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Research Article

Warfarin Care: Warfarin Management System for Older Adults

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Abstract: Warfarin Care emerges as a transformative solution in digital healthcare for the elderly reliant on warfarin. Addressing specific needs, Warfarin Care serves as a communication and information exchange among medical personnel, elderly patients, and family members or caregivers. With a user-friendly interface, rigorous content evaluation, and a shared database architecture, Warfarin Care endeavors to mitigate medication errors and augment overall treatment outcomes. Through the integration of risk assessment, medication history, and warfarin knowledge, medication reminders, and educational tools, the application fosters a deeper understanding of proper medication behavior. The research is based on the clinical trial, in which 60 cases of elderly patients and family members, 30 elderly patients, and 30 family members or caregivers were selected as the sample receiving treatment in the outpatient department of Sakonnakhon Hospital. The study from the clinical trial revealed that the majority of elderly participants fall within the 60–69 age group, predominantly women and married. The data reveals high satisfaction among both elderly users and caregivers, underscoring Warfarin Care's positive impact on enhancing knowledge, confidence, and support for proper medication adherence with user-friendly communication. Users agreed that the use and suitability of the Warfarin Care application

had an average of 4.57 and a S.D. of 0.57 from elderly users and an average of 4.67 and a S.D. of 0.61 from caregivers or family members. The robust data analysis utilizing mean and standard deviation values underscores the application's effectiveness.

1. Introduction

The primary concern in preparing for an era where technology plays a crucial role in an aging society is how to ensure that technological applications support and enhance the quality of life for the elderly across various dimensions. This involves providing access to information technology and innovations that contribute to health promotion, assistance with daily activities, and reduced dependency on others. The goal is to enable active aging, empowering the elderly to rely on themselves and lead fulfilling lives. While longer lifespans are indicative of advancements in medical technology, the changing circumstances bring about shifts in the types of illnesses prevalent among the elderly. While aging, there is an increased likelihood of suffering from chronic diseases, leading to the use of numerous medications with complex management requirements. Some elderly individuals are responsible for their own medication management, posing potential risks such as inappropriate use, overmedication, side effects, and drug interactions. This complexity makes disease control and the prevention of complications more challenging for the elderly. Warfarin serves as an anticoagulant (Choicharnchaikul, Malathi, & Kanchanachai, 2008), employed to prevent and manage blood clots within blood vessels—a condition particularly prevalent among the elderly. Consequently, its usage has surged in this demographic. Even though it works, warfarin is known to be a high-risk drug (Panichsombat, 2017), with a narrow treatment range based on the INR value, complicated pharmacokinetics and pharmacodynamics, and patients having different reactions to it (Warfarin Clinic, 2014). The general target for warfarin therapy is to maintain the INR within the range of 2–3. However, for certain diseases or specific patients, physicians may consider different INR targets, and it is advisable to consult the attending physician for personalized guidance. If the INR value exceeds 3, it indicates increased blood fluidity, putting the patient at risk of abnormal bleeding, which will be more critical with elderly patients. Conversely, if the INR is below 2, it suggests increased blood viscosity, leading to the formation of blood clots. Patients with low INR values are at risk of developing clots that may block various parts of the body. Numerous factors, including irregular medication intake, patient communication, and various drug interactions, pose potential complications, notably severe bleeding with the potential to cause permanent impairment or death.

For elderly patients undergoing warfarin treatment, stringent monitoring and adherence to prescribed behaviors are imperative due to the drug's narrow treatment window. Inadequate dosage may result in ineffective

treatment and heightened clotting risks, while excessive consumption may induce life-threatening bleeding. Regular INR blood tests are crucial to assessing treatment effectiveness guiding physicians in adjusting individual dosages. While warfarin is undeniably valuable, its use entails considerable risks from the medication, patient factors, and healthcare service systems. Regular monitoring, education on proper drug use, and behavioral guidance are particularly crucial for the elderly within this patient group to ensure optimal treatment outcomes and safety. But there are still problems with how things work. For example, there isn't a good way to make appointments for patients, lab results that aren't normal aren't being checked properly, and there aren't any clear identification tools for warfarin patients or a full list of drugs that interact with warfarin in Thai hospital clinics. The existing warfarin clinics in Thailand predominantly rely on face-to-face interactions, with pharmacists providing counseling and guidance and utilizing the Line Application to track INR values and dispense advice. While applications have been developed for medicine reminders and basic management advice, they fall short in addressing the intricate issues associated with medication use in the elderly. Therefore, incorporating technology and innovative tools into medication management is pivotal to enhancing health outcomes, reducing adverse drug events, and establishing standardized practices in the care of elderly patients.

Considering the aforementioned reasons, the researcher has conceived the idea to create a mobile phone application tailored for elderly individuals utilizing warfarin. The proposed innovation seeks to enhance effective warfarin management by allowing users to regulate their INR levels and monitor potential adverse events from drug usage. The application facilitates consistent adherence to healthcare provider recommendations, enabling users to adjust warfarin dosage according to the treatment plan, link patient information systems with families, and access individual health information. This ensures accurate medication intake in terms of dosage, quantity, and timing, while maintaining optimal drug properties. The research team has selected Sakon Nakhon Hospital for its leadership in collecting patients' data, warfarin information, and enrolling in the warfarin platform, as it aptly represents hospitals under the Ministry of Public Health. The hospital's warfarin administration system and network closely mirror those of other public health facilities, enabling seamless integration with the Ministry of Public Health's network. Upon completion of the research plan, the developed applications and websites can be expanded to enhance the capabilities of existing Warfarin clinic service systems. Especially in the critical context of the COVID-19 outbreak, this initiative aims to improve health outcomes for patients using warfarin.

Consequently, the primary objective of this research is to develop a warfarin management service, Warfarin Care, that

aims to facilitate the monitoring and administration of warfarin usage among elderly individuals. It is designed to empower elderly patients with knowledge about warfarin usage, promote collaboration in medication intake, and ensure self-care while using warfarin under supervised support. This platform relies on the aid of family members and coordinates with nurses and pharmacists, all guided by consultations from cardiovascular physicians. The application is for elderly warfarin users, with the dual purpose of reducing the occurrence and severity of medication errors and establishing a warfarin medication management and monitoring website for medical personnel. This Warfarin Care will assist medical personnel in monitoring the medication-taking behavior of elderly individuals, contributing to enhanced patient safety and overall well-being.

