Mal J Nutr 31(3): 505-516, 2025

Development of nutritional status monitoring application PEMSAGI in detecting nutritional problems among toddlers in Bali, Indonesia

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ABSTRACT

Introduction: Mobile technology offers an innovative solution to nutritional challenges by providing real-time, accessible dietary information. However, the effectiveness of nutritional status monitoring applications remains under-explored in Indonesia. This study aimed to develop and evaluate the nutritional status monitoring application PEMSAGI, designed for mothers of toddlers in Bali to improve child nutrition through digital support. **Methods:** Using a Design Science Research approach, the application was developed and tested in two stages. The initial phase focused on prototype design informed by stakeholder interviews, followed by a demonstration phase involving 123 respondents. Usability was evaluated using the Post-Study System Usability Questionnaire (PSSUQ), assessing system usefulness, information quality, and interface quality. Quantitative data were analysed with RStudio, while qualitative feedback underwent thematic analysis to enhance system functionality. **Results:** Most participants (90.2%) were housewives, averaging 30 years of age. The PSSUQ results showed high satisfaction, with mean scores above 5.9 across all dimensions. The application featured tools for recording maternal and child health data, receiving expert nutrition recommendations, accessing nearby healthcare services, obtaining educational materials, and tracking toddlers' nutritional progress. Scores of 5.9 for system usefulness, 5.9 for information quality, and 6.0 for interface quality reflected strong user acceptance and usability. **Conclusions:** The nutritional status monitoring application PEMSAGI demonstrated excellent usability and acceptance among mothers of toddlers in Bali, emphasising the potential of mobile health tools to improve child nutrition and support public health efforts in underserved communities.

Keywords: Bali Indonesia, child nutrition, growth monitoring, maternal health, mHealth, public health intervention

INTRODUCTION

Despite making enormous strides in various health indicators, Indonesia continues to face numerous nutrition-related health challenges as a result of the nuanced interplay between socio-

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doi: https://doi.org/10.31246/mjn-2025-0011

economic, cultural, and environmental factors. The high prevalence of malnutrition, such as stunting (21.6%), wasting (7.7%), and underweight (17.1%) in Indonesia (Kemenkes RI, 2023), particularly among vulnerable populations, causes immediate and long-term health concerns that affect cognitive development, educational attainment, and general well-being of the communities (Rah *et al.*, 2021; De Pee *et al.*, 2021; Oddo, Roshita & Rah JH, 2018). Therefore, it becomes essential to address these challenges if the country aims to achieve its larger health and development objectives.

Given their rapid growth and development during the critical early childhood period, toddlers stand out as a particularly vulnerable group within the spectrum of populations impacted by nutrition-related health concerns (Fadilah & Romadona, 2022). This stage is characterised by high nutritional requirements; any deficiencies incurred may bring about profound and lasting effects on both physical and cognitive development (Suryawan *et al.*, 2022; Mitra *et al.*, 2020). Thus, urgent and targeted interventions must be made against the heightened risks faced by toddlers, especially in Bali and other underdeveloped regions in Indonesia, to ensure their optimal health and well-being.

To deal with nutrition-related health issues at the national level, Indonesia has instituted a variety of measures and programmes, including supplementation initiatives, nutritional education campaigns, and community-based interventions (Soviyati *et al.*, 2023; Onyango, Nikiema & Kimokoti, 2021; Suharto, Wildan & Handayani, 2020). Nonetheless, translating these efforts into tangible improvements remains challenging, particularly in remote areas.

The rapid evolution of technology has drastically transformed various aspects of daily life, including healthcare. Telemedicine has now appeared as a powerful and reliable instrument in overcoming geographical barriers and improving access to healthcare, particularly in remote and underserved areas (Wijaya, Octavius & Hwei, 2022). It offers various advantages to enhance healthcare services through virtual consultations, remote monitoring, and mobile health applications. In underserved areas in Indonesia, including Bali, telemedicine has made healthcare services more accessible for mothers and their toddlers.

