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Acceleration of Malaria Monitoring Program Led by Nurses Using Electronic Data Systems on the Shore of Lake Sentani

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ABSTRACT
The global adoption of Electronic Data Systems (EDS) presents a significant opportunity to enhance malaria case recovery and monitoring programs. This research aims to determine the causal relationship between EDS-based applications and accelerating malaria monitoring efforts. An experimental design was employed, involving 148 respondents selected through cluster random sampling and divided equally into two groups: the treatment group (74 participants) received EDS interventions. In contrast, the control group (74 participants) followed conventional methods. The dependent variable was malaria, while the independent variables were the malaria monitoring program and EDS. Inclusion criteria included residents with a history of malaria, whereas exclusion criteria comprised residents without prior exposure to malaria. Data were processed using SPSS and analyzed quantitatively and comparatively through the Paired Sample T-Test. Results showed most respondents with malaria exposure were aged 25–40 years (31.8%). The use of EDS improved treatment outcomes by 33.3%. A notable difference in efficiency was observed between the control group (average score: 16.6, categorized as "Fair") and the treatment group (average score: 25.5, categorized as "Very Good"). P-values for malaria screening and monitoring using EDS were 0.039, 0.035, and 0.008, all of which were below the 0.05 threshold. Similarly, the p-value comparing conventional methods with EDS usage was 0.008, indicating a statistically significant difference. The findings suggest that EDS applications significantly enhance the efficiency and effectiveness of malaria monitoring programs by nurses compared to conventional methods. Future studies should explore the nationwide implementation of EDS, stakeholder engagement on the shore of Lake Sentani, and comparative analysis with established healthcare apps.
Keywords: *Electronic Data System (EDS), Lake Sentani, malaria monitoring.*

INTRODUCTION

One of the primary disparities of rural healthcare communities in addressing malaria in the digital era lies in the empowering nurses and the availability of information technology (IT) infrastructure. In this technological era, the role of nurses in dealing with various tropical diseases such as malaria is very important [1], [2]. Malaria eradication efforts involving nurses in this era are increasingly reliant on IT tools [3]. The government of Indonesia for example, has long advocated for the integration of IT across all sectors of health development, including malaria control programs [4]. Despite various mitigation programs using IT, malaria remains one of Indonesia's top national health priorities, and its eradication requires integrated, targeted, and sustainable efforts [5]. Many studies have shown the central role of nurses in addressing various public health problems, including malaria [6]–[8].

Nurses are leading health professionals who are involved in many prevention programs in Indonesia [2], [9]. Many experts recommend nurses are collaboratively encouraged to empower their competencies in malaria eradication programs by using technology [10], [11]. Some of them suggest an integrated approach with the involvement of various agencies and institutions [12]. A targeted approach means that each malaria eradication initiative must have clear, measurable objectives, and sustainable such as the goal of a malaria-free Indonesia by 2030 [13]. Sustainability refers to the continuity of efforts across years, ensuring that actions from one year build upon those of previous years [14]. In this digital age, achieving integration, focus, and sustainability almost certainly depends on the adoption of Electronic Data Systems (EDS) [15]. Numerous studies highlight the advantages of EDS in health programs [16], [17]. Kruse and

Bean suggest health programs without adequate EDS support tend to experience delays, data inaccuracies, and poor distribution of information [18].

Data from the Ministry of Health reveals that Indonesia recorded 415,140 malaria cases in 2022, a 36.29% increase compared to the previous year's 304,607 cases [19]. Despite a consistent decline in cases until 2015, the prevalence of malaria has shown a slight increase since 2020, rising from 0.6 in 2018 to 1.4 in 2020 [20]. The Annual Parasite Incidence (API) noted a measure of malaria cases per 1,000 population, was 1.51 in 2021, up from 1.12 in 2020 [21]. In Indonesia, 372 districts/cities in Indonesia have successfully eliminated malaria, surpassing the target of 365 districts set for 2022[22]. Those achievements would not have been possible without the support of EDS at both central and regional levels [15]. At the same time, nurses are the majority of healthcare workers who are most directly connected to malaria cases in remote areas [23]. The main challenge of their work is the lack of technological infrastructure that can hinder the achievement of malaria eradication programs [11].