2. Related Work

Presently, healthcare systems globally are placing significant emphasis on the integration of digital technology and health innovations to enhance the efficiency of various components within the health system. Though our research topic mainly focuses on Warfarin's web-based application for effective medication and monitoring for older adults patients and medical personnel, relevant research on Warfarin's digital technology was not provided. On related surveillance and healthcare management systems, systems have been introduced to monitor and assess the risk of various diseases. In United States (US) healthcare's dynamic landscape, the American Hospital Association (AHA) urges Congress to establish a lasting regulatory framework for enduring telehealth accessibility (American Hospital Association, 2021). Aligned with this, a report on COVID-19's impact supports sustained policy changes for telehealth, emphasizing expanded care access and reduced disease exposure (Koonin *et al*., 2020). The eHealth system, a transformative tool connecting service providers and recipients, proves beneficial in Australia's Hospital in the Home models, reducing readmission risks and costs (Brown *et al*., 2023; Amar, April, & Abran, 2024). Meanwhile, the pervasive use of mobile devices, defined by the WHO as Mobile Health, contributes significantly to healthcare delivery through innovative apps (Leavy, 2019; World Health Organization, 2020). Mobile health industry growth, exemplified by over 318,000 health apps in 2018, which benefit from global connectivity (Leavy, 2019). In developing nations, internet and mobile technology adoption, even among low-income households, provides a unique opportunity to bridge healthcare accessibility gaps (World Bank, 2016). This highlights mHealth's potential to connect isolated regions cost-effectively.

In the context of Asian healthcare, Singapore emerges as a key player, with its prioritization of eHealth and innovative healthcare approaches. Insights from the European Commission's report highlight Singapore's globally recognized strategies and tools, showcasing the potential impact

of well-implemented eHealth programs, emphasizing the importance of addressing barriers and understanding user perspectives (European Commission, 2018). In India, studies unravel the transformative potential of Online Health Communities, technological integration in education, and evidence-based approaches for a more effective healthcare system (Kalra, Taneja, & Singhal, 2023; Kant Pal *et al*., 2023; Kumar *et al*., 2023). In Japan, a cross-sectional study on eHealth literacy among nursing students emphasizes the need for addressing low perceived eHealth literacy, providing valuable insights for nursing educators (Tanaka *et al*., 2020). In the dynamic landscape of eHealth research in Southeast Asia (SEA), a comprehensive bibliometric review reveals exponential growth, emphasizing the escalating demand for eHealth in Indonesia, Malaysia, Singapore, and Thailand. While eHealth needs comprehensive guidelines adaptable to local contexts, Singapore stands out for its inclusiveness (Lwin, Punnakitikashem, & Thananusak, 2023; Sabrina & Defi, 2021). In the pursuit of healthcare transformation in Vietnam, studies focus on patient-centered care and eHealth challenges. The evaluations highlight the need for strategic interventions to overcome challenges caused by government efforts (Dang *et al*., 2021; Nguyen *et al*., 2013). Similarly, Indonesia's exploration of eHealth implementation in Surabaya Municipality identifies persistent obstacles and opportunities for improvement, emphasizing the crucial role of government commitment (Kusumasari, Setianto, & Pang, 2018). Together, these studies contribute valuable insights into shaping patient-centric healthcare models, overcoming challenges, and guiding effective eHealth interventions in diverse Asian contexts.

In Thailand, the "eHealth Strategy - Ministry of Public Health (2017 – 2026)" outlines Thailand's vision for leveraging information and communication technologies (ICT) in healthcare (Ministry of Public Health, 2017). The strategy focuses on improving patient care, supporting clinical practice and service management, and fostering research and policy through electronic health records. Challenges include the need for digital skills among healthcare personnel and public understanding of eHealth, emphasizing the goal of a robust eHealth strategy by 2021. The eHealth Open Data Platform serves as a centralized hub for health information from hospitals and patients, accessible digitally through websites and mobile applications. This platform includes crucial details such as a list of medicines received, drug allergy information, and laboratory test results for specified items. Furthermore, it facilitates the dissemination of various information to medical personnel, contributing to a more interconnected and responsive healthcare system. In order to assist patients and the elderly with knee issues during the physical therapy session, the knee joint muscle measurement application (Pintusirakun *et al*., 2023) was created. The gyroscope sensor recorded movement signals that were utilized to record leg movement degree, duration of treatment, and postures used in physical

therapy exercises. After ten participants tried the equipment, the results showed that, with a satisfaction rating of 3.95, people in their 20s were content with the knee joint muscle measurement instrument for physical therapy.

In the pursuit of advancing eHealth service systems and applications for medicine management, several noteworthy initiatives stand out. Notably, the medication reminder application utilizing Optical Character Recognition (OCR) for reading medicine labels demonstrated high user satisfaction, emphasizing the efficacy of systematic drug storage and adherence efforts (Lin *et al*., 2013). Thai question-answering systems for diabetes employed advanced methods like Cosine, Dice, and Jaccard, with the cosine method achieving a remarkable precision value of 92.50 percent (Chamnanhan *et al*., 2023). The ST-Med-Box system integrated deep learning methods, providing a comprehensive drug recognition system with a mobile application and cloud management platform, contributing to enhanced medication adherence and management (Chang *et al*., 2019). Additionally, the AppG health application's clinical trial showcased improved outcomes in warfarin administration, with fewer bleeding events and lower weekly doses in the experimental group compared to the control group (Moraes, Winkelmann, & Colet, 2022). Another study employing the Alfalfa application during the COVID-19 outbreak emphasized the efficiency and safety of online warfarin management, further underscoring the positive impact of digital solutions in healthcare (Jiang *et al*., 2022). These diverse applications exemplify the transformative potential of eHealth technologies in medicine management, providing valuable insights for future innovations and improvements in patient care. Additionally, Tang *et al*. (2023) explored Japanese consumers' attitudes toward the digital transformation of over-the-counter (OTC) medicine purchase behavior, finding a preference for a hybrid digital experience design. The study highlighted a positive association between eHealth literacy and digital behaviors in OTC medicine information acquisition, emphasizing the evolving role of digital platforms in medicine management. The "Kinyalaew" application was developed for elderly individuals with chronic illnesses (Hnoohom, Yuenyong, & Chotivatunyu, 2018). This application provides notifications and knowledge about taking medicine for elderly patients with general chronic diseases, lacking specificity for those taking warfarin. While there is no dedicated website for managing and monitoring warfarin use in Thailand, a hospital information exchange website has been developed (Jirapanthong, 2016). This website facilitates cooperation and information sharing among hospitals and organizations, supporting various services. The research aims to explore the use of computer technology to enhance health services in Bangkok, conducting a survey of health services in hospitals and analyzing the attitudes and abilities of medical students and doctors. The objective is to provide recommendations on website services that support health services. A case

Table 1. Literature review of eHealthcare.