Traditionally, mothers have relied on health professionals as the primary source of information concerning the nutrition of their toddlers (Rahmawati *et al.*, 2021). However, this reliance is constrained by geographical boundaries, a lack of healthcare resources, and unequal access to accurate and timely information. With technology, mobile applications, online platforms, and wearable devices have made it easier to obtain health-related information, thus fostering a more proactive and knowledgeable approach to healthcare (Handayani, Indriani & Pinem, 2021). This highlights the potential of technology as a promising avenue to bridge informational gaps and provide evidence-based knowledge and real-time nutritional guidance and support.

Notwithstanding the escalating prominence of technology in the health sector, there is a noticeable scarcity of published studies examining the effectiveness of nutritional status monitoring applications in the Indonesian context, especially regarding toddlers. This underscores the existing research gap, emphasising the need for empirical evidence to support technology integration into public health interventions. With that, this study aimed to develop a nutritional status

monitoring application and assess the effectiveness of its usage by mothers of toddlers in Bali.

METHODOLOGY

This study employed the Design Science Research (DSR) approach, a research methodology commonly used in information systems and health informatics to create and evaluate innovative technological solutions to real-world problems. DSR emphasises iterative development, where artefacts (in this case, the nutritional status monitoring application) are systematically designed, built, tested, and refined with stakeholders' input. The process involved problem identification, objective definition, prototype design and development, demonstration, evaluation and communication, and conclusion (Hevner, vom Brocke & Maedche, 2019). Offline in-depth interviews and focus group discussions were held with relevant stakeholders during the initial stages of problem identification and objective definition. The focus group discussion (FGD) involved ten participants, including four health cadres (two nutritionists and two midwives), two village heads, and four mothers of toddlers from two different villages. These participants were selected purposively to represent key community perspectives. The data gathered throughout these phases guided the prototype design and development. Subsequently, the prototype went through the demonstration stage of testing with stakeholders and the target population. Finally, a comprehensive evaluation was carried out using qualitative and quantitative methods, followed by refinements and the eventual creation of the final model.

The prototype development and evaluation process in this study consisted of two iterations. In the first iteration, an activity diagram was utilised to enable users to assess the information flow within the system. In-depth face-to-face interviews were conducted with eight participants, comprising health cadres (two nutritionists and two midwives), two village heads, and two mothers from two villages. These interviewees were selected using a purposive sampling technique and they actively participated in the entire prototype development process. The interviews discussed the existing nutritional status monitoring procedure in Bali, the health system model for nutritional status monitoring applications, and the needs assessment for prototype development. Findings from both the in-depth interviews and FGDs were synthesised to identify existing challenges in nutritional status monitoring and to shape the initial prototype requirements.

A prototype compatible with the Android and iOS operating systems was developed in the second iteration. The Post-Study System Usability Questionnaire (PSSUQ) was prepared to assess the effectiveness of this prototype by focusing on three dimensions: system usefulness, information quality, and interface quality (Rotaru *et al.*, 2020). The PSSUQ comprised 19 items, each rated on a 7-point Likert scale. The prototype was considered satisfactory if the average score across all dimensions exceeded 4 points (median).

An online survey was conducted for the evaluation, involving 123 mothers of toddlers living in Bali, who were the primary caregivers of their children. The inclusion criteria were (1) being a mother of at least one toddler (aged 12–59 months), (2) residing in Bali during the study period, (3) owning or having access to a smartphone with internet connectivity, and (4) willingness to provide informed consent. Participants were selected through purposive sampling.

