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Usability and usefulness of "smart indetect" for diabetic foot ulcer prevention

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ABSTRACT

The utilization of the smart detection application has the potential to mitigate the incidence of decubitus ulcer infection. Smart InDetect incorporates artificial intelligence technology and is based on the internet of things and has the ability to detect the likelihood of infection and provide information regarding the proper management of wounds, as well as the care and treatment of infections. The objective of this study is to assess the usability, usefulness, and perceived satisfaction of potential users of the program. The present study employs a quantitative research methodology, utilizing a sample size of 30 participants. The findings of the research on usability and usefulness testing yielded an efficacy rate of 89% and 88.89% respectively, along with an average satisfaction score of 4.14 on a 5-point scale. Users perceive this program as both useful and efficient in its usability, particularly in relation to its ability to detect the risk of infection.

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1. INTRODUCTION

Diabetes mellitus is a chronic condition causing impaired glucose regulation, with a global prevalence trending upwards, making it the leading cause of mortality [1]. Diabetes affects over 10.8 million people in Indonesia, with 6.2% of patients affected annually. About 79% of those diagnosed live in low- and middle-income countries [2], [3]. The prevalence of diabetes among 15-year-olds has increased significantly, from 6.9% in 2013 to 10.9% in 2018. However, 50.1% of those with diabetes remain undiagnosed. The annual expenditure for treating diabetes is 2 trillion rupiahs [3]. This data is based on a 2017-2019 analysis of the relationship between diabetes costs and overall healthcare expenditure [2].

A diabetic foot ulcer (DFU) refers to a wound that occurs in individuals with diabetes mellitus (DM), and it represents one of the most common complications associated with this condition. The presence of DFUs has significant implications, as it leads to an escalation in both treatment expenses and the duration of hospitalization [4], [5]. According to Armstrong *et al.* [6], available data indicates that a significant global population, ranging from 9.1 to 26.1 million individuals, experiences DFU. The prevalence of diabetic foot ulcers in Indonesia is reported to be 15%, with significant implications including a 30% risk of amputation, a mortality rate of 32%, and an 80% increase in hospitalization [7], [8]. DFU have been identified as a potential cause of lower extremity amputation, leading to a decline in quality of life and even mortality [9]–[12]. Early preventative measures are crucial for monitoring infection risk in DFU in a convenient and patient-friendly manner, ensuring accurate outcomes.

The fourth industrial revolution has seen significant advancements in the use of artificial intelligence and internet of things technology in healthcare. These advancements have enabled real-time prediction and remote monitoring of diabetes mellitus patients' health status. The integration of AI is driving technology advancements to improve the identification and diagnosis of damage in individuals with diabetes mellitus [13]–[15]. The study conducted by Hsu *et al.* [16] titled "chronic wound assessment and infection detection method" presents a novel approach for the segmentation of wound pictures and the evaluation of wound infection following surgical procedures [17]–[19]. The initial section presents a method for picture segmentation that utilizes a self-adaptive threshold-based edge detection technique to exclude unaffected regions from the original image [20]. Both parts provide a comprehensive analysis of techniques employed in the evaluation of wound infection utilizing a machine learning framework, as outlined by Hsu *et al.* [16].

Research has been conducted to ascertain the characteristics of the skin in individuals with diabetes mellitus, based on the underlying physiological processes. In a study conducted by Toledo *et al.* [21]. titled "An Application for Skin Macules Characterization Based on a Three-Stage Image-Processing Algorithm for Patients with Diabetes," the initial stage involves acquiring a color digital photograph of the macular skin on the lower leg. The wireless image acquisition system (WIAS) is employed for this particular objective. The device incorporates a digital wireless camera, namely the Sony DCS-QX100 model with a resolution of 18 megapixels, that captures photographs in the red, green, and blue (RGB) color space. The utilization of Zoom and Grey is intentionally avoided in order to prevent alterations in resolution or the capture of excessively illuminated regions. Skin photographs are used to document alterations in the extent, shape, and color of the macula. The macules examined in this study encompassed vascular macules, petechiae, macules resulting from trophic alterations, and macules resulting from trauma. The research was carried out at the Cardiac Rehabilitation Service of the National Institutes in Mexico, as documented by [21]–[23].