Topics	Overview of the studies	Author	Country
Healthcare Land-scape	Telehealth impacts on emergence of the Pandemic.	Koonin *et al*. (2020)	US
	Improving of Home-based care using virtual care tech-nology.	Brown *et al*. (2023)	Australia
	Quality improvement of shared clinical data by struc-turing and mapping using Fast Healthcare Interopera-bility Resources.	Amar, April, & Abran (2024)	Canada
Asian eHealth-care Dynamics	Leading Singapore eHealth policies and activities.	European Commission (2018)	Singapore
	Transformative potential of digital health platforms in empowering patients.	Kalra, Taneja, & Singhal (2023)	India
	The integration of digital technologies for its trans-formative potential, contributing to a more dynamic and engaging educational experience.	Kant Pal *et al*. (2023)	India
	Health payment system solution for student health after pandemic through health technology assessment.	Kumar *et al*. (2023)	India
	Cross-sectional study to explore the perceived eHealth literacy and learning experiences among Japanese undergraduate nursing students.	Tanaka *et al*. (2020)	Japan
	Japanese consumers' behavior and correlation toward the digital transformation of over-the-counter medi-cine purchase.	Tang *et al*. (2023)	Japan
	The exponential growth of demand for eHealth in SEA.	Lwin, Punnakitika-shem, & Thananusak (2023)	SEA
	Review of telemedicine guidelines in SEA.	Sabrina & Defi (2021)	SEA
	Opportunities, challenges, and necessary conditions for Vietnam in digital transforming for patient-centered care model.	Dang *et al*. (2021)	Vietnam
	Challenges of the implementation of e-Health in Sura-baya Municipality, Indonesia.	Kusumasari, Se-tianto, & Pang (2018)	Indonesia
	Knee joint muscle measurement application for physi-cal therapy treatment.	Pintusirakun *et al*. (2023)	Thailand
eHealth with Aging Population	Influential factors on medicine usage in older adults.	Rafhi *et al*. (2023)	Australia
	Integrating of eHealth platform for aged society.	DEPA (2023)	Thailand
	Influential factors on eHealth utilization behaviors among older adults in Bangkok.	Wongkampun & Pani-trat (2023)	Thailand

study focused on patients with cardiovascular disease, creating a prototype website to simulate the use of computer-based equipment to support clinic operations. The results show satisfaction with the website's use in various scenarios. The CLIPS language was utilized to create an expert system for warfarin dosing management, achieving 100% accuracy in the evaluation with positive feedback (Olomu *et al*., 2018). Simultaneously, surveyed warfarin patients, particularly younger individuals with internet access, show interest in using mobile devices for improved communication with healthcare providers, indicating the potential benefits of an online or mobile application in enhancing care quality (Sratthaphut, 2015).

As the global population ages, the nuanced interplay of social and individual factors in medication use among older adults becomes a focal point in healthcare research, as evidenced by the study conducted by Rafhi *et al*. (2023) in Australia. The research with 24 participants sheds light on diverse perspectives on medicine use, uncovering varying scores on factors like BMQ necessity, specific concerns, general overuse, and suggested general harm. A prevalent belief emerged that medicines might pose more harm than good, underscoring the complexity of prescription practices among older adults and emphasizing the crucial role of individual experiences and trust in prescribers in influencing medication adherence. Simultaneously, Thailand actively addresses the challenges posed by an aging society, with the eHealth Open Data Platform poised to play a pivotal role (DEPA, 2023). Projected to be fully operational by 2021, the platform facilitates seamless access to health records for older adults, integrating with wearable devices for continuous health monitoring. This collaborative effort between the public and private sectors aligns with global trends in digital health technologies, representing a significant stride toward establishing a digitally enabled healthcare ecosystem in Thailand. In Bangkok Metropolitan, study of Wongkampun & Panitrat (2023) exploring factors influencing Health Information Technology Utilization Behaviors (HITUB) among older people underscores the importance of tailored activities and collaborative efforts involving family, friends, healthcare professionals, public health service centers, and local communities. These studies collectively provide valuable insights into addressing the multifaceted challenges and opportunities associated with medication use and healthcare technology adoption among the elderly.

3. Materials and Methods

3.1 Warfarin Care

The knowledge and expertise in treating patients in the warfarin clinic was applied from the Sakonnakhon hospital for the elderly who use warfarin in using the application and for medical personnel in using the website. The application and website will allow us to expand the scope of care and monitoring for the elderly and to achieve maximum treatment results and safety.

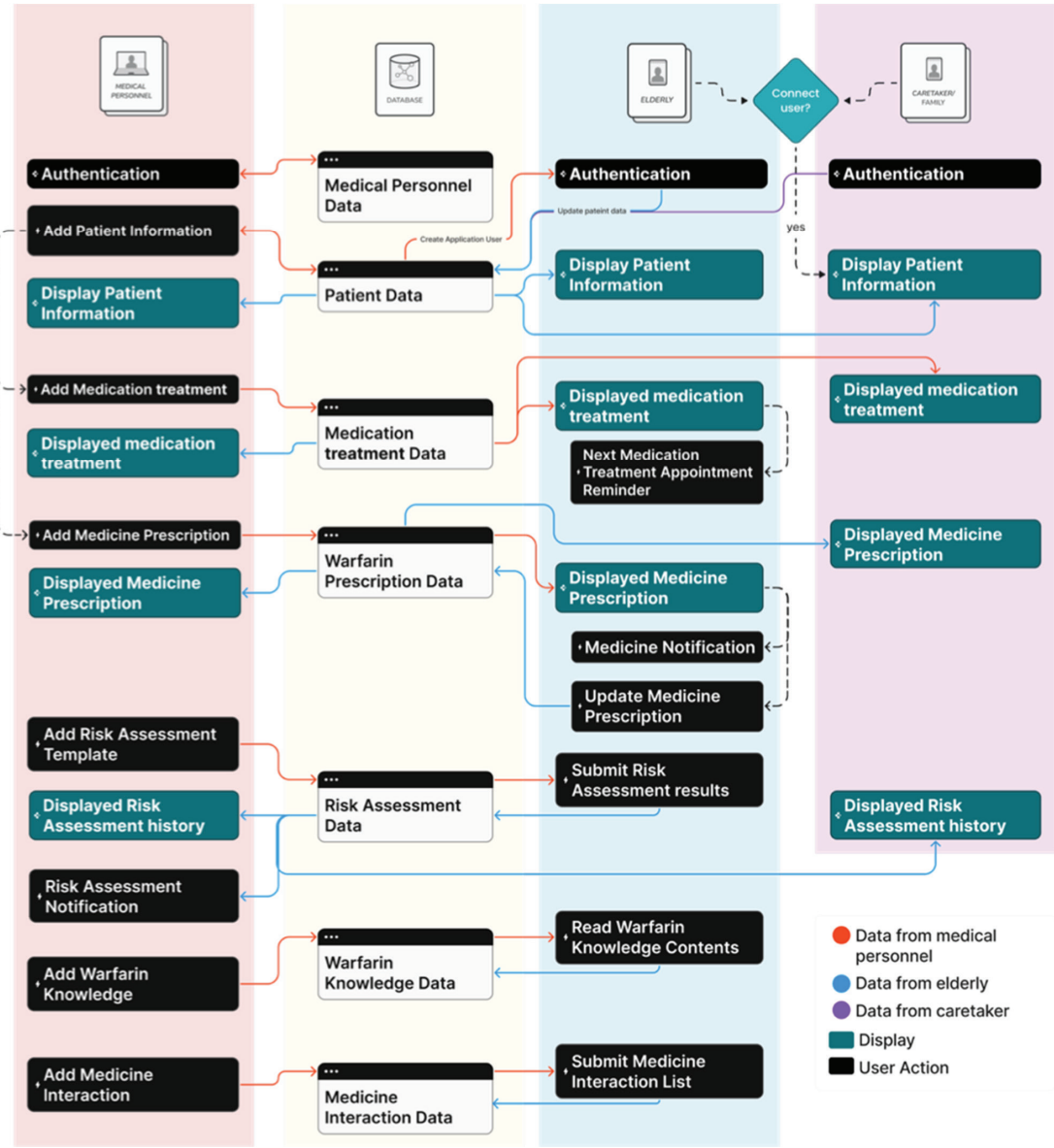

Figure 1. User flow diagram for Warfarin Care.