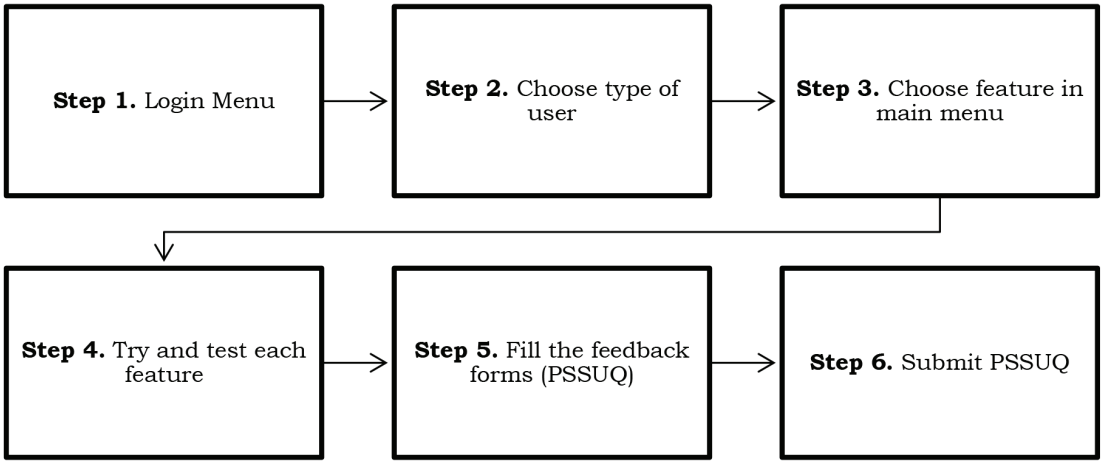


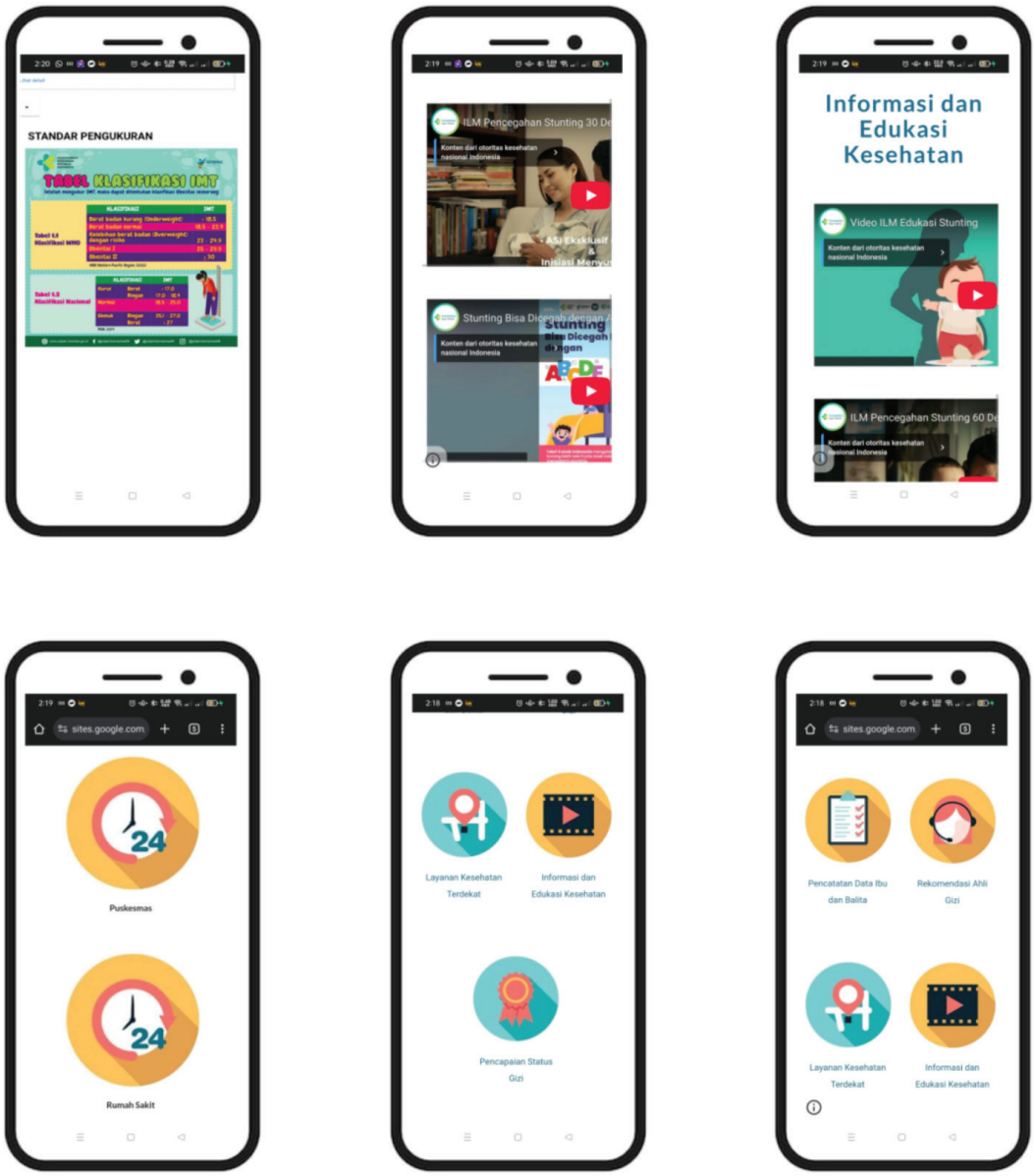
Figure 1. Workflow of the PEMSAGI prototype