While IT infrastructure has been distributed across both urban and remote areas, factors such as geography, socio-economic status, culture, education, and the environment contribute to disparities in malaria control [20]. This is particularly evident in Papua, which, despite the digital era, continues to have the highest malaria burden in Indonesia [24]. The region's high malaria incidence has made it a focal point for malaria research [25], [26]. Zali et al. designed and evaluated a mobile-based application to support malaria surveillance in Indonesia [27]. Many other studies on mobile application for health monitoring purposes [28], [29]. The latest research related to malaria involving nurses in Papua is on control strategies among health students [19]. The difference is, the previous research did not include the use of application technology.

This research employs an experimental design, utilizing an EDS-based application on Android devices to track malaria case development led by nurses along the shore of Lake Sentani, Papua. The study aims to assess whether EDS can accelerate malaria case coverage and improve monitoring efforts. The hypothesis is that faster and more efficient monitoring, facilitated by EDS, will expedite malaria control and, in turn, contribute to the achievement of malaria elimination by 2030. This research underscores the importance of EDS in malaria prevention programs and demonstrates its feasibility as a tool for enhancing the effectiveness of eradication efforts.

MATERIALS AND METHODS

a) Study populations and design

This quantitative research employed an experimental design. The research began by opening of Tukayo Malaria application in Play Store (https://play.google.com/store/apps/details?id=com.tukayomalariaapp&pli=1), which is tailored for Indonesian users. More than 50% of the data guide content is written bilingually in English and Indonesian. The research sample consisted of residents living around Lake Sentani, Papua. The sample included 148 adults—native Sentani residents and individuals who had been exposed to malaria—recruited through direct home visits. Lake Sentani was selected due to its status as one of the regions in Papua with the highest malaria prevalence rate . The sampling technique combined cluster random sampling—considering the location and geographical conditions of Lake Sentani—and purposive sampling, given the area's high malaria risk.

b) System design

The design process focused on the software architecture, data structure, interface representations, and procedural details. The application was developed by the researchers collaborated with an IT agency, following a process sequence based on the Waterfall Model. The model illustrates the process of creating an Android-based application [30]. The Waterfall methodology is a well-established, sequential software development framework [31], [32]. Its linear structure, likened to a waterfall, comprises six discrete phases: Requirements, Design, Implementation, Testing, Integration, and Maintenance (Bani and Sutjiatmo, 2024). The model emphasizes a systematic progression, where each phase is completed before proceeding to the next, thereby reducing overlap and iterations [32]. The waterfall model endures as a widely recognized and applied methodology in software development and project management, including in healthcare [32]. A similar model and process have been utilized in a previous study involving web- and Android-based applications [33]. The domain displays include key features such as home, user management, malaria signs and symptoms, supporting data, patient data, and reports. The application provides two types of users—administrators and healthcare professionals as shown in Table 1.

Table 1: Functional Requirements

User	Requirements
Administrator (web)	Managing data of users Managing malaria patient's data
Healthcare officers include: doctors, nurses, lab technicians, and sanitarians	Demography Data record History of malaria Other illnesses Treatment history Admission history Laboratory Examination

The table outlines user requirements for a malaria patient data management system, categorizing users into Administrator (web) and Healthcare Officers. Administrators manage user data and malaria patient information. Healthcare Officers, including doctors, nurses, lab technicians, and sanitarians, require access to demography data records, malaria history, other illnesses, treatment history, admission history, and laboratory examination data. This system aims to improve data accuracy, enhance patient care, and facilitate efficient malaria surveillance, aligning with World Health Organization (WHO) and Centers for Disease Control and Prevention (CDC) guidelines on malaria data management and surveillance [1], [34]. The Tukayo application was built using React Native and the JavaScript programming language. React Native enables the simultaneous creation of Android and iOS applications using a single programming language, eliminating the need to build each platform from scratch (Iribarren et al., 2021).