Warfarin Care was composed of a Warfarin application for the elderly and a Warfarin monitoring website for medical personnel. The warfarin application acted as a reminder and knowledge for the elderly and caregivers or family that use warfarin to understand and be conscious of the importance of warfarin correct usage. While the website will serve as a medium for medical service providers to track the medication intake and treatment history of each elderly patient, medical personnel can update and send information about treatment, precautions, and medication adjustments as appropriate for each patient's condition.

The application is a medium for patients and caregivers to receive information or follow up on treatment, including sending a preliminary risk assessment to medical service providers to receive timely treatment. The application and website consist of three types of users:

1. Medical personnel user: the user responsible for controlling and accessing all data to analyze and treat patients via the website.
2. Patient user: the elderly user for receiving information on taking medicine and sending information on taking warfarin and symptoms that may be at risk from taking warfarin via application.
3. Caregiver/patient's family user: the user who receives information on medication and treatment and risk assessment from connected elderly users to monitor patients via application.

In Figure 1, which illustrates the workflow diagram of Warfarin Care, the users will consist of three types of users, as mentioned in the previous paragraph. The diagram shows the in-depth information about the Warfarin Care process between each user. The medical personnel mainly provide medicine information and track elderly user data, which creates medication and risk information via application. While caregivers are tracking elderly data to provide safety action in case of emergencies. Warfarin Care can provide user connections to collect all information so that users, including medical personnel, service providers, patients, or caregivers, can access information efficiently and communicate across devices. The website can access information and make analysis of patient information, including treatment history, history of taking medicine, and risk assessment. The application system will have access to self-information, including treatment history, history of taking medicine, risk assessment, and risk assessment history. By doing a risk assessment or updating the medicine interactions list and medicine taken confirmation, patient information will be recorded and displayed on both the website and application. The website and application are composed of six main functions, which are:

1. user data authentication and configuration: user data authentication and configuration are integral parts of creating a secure and personalized user experience. Authentication ensures the security of the system by confirming the identity of users, while configuration allows users to set their preferences.
2. medication treatment of patients: the medication treatment of patients is a vital component of healthcare, aiming for diagnosis, monitoring, and medical records. The medical personnel were the information providers to keep track of warfarin patients and

update medication data on the Warfarin Care website, as elderly patients and their families could acknowledge the data given by medical personnel through an application.

3. warfarin prescription and taken records of patients: the medical personnel provided medication dosage prescription and medication schedule to keep track of warfarin patients through the Warfarin Care website, as elderly patients and family used applications to confirm warfarin taken, as warfarin needed specific dose and time intake to maintain INR value. The warfarin prescription can be updated via the website, as patients might show signs and symptoms of important blood-related conditions or a heart attack.

4. risk assessment and history records, as warfarin was known to exhibit interactions with various foods and medications. The website provided a risk assessment questionary (Tomaselli *et al*., 2020) for medical personnel to adjust and confirm a list of risk assessments such as blood-related conditions, heart attacks, or medicine interaction questions for the application's users. While the elderly users were able to submit assessments to evaluate preliminary assessments of warfarin effects via application, the risk assessment resulted in high risk, and no warfarin confirmation after 12 hours will be reported to medical personnel.

5. warfarin knowledge data contents: The website provides a content editor page for medical personnel to later add or edit warfarin knowledge for patients. Patients can directly access the warfarin knowledge content list through the warfarin knowledge section of the application.

6. Medical interaction data: The website provides lists of foods and medicines that may interact with warfarin intake; these include vitamin K-rich vegetables, specific fruits, alcoholic beverages, cigarettes, traditional medicine, herbal supplements, antibacterial medications, and other biocidal drugs. Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) are crucial to avoid, as this combination heightens the risk of severe bleeding. Patients can directly access the warfarin interaction list through the warfarin interaction section in the application, as the elderly can add medicine or food to the warfarin interaction lists

that had to be taken. The medical personnel can visualize the list on the website and provide proper prescriptions to patients.

From Figure 2, the Warfarin Care had been designed to share the database to connect data across devices. The FastAPI was used to create a RESTful API to retrieve or send information from the PostgreSQL database and file storage. The website contained a user interface for visualized data to medical personnel users on a secured website, with a socket.io library to control notification of the website between the client and the server. While the application contained user interfaces for Android and iOS applications using the React Native framework. Firebase cloud messaging was in charge of controlling the notification service to send notifications to application users. As the application was designed for elderly patients, it helped with potential challenges such as decreased eyesight and hearing. The application provided readable text by using clear and legible fonts, maintaining a high contrast between text and background, a simple application layout by utilizing intuitive and large icons with text labels to enhance understanding of the function, touch-friendly buttons, and interactive elements. The website and application language and contents appropriation were adjusted and confirmed by five medical experts with clear and easy-to-understand language. The risk assessment and warfarin knowledge data contents can utilize the “TalkBack” or “VoiceOver” service on mobile devices to read the contents shown in the application.

3.2 Data Analysis

3.2.1 Data collection and measurement setting

The research questionnaire is prepared to evaluate an application for elderly people who use warfarin by conducting a closed-ended questionnaire where the respondents fill out the details in the questionnaire and follow the choices given. The study population is a group of elderly patients and family members from a total of 60 cases, with 30 elderly patients and 30 family members or caregivers, as the sample receiving treatment in the outpatient department of Sakonnakhon Hospital. An area for collecting data is distributing questionnaires by organizing activities for volunteers to test the use of the application for elderly people who use warfarin and making 60 questionnaires to collect research results. The participants had been assigned to use the application for four weeks as a warfarin reminder, warfarin taken history, medication treatment, medication appointment, risk assessment questionnaires, warfarin interaction, and warfarin knowledge contents.

Information used in the study process includes data preparation, data collection Data analysis, interpretation, and conclusion include primary data. It is information collected directly from the source. By using a closed ended questionnaire, data was collected on the sample population.