A thematic analysis was performed to examine the qualitative data obtained in this study, while RStudio (© 2025 Posit Software, PBC, formerly RStudio, PBC) was utilised to analyse the quantitative data on respondents' demographic characteristics and PSSUQ evaluation. The Research Ethics Commission of the Medical Faculty of Udayana University approved the research protocols with approval number 1372/UN 14.2.2.VII/LT/2023. All subjects provided informed consentbefore the study was conducted.

RESULTS

Design and development

A prototype for PEMSAGI was developed, structured into six workflow steps (Figure 1). Users began by logging in with a username and password. They then selected their role – public users (mothers of toddlers) or health cadres (nutritionists and midwives); this determined their access to specific features. Given the diverse roles in nutrition programme, available features varied accordingly. The PEMSAGI prototype includes eight key features: (1) maternal and child health data recording, where respondents input anthropometric data such as body weight, body length/height, and age of toddlers; these inputs are processed using the World Health Organization (WHO) *z*-score formulation to provide feedback on whether the child is underweight, stunted, wasted, or within normal nutritional status; (2) nutrition expert recommendations, which provide tailored advice based on the child's recorded nutritional status (e.g., specific dietary adjustments for undernourished toddlers versus general balanced diet guidelines for toddlers of normal status); (3) nearby healthcare services, which display contact details and maps of the nearest *posyandu*, *puskesmas*, and hospitals for further consultation or referral; (4) health information and education, which present educational modules and visual infographics on breastfeeding, complementary feeding, hygiene, and common nutrition problems among toddlers; and (5) nutritional status tracking, which allows caregivers to monitor progress over time through growth charts and historical records of anthropometric measurements. The prototype, accessible at the PEMSAGI website (https://bit.ly/pemsagi), was developed using Google Sites and

