Design and development of a mobile application for emergency medical assistance for running-related injuries in a marathon event

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ABSTRACT

This research was dedicated to the creation and refinement of a mobile application, specifically crafted for providing Emergency Medical Assistance at marathon events in Thailand. As the popularity of marathons surges, propelled by a growing health consciousness and a rising trend in regular exercise among Thais, the demand for efficient medical support in these settings has intensified. This study explored the necessity of instant access to runners' medical data to facilitate clinical decision-making and potential hospital admissions for specific symptoms. Key aspects investigated included essential features for the application, prevalent injuries among marathon runners, and the application's perceived utility and user-friendliness by medical professionals. The developed system integrates health records and real-time location data, ensuring swift pre-hospital intervention. The research was conducted during the Khao Yai marathon, involving 7,728 runners and 40 medical personnel. Findings highlighted the importance of rapid access to medical histories, emergency contacts, real-time location tracking, and efficient medical team coordination. Common injuries noted were swollen feet and legs. While the application proved useful and user-friendly, recommendations for future enhancements, particularly a more intuitive interface, were identified.

1. Introduction

Many people are concerned about their well-being and health these days. People have studied and discovered various useful ways to improve and nourish their bodies and health in order to have a happy and healthy life. Running is one of the effective ways that people are particularly interested in because it can be a fun activity or exercise that helps promote their health (Lee et al., 2017). A lot of marathon events have been held in many parts of the world, proving that running promotes a healthy life. Although running supports good health, it is occasionally associated with a significant risk of running injury. According to Dempster et al. (2021), 37% of running-related injuries are connected to the lower limb. Female runners were more likely to suffer injuries in the lower limb and calf, whereas male runners were more likely to be injured in the upper limb, pelvis, and hip. Therefore, immediate medical services and treatment are required to treat a runner with running-related injuries or accidents. Emergency management system (EMS) has a significant role in saving lives and decreasing rates of morbidity and mortality (Aringhieri et al., 2017). EMS is an essential component of current healthcare systems as it oversees the pre-hospital component of healthcare services. It comprises medical treatment and transportation services provided from the moment an emergency call is made up to the time that the patient is sent to a hospital (Bélanger et al., 2018). The rate of death among emergency patients can be reduced if emergency management services respond quickly (Wilde, 2013). Given the benefits of EMS, it has been widely used in the healthcare sector to aid in providing urgent medical services and treatment to reduce a patient's severe condition.

As our study focused on running-related injuries, it is crucial to develop an emergency management system that can help prevent and reduce the morbidity and mortality rates of marathon events. Therefore, in this study, we aim to develop an emergency management system in the form of a mobile application that provides pre-hospital

treatment to runners who experience unexpected accidents or injuries during a marathon. We propose a medical support and emergency system for runners, which includes a field medical team. We provide a case study of our application's system during the Khao Yai Marathon event. The structure of this paper is as follows: In Sector 2, we discuss related work. In Sector 3, we present the proposed study. The methodology is described in Sector 4, and in Section 5, we demonstrate the data analysis and results of the fact-finding procedures and data collection. We present our results in Sector 6, and in Sector 7, we describe the findings and discuss the research, including limitations and conclusions.

2. Related works

This section covers studies of an emergency management application designed for mobile devices. Wu et al. (2021) have shown that the smartphone platform application incorporating suggested procedures for all phases of first aid is a helpful approach to assist Acute Ischemic Stroke (AIS) emergency management. Prompt thrombolytic treatment is critical for improving the results of acute ischemic stroke (AIS). "Green," a smartphone platform, was developed with the intention of decreasing door-to-needle (DTN) time for AIS (Wu et al., 2021). DNT was described as the distinction between door-time and needle-time. The door-time was defined as the time the patient with a stroke arrived at the emergency room. The examination time of a neurologist was considered door-time once the patient arrived and was admitted to the hospital. The needle-time was described as the moment at which the (bolus of) rtPA was delivered (Kuhrij et al., 2019). The smartphone platform, Green, can assist in several areas, including field evaluation, hospital suggestion, pre-hospital notice, clinical record production, real-time transmission, crucial time stamping, and control of quality and systematize the entire AIS emergency management approach. Regarding the result, the authors revealed that DTN time decreases proved that AIS emergency management approaches improvement (Wu et al., 2021). In addition, Stop Stroke, the medical application, was developed by doctors to improve the coordination and communication activities needed for the prompt evaluation and treatment of AIS patients (Dickson et al., 2017). Patients who had been admitted to the emergency department (ED) with an acute ischemic stroke (AIS) were studied for Stop Stroke's effect on door-to-needle (DTN) time (ED). When inpatients are suspected of having AIS, medical or EMS personnel can enable the application. A picture of the patient's clinical appearance is captured, and it is sent out to every member of the stroke care team together with the patient's information. The stroke care team has immediate access to the patient's health data and real-time updates. The result on the effect of the application on door-to-needle time of patients with AIS admitted to the ED was found that it could