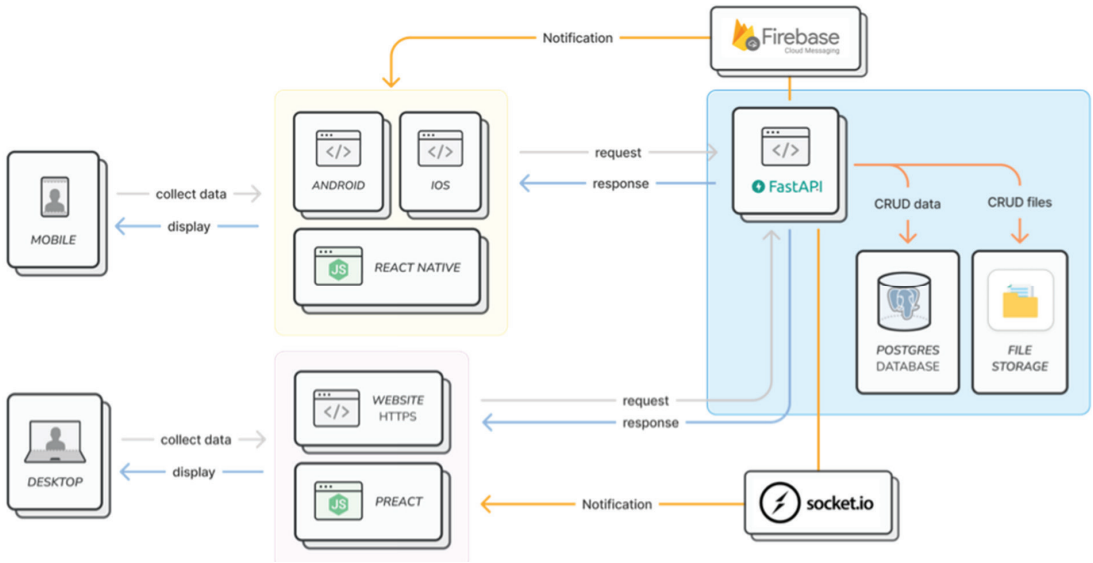

Figure 2. System diagram of Warfarin Care.

3.2.2 Data analysis interpretation

The researcher has set the statistical values for data analysis, describing the variables of this study as follows:

1. Analysis with descriptive statistics: the researcher has taken all the questionnaires and examined them. Analysis was performed using descriptive statistics to explain the results of the study in the following areas:

1.1 Some of the sample characteristics variables are age and gender. These are nominal measures because they can only describe the number of samples based on their properties and not their values. Therefore, appropriate statistics are frequency values and percentage values (Vanichbuncha, 2007).

1.2 Opinion level variables include satisfaction and behavior about perceived benefits from the application, divided into two sections consisting of:

- user satisfaction in knowledge on the use of warfarin, confidence in using warfarin, taking medicine correctly, risk of adverse warfarin reactions management, risk of adverse reactions knowledge from the use of warfarin, and medical personnel can track medication from patients.
- user satisfaction in using the application, including factors such as informative content, user interface design, use of language, usability, and appropriateness.

The questionnaire is a closed-ended question consisting of sub-answers divided into five levels using a rating scale and giving each level a score from the lowest score of 1 to the highest score of 5. The statistics used are frequency, mean, and standard deviation (Vanichbuncha, 2007).

The questionnaire results were used to calculate floor values for data interpretation by determining the range of data to be interpreted. The calculation formula and explanations for each grade level are as follows:

$$Floorvalue = \frac{(maximum-minimum)}{floors} \quad (1)$$

$$Floor = \frac{(5-1)}{5} = 0.80$$

Range interpretation can be concluded as:

- 1.00 – 1.80 : Disagreed
- 1.81 – 2.61 : Slightly disagreed
- 2.62 – 3.42 : Moderate
- 3.43 – 4.23 : Slightly agreed
- 4.24 – 5.00 : Agreed

4. Experimental Results

4.1 Warfarin Care

Warfarin Care had been developed to create communication between medical personnel and elderly patients taking warfarin through a website and application. The website provided information about correct usage of warfarin, medicine interactions, or risk assessment criteria for receiving warfarin and notified medical personnel users when patients submitted a risk assessment at high risk. Figure 3 shows the risk assessment submitted by the elderly patient. The website provided high-risk notifications such as blood-related conditions, heart attacks, or medicine interaction questions, and no warfarin confirmation after 12 hours will be reported to medical personnel. The medical personnel can visualize the details of a certain notification, as shown in the image on the right side.

Figure 4 shows the interfaces of the Warfarin Care website for medical personnel and applications for patients and caregivers.

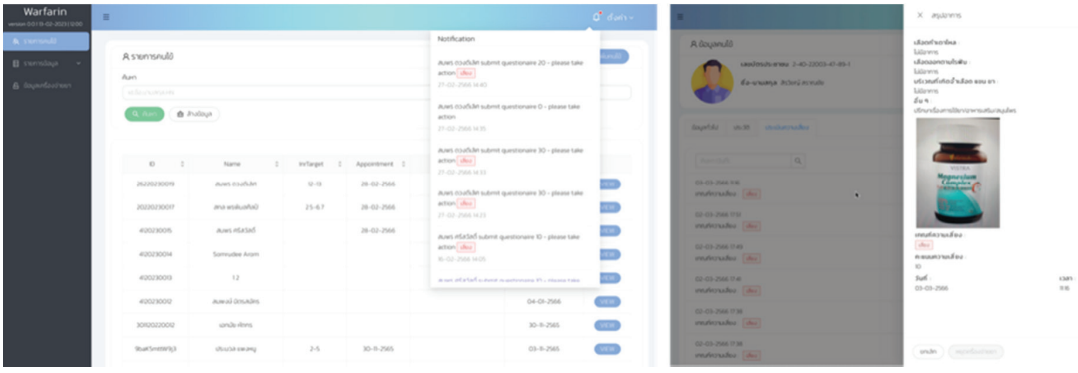

Figure 3. User interfaces of Warfarin Care website for medical personnel.

Figure 4. User interfaces of Warfarin Care application for patients and caregivers.

The main page, warfarin knowledge data contents, and medical interaction data, respectively. Patients can directly access the warfarin knowledge content list through the warfarin knowledge section and can access the warfarin interaction list through the warfarin interaction section in the application, as the elderly can add medicine or food to the warfarin interaction lists that had to be taken. The medical personnel can visualize the list on the website and provide proper prescriptions to patients.

4.2 Data Analysis

In this section, we presented the outcomes of an investigation into user satisfaction with the Warfarin Care application, focusing on various facets such as knowledge acquisition, confidence levels, guidance, risk awareness, and support for anticoagulation medication adherence. The utilization of mean and standard deviation as analytical tools offered a thorough examination of user sentiments.

4.2.1 Analysis interpretation of the elderly satisfactory

In this section, the study presents the findings of an examination of the personal data of elderly individuals, including age, gender, and marital status. The data is elucidated through frequency and percentage values. The results show that the majority of the 30 participants who took the test and completed all 30 assessments fall within the age range of 60–69 years (46.66 percent), then 70–79 years (36.66 percent), 80–89 years (13.33 percent),

Table 2. Satisfaction in using the application among the elderly group that affects the benefits received from the application and the use of the application by the elderly group that affects the usability and suitability received from the application.