Moreover, the current technology was developed by two Indonesian companies operating in the healthcare industry, specifically CekMata.com and Caredise.com. The technology used is artificial intelligence. This device has the potential to assist patients in early detection of diabetes-related wound problems. With the assistance of deep learning technology, wounds can be classified into three distinct categories: wounds undergoing normal healing, wounds exhibiting signs of infection, and wounds displaying necrotic tissue [24]–[26]. This technological product requires users to access Cekmata.com via a smartphone web browser application. The user authenticates their identity using Google or Facebook accounts and uses their smartphone's camera to capture an image of a wound. However, the diabetes wound check option on CekMata.com website has limitations, including the absence of a dedicated mobile application for easy installation on the user's device. Currently, accessing this functionality is not possible due to the growing trend in technology where artificial intelligence (AI) is being utilized to improve patient injury detection capabilities. This study aimed measured the usability and usefulness of Smart InDetect and its effectiveness as perceived by potential end-users.

2. METHOD

2.1. Study design

The study uses a quantitative research design to assess the usability of the Smart InDetect application. This study was conducted at the Diabetic Wound Care Centre in Bandung City from May to June 2023. The Smart InDetect is an artificial intelligence-based device designed for early detection of infection risk in diabetic wounds. It uses the internet of things to identify inflammation indicators like temperature, color, and depth as shown in Figure 1. The system also provides educational resources on urinary tract infections and infection control, providing valuable information and guidance for individuals with diabetes mellitus to effectively implement preventive measures. The integration of AI and IoT technology ensures efficient infection prevention and control.

2.2. Sample

The study involved 30 diabetic ulcer patients, aged above 18 years old, grade 1 to 3 of DFU, and lived in nursing homes in Bandung City. The study was surveyed using convenience sampling. The success rate of smartphone usage was measured using a sample size of 30 respondents. The participants were required to be fully conscious, have effective communication skills, not have vision or hearing impairments, and demonstrate the ability to articulate their desires and know how to operate a smartphone. The exclusion criteria included individuals with cognitive impairment and those who lacked ownership and proficiency in smartphone usage.

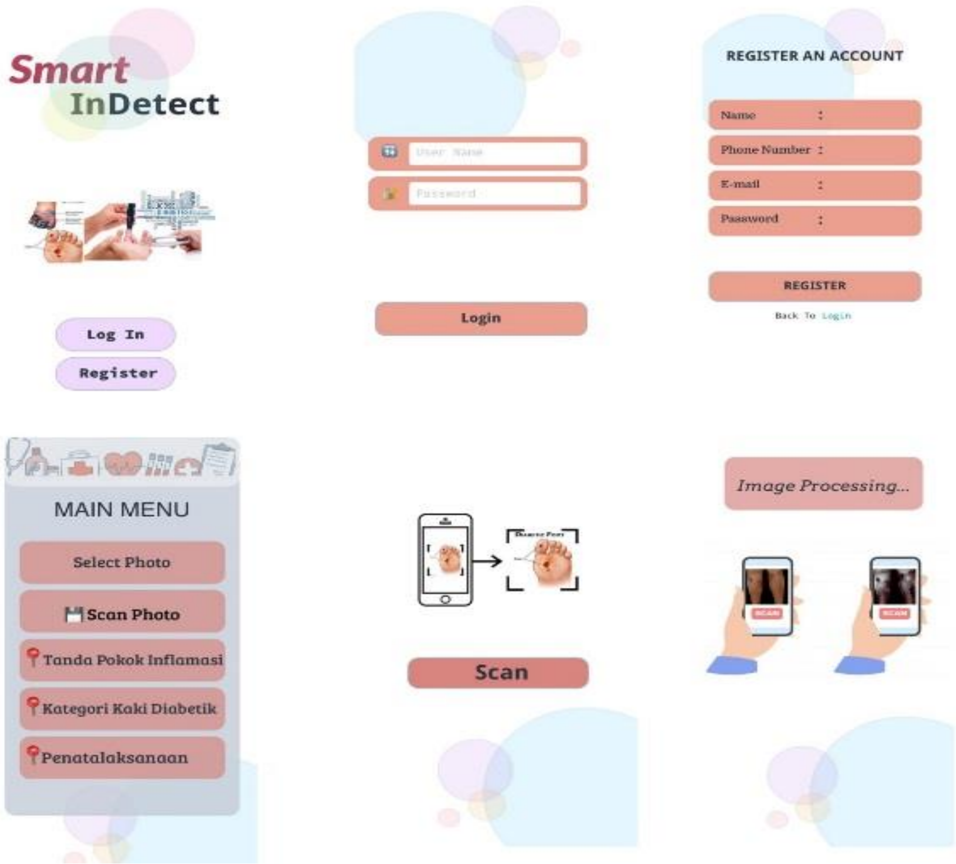

Figure 1. Smart InDetect application

2.3. Measure

The study will use a survey instrument to collect demographic data on participants, including age, gender, education level, occupation, and duration of diabetes mellitus diagnosis. Usability testing measure effectiveness, efficiency, and user satisfaction. Observation sheets was used for effectiveness and efficiency, while a post-task questionnaire was measured satisfaction. Scenarios was used to provide clear guidance for users, with scenarios designed for all application functions F1 through F6. A hypothetical situation involving functions F1 and F2 was presented.

