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The effectiveness of the SIGMA app, based on clinical data and the health belief model, in the early prevention of stunting in pregnant women

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Abstract

Background: Stunting is still a significant public health problem in Indonesia with long-term impacts on physical growth, cognitive development, and the quality of human resources. Prevention efforts since pregnancy, especially in the early trimester, have not been optimal due to the limitations of conventional education that has not been integrated with clinical data and behavior change approaches.
Purpose: To analyze the effectiveness of SIGMA Application based on clinical data and Health Belief Model in early prevention of stunting in pregnant women.
Method: A quasi-experimental study with a pretest–posttest control group design was conducted on pregnant women in the first trimester for four weeks. The sample was divided into an intervention group that used the SIGMA Application and a control group that received standardized education. The variables measured included knowledge, attitudes, stunting prevention behaviors based on the Health Belief Model construct, as well as clinical indicators in the form of hemoglobin (Hb), Upper Arm Circumference (LILA), and Body Mass Index (BMI). Data analysis was carried out using paired t-test, wilcoxon test, mann whitney test and independent t-test.
Results: The intervention group showed significant improvements in knowledge, attitude, and behavior scores compared to the control group ($p<0.05$). In addition, there was a tendency to improve clinical indicators (Hb, LILA, and BMI) in the intervention group after four weeks of application use.
Conclusion: The SIGMA application is effective as a digital health intervention in improving literacy and stunting prevention behavior in pregnant women. The integration of clinical data-driven applications and the Health Belief Model approach is recommended as an innovative strategy in maternal and child health services to support the acceleration of stunting reduction.

Keywords: Early Prevention; Health Belief Model; Pregnant Women; SIGMA Application; Stunting.

INTRODUCTION

Stunting remains a global public health priority because of its effects on human capital and socioeconomic development. It reflects impaired linear growth associated with chronic malnutrition and environmental exposures from early life. Childhood stunting is linked to poorer cognitive development, lower educational attainment, and reduced adult earning potential (Deshpande & Ramachandran, 2022). In Indonesia, stunted children have lower cognitive and numeracy scores and shorter schooling duration than their non-stunted peers (Lestari et al., 2024). Childhood malnutrition is also associated with long-term risks of impaired glucose metabolism, cardiovascular disease, hypertension, and metabolic syndrome (Grey et al., 2021). These consequences can reduce labor productivity and cause substantial economic losses through lower worker incomes and private-sector productivity (Akseer et al., 2022; Suryana & Azis, 2023). Therefore, stunting prevention represents a long-term investment in health and

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human capital. It requires comprehensive, sustainable interventions beginning as early as possible, particularly during the first 1,000 days of life, from pregnancy to a child's second birthday (Dinata et al., 2021; Permatasari et al., 2021; Fadhil et al., 2021).

The first 1,000 days of life are critical for determining children's growth, development, and long-term health. Maternal nutrition and health during pregnancy are essential for fetal growth and stunting prevention (Permatasari et al., 2021). In Indonesia, pregnancy provides an important opportunity to prevent stunting through improved knowledge of nutrition, reproductive health, and maternal health behaviors (Nastiti et al., 2025). Inadequate nutrient intake and poor maternal nutritional status may increase the risk of fetal growth restriction and subsequent health problems. Therefore, prevention efforts should begin during pregnancy rather than focus exclusively on the postnatal period. Antenatal education and care provide opportunities to improve understanding of maternal and fetal health, nutrition, and early stunting prevention (Jhaveri et al., 2023). However, limited maternal knowledge and health literacy, together with unequal access to health information, remain important challenges.

Health literacy influences pregnant women's ability to access, understand, evaluate, and apply health information when making decisions about pregnancy and child health. Low health literacy may affect antenatal care utilization and healthy behaviors during pregnancy (Nurlina, 2024). However, knowledge alone may not ensure behavioral change, as preventive behaviors are also shaped by attitudes, beliefs, risk perceptions, and perceived benefits and barriers. The Health Belief Model (HBM) provides a relevant framework for understanding these factors through six constructs: perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy. Indonesian studies have linked perceived benefits, perceived barriers, and cues to action with behaviors related to meeting nutritional needs during pregnancy, supporting the use of HBM to design targeted educational interventions (Widyastuti et al., 2023; Nenobais & Katmini, 2021). These constructs also appear important in explaining pregnant women's participation in nutrition interventions, suggesting that HBM-based maternal education may improve adherence to nutritional behaviors that support stunting prevention (Rosdiana et al., 2025).

Maternal health literacy is also positively associated with adherence to antenatal care (ANC) visits, highlighting its potential to promote healthy behaviors during pregnancy (Putri et al., 2023). Nutritional literacy and education are linked to dietary quality, while behavior-oriented nutrition education can improve dietary diversity. Nevertheless, knowledge must be complemented by interventions addressing perceived risks, benefits, barriers, and confidence in performing health-promoting actions. Studies involving pregnant women indicate that HBM-based interventions can improve health knowledge and behavior by addressing the beliefs underlying health decisions (Abd Rahman et al., 2022). An experimental study further found that nutrition education integrating HBM and the Theory of Planned Behavior improved dietary diversity, with literacy also associated with better dietary patterns (Beressa et al., 2024). Similarly, Indonesian evidence links perceived benefits, perceived barriers, and cues to action with maternal nutritional behaviors, supporting theory-based educational interventions (Mahmudiono et al., 2022).