Satisfaction with using the application Warfarin Care and the benefits received from the application	$\overline{X}$	S.D.	Interpretation
Have knowledge about the use of anticoagulants.	4.60	0.56	Agreed
Gain confidence in using anticoagulants.	4.66	0.55	Agreed
Take medicine correctly, both in dosage and time.	4.63	0.56	Agreed
It helps with the use of anticoagulants according to the treatment plan.	4.76	0.50	Agreed
Know the guidelines if there is a risk of adverse reactions from medication, such as easy bleeding or blood clots in important organs, etc.	4.63	0.56	Agreed
Reduce the risk of adverse reactions from the use of anticoagulants.	4.70	0.47	Agreed
Family members are aware and encourage the use of anticoagulants according to the treatment plan.	4.83	0.38	Agreed
It helps health team personnel track medication uses by patients.	4.73	0.45	Agreed
Appropriate content	4.63	0.56	Agreed
Good user interface design	4.60	0.62	Agreed
The media and content language are easy to understand.	4.67	0.55	Agreed
The application is convenient to use and not complicated.	4.47	0.68	Agreed
Overall use and suitability of the Warfarin Care application.	4.57	0.57	Agreed

and over 90 years (3.33 percent). Regarding gender, the majority are women, accounting for 53.30 percent, while men account for 46.70 percent. Regarding gender, the majority are women, accounting for 53.30 percent, while men account for 46.70 percent. The study also categorizes participants by marital status, revealing that the majority are married (66.60 percent), with 30 percent being widowed and 3.33 percent single.

In the next section of the questionnaire, the study focuses on evaluating user satisfaction with the Warfarin Care application in terms of awareness and support for using warfarin medication through the application. Utilizing mean and standard deviation values to analyze the data, Table 2 shows that participants are most satisfied with being aware of and getting help with taking their warfarin medications as prescribed, which is in line with the treatment plan. The mean score is 4.83 with a standard deviation of 0.38, indicating the highest level of satisfaction. The patients have gained knowledge about the use of anticoagulants with an average of

4.60 and a standard deviation (S.D.) of 0.56; on-time medicine taken; and understanding guidelines for the risk of adverse reactions from medication with an average of 4.63 and a S.D. of 0.61; family members are aware of and encourage the use of anticoagulants according to the treatment plan, with an average of 4.83 and a S.D. of 0.38; and Warfarin Care can help health team personnel track medication use by patients with an average of 4.73 and a S.D. of 0.45. Simultaneously, the presentation of data on application usage and user suitability in terms of language communication reveals the highest satisfaction level with easy-to-understand language communication. The mean score is 4.67 with a standard deviation of 0.55, indicating the highest level of satisfaction.

4.2.2 Analysis and interpretation of the family members or caregivers satisfactory

In this section, the study presents findings related to the personal data of relatives of elderly participants, including details such as age, gender, and familial relationships. The

Table 3 Satisfaction in using the application among the family members or caregiver group that affects the benefits received from the application and the use of the application by the elderly group that affects the usability and suitability received from the application.

Satisfaction with using the application Warfarin Care and the benefits received from the application	$\overline{X}$	S.D.	Interpretation
Have knowledge about the use of anticoagulants.	4.70	0.53	Agreed
Gain confidence in using anticoagulants.	4.60	0.56	Agreed
Take medicine correctly, both in dosage and time.	4.70	0.53	Agreed
It helps with the use of anticoagulants according to the treatment plan.	4.67	0.55	Agreed
Know the guidelines if there is a risk of adverse reactions from medication, such as easy bleeding or blood clots in important organs, etc.	4.67	0.61	Agreed
Reduce the risk of adverse reactions from the use of anticoagulants.	4.60	0.62	Agreed
Family members are aware and encourage the use of anticoagulants according to the treatment plan.	4.67	0.55	Agreed
It helps health team personnel track medication uses by patients.	4.63	0.56	Agreed
Appropriate content	4.63	0.52	Agreed
Good user interface design	4.60	0.66	Agreed
The media and content language are easy to understand.	4.67	0.58	Agreed
The application is convenient to use and not complicated.	4.47	0.78	Agreed
Overall use and suitability of the Warfarin Care application.	4.57	0.61	Agreed

analysis involved the use of frequency and percentage values. A total of 30 participants participated in the assessment, resulting in the completion of thirty evaluations. The outcomes highlight that the majority of respondents fall within the age range of 20–29 years, constituting 23.33 percent. Furthermore, participants aged 30-39 years account for 20.00 percent, those aged 40–49 years make up 33.33 percent, individuals aged 50–59 years represent 16.66 percent, and those over 70 years comprise 3.30 percent. Regarding gender distribution, the study indicates that the majority of respondents are female, making up 63.30 percent, while males constitute 36.70 percent. Further categorization of the elderly participants' relatives based on familial relationships reveals that the majority of respondents are children, representing 70 percent. Other relationships include spouses (6.70 percent), siblings (16.70 percent), and sons-in-law (6.70 percent).

The study presented the results of user satisfaction with the Warfarin Care application concerning knowledge, confidence, guidelines, risks, and support for using anticoagulant medication through the application. The chosen analytical tools for this assessment include the calculation of the mean and standard deviation. The summarized findings are detailed in Table 3. With a mean score of 4.70 and a standard deviation of 0.53, the Warfarin Care application has the highest level of satisfaction when it comes to the benefits of learning about how to use anticoagulant medications and the right way to take them, including the right dosage and timing. The family members know more about anticoagulants and make sure they take their medicine on time (with an average score of 4.70 and a standard deviation of 0.53) and understand the risk of bad reactions to medications (with an average score of 4.67 and a standard deviation of 0.61). The family members also know and encourage the use of anticoagulants according to the treatment plan (with an average score of 4.67 and a standard deviation of 0.55), and Warfarin Care can help health team members keep track of medication use. Additionally, the study examines user satisfaction with the Warfarin Care application in terms of usage and appropriateness among participants. The analysis results show the highest satisfaction levels with content suitability and easy-to-understand language communication, with a mean score of 4.73 and standard deviations of 0.52 and 0.58.

5. Conclusion

5.1 Summary of Warfarin Care

Warfarin Care represents a crucial advancement in digital healthcare technology tailored to the specific needs of the elderly population using warfarin. By facilitating efficient communication and information exchange among medical personnel, elderly patients, and their caregivers, the application and website aim to reduce medication errors and enhance overall treatment outcomes. The user-friendly interface, rigorous content evaluation, and shared database architecture

demonstrate a thoughtful and comprehensive approach to addressing the challenges associated with warfarin usage. Warfarin Care's impact on achieving its objectives is evident in the successful integration of risk assessment, medication history, and knowledge of warfarin usage. The application serves as a medication reminder and educational tool, fostering a better understanding of proper medication behavior. Medical personnel benefit from real-time access to patient data, enabling them to make informed decisions and provide timely interventions.