The post-task questionnaire is a set of 27 questions from the evaluation of the Questionnaire for User Interface Satisfaction [27], [28]. This study focuses on the application's relevance, focusing on its appearance, functionality, visual appeal, user interest, language, menu display, image symbols, and user desire to use the application. It examines the ease of recognizing the application's appearance, operation, color display, language, menu reading, and image symbols. Post-task surveys use a comprehensible language to assess user satisfaction using a Likert scale from 1 to 5. The scale, along with a smileyometer picture, helps users express their satisfaction levels with the system. The questionnaire measures satisfaction levels from very dissatisfied to very satisfied, allowing users to express their satisfaction level.

2.4. Data analysis

The assessment of efficacy and efficiency is conducted through the utilization of the user success rate, which quantifies the proportion of tasks accurately accomplished by the user. The calculation of effectiveness and efficiency is determined by the utilization of the subsequent equation. $Effectiveness, Efficiency = \frac{(\sum_i^n{=}_1 Xi)}{N} \times 100\%$. Where Xi represents the success score attributed to the "1-th respondent" Xi={0,1}.

Satisfaction can be calculated by multiplying the maximum weight of the Likert scale by the number of respondents (n) and comparing it to the satisfaction reported by the i-th respondent (Xi). Satisfactio$n \frac{\sum_i^n{=}_1 Xi}{5\ x\ n} \times 100\%$. Xi represents the success score of the i-th respondent {0,1,2,3,4,5}. The concept of application usability can be quantified as the mean value derived from the combination of effectiveness, efficiency, and satisfaction, as represented by the following mathematical equation. $\text{Usability (100\%)} = (\text{effectiveness} + \text{efficiency} + \text{satisfaction}) \times 100\%/3$

3. RESULT

Out of the total sample size of 30 participants, a majority (60%) were identified as female. The average age of the participants was found to be 48.9 years, with a standard deviation of 4.75. The average duration of the disease among the participants was 6.66 years, with a standard deviation of 2.48. Additionally, a majority (66%) of the participants reported not being employed. It is worth noting that all participants reported being able to use a mobile phone as presented in Table 1.

Table 1. The observation sheet and the outcomes obtained from conducting usability testing with a sample size of 30 participants

Observation list	n (%)
Scenario to unlock the system (F01)	
Respondents managed to find Smart InDetect	100
Respondent successfully opened Smart InDetect	96.6
Scenario information function (F02)	
Respondents opened the wound care information menu, handling surgery easily	100
Respondents easily move from one page to another	80
Respondents move to the main menu easily	70
Profile filling function scenario (F03)	
Successfully logged in/registered	100
Successfully filled in the name	100
Successfully used the back button	76.6
Easy to read writing	80
Effectiveness	89

Table 2 presents the observation sheet and the outcomes obtained from conducting usability testing with a sample size of 30 participants. The effectiveness of the measure indicates a result of 88.9%. The value of the aforementioned variable is influenced by the respective scenarios of the opening system function, the information function, and the profile filling function. The scenario with the lowest level of efficacy is the information function in the context of switching to the main menu, which yields a result of 70%. The difficulty in locating the menu transition to the main menu is the reason behind this.

Table 2. Observation sheet and efficiency results of usability testing with 30 respondents

Observation list	n (%)
Scenario to unlock the system (F01)	
The patient works correctly	100
Asking the observer is rare	86.6
Low observational guidance and aid	83.3
Scenario information function (F02)	
Patients comprehend infection treatment, postoperative care, wound care, and ulcer recurrence.	83.3
Asking the observer is rare	80
Low observational guidance and aid	80
Profile filling function scenario (F03)	
Few mistakes were made	100
Asking the observer is rare	90
Low observational guidance and aid	96.6
Efficiency	88.9

A study was conducted to assess the efficiency of a process, with a sample size of 30 participants. The findings revealed an efficiency rate of 88.89% as shown in Table 2. The value of the aforementioned factors, namely the opening system function scenario, the information function scenario, and the profile filling function scenario, has an impact on this number. During the efficiency test, no participants were found to have made errors or sought assistance from the low observer. Additionally, the frequency of guidance and support provided by the low observer was examined.

