three constraints indicated, it is imperative to undertake additional investigations and inquiries that center on two aspects. The primary inquiry concentration pertains to the exploration for commercial smartwatches that possess attributes enabling instantaneous data retrieval. The secondary inquiry concentration entails embarking on a more profound examination of BLE equipment sensor directives and the transformation of measurements originating from such equipment into essential physiological indicators.

Validity testing has been conducted by means of comparing the outcomes of vital sign readings obtained via sensors on watches with those of devices used for reading patient vital signs in hospitals. The results of the t-test we conducted during prior research [24] indicate that the data comparison between the two sources is not significantly different. However, the effectiveness of this system has yet to be examined in the present study.

4. Conclusion

This paper proposes a vital sign monitoring system that can be used as an alternative to manual vital sign measurement for home care patients. The system consists of a smartwatch as a vital sign data acquisition tool connected to a mobile application installed on the patient's smartphone, a web server, and a web application. This system allows vital sign data and the risk of patient condition deterioration to be available remotely. Doctors and nurses can enroll patients and monitor changes in vital signs remotely. Home care patients and their families can also send consultation messages and find out vital sign values and the level of patient health condition risk. Because it uses an affordable smartwatch, this vital sign monitoring system can save costs compared to using available vital sign monitoring devices.

At the moment of execution, various challenges encountered in this investigation have been cited. The primary hindrances encompass the acquisition of essential physiological information, which is not achievable autonomously sans patient intervention. Consequently, real-time monitoring becomes unattainable. Within mobile applications, there remain two critical parameters for Early Warning Score (EWS) computations that necessitate manual configuration, specifically oxygen consumption and patient consciousness, as these necessitate external input to ascertain their respective magnitudes.

For future work, other researchers can search for smartwatches or wearable sensor options that can measure and send vital sign data in real-time with an easy-to-use SDK. The consultation feature can also be improved by using a chat framework so consultations can be done in real-time.

Acknowledgment

This research is the result of a final project in the Computer Science Department, Faculty of Mathematics and Natural Sciences, Lambung Mangkurat University.

References

[1] R. S. Yonathan and M. Nadjib, "The Roles and Policies for the Use of Telemedicine in Handling Covid-19 Self-Isolation: Literature Review," *J. Indones. Heal. Policy Adm.*, vol. 7, no. 2, p. 245, 2022, doi: 10.7454/ihpa.v7i2.6111.

[2] A. Barney, S. Buckelew, V. Mesheriakova, and M. Raymond-Flesch, "The COVID-19 Pandemic and Rapid Implementation of Adolescent and Young Adult Telemedicine: Challenges and Opportunities for Innovation," *J. Adolesc. Heal.*, vol. 67, no. 2, pp. 164–171, 2020, doi: 10.1016/j.jadohealth.2020.05.006.

[3] G. G. Sari and W. Wirman, "Telemedicine sebagai Media Konsultasi Kesehatan di Masa Pandemic COVID 19 di Indonesia," *J. Komun.*, vol. 15, no. 1, pp. 43–54, 2021, doi: 10.21107/ilkom.v15i1.10181.

[4] R.A. Wita Ferani Kartika, Pujiyanto, and C. A. Putri, "Telemedicine for emergency patients in pre-hospital care: A scoping review," *J. Ilmu Kesehat. Masy.*, vol. 13, no. 2, pp. 127–144, 2022, doi: 10.26553/jikm.2022.13.2.127-145.

[5] D. R. Pertiwi, C. E. Kosasih, and A. Nuraeni, "Tinjauan sistematis: faktor-faktor yang mempengaruhi implementasi early warning score (EWS) oleh perawat di rumah sakit," *J. Kesehat.*, vol. 11, no. 2, pp. 124–132, 2020, doi: 10.38165/jk.v11i2.223.

[6] E. Itelman *et al.*, "Assessing the Usability of a Novel Wearable Remote Patient Monitoring Device for the Early Detection of In-Hospital Patient Deterioration: Observational Study," *JMIR Form. Res.*, vol. 6, no. 6, pp. 1–10, 2022, doi: 10.2196/36066.

[7] S. Soon, H. Svavarsdottir, C. Downey, and D. G. Jayne,

Creative Commons Attribution 4.0 International License (CC BY 4.0)

"Wearable devices for remote vital signs monitoring in the outpatient setting: An overview of the field," *BMJ Innov.*, vol. 6, no. 2, p. 55, 2020, doi: 10.1136/bmjinnov-2019-000354.

[8] S. Finnikin and V. Wilke, "What's behind the NEWS? National early warning scores in primary care," *Br. J. Gen. Pract.*, vol. 70, no. 695, pp. 272–273, 2020, doi: 10.3399/bjgp20X709361.

[9] J. Ehara, E. Hiraoka, H. C. Hsu, T. Yamada, Y. Homma, and S. Fujitani, "The effectiveness of a national early warning score as a triage tool for activating a rapid response system in an outpatient setting: A retrospective cohort study," *Med. (United States)*, vol. 98, no. 52, 2019, doi: 10.1097/MD.0000000000018475.