However, it's essential to acknowledge certain limitations. Warfarin Care's effectiveness heavily relies on user adherence and regular engagement, which might vary among elderly users. Additionally, factors such as technological literacy and access to smartphones or tablets may influence the user's reach. Ongoing efforts should be directed toward addressing these limitations, potentially through user training programs or alternative communication channels. Additionally, the Warfarin Care application did not offer notification sounds, real-time pop-up notifications, or medicine confirmation services to alert the elderly to confirm medication intake, even though users were required to do so by navigating to specific application pages.

In conclusion, while Warfarin Care has showcased promising potential toward maximizing its impact, it requires an ongoing commitment to refinement and adaptation. Warfarin Care can contribute significantly to the advancement of anticoagulant therapy management for the elderly. This commitment ensures that Warfarin Care remains a relevant, effective, and sustainable tool for both patients and healthcare providers in the dynamic landscape of digital healthcare.

5.2 Summary of the Analysis of Usage Data of the Users

In conclusion, the comprehensive analysis of usage data for both elderly individuals and their caregivers or relatives regarding the Warfarin Care application yielded insightful findings from this clinical trial. Among the elderly participants, the majority, particularly those aged 60–69 years, demonstrated a high level of satisfaction with the application's features, emphasizing its effectiveness in promoting awareness and supporting adherence to anticoagulation medication. The caregivers or relatives, predominantly falling in the age range of 40–49 years, also expressed significant satisfaction, particularly in terms of the application's contribution to knowledge, confidence, and guidance related to anticoagulation medication. Furthermore, overall user satisfaction with the application's language communication and content appropriateness was notably high, highlighting its user-friendly nature. These findings collectively underscore the positive impact of the Warfarin Care application on both elderly users and their caregivers, emphasizing its effectiveness in enhancing knowledge, confidence, and support for proper medication adherence.

6. Discussion

Expanding on further research, A comprehensive longitudinal study could provide valuable insights into Warfarin Care's effectiveness over an extended period of time. This includes assessing whether improved adherence to warfarin regimens translates into better health outcomes for the elderly population, such as reduced incidences of adverse events or hospitalizations related to anticoagulant therapy. Warfarin Care's user experiences and insights can inform iterative improvements, ensuring that Warfarin Care remains responsive to the evolving needs and preferences of its diverse user base.

The traditional practice of nurses and pharmacists making phone calls to monitor patients' medication adherence can be streamlined through the implementation of a dedicated mobile application. The medical team has expressed approval of this approach through its website and application. Notably, patients' knowledge regarding medications and dietary considerations has significantly improved through the use of the application, which is curated based on information provided by medical personnel. Moreover, the involvement of family members in facilitating medication adherence has been instrumental. Users agreed that the use and suitability of the Warfarin Care application had an average of 4.57 and a S.D. of 0.57 from elderly users and an average of 4.67 and a S.D. of 0.61 from caregivers or family members. Incorporating user feedback mechanisms, perhaps through user surveys, focus groups, or usability testing, will enable developers to identify areas for enhancement and address any emerging challenges promptly.

Additionally, staying attuned to emerging technologies and healthcare trends is paramount for the sustained success of Warfarin Care. The field of digital healthcare is dynamic, with innovations and advancements occurring regularly. Integrating these developments into Warfarin Care's service, such as incorporating artificial intelligence for personalized risk assessments or leveraging wearable devices for real-time health monitoring, can enhance its capabilities and overall impact.

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References

Amar, F., April, A., & Abran, A. (2024). Electronic health record and semantic issues using fast healthcare interoperability resources: Systematic mapping review. *Journal of Medical Internet Research*, *26*(e45209). https://www.jmir.org/2024/1/e45209

American Hospital Association. (2021). *AHA statement on the Future of Telehealth*: *COVID-19 is Changing the Delivery of Virtual Care*. Retrieved 10 October 2023, Retrieved from https://www.aha.org/2021-03-02-aha-statement-future-telehealth-covid-19-changing-delivery-virtual-care

Brown, J., Cavanagh, J., Dorricott, B., Irving, V., & LaRiviere, C. (2023). Improving the quality and sustainability of home-based acute care models using virtual care technology. *Asia Pacific Journal of Health Management*, *18*(3). https://doi.org/10.24083/apjhm.v18i3.2785

Chamnanhan, T., Phetkrachang, K. ., Sathiwantana, S., Pongsagorn, P., & Choosong, C. (2023). Measurement of word similarity for diabetes question answering system. *Journal of Applied Informatics and Technology*, *5*(2), 86–99. https://doi.org/10.14456/jait.2023.7 [In Thai]

Chang, W.-J., Chen, L.-B., Hsu, C.-H., Lin, C.-P., & Yang, T.-C. (2019) A deep learning-based intelligent medicine recognition system for chronic patients. *IEEE Access*, *7*(1), 44441-44458. https://doi.org/10.1109/ACCESS.2019.2908843.

Choicharnchaikul, S., Malathum P., & Kanchanachai, S. (2008). Warfarin use in the elderly: A case study and care. *Ramathibodi Nursing Journal*, *14*(3), 366-384. https://www.researchgate.net/publication/277153283_The_Use_of_Warfarin_in_Older_Adults_A_Case_Study_and_Caring [In Thai]

Dang, T. H., Nguyen, T. A., Hoang Van, M., Santin, O., Tran OMT, & Schofield, P. (2021). Patient-centered care: Transforming the health care system in Vietnam with support of digital health technology. *J Med Internet Res*, *23*(6), e24601. https://doi.org/10.2196/24601

DEPA. (2023). *Digital society series*: *e-Health open data platform for aged society*. Retrieved 15 October 2023, Retrieved from https://www.depa.or.th/th/article-view/digital-society-series-e-health-open-data-platform-aged-society

European Commission. (2018). *Information paper on main eHealth activities outside of the EU*. Retrieved 10 October 2023, Retrieved from https://health.ec.europa.eu/system/files/2018-09/ev_20180515_co23_en_0.pdf

Hnoohom, N., Yuenyong, S., & Chotivatunyu, P. (2018) MEDiDEN: Automatic medicine identification using a deep convolutional neural network. In *2018 International Joint Symposium on Artificial Intelligence and Natural Language Processing (iSAI-NLP)*. Springer. https://doi.org/10.1109/iSAI-NLP.2018.8692824

Jiang, S. *et al*. (2022) Efficacy and safety of app-based remote warfarin management during COVID-19-related lockdown: a retrospective cohort study. *J Thromb Thrombolysis*, *54*(1), 20-28. https://doi.org/10.1007/s11239-021-02630-0.

Jirapanthong, W. (2016) The use of web-based application to support medical operations in Thailand. *Journal of Information Science and Technology (JIST)*, *6*(1), 1-7. https://doi.org/10.14456/jist.2016.1.