Health literacy remains a challenge in health promotion, particularly among populations with limited access to information, education, and health services. Accordingly, health information should be tailored to individuals' capacity to understand and apply it (Rohani, 2025; Khan et al., 2024). Among pregnant women, health literacy also influences the understanding of pregnancy risks and the adoption of preventive measures. HBM-based education has improved health literacy and pregnancy risk perceptions among primiparous women, indicating that knowledge should be accompanied by stronger risk awareness and decision-making capacity (Şenol et al., 2024). Consistent with this, HBM constructs can predict preventive behaviors among pregnant women, particularly through perceived susceptibility and cues to action (Hatamzadeh et al., 2024). In Indonesia, HBM application in antenatal care has also been associated with ANC service utilization (Purwanti et al., 2024). Furthermore, HBM-based educational interventions have improved knowledge, health beliefs, physical activity, and nutritional behaviors during pregnancy (Jeihooni et al., 2024). Integrating

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health literacy with HBM may therefore support more effective educational strategies by strengthening risk perceptions, perceived benefits, barrier management, and motivation to adopt behaviors that prevent stunting.

Maternal and child health (MCH) services continue to face challenges in ensuring that health education is continuous and translated into daily practice. Conventional education relies heavily on face-to-face communication and materials delivered during visits, creating opportunities for more accessible and sustained information delivery. In Indonesia, structured educational media, such as pregnancy nutrition guidebooks, have improved pregnant women's knowledge, attitudes, and nutritional management behaviors to prevent fetal growth restriction (Shariff et al., 2023). Moreover, differences in individual characteristics and clinical conditions may limit the effectiveness of standardized education. Clinical and anthropometric indicators, including hemoglobin (Hb), nutritional status, and body mass index (BMI), can inform individualized education and health monitoring (Marshall et al., 2022). Digital technology offers opportunities to address these limitations through flexible, continuous information delivery, reminders, and self-monitoring features.

A systematic review found that pregnancy applications offer health information, pregnancy monitoring, reminders, and communication support, although their quality and usefulness vary (Habibi et al., 2024). Other studies suggest that health applications can improve maternal healthcare utilization, pregnancy weight management, and health behaviors. More than half of pregnant women reportedly use smartphone-based pregnancy applications, yet some applications lack high-quality information, healthcare professional involvement, and strong scientific evidence (Nissen et al., 2024). These limitations underscore the need for applications that integrate clinical data and individual needs into personalized interventions. Combining maternal health data, self-monitoring, reminders, and theory-based education may enable more adaptive and sustainable interventions to prevent nutritional problems and stunting from pregnancy onward.

The SIGMA (Maternal Nutrition Screening and Early Monitoring) application was developed to address these needs. It integrates maternal clinical indicators, including Hb, mid-upper arm circumference (LILA), and BMI, with HBM-based educational materials. An algorithm-based risk assessment feature supports early stunting risk detection, while daily reminders, self-monitoring, and behavior tracking aim to improve user engagement. A data visualization dashboard facilitates progress monitoring by users and healthcare workers, and offline accessibility supports use in areas with limited connectivity. Despite these features, SIGMA's effectiveness requires systematic evaluation.

Accordingly, this study examined the effectiveness of the SIGMA application in preventing stunting among pregnant women using a quasi-experimental design comparing intervention and control groups. Outcomes included knowledge, attitudes, stunting prevention behaviors, and maternal clinical indicators. The findings are expected to contribute to the evidence base for digital health interventions and inform policies on integrating technology into MCH services, thereby supporting efforts to accelerate stunting reduction in Indonesia.

RESEARCH METHOD

A quasi-experimental study with a pretest–posttest control group design was employed to analyze the effectiveness of the SIGMA (Maternal Nutrition Screening and Early Monitoring) application based on clinical data and the Health Belief Model in the early prevention of stunting among pregnant women. The study was conducted in the service area of the Puncu Community Health Center, Kediri Regency, East Java, from May through June 2026. The study population consisted of all first-trimester pregnant women who underwent prenatal checkups at the health facility. The sample was selected using purposive sampling, with a total of 30 participants divided into two groups: an intervention group and a control group, each comprising 15 participants. Inclusion criteria included being a first-trimester pregnant woman, owning an Android-based smartphone, being able to operate basic digital applications, and being willing to participate in the entire study process. Exclusion criteria included pregnant women with specific medical conditions such as preeclampsia, uncontrolled gestational diabetes, severe anemia, or other pregnancy complications requiring intensive care. This study received ethical approval from the health research

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ethics committee, and all participants provided written informed consent before participating.

The initial phase of the research involved the development of the SIGMA app through several systematic processes. A needs analysis was conducted by engaging first-trimester pregnant women and healthcare workers to identify literacy needs related to pregnancy nutrition, anemia, stunting, and monitoring of initial nutritional status indicators such as hemoglobin (Hb), upper arm circumference (UAC), and body mass index (BMI). In addition, user preferences regarding digital educational media and features