reduce the DNT times by 28%. Additionally, significant improvements were shown in the time spent—less than 60 minutes—from stroke activation to treatment (Utami and Ramdani, 2022). According to the findings of the preceding studies, the use of emergency management applications has been developed to help emergency patients who require immediate examination and treatment by an emergency team.

The purpose of this study is to investigate and develop an emergency management application for providing medical support to runners who sustain running-related injuries during the Khao Yai marathon. Additionally, we collect and analyze feedback from the medical team regarding the perceived usefulness and ease of use of the application. The study aims to answer the following research questions:

RQ1) What are the key features required in an emergency management application for providing medical support to runners during the marathon event in Thailand?

RQ2) What are the most common running-related injuries sustained by runners during the marathon event, and how can the emergency management application be tailored to provide effective medical assistance for these injuries?

RQ3) What is the perceived usefulness and ease of use of the emergency management application among the medical team during the marathon event, and how can the application be improved to better meet their needs?

To address these research questions, we developed and utilized an emergency assistance system application to be used by participants and medical staff during the running event. In case of an emergency, the field medical team can quickly access runners' health records or medical histories, locate them, and provide medical support on-site.

3. Methodology

The development of an emergency assistance system for marathon runners was accomplished through the integration of hardware and software technologies, based on the CMU marathon (Sirasakamol et al., 2022). The system was designed to deliver prompt pre-hospital treatment to runners in need and involved the creation of a medical application for a field medical team. This application enabled medical staff to access runner health records and instantly locate them, ensuring that emergency medical treatment could be provided in a timely and efficient manner. The emergency assistance system collected health records and location data from the runners. In the event of an emergency, the medical staff could access this information and send an alert to a centralized monitoring and response system. This centralized system was responsible for dispatching emergency responders to the runner's location. The

implementation of this emergency assistance system played a crucial role in ensuring the safety of marathon runners, as it facilitated quick and efficient emergency medical treatment, thus reducing the risk of severe injury or fatality. This system serves as a significant example of successful hardware and software technology integration in the field of emergency medical care. To develop the system, we distinguished three components: The Registration for Personal Health Record system, the Mobile Application and Hardware Implementation system, and the Centralized Monitoring system. In other sections, an overview will be provided of these systems. In this section, we will provide a step-by-step description of the emergency assistance system for marathon runners.

- Registration for personal health record system: The purpose of this system is to collect the runner's personal health record (PHR) in an electronic database that contains an individual's health information, including medical history, test results, medications, allergies, and other relevant health information for marathon events. This information proves invaluable for medical staff at marathon events as it enables them to swiftly access and review the health information of runners in need of medical attention. For instance, this database equips medical staff with vital information regarding a runner's medical history, encompassing pre-existing conditions, allergies, medications, and immunizations. This information can be crucial in case of a medical emergency during the marathon, as medical professionals can quickly access the runner's health information and provide appropriate treatment. This system collects data during the first registration process for the Khao Yai Marathon event.
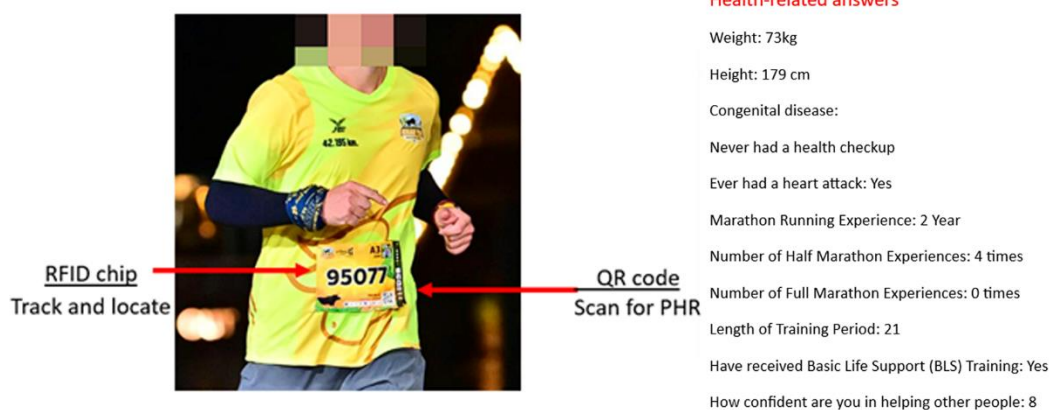
- Mobile application and hardware implementation: In our system, we have separated the design between software and hardware to ensure that runners are supported in the event of a serious emergency. Regarding the hardware design, our project team opted to utilize RFID Wet Inlay hardware for tracking the runners' positions, along with QR CODE prints for Bib Tagging. The RFID Wet Inlay hardware is used to track the runners' movements, while the QR CODE prints display the runners' health information and history, as shown in Fig. 1.