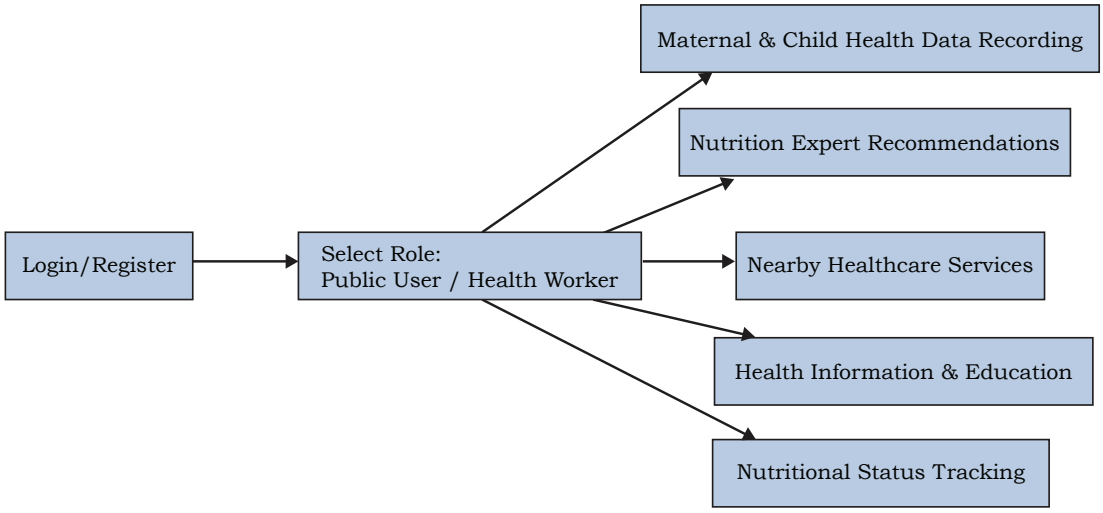


A. User Interface

integrated with Google Forms for database management. Both platforms are opensource, so users can access the system from any smartphone without installing an application. An example of the PEMSAGI user interface is shown in Figure 2.

Demonstration and evaluation

This study involved 123 mothers of toddlers as respondents. Most respondents were young mothers between the ages of 21 and 30 years old (45.5%), with a mean age of 29.5 years (Table 1). Most of the respondents were



B. User-case workflow

Figure 2. PEMSAGI mobile application (A) example of user interface of the mobile application and (B) user-case workflow of the mobile application

senior high school graduates (46.3%) and housewives (90.2%).

Table 1. Demographic characteristics of respondents (*N*=123)

Characteristics		*n*	*%*
Age, years (mean±*SD*)	30±8		
< 20 years old		13	10.6
21-30 years old		56	45.5
31-40 years old		41	33.3
>40 years old		13	10.6
Education attainment			
No school		1	0.8
Elementary school		6	4.9
Junior high school		11	8.9
Senior high school		57	46.3
Diploma		5	4.1
Undergraduate		40	32.6
Postgraduate		3	2.4
Occupation			
Physician		1	0.8
Contract		1	0.8
Housewives		111	90.3
University student		3	2.4
Government employee		3	2.4
Private employee		4	3.3

In addition to the survey results, qualitative interviews and FGDs provided a deeper understanding of user acceptance. Health workers and district programme managers explained that they currently rely on the Ministry of Health's e-PPGBM application for monitoring child nutrition. One officer noted: *"The nutrition monitoring application we currently use is the e-PPGBM from the Ministry of Health*". However, participants also mentioned the upcoming ASIK application, which is expected to replace e-PPGBM, expressing concerns that learning yet another complex system would increase their workload. As one nutrition officer admitted: *"If we are asked to learn new things again, I feel tired and exhausted. Our workload at the community health centre is already heavy".*

Participants consistently highlighted the importance of simplicity. They expressed a preference for applications that reduce rather than add to their reporting burden. As one respondent explained: *"Simple here means not*

complicated when entering each child's data or choosing options such as the position for height measurement, which can affect the nutritional status result if entered incorrectly". This reflects a broader desire for digital tools that are efficient and practical, especially given the time constraints faced by frontline staff.