c) Instruments

A questionnaire was used and based on the web domain www.tukayoisakmalaria.com and divided into three sections. All items were derived from validated sources: Session A: Four questions on demographic data, sourced from the "Malaria Indicator Survey 2016 Final Report National Malaria Control Programme" [35]. Session B: Five questions about malaria exposure, adapted from the article "Malaria prevention knowledge, attitudes, and practices (KAP) among adolescents living in an area of persistent transmission in Senegal" [36]. Session C: Six questions about the malaria electronic data system, based on the "Malaria surveillance assessment toolkit" [37]. Content and construct validity were ensured by consulting two experts in electronic data systems (EDS) from an information technology agency based in Surabaya, Indonesia. A pilot test was conducted with non-sample respondents to further verify the instrument's validity. All structured questions were designed in Google Forms and divided into two groups: a treatment group and a control group, using multiple-choice questions. The treatment group utilized EDS, while the control group did not. Additional data collection was performed through non-test methods, including observation and documentation.

d) Data collection

Data collection was conducted from June to July 2024. Respondents were informed about their rights during the research process, including the right to withdraw and the assurance of personal data protection (confidentiality). Each respondent signed an informed consent form before participating. Respondents were selected based on the inclusion criteria: residents of the Lake Sentani area, adults, and had a history of malaria exposure. The dependent variable in this study was malaria, while the independent variables were the use of EDS (Electronic Data System) and program monitoring. Data collection was divided into two groups: Control group: Data collection was done manually. Treatment group: Data collection was conducted using EDS.

d) Data analysis

The data analysis aimed to address three key research questions: Can EDS effectively accelerate malaria case detection? Can EDS effectively accelerate the monitoring of malaria patient data? Is there a significant difference between conventional methods and EDS? Data testing was conducted once using a post-respond test, which involved conventional models and observations after the experiment. Univariate and bivariate analysis were used in data analysis in this study. Bivariate analysis was conducted using SPSS by applying the Paired Sample T-Test to compare the effectiveness of the EDS (Early Detection System) intervention in the treatment group (74 participants) with the conventional method in the control group (74 participants). Data collected from both groups were analyzed quantitatively to see significant differences in reducing malaria cases. The Paired Sample T-Test was used because the study design involved two paired groups, so this test was appropriate for measuring the average difference between the two groups. If the test results show a p-value <0.05, it can be concluded that the EDS intervention is statistically more effective than conventional methods in controlling malaria. Demographic data were

analyzed univariately (Table 2). Evaluation of malaria case screening acceleration (Table 3), and Evaluation of monitoring coverage acceleration (Table 4) were analyzed using SPSS. Results of Treatment and Control Groups were tested using T-test (Table 5).

e) Ethical considerations

This research received ethical approval from the Health Research Ethics Committee of the Jayapura Health Polytechnic under protocol number 130/KEPK-J/V/2024. The proposal detailed the research topic, background, objectives, methods, target participants, and ethical considerations, including the right to withdraw, informed consent, anonymity, and confidentiality.

RESULTS

a) Demographic data

Table 2: Demography Characteristics (n=148)

Age	Occupation			Education		
	Private	Government	Unemployed	Primary School	Secondary School	Graduates
<25	6 (4.1%)	6 (4.1%)	8 (5.4%)	2 (1.3%)	30 (20.3%)	5 (0%)
25-40	18 (12.2%)	12 (8.2%)	17 (11.5%)	8 (5.4%)	107 (72.3%)	11 (4,8%)
> 40	17 (11.4%)	45 (30.3%)	19 (12.8%)	3 (2.0%)	11 (7.4%)	3 (2,0%)
Σ	41 (17.7%)	63 (42.6%)	44 (29.7%)	15 (10.1%)	114 (77.0%)	19 (6,8%)

Source: Primary Data 2024

Table 2 shows the distribution of occupations and education levels across age groups. Government occupation dominates (42.6%), with private occupation second (17.7%), and unemployed individuals significant in younger age groups. Secondary school graduates are the largest group (77%), with primary school education relatively rare (10.1%) and graduate education least common (6.8%). Age group analysis reveals high unemployment among those under 25 (5.4%), balanced occupation distribution among those 25-40, and high government employment among those over 40 (30.3%).

b) Evaluation of malaria case screening acceleration

Table 3: Characteristics of the Acceleration of Malaria Case Screening (n=148)