The satisfaction test yielded 4.14 (SD=1.19) on a scale ranging from 1 to 5 as shown in Table 3. The results of this study indicate that the use of usability testing on applications has the potential to improve their performance and offer a range of benefits. Moreover, each item of satisfactory range from 3 to 4, indication good and very good satisfaction.

Table 3. Satisfaction level of 30 respondents on usability testing

Items	Mean±SD
Can the application's appearance be readily identified?	4.0±1.02
Is the operation of the application user-friendly?	4±0.89
Does the color display elicit visual satisfaction and avoid monotony?	4.03±1.32
Is this application deemed intriguing to utilize?	4.66±1.57
Is the language used in the program easily comprehensible?	4.14±0.75
Is the visual presentation of the menu within the program readily discernible?	4.03±0.91
Is the readability of the application's menu satisfactory?	3.93±1.28
Are the visual representations easily comprehensible?	3.90±0.65
Would you like to utilize this application?	4.55±1.82
Satisfaction	4.14±1.19

The obtained usability value in the conducted usability test is 88.94%. The value in question is subject to an 89% influence from the effectiveness of the respondents, while the efficiency of the respondent's accounts for 88.89% as presented in Table 4. The findings from the conducted usability test indicate the presence of several shortcomings, notably the challenges encountered when attempting to transition to the primary menu. The absence of this particular application serves as a stimulus for enhancing the prototype of the Smart InDetect application.

Table 4. Analysis of usability testing

Testing	n (%)
Effectiveness	89.00
Efficiency	88.89
Usability	88.94

4. DISCUSSION

A study assessing the efficiency of a process with 30 participants found a usability rate of 88.89%. The value of this variable is influenced by the opening system function, information function, and profile filling function scenarios. No participants committed errors, sought assistance from low observers, or required frequent direction or support [29], [30]. The evaluation of the application's efficacy and efficiency involves the assessment of responders' performance. The evaluation of the observer's efficacy and efficiency commences from the respondent's initiation of the download process, encompassing both the proficiency in using the application and comprehending its contents. The data shown that the success value for effectiveness and efficiency exceeds 60%, surpassing both the threshold of 50% and the mean value on a scale ranging from 0% to 100%.

The observed usability value in the conducted usability test is 88.94%. The value in question is subject to an 89% influence from the effectiveness of the respondents, while the efficiency of the respondent's accounts for 88.89%. The findings from the conducted usability test indicate the presence of certain shortcomings, notably the challenges encountered when attempting to transition to the main menu. The absence of this particular application serves as a stimulus for enhancing the prototype of the Smart InDetect application. Usability testing plays a crucial role in the development of applications as it allows for the collection of user input and the enhancement of usability values, hence increasing the likelihood of user acceptance.

The post-task questionnaires collected data on user satisfaction with apps, utilizing a Likert scale ranging from 1 to 5. The average score obtained was 4.14, which above the threshold of 3 or the mean value. This indicates that users generally agreed with or were satisfied with the application. The respondents completed a questionnaire consisting of 9 questions pertaining to the application. The total number of respondents was 30. The satisfaction rating for the "easy to recognize application display" is 4, indicating that respondents expressed satisfaction with the presentation of the application.

The individuals who took part in this research were self-selected volunteers, perhaps possessing a higher level of proficiency in utilizing mobile applications compared to non-volunteering students. Consequently, this may have influenced the outcomes related to performance. This study did not include some of important information such as history of angiography/angioplasty or data about bedsore that might affect the usability and usefulness of Smart InDetect mobile application. Future studies could take into consideration some important factors on usability testing.

5. CONCLUSION

Despite encountering some usability challenges, users expressed overall enthusiasm for Smart InDetect. They found the information provided by the app to be valuable and capable of meeting their objectives. Nevertheless, the effectiveness of the online consultation offered in the application was significantly hindered by usability challenges. The findings from this study's usability assessment can inform recommendations for the future development of Smart InDetect. The study's findings shed light on the potential impact of health app development on the effectiveness of behavior change among users. In the development of health-care apps, it is crucial to employ an iterative user experience (UX) engineering and management (UEM) methodology, involve a heterogeneous team, and engage the target community from the initial stages. Future generations of Smart InDetect have the potential to serve as a robust tool for the prevention of DFU.

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