Feedback also emphasised the need for supportive features. Officers and cadres suggested that future versions of PEMSAGI should include growth charts and key nutrition messages to assist with counselling. As one district health staff member stated: *"In developing a new application, there should be features that make it easier for cadres to explain the results, such as showing a growth chart and key nutrition messages".*

Despite these concerns, respondents in the FGD found PEMSAGI attractive and easy to use. Mothers and village representatives described the application as visually appealing and practical: *"The application is interesting, with clear pictures and text, and the colours are eye-catching".* Mothers also expressed personal satisfaction: *"I personally am very happy with this application. Previously, I was confused about knowing my child's nutritional condition, but now it is clear".*

Nonetheless, cadres and midwives raised challenges around data entry, particularly regarding information on micronutrients and clinical signs, which are not routinely collected at *posyandu*. One midwife explained: *"At the posyandu, we don't have micronutrient or clinical signs data, which would support anthropometric data but are difficult to collect due to cadres' skills and costs".* In contrast, most participants agreed that inputting only anthropometric data would be sufficient and more feasible for real-world use.

Another recurring expectation was for the application to provide real-time outputs. Several participants emphasised that having immediate results would improve both service delivery and communication with families. As one cadre noted: *"If the application can present results directly at the posyandu, it will help us explain the child's nutritional status immediately".* Village officers also highlighted the value of real-time reporting for local decision-making: *"If the application provides real-time information, the village head will immediately know the condition of children in his area".*

Finally, respondents suggested small but important administrative improvements, such as including the child's National Identification Number (NIK) to prevent confusion between children with similar names and identifying who entered the data (mother, cadre, or midwife). These additions were considered essential for ensuring data accuracy and accountability.

Overall, the qualitative findings suggested that PEMSAGI was perceived as attractive, simple, and useful, while also highlighting barriers such as non-routine data requirements, potential workload increment, and the critical importance of real-time outputs. These findings aligned with the quantitative results, indicating strong acceptance (72.4% willingness to continue using) but also pointed to refinements needed for successful integration into routine health services.

The distribution of respondents' responses to each PSSUQ item is presented in Table 2. For clarity, all 19 questions from the PSSUQ are listed as Q1–Q19 in the table, covering aspects of system usefulness, information quality, and interface quality. The heat map table demonstrated that the respondents tended to give scores between 5 and 7 for all items, with the majority of the darkest green shade falling into the 6-score category. The average score was also

Table 2. Respondents' responses on the Post-Study System Usability Questionnaire (PSSUQ) items (*N*=123)

Question	*Respondents' responses on PSSUQ (%)*							*Average score*
	Score 1	*Score 2*	*Score 3*	*Score 4*	*Score 5*	*Score 6*	*Score 7*	
Q1. Overall, I am satisfied with how easy it is to use this application	0.8	1.6	1.6	8.1	8.9	47.2	31.7	5.9
Q2. The application has all the functions and capabilities I expect it to have.	0.8	0.8	0.0	4.1	17.1	51.2	26.0	5.9
Q3. The application helps me complete the nutritional monitoring tasks effectively.	1.6	0.0	0.0	6.5	15.5	53.7	22.8	5.8
Q4. The application meets my nutritional information needs as a mother of a toddler.	0.8	0.0	0.8	4.1	15.5	53.7	25.2	6.0
Q5. The application saves me time when monitoring my child's nutritional status.	0.8	2.4	0.0	4.9	14.6	52.9	24.4	5.9
Q6. The application improves the quality of my decisions about my child's nutrition.	0.8	0.8	0.0	4.1	14.6	51.2	28.5	6.0
Q7. The information provided by the application is clear.	0.8	0.0	0.8	4.1	13.0	48.8	32.5	6.0
Q8. It is easy to understand the nutritional information given by the application.	0.8	1.6	0.0	4.0	12.2	48.8	32.5	6.0
Q9. The application provides all the information I need to monitor my child's nutrition.	0.8	1.6	0.0	6.5	10.6	54.5	26.0	5.9
Q10. The nutritional information in the application is accurate.	0.8	0.8	0.0	6.5	16.3	55.3	20.3	5.8
Q11. The application presents information in a useful format (tables, graphs, guidance).	0.8	0.8	0.0	4.1	15.5	52.0	26.8	6.0
Q12. I feel confident in the nutritional information provided by the application.	1.6	0.0	0.0	7.3	12.2	51.2	27.6	5.9
Q13. The interface of the application is pleasant to use.	0.8	0.8	0.8	3.3	15.5	50.4	28.5	6.0
Q14. I like the way the application looks.	0.8	0.8	0.8	4.1	15.5	51.2	26.8	5.9
Q15. The layout of the application is easy to navigate.	1.6	0.0	0.8	6.5	11.4	49.6	30.1	6.0
Q16. The application responds quickly to my inputs.	1.6	0.8	0.0	5.7	14.6	46.3	30.9	5.9
Q17. The labels and instructions on the screens are easy to follow.	0.8	1.6	0.0	6.5	13.8	52.0	25.2	5.9
Q18. The overall organization of the application is logical.	1.6	0.8	0.0	2.4	15.5	51.2	28.5	6.0
Q19. Overall, I am satisfied with the application interface.	0.8	0.8	0.8	4.1	14.6	43.1	35.8	6.0