Characteristics	Respond Frequency of control group	Respond Frequency of treatment group
Efficiency of		
Time	6.2	8.2
Money	6.1	9.1
Human resource	6.7	8.5
Data Coverage	7.5	8.3
Area coverage	6.5	7.3
Averages of Respondent' scores	6.6	8.28

Source: Primary Data 2024

Table 3 compares the response frequencies of a control group and a treatment group across various characteristics. The treatment group scores higher in all categories: Efficiency of Time (9.1 vs 6.2), Money (8.5 vs 6.1), Human Resource (8.2 vs 6.7), Data Coverage (8.3 vs 7.5), and Area Coverage (7.3 vs 6.5). The average respondent score is significantly higher for the treatment group (82.8) compared to the control group (6.6), indicating a substantial positive impact of the treatment on overall efficiency and effectiveness. This suggests the treatment group has better resource allocation, data coverage, and area coverage, and is more efficient in utilizing time and human resources.

c) Evaluation of monitoring coverage acceleration

Tabel 4: Characteristic of Acceleration of Monitoring Coverage (n=148)

Characteristics	Control Group	Treatment Group

	Value	Criteria	Value	Criteria
Efficiency of				
Time	13,9	Poor	26,2	Very good
Money	16,5	Fair	22,7	Good
Human resource	18,6	Fair	28,4	Very good
Data Coverage	19,2	Fair	25,9	Very good
Area coverage	14,8	Poor	23,5	Good

Source: Primary Data 2024

Table 4 show the comparisons between the control and treatment groups' performance across various characteristics, evaluated against specific criteria. The treatment group outperforms the control group in all categories: Efficiency of Time (26.2 vs 13.9), Money (22.7 vs 16.5), Human Resource (28.4 vs 18.6), Data Coverage (25.9 vs 19.2), and Area Coverage (23.5 vs 14.8). Consequently, the treatment group receives higher criteria ratings: "Very good" for Time, Human Resource, and Data Coverage, and "Good" for Money and Area Coverage, whereas the control group is rated "Poor" or "Fair" across all characteristics. In the control group, the majority of respondents fell into the Fair category, while in the treatment group, most were categorized as Very Good. The average difference between the control and treatment groups in terms of efficiency scores was 16.6 (Fair) and 25.5 (Very Good), respectively. This indicates a significant difference in efficiency levels between the two groups, and requires significant improvements in resource allocation and efficiency in the treatment group.

Table 5: T-test Results of Treatment and Control Groups (n=148)

Variables	Mean	T-Count	Alpha (α)	p-value
Screening of malaria cases with EDS	-9,132	-2,419	0,05	0,039
Monitoring of malaria malaria patients with EDS	-9,423	-1,857	0,05	0,035
Conventional methods comparison with EDS	-7,999	-2,315	0,05	0,008

Table 5 reveals statistical analysis results for three variables related to malaria case management using Electronic Data Systems (EDS) by nurses. The mean values are negative, indicating significant reductions in malaria cases/patients. T-count and p-value results show statistically significant differences ($p<0.05$) for all variables. Specifically, screening malaria cases with EDS reduced cases by 9.132 ($p=0.039$), monitoring malaria patients with EDS reduced patients by 9.423 ($p=0.035$), and comparing conventional methods with EDS showed a 7.999 reduction ($p=0.008$). These results suggest EDS implementation by nurses significantly improves malaria case management efficiency and effectiveness, highlighting its potential for healthcare systems.

DISCUSSION

This research identifies two fundamental issues. In this study the health issues are malaria-related, including malaria cases, patients, monitoring, and screening, alongside broader healthcare concerns: healthcare data management, Electronic Data System (EDS), laboratory examination, treatment history, and admission history, highlighting a focus on malaria management and efficient healthcare systems. Demographically, the results of this study show that malaria cases mostly occur in those over 40 years of age. Although malaria affects individuals of all ages, children under five are particularly vulnerable found in Papua (Yogi and Kabak, 2023). Older adults and pregnant women are also at higher risk of severe outcomes, especially in unhygienic environments (Istiana, Prenggono, et al., 2021). Many findings have identified multidrug resistance, severe and fatal malaria, and high malaria burden as significant concerns in Indonesia, particularly in Papua. Papua has the highest malaria prevalence, with an annual incidence rate of 885 per 1,000 person-years, making it a critical priority area for research and intervention [38]. To address this, comprehensive malaria surveillance networks monitor cases and track intervention effectiveness are needed. Previous researchers also recommended the evaluation of treatment regimens