[10] L. J. Scott, N. M. Redmond, A. Tavaré, H. Little, S. Srivastava, and A. Pullyblank, "Association between National Early Warning Scores in primary care and clinical outcomes: An observational study in UK primary and secondary care," *Br. J. Gen. Pract.*, vol. 70, no. 695, pp. E374–E380, 2020, doi: 10.3399/bjgp20X709337.

[11] L. J. Mena *et al.*, "Mobile Personal Health Monitoring for Automated Classification of Electrocardiogram Signals in Elderly," *Comput. Math. Methods Med.*, vol. 2018, no. Figure 1, 2018, doi: 10.1155/2018/9128054.

[12] N. Q. Al-Naggar, H. M. Al-Hammadi, A. M. Al-Fusail, and Z. A. Al-Shaebi, "Design of a Remote Real-Time Monitoring System for Multiple Physiological Parameters Based on Smartphone," *J. Healthc. Eng.*, vol. 2019, 2019, doi: 10.1155/2019/5674673.

[13] S. Hadiyoso, A. Alfaruq, R. Tulloh, Y. S. Rohmah, and E. Susanto, "Internet of things based real-time vital sign monitoring system using mobile application," *J. Appl. Eng. Sci.*, vol. 19, no. 3, pp. 807–813, 2021, doi: 10.5937/jaes0-28774.

[14] A. Zafia, "Prototype Alat Monitoring Vital Sign Pasien Rawat Inap Menggunakan Wireless Sensor Sebagai Upaya Physical Distancing menghadapi Covid-19," *J. Informatics, Inf. Syst. Softw. Eng. Appl.*, vol. 2, no. 2, pp. 61–68, 2020, doi: 10.20895/inista.v2i2.126.

[15] B. Utomo, T. Triwiyanto, S. Luthfiyah, W. R. Hidayani, and L. Handoko, "Low-cost Physiological Parameter Development using Internet of Things Based for Monitoring Health Elderly," *Open Access Maced. J. Med. Sci.*, vol. 10, no. B, pp. 1726–1730, 2022, doi: 10.3889/oamjms.2022.8818.

[16] A. Pantelopoulos and N. G. Bourbakis, "A survey on wearable sensor-based systems for health monitoring and prognosis," *IEEE Trans. Syst. Man, Cybern. Part C (Applications Rev.*, vol. 40, no. 1, pp. 1–12, 2009.

[17] N. Kagiyama *et al.*, "Validation of telemedicine-based self-assessment of vital signs for patients with COVID-19: A pilot study," *J. Telemed. Telecare*, 2021, doi: 10.1177/1357633X211011825.

[18] N. Kagiyama *et al.*, "Impact of a telemedicine system on work burden and mental health of healthcare providers working with COVID-19: A multicenter pre-post prospective study," *JAMIA Open*, vol. 5, no. 2, pp. 1–6, 2022, doi: 10.1093/jamiaopen/ooac037.

[19] M. D. Santos *et al.*, "A real-time wearable system for monitoring vital signs of COVID-19 patients in a hospital setting," *Front. Digit. Heal.*, vol. 3, p. 630273, 2021.

[20] F. de Arriba-Pérez, M. Caeiro-Rodríguez, and J. M. Santos-Gago, "Collection and processing of data from wrist wearable devices in heterogeneous and multiple-user scenarios," *Sensors (Switzerland)*, vol. 16, no. 9, 2016, doi: 10.3390/s16091538.

[21] E. Escobar-Linero, L. Muñoz-Saavedra, F. Luna-Perejón, J. L. Sevillano, and M. Domínguez-Morales, "Wearable Health Devices for Diagnosis Support: Evolution and Future Tendencies," *Sensors*, vol. 23, no. 3, pp. 1–23, 2023, doi: 10.3390/s23031678.

[22] Y. S. Triana, H. Gunawan, D. Prasetyo, and K. Pangestu, "Alat Bantu Pedoman Ibadah Umat Islam Melalui Aplikasi ZipediaBerbasis Mobile," *J. RESTI Rekayasa Sist. dan Teknol. Inf.*, vol. 4, no. 1, pp. 83–89, 2020.

[23] M. N. Badr, N. S. Khalil, and A. M. Mukhtar, "Effect of national early warning scoring system implementation on cardiopulmonary arrest, unplanned ICU admission, emergency surgery, and acute kidney injury in an emergency hospital, Egypt," *J. Multidiscip. Healthc.*, vol. 14, pp. 1431–1442, 2021, doi: 10.2147/JMDH.S312395.

[24] N. Azizah *et al.*, "A Vital Sign Monitoring System Exploiting BT/BLE on Low-cost Commercial Smartwatch for Home Care Patients," in *2023 International Seminar on Intelligent Technology and Its Applications (ISITIA)*, 2023, pp. 405–410. doi: 10.1109/ISITIA59021.2023.10221157.

DOI: https://doi.org/10.29207/resti.v7i6.5126
Creative Commons Attribution 4.0 International License (CC BY 4.0)