Kalra, S., Taneja, C., & Singhal, N. (2023). Participation in online health communities: Decoding the antecedents and outcomes. *Asia Pacific Journal of Health Management*, *18*(2). https://doi.org/10.24083/apjhm.v18i2.1387

Kant Pal, S. *et al*. (2023). Analysing the impact of student health post COVID-19 pandemic and providing a solution using digital technologies. *Asia Pacific Journal of Health Management*, *18*(2). https://doi.org/10.24083/apjhm.v18i2.2411

Koonin, L. M. *et al*. (2020). Trends in the use of telehealth during the emergence of the COVID-19 pandemic — United States, January–March 2020. *MMWR Morb Mortal Wkly Rep*, *69*, 1595–1599. http://dx.doi.org/10.15585/mmwr.mm6943a3

Kumar, A., Mathur, R., Shirmila, T., More, R., Kaikini, R., & Bhalerao, K. (2023). An effective health care system through health technology assessment and evidence based payment system in India. *Asia Pacific Journal of Health Management*, *18*(2). https://doi.org/10.24083/apjhm.v18i2.2403

Kusumasari, B., Setianto, W., & Pang, L. (2018). A study on digital democracy practice: Opportunities and challenges of e-health implementation in Indonesia. *Jurnal Ilmu Sosial dan Ilmu Politik*, *22*(1), 1-10. https://doi.org/10.22146/jsp.28863

Leavy, M. (2019). *The Use of Mobile Devices in Healthcare. Elite Learning*. Retrieved 10 October 2023, Retrieved from https://www.elitelearning.com/resource-center/health-systems-management/the-use-of-mobile-devices-in-healthcare/

Lin, R., Lai, P., Chin, C., & Kuo, Y. (2013). Intelligent taking medicine reminding system. In *2013 1st International Conference on Orange Technologies (ICOT) (pp. 39–42)*. IEEE. https://doi.org/10.1109/ICOT.2013.6521152.

Lwin, H.N.N., Punnakitikashem, P., & Thananusak, T. (2023). E-health research in Southeast Asia: A bibliometric review. *Sustainability*, *15*(3), 2559. https://doi.org/10.3390/su15032559

Ministry of Public Health. (2017). *eHealth strategy, Ministry of Public Health (2017 – 2026)*. Retrieved 10 October 2023, Retrieved from https://ict.moph.go.th/upload_file/files/eHealth_Strategy_ENG_141117.pdf

Moraes, R. M., Winkelmann, E. R., & Colet, C. d. F. (2022). Use of a mobile application for the control of anticoagulation with warfarin: a cluster randomized controlled clinical trial - Ijui/RS/Brazil. *Journal of Pharmaceutical Sciences*, *58*. https://doi.org/10.1590/s2175-97902022e19153

Nguyen, Q. T., Naguib, R. N. G., Tawfik, H., & Phuong, N. H. (2013). Strategic challenges facing user- and patient-centred e-health in Vietnam. *International Journal of Healthcare Technology and Management*, *14*(5/6), 378-394. https://doi.org/10.1504/IJHTM.2012.052551

Olomu, I. O. *et al*. (2018). Technology use among patients undergoing Warfarin therapy: A report from the michigan anticoagulation quality improvement initiative (MAQI2). *Circulation*: *Cardiovascular Quality and Outcomes*, *7*, A176. https://doi.org/10.1161/circoutcomes.7.suppl_1.176

Panichsombat, T. (2017). *Development of the pharmacy care system for patients using warfarin at Ban Tak Hospital* [Unpublished document]. Tak : Technical Services Pharmacy Group, Ban Tak Hospital.

Pintusirakun, W., Netphlap, R., Koson, T., & Tangwongcharoen, W. (2023). Knee joint muscle measurement application for physical therapy treatment. *Journal of Applied Informatics and Technology*, *6*(1), 98–112. https://ph01.tci-thaijo.org/index.php/jait/article/view/251883 [In Thai]

Rafhi, E., Stupans, I., Park, J. S., & Wang, K. (2023). The influence of social and individual factors on medicine use in older adults. *Asia Pacific Journal of Health Management*, *18*(3). https://doi.org/10.24083/apjhm.v18i3.2691

Sabrina, M.I. & Defi, I.R. (2021). Telemedicine Guidelines in South East Asia—A Scoping Review. *Front. Neurol*, *11*, 581649. https://doi.org/10.3389/fneur.2020.581649

Sratthaphut, L. (2015). Development of an expert system for recommendation on Warfarin dosing adjustment guideline in patient for pharmacist: A pilot study using CLIPS language. *International Journal of Pharmaceutical Sciences*, *11*(2), April-June 2015. https://doi.org/10.14456/ijps.2015.2

Tanaka, J., Kuroda, H., Igawa, N., Sakurai, T., & Ohnishi, M. (2020). Perceived e-health literacy and learning experiences among Japanese undergraduate nursing students: A cross-sectional study. *Computers, informatics, nursing*: *CIN*, *38*, 198-203. https://doi.org/10.1097/CIN.0000000000000611

Tang, G., Izumi, K., Izumisawa, M., & Koyama, S. (2023). Analysis of Japanese consumers' attitudes toward the digital transformation of OTC medicine purchase behavior and eHealth literacy: an online survey for digital experience design. *Front Digit Health*, *5*, 1173229. https://doi.org/10.3389/fdgth.2023.1173229

Tomaselli, G. F. *et al*. (2020). 2020 ACC Expert consensus decision pathway on management of bleeding in patients on oral anticoagulants: A report of the American College of Cardiology Solution Set Oversight Committee. *Journal of the American College of Cardiology*, *76*(5), 594–622. https://doi.org/10.1016/j.jacc.2020.04.053

Vanichbuncha, K. (2007). *Statistical analysis*: *Statistics for management and research* (10th ed.). Bangkok: Chulalongkorn University Printing House [In Thai].

Warfarin Clinic. (2014). *Knowledge for patients treated with anticoagulant medication* (Warfarin: WARFARIN) [Brochure]. Bangkok : Faculty of Medicine Siriraj Hospital.

Wongkampun, S. & Panitrat, R. (2023). Factors influencing health information technology utilization behaviors among older people in Bangkok metropolitan. *The Journal of Thailand Nursing and Midwifery Council (JTNMC)*, *38*(3). https://doi.org/10.60099/jtnmc.v38i03.263587

World Bank. (2016). *Digital Dividends*: *World Development Report 2016*. Retrieved 15 October 2023, Retrieved from https://documents1.worldbank.org/curated/en/896971468194972881/pdf/102725-PUB-Replacement-PUBLIC.pdf

World Health Organization (WHO). (2020). *World health statistics 2020*: *Monitoring health for the SDGs, sustainable development goals (Global report)*. Retrieved 15 October 2023, Retrieved from https://www.who.int/publications/i/item/9789240005105