and control measures, including insecticide-treated nets and indoor residual spraying [39]–[41]. Yet, focus on innovative strategies for disease prevention, elimination, and maintenance, aiming for malaria elimination in Indonesia is required. Studies recommend that nurses in the community need to be involved considering their leading role in malaria control programs [9], [42], [43]. In Indonesia, the role of community nurses is very important in healthcare services related to the malaria eradication program [44], [45]. It also requires multisectoral involvement, particularly in regions with challenging environmental health conditions [46], [47]. Collaboration among local governments, health workers, community leaders, religious figures, and health students is essential for implementing effective community service programs [48], [49]. However, leveraging information technology is crucial for accelerating communication and information dissemination, especially in geographically challenging regions like Papua [3], [50]. The results of this study confirm the importance of using technology in remote areas by empowering the competence of nurses in the community.

Secondly, the use of EDS in this study has proven to accelerate malaria case screening programs, achieving a 33.3% higher score compared to manual methods. Furthermore, EDS led by nurses has also been more effective in expediting the monitoring of malaria cases, compared to traditional approaches. Numerous studies have highlighted the effectiveness and efficiency of information technology tools in various health programs [3], [51]. Over time, technological advancements in the medical field, particularly mHealth, have played a pivotal role in enhancing governmental efforts to reduce malaria cases [52]. The use of mobile phones via Short Messaging Service (SMS) for reporting malaria cases or capturing images for Rapid Diagnostic Test (RDT) analysis has been widely documented in the literature [53]. Mobile application is recognized as a cutting-edge tool for health promotion, leveraging smartphone applications to align with the demands of the digital era [54]. Android application systems can be utilized on a variety of devices such as cellphones, tablets, smartwatches, and even Android TVs [55]. The Android operating system facilitates seamless adaptability for users switching to new devices, as well as easier data transfer between Android-based devices [27]. This research findings show EDS significantly improved malaria screening and monitoring compared to conventional methods. The small p-values (all <0.05) indicate that these results did not occur by chance, but rather due to the effectiveness of EDS, and the success rate of EDS can be said to be high, because significant and consistent differences were seen in all variables tested. The creation of an Android-based application in this research initiated and led by nurses is concrete evidence of the contribution of nurses in monitoring and acceleration eradicating malaria in Indonesia. However, challenges remain with Android applications, such as: applications must be downloaded from the Google Play Store, which does not include all available apps [56]. Some apps lack user-friendly designs, are prone to crashes, or are not regularly updated by developers. Performance issues, such as slow operations, can occur due to high storage requirements, which not all devices can accommodate. The ease of development and publishing on the Google Play Store results in a proliferation of similar applications, complicating user choices. To address those challenges, the Tukayo application was developed using React Native and Javascript programming. The application is available on the Play Store at the following link: https://play.google.com/store/apps/details?id=com.tukayomalariaapp. React Native enables the development of cross-platform applications, ensuring compatibility with both Android and iOS systems. A similar cross-platform solution was employed in a healthcare application study titled "Cross-platform mobile app development for disseminating public health information to travelers in Thailand: Development and usability", which also addressed malaria-related issues (Meankaew et al., 2022).

CONCLUSION

In summation, this study has demonstrated that the EDS application led by nurses significantly improves the efficiency and effectiveness of malaria monitoring programs compared to conventional paper-based methods. Limitations of the study include: a small geographic and population coverage area, limiting its generalizability, and the absence of direct field testing due to the requirement for local government approval. Future research recommendations include expanding the EDS application nationwide, promoting adoption among policymakers and healthcare authorities in Lake Sentani, and conducting comparative analyses with existing healthcare applications.

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AVAILABILITY OF DATA AND MATERIALS

This research data and materials can be accessed through a properly submitted request.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest regarding the publication of this research. This study was conducted independently, without any personal influence from external parties.

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