Different colours indicate proportion levels. Darker colours indicate higher proportions.

Table 3. PSSUQ values based on each component (*N*=123)

System usefulness (Q1-Q8)	*Information quality (Q9-Q15)*	*Interface quality (Q16-Q19)*	*Average score*	*Note*
5.9	5.9	6.0	5.9	Above the median (4) is considered good

higher than 5, revealing a pattern that aligns with the proportion distribution.

Table 3 displays the PSSUQ values on system usefulness, information quality, and interface quality. With an average system usefulness score of 5.9 (>4), the respondents considered the developed prototype useful. Similarly, the average score for the information quality component was also 5.9 (>4). This result showed that, according to the respondents, the information contained in the developed prototype, particularly in relation to nutritional status monitoring, was of high quality. Furthermore, the average score for interface quality was 6 (>4), indicating that the prototype had a good design and user interface quality. The average score of 5.9 (>4) further validated the values of these three components, suggesting that the respondents generally approved of the developed prototype.

DISCUSSION

The results of this study showed the great potential of a mobile nutritional status monitoring application specifically designed for mothers of toddlers in Bali, Indonesia. PEMSAGI was highly praised in all three dimensions of the PSSUQ, namely system usefulness, information quality, and interface quality, with average scores above 5.9. These results indicated that users responded favourably to this application and considered it effective in providing important nutritional information in an accessible and user-friendly manner. This highlights the viability of leveraging digital health technologies to address nutritional challenges faced by vulnerable populations, particularly toddlers.

Specifically, the challenges addressed by PEMSAGI include the limited accessibility of timely and reliable nutritional information in rural and underserved areas, the lack of personalised monitoring tools that allow mothers to track their toddlers' growth status, and the absence of integrated features that connect users directly with nearby health services and nutrition experts. Unlike general health information available through open sources, such as YouTube, PEMSAGI provides a structured, interactive, and localised platform designed for continuous monitoring and direct support, thereby offering greater relevance and usability for mothers of toddlers in Bali.

In comparison with several existing national applications for child health monitoring, such as e-PPGBM, PrimaKu, and ASIK, PEMSAGI fills a notable gap. These platforms primarily serve as data collection and reporting tools for healthcare workers or provide general child health information, often lacking interactive, user-friendly features tailored for mothers' daily nutritional monitoring needs. PEMSAGI integrates nutritional status tracking with personalised recommendations, educational content, and accessibility through a lightweight, open-source design that does not require installation, making it particularly relevant for communities in Bali and other underserved regions, where mothers face barriers in accessing

timely, practical, and context-specific nutritional guidance.

The high level of user satisfaction with the application's functionality is among the most notable outcomes of this study. This confirms the findings of previous studies that mobile health (mHealth) interventions can be highly effective in filling in information gaps in remote or underserved areas. The application provides timely, evidence-based nutritional guidance, mitigating barriers that have traditionally restricted access to healthcare services, including geographical isolation and limited healthcare resources. The user-friendliness and accessibility of PEMSAGI accommodate people with varying literacy levels and technological proficiency, especially considering the demographic profile of the respondents, who were primarily housewives with less formal education. Additionally, recognising that internet connectivity in many rural or remote areas is often unstable, PEMSAGI was designed using Google Sites integrated with Google Forms, enabling both online and limited offline functionalities. Users can record and temporarily store nutritional data offline, which will automatically be synchronised once an internet connection becomes available. This feature ensures that PEMSAGI can support nutritional monitoring in geographically isolated communities.