In terms of software implementation, we developed a mobile application called Medic and Application Track for medical staff with specific use in marathon events. The Medic application is specifically designed to aid medical staff and furnish crucial information for serious emergency situations throughout the marathon event. It displays the health information and history of runners, including telephone numbers and contact information of relatives for emergency cases. Medical staff scan the runner's unique QR code, which reveals the individual's name, health history, and emergency contact information, as depicted in Fig. 1. Please note that after the marathon event, the QR code is disabled and only available for three days. This ensures the privacy of the runner's information.

Application Track employs location-based technology, enabling medical staff to pinpoint the runner's emergency and transport the patient to the designated rescue point, as illustrated in Fig. 2, from where an ambulance can transport the runner to the hospital. The location of runners can be tracked by the RFID chip located on the back cover of the BIB.

Fig. 1: BIB tagging to embed the RFID and QR code

- Centralized monitoring system: In addition to the hardware and software designs described above, we have also implemented a centralized monitoring system to ensure the safety of the runners during the marathon event. The system actively monitors the position of the runners to assist the medical staff in identifying any anomalies that may signal a serious emergency. The centralized monitoring system includes a team of medical professionals who are stationed at the office center of the marathon route and can quickly contact the field medical staff. to identify any runners who may require medical attention and provide prompt assistance. In case of a serious emergency, the centralized monitoring system is designed to promptly notify the hospital and first

aid doctors. The system is equipped with a dedicated emergency hotline, which medical staff can use to quickly report any emergencies to the hospital and first aid doctors. The hotline is staffed by trained professionals who can provide immediate guidance and support to the medical staff and runners. The centralized monitoring system (Fig. 3) is a critical component of our emergency system for marathon events, offering a comprehensive solution for monitoring runners and ensuring their safety throughout the event. With this system in place, we can provide prompt medical attention to any runners who may require it and ensure that they receive the necessary care and support in the event of a serious emergency. Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used

as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as "3.5-inch disk drive."
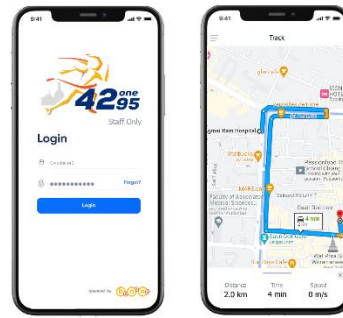

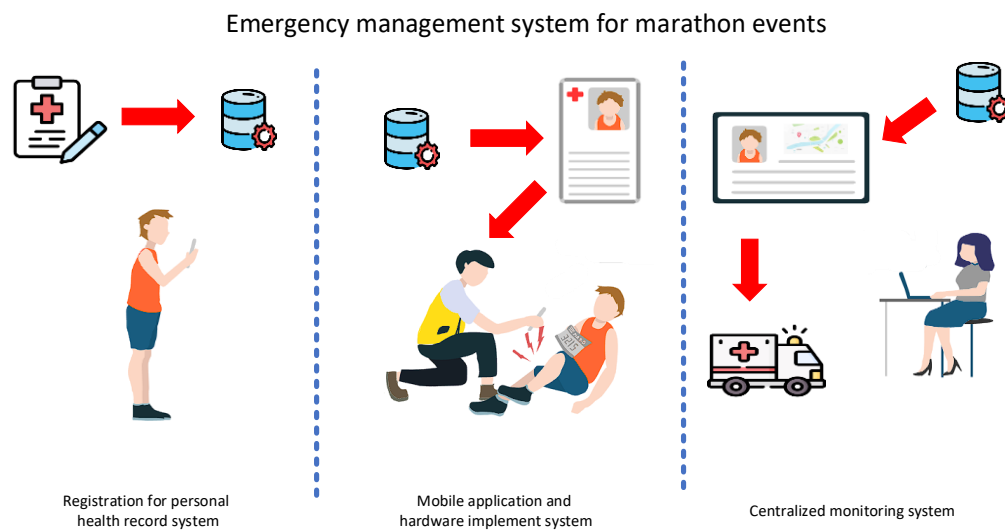**Fig. 2:** The application track to locate the runner

Fig. 3: Overview of emergency management system for marathon events

3.1. Participants

- Runners: Participants in the marathon events were analyzed to prepare the medical team for emergencies. In total, 7,728 people participated in the Khao Yai Marathon 2019, with 448 participants in the Family Run (6%), 1,073 in the Marathon (14%), 2,231 in the Half Marathon (29%), 2,373 in the Mini Marathon (30%), and 1,603 in the Run for Health (21%). Furthermore, data from 419 runners with pre-existing medical conditions showed that hypertension, asthma, and hyperlipidemia were the top three most common conditions. Of the participants, 116 reported discomfort or aches when resting or performing an activity, with the most common symptoms being swollen feet and legs, chest, neck, and jaw pain, fainting, and fatigue while lying down, respectively.
- Medical staff: The system involved a team of 40 Thai medical staff, including doctors, nurses, and assistants. Twenty-five of the staff were female and 15 were male, and they were assigned to provide medical care and treatment for runners at designated rescue points along the marathon route during the Khao Yai Marathon 2019.

3.2. Procedure

We collected data from the Khao Yai Marathon 2019. During the registration period, we asked runners for their consent to participate in the marathon event for research purposes and emergency cases by filling out an online form. We then trained the medical staff to use our system one month prior to the event. After the event, we asked the medical staff to complete a Google Form questionnaire about the application's ease of use and usefulness. The data provided by the medical staff was analyzed in the Data Analysis and Results section. Lastly, we analyzed the comprehensive system data to address our research questions

3.3. Instruments

We collected data using our system, which included participants' medical records. This information enabled the medical team to investigate patients and provide appropriate treatment. Additionally, we evaluated the application's usability and acceptance by adopting a user-centered questionnaire (Hajesmaeel-Gohari et al., 2022) and

using Google Form questionnaires to gather feedback from 40 field medical staff members. The questionnaires focused on identifying the key features required in an emergency management application for providing medical support and evaluating our system in terms of usability and acceptance. Finally, we analyzed the most common running-related injuries sustained by runners by reviewing user response reports in the personal health record database, as well as real cases that occurred during the marathon events.

4. Data analysis and results

We developed a mobile application for the Khao Yai Marathon 2019 with the purpose of assisting medical teams in delivering treatment to injured participants. Participants and medical staff could download and install the Medic application and Application Track from the App Store and Play Store in both iOS and Android versions. The runners were requested to submit personal information by filling out a survey on the mobile application. Regarding the application's outcomes, we collected data in both quantitative and qualitative formats by soliciting

feedback and responses from the medical team through a Google Form questionnaire.

4.1. Quantitative data analysis

We recruited 40 people at random from the medical team to be on standby for the running race in case of an emergency or accident. There were 25 female doctors and 15 male doctors who used our application and completed surveys on its efficacy and usability. To learn how the medical staff used the system in emergency management practice as well as their comments on the proposed system, we designed this survey to collect the data from them. Our quantitative data consisted of a 17-item questionnaire, covering various aspects such as Perceived Ease of Use (five items), Perceived Usefulness (three items), Behavioral Intention to Use (two items), Information Quality (three items), Mobile Application Design (two items), and Navigation (two items). All items were scored on a 5-point Likert scale, with scores ranging from 1 (very poor) to 5 (very good). Tables 1 and 2 show the questionnaire results of the users' responses, presented as a mean value and standard deviation.

Table 1: Results of questionnaire responses for technology acceptance issues

Topic	Questionnaire	Mean	SD
Perceived ease of use	Easy to operate the marathon event with the proposed mobile application	4.175	0.44
	Clear and understandable interaction with the proposed mobile application	3.825	0.74
	The flexibility of the mobile application in terms of interaction	4.025	0.57
	The mobile application is simple to use by new medical staff	4.175	0.38
	Easy and learn how the proposed mobile application works	4.15	0.48
Perceived usefulness	The mobile application can improve medical staff operator work effectiveness	3.875	0.722
	Mobile application usefulness in terms of emergency handling in marathon events	4.2	0.56
	The mobile application helps the medical staff operator accomplish the task more quickly	4.15	0.48
Behavioral intention to use	I tend to use the proposed mobile application again	4.275	0.45
	I recommend using the proposed mobile application in the next marathon event	4.225	0.73

Table 1 shows the results of participants' survey responses on technology acceptance issues, including Perceived Ease of Use, Perceived Usefulness, and Behavioral Intention to Use. Regarding the five items related to Perceived Ease of Use, participants predominantly rated the ease of operation during the marathon event and the simplicity of use for new medical staff (4.175). Several users provided feedback stating that the interaction with the proposed system was unclear

and challenging to comprehend (3.825). In terms of Perceived Usefulness, the users remarked the mobile application had usefulness in regard to emergency handling in the running event (4.2). They also rated the app's potential to improve medical staff's ability to perform in and manage emergency situations (3.875). Regarding behavioral intention to use, the respondents agreed that the mobile application was worthwhile to use and recommend at the next running event (4.225).

Table 2: Results of questionnaire responses for usability issues

Topic	Questionnaire	Mean	SD
Information quality	The proposed mobile application provides information that is relevant to the emergency management field	4.50	0.42
	The proposed mobile application provides useful runner information	4.40	0.48
	The proposed mobile application provides comprehensive information	4.45	0.78
Mobile application Design	The interface of the mobile application was clear	4.15	0.52
	The color combination of the proposed mobile application	3.90	0.48
Navigation	The proposed mobile application provides clear navigation	3.80	0.66
	The proposed mobile application was easy to navigate	3.75	0.74

Table 2 presents the results of survey responses from participants on usability concerns, such as Information Quality, Mobile Application Design, and Navigation. Participants rated all three items of Information Quality above 4 points, with the highest rating given to the relevance of information for emergency management (4.50). For two items

related to Mobile Application Design, Participants mainly responded that the mobile application's interface was understandable (4.15), although the color combination design was not dynamic and vibrant (3.90). The application might need to be improved by being more vivid and visually appealing. Regarding the two items related to

Navigation, participants provided scores below 4 points for both, with the ease of navigation receiving the lowest rating (3.75), followed by the clarity of navigation (3.80).

4.2. Data analysis of runners' database

We analyzed the runners' database and identified 419 participants who had pre-existing medical conditions and filled out the registration form.

Among these conditions, hypertension, asthma, and hyperlipidemia were the three most frequently reported shown in Fig. 4. During the marathon events, 116 cases of discomfort or aches while resting or engaging in activities were reported. The most commonly reported symptoms included swollen feet and legs, chest, neck, and jaw pain, fainting, and fatigue while lying down shown in Fig. 5.
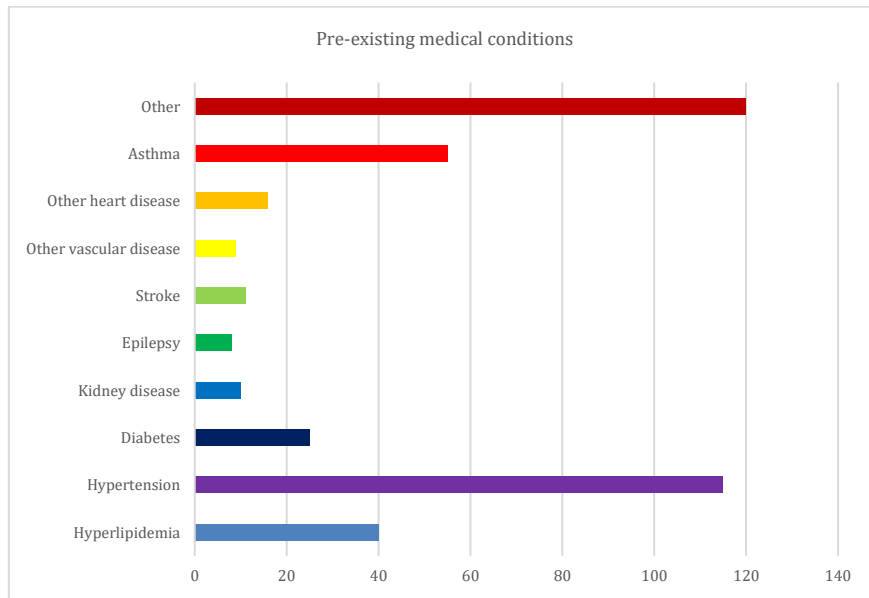

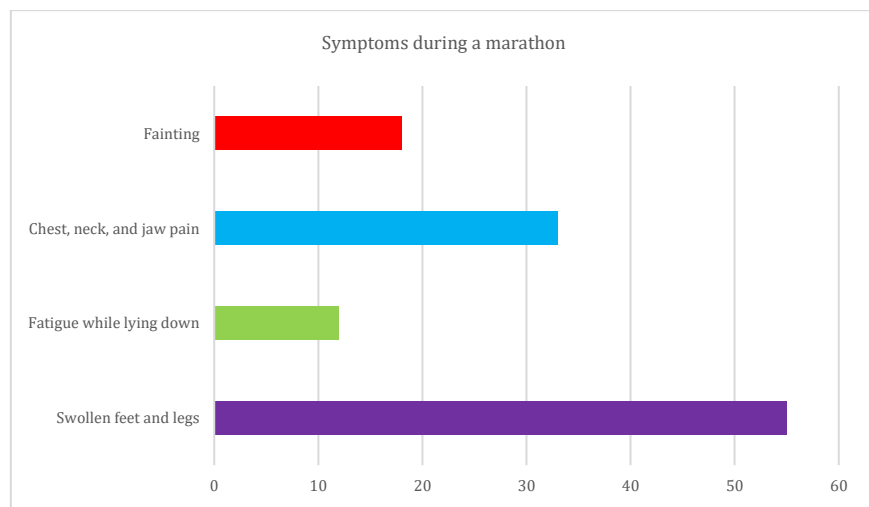**Fig. 4:** The data analysis of runners' symptoms

Fig. 5: The data analysis of symptoms during a marathon

4.3. Qualitative data analysis

After the running event, we collected qualitative data from medical staff for 40 individuals using a survey form for the satisfaction questionnaire. However, only 18 of them provided comments. The survey featured an open-ended question: "Is there any suggestion for the application?" The open-ended question received both positive and negative comments, as well as suggestions for improvement.

- Positive feedback: Seven individuals provided positive feedback, four men and two women. They

stated that "the application is helpful for emergency management" and "this mobile app is easy to use for new users." One person also said "I will recommend this app to be used in the next running event." and another stated that, "I think it was very useful to display the personal health record quickly in case of a serious emergency during the events."

- Negative feedback: There were three negative comments about the proposed system. Although most respondents found the application easy to use, some mentioned, "I find it quite confusing to interact with the application," "the navigation is

unclear," and "the navigation system should be more user-friendly."

- Application improvement suggestions: We received eight suggestions on the proposed system of the application, which fell into two categories: design and experience, and technology.
- Design and experience: Respondents provided feedback on the design and experience of the application. They suggested that it could be more aesthetically appealing and that the color scheme should be more colorful.
- Technology: Users encountered difficulties using the proposed system in terms of technology. The biggest problem they experienced was the accuracy of the navigation. They stated that "the navigation system is confusing to use" and "the navigation sometimes did not provide clear directions to a patient." Some suggested that the Track Application and the Medic Application be combined for ease of use and system access.

5. Findings and discussion

In order to answer the research questions, we also tested our approach on a large number of participants in the Khao Yai marathon events with 7,728 runners participating. We also collect both qualitative and quantitative data from the runners and medical staff who are involved in the marathon events. We conclude the findings below:

RQ1: Based on questionnaire responses and open-ended questions, the study identified the key features required in an emergency management application for providing medical support to runners during a marathon event in Thailand. The sample consisted of 40 medical staff respondents who provided valuable insights. The findings revealed that the two most important features were quick and easy access to medical history and emergency contact information, and real-time location tracking. These features are crucial for ensuring a prompt and efficient response from the medical team in the event of an emergency. Additionally, the study emphasized the importance of designing the emergency management application to facilitate effective communication and coordination among medical personnel, ultimately ensuring the safety and well-being of the runners. These findings have significant implications for the development of future emergency management applications in the context of marathon events.

RQ2: The second finding of our study focused on identifying the most common running-related injuries sustained by runners during marathon events and exploring how our emergency management application can effectively address these injuries. To gather this information, we analyzed the runners' database both before and during the marathon event. The analysis revealed that the most prevalent pre-existing medical conditions among the runners were hypertension, asthma, and hyperlipidemia, as depicted in Fig. 4.

Furthermore, we found that swollen feet and legs were the most common running-related injuries, as shown in Fig. 5. To address these injuries, our emergency management application offers immediate access to personal health records through a mobile application by scanning the QR code on the BIB tagging. This feature enables the medical staff to promptly administer first aid in the event of runners experiencing severe symptoms during the marathon. By tailoring our application to address these common injuries, we aim to enhance the medical assistance provided to runners and ensure their well-being during the marathon event.

RQ3: Our third finding focused on the evaluation of our emergency management system in terms of its usefulness and ease of use. The results, presented in Tables 1 and 2, indicate positive user responses towards the proposed mobile application for managing medical emergencies during a marathon event. Participants found the application to be easy to use and useful, with a strong intention to use it in the future. However, the findings also revealed areas that require improvement, particularly in the app's navigation design and visual appeal. These aspects can be further enhanced to enhance the overall usability of the application.

While our work successfully addressed the tracking of injuries by providing immediate access to personal health records through the mobile application, it is important to note that other relevant works, such as Leou et al. (2022) and Chokchai (2018), proposed the use of the Internet of Things (IoT) to track runner behavior, including monitoring heart rate and implementing other emergency systems. These systems have shown high effectiveness; however, they come with a higher implementation cost for every runner. Additionally, the work of Ousaka et al. (2019) focused on real-time electrocardiographic telemonitoring, utilizing a wireless ECG sensor and smart telephones as transmitters. This system enables real-time remote monitoring through cloud servers via a cellular/Wi-Fi network. While these approaches are specifically designed for patients who require special care, they may not be feasible for implementation in real marathon events.

Finally, the study's findings highlight the importance of having an emergency management application for providing medical support to runners during a marathon event in Thailand. The study identified the key features required in such an application and proposed how the application can be tailored to provide effective medical assistance for the most common running-related injuries sustained during the marathon.

Based on our knowledge and the experimental results from using the emergency management system during the Khao Yai Marathon in Thailand, which had 7,728 participants, we can summarize the knowledge gained for other researchers and development teams into three aspects:

- Development of the System: The system should identify key stakeholders, including emergency responders, medical personnel, runners, and hospitals, to ensure that the system's requirements can effectively support the marathon events.
- Communication: As the registration form requires runners to fill in a lot of personal health information, some runners may feel that the information is useless. Therefore, the team should communicate to the runners the benefits and the reasons why they need to provide this information clearly and concisely.
- Training the application: Training the system is an essential component of an effective emergency management system. All stakeholders should be trained on emergency procedures and response protocols, including volunteers who may be called upon to assist in emergency situations. In our experience, it is best to train at least two times before the event."

6. Conclusion and limitation

In conclusion, our study represents a novel contribution to the development and evaluation of an emergency management application specifically tailored for providing medical support to runners during the Khao Yai Marathon in Thailand. The findings of this study shed light on the essential features and functionalities required for an effective emergency management application in the context of marathon events. Our study highlights the significance of quick and easy access to runners' medical history and emergency contact information, real-time location tracking, and immediate provision of personal health records to facilitate prompt and appropriate medical response. The identification of the most common running-related injuries, such as swollen feet and legs, further underscores the importance of personalized medical support during marathon events.

Moreover, our study identifies areas for improvement, particularly in the navigation design and visual appeal of the application, which can enhance user experience and acceptance. By emphasizing the involvement of key stakeholders, effective communication, and training in emergency procedures and response protocols, this research provides valuable insights for the development of future emergency management applications. It is important to acknowledge the limitations of our study, including its focus solely on the Khao Yai Marathon in Thailand, which may restrict the generalizability of the findings to other marathon events in diverse locations or contexts. Additionally, the study's proposed emergency management application was constrained by the technology available at the time. As technology continues to advance, there is vast potential for the integration of new features and capabilities to further enhance the effectiveness and impact of such applications.

Overall, our research contributes to the field by addressing the specific needs of marathon events and providing guidance for the development of innovative emergency management applications. This study serves as a stepping stone for future research endeavors aimed at optimizing medical support and ensuring the safety of runners in marathon events worldwide.

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Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Aringhieri R, Bruni ME, Khodaparasti S and van Essen JT (2017). Emergency medical services and beyond: Addressing new challenges through a wide literature review. Computers and Operations Research, 78, 349-368. https://doi.org/10.1016/j.cor.2016.09.016

Bélanger V, Ruiz A, and Soriano P (2019). Recent optimization models and trends in location, relocation, and dispatching of emergency medical vehicles. European Journal of Operational Research, 272(1): 1-23. https://doi.org/10.1016/j.ejor.2018.02.055

Chokchai C (2018). Low cost and high performance UHF RFID system using Arduino based on IoT applications for marathon competition. In the 21st International Symposium on Wireless Personal Multimedia Communications, IEEE, Chiang Rai, Thailand: 15-20. https://doi.org/10.1109/WPMC.2018.8713018

Dempster J, Dutheil F, and Ugbolue UC (2021). The prevalence of lower extremity injuries in running and associated risk factors: A systematic review. Physical Activity and Health, 5(1): 133-145. https://doi.org/10.5334/paah.109

Dickson R, Nedelcut A, and Nedelcut MM (2017). Stop stroke: A brief report on door-to-needle times and performance after implementing an acute care coordination medical application and implications to emergency medical services. Prehospital and Disaster Medicine, 32(3): 343-347. https://doi.org/10.1017/S1049023X17000097 PMid:28219452

Hajesmaeel-Gohari S, Khordastan F, Fatehi F, Samzadeh H, and Bahaadinbeigy K (2022). The most used questionnaires for evaluating satisfaction, usability, acceptance, and quality outcomes of mobile health. BMC Medical Informatics and Decision Making, 22: 22. https://doi.org/10.1186/s12911-022-01764-2 PMid:35081953 PMCid:PMC8793175

Kuhrij LS, Marang-Van De Mheen PJ, Van Den Berg-Vos RM, de Leeuw FE, and Nederkoorn PJ (2019). Determinants of extended door-to-needle time in acute ischemic stroke and its influence on in-hospital mortality: Results of a nationwide Dutch clinical audit. BMC Neurology, 19(1): 265. https://doi.org/10.1186/s12883-019-1512-2 PMid:31684901 PMCid:PMC6827229

Lee DC, Brellenthin AG, Thompson PD, Sui X, Lee IM, and Lavie CJ (2017). Running as a key lifestyle medicine for longevity. Progress in Cardiovascular Diseases, 60(1): 45-55.

https://doi.org/10.1016/j.pcad.2017.03.005
PMid:28365296

Leou EC, Ruan RM, and Yu R (2022). Internet of things and its applications to marathon events: from the prospect of sport tourism and urban development. International Journal of Grid and Utility Computing, 13(2-3): 231-239. https://doi.org/10.1504/IJGUC.2022.10049075

Ousaka D, Sakano N, Morita M, Shuku T, Sanou K, Kasahara S, and Oozawa S (2019). A new approach to prevent critical cardiac accidents in athletes by real-time electrocardiographic tele-monitoring system: Initial trial in full marathon. Journal of Cardiology Cases, 20(1): 35-38. https://doi.org/10.1016/j.jccase.2019.03.008
PMid:31320952 PMCid:PMC6612032

Sirasakamol O, Ariya P, Nadee W, and Puritat K (2022). Development of a mobile-healthcare application for safety and prevention in emergency assistance at marathon events: A case study in CMU marathon. International Journal of Online and Biomedical Engineering, 18(6): 65-81. https://doi.org/10.3991/ijoe.v18i06.29515

Utami IQ and Ramdani F (2022). GEMAR: Web-based GIS for emergency management and ambulance routing. Informatics for Health and Social Care, 47(2): 123-131. https://doi.org/10.1080/17538157.2021.1948856
PMid:34379038

Wilde ET (2013). Do emergency medical system response times matter for health outcomes? Health Economics, 22(7): 790-806. https://doi.org/10.1002/hec.2851 **PMid:22700368**

Wu Y, Chen F, Song H, Feng W, Sun J, Liu R, and Liu Y (2021). Use of a smartphone platform to help with emergency management of acute ischemic stroke: Observational study. JMIR MHealth and UHealth, 9(2): e25488. https://doi.org/10.2196/25488
PMid:33560236 PMCid:PMC7902188