With an average overall score of 5.9, the prototype's ability to provide high-quality information is particularly noteworthy in addressing malnutrition, stunting, and undernutrition among toddlers in Indonesia. In this study, 'high-quality information' refers to evidence-based nutritional guidance adapted from national guidelines and recommendations from health experts, which were integrated into the system during development. The application also allows users to access individualised feedback by entering their toddler's anthropometric data, which the system then analyses to provide tailored nutritional advice. Furthermore, users can submit questions through an integrated form, enabling two-way interaction with nutrition experts when necessary. These features ensure that the information provided is both relevant and actionable, thereby enhancing its perceived quality. Considering the critical early childhood period and the serious consequences of nutritional deficiencies on physical and cognitive developments, this application can be a valuable resource for mothers to use when making informed decisions about their children's health. While the information quality of this application was rated highly, it remains crucial to continuously update its content to reflect the latest nutritional guidelines and research to ensure that users receive the most accurate and relevant advice.

The application's acceptance was also highly influenced by its interface quality, which received an average score of 6. A straightforward and visually appealing interface can significantly enhance user engagement, particularly in health applications. This finding underscores the importance of user-centred designs in the development of digital health interventions since a poorly designed interface may discourage users from fully engaging with the application, regardless of its content quality.

Despite the positive feedback, this study also identified a significant gap in the empirical literature about the effectiveness of nutritional status monitoring applications in the Indonesian context. While the current findings indicate high user satisfaction, further investigation is required to assess the long-term effects of these health applications on actual health outcomes. Future studies should specifically investigate whether the

use of such an application results in measurable improvements in toddlers' nutritional status and overall well-being. Further studies should also examine the application's scalability and integration into the more extensive healthcare system to ensure sustainable and equitable access.

Nevertheless, several limitations should be acknowledged. Firstly, the application was developed and tested using a relatively small and purposively selected sample of mothers in Bali, which limits the generalisability of the findings to other regions in Indonesia. Secondly, as the prototype relied on Google Sites and Google Forms for its backend system, its current functionality and scalability are restricted compared to fully independent mobile applications. Thirdly, the evaluation relied on self-reported usability assessments, which may introduce response bias and do not directly measure improvements in toddlers' nutritional outcomes. Finally, access to smartphones and stable internet connections may still be limited in some rural areas, potentially hindering widespread adoption of the application.

CONCLUSIONS

This study contributed significantly to the scant literature on mHealth applications for nutritional monitoring in Indonesia. Digital tools have the potential to support public health interventions, particularly in remote or underdeveloped areas, as evidenced by the prototype's high usability and acceptance among mothers of toddlers in Bali. However, continuous content development and further research into its long-term effects on public health remain crucial to optimise the application's effectiveness and reach.

Acknowledgements

We would like to express our deepest gratitude to the Institute for Research and Community Service of Udayana University for funding this study through the Research and Community Service Grant Scheme (Number B/1.484/UN14.4.A/PT.01.03/2023). We are also profoundly grateful to all parties involved, namely the *Posyandu* cadres, village midwives, and Labasari Village officials of the Karangasem Regency for their support throughout this study, from the initial needs assessment to the field testing of the prototype.

Author's contributions

Sutiari NK, conceived the idea and reviewed the manuscript; Anom Harjana NP, analysed the data and wrote the manuscript; Wulandari KNP, conducted data collection and field tests; Solechah SA, conducted data collection and proofread the manuscript.

Conflict of interest

The authors declare that they have no conflicts of interest related to the research, authorship, or publication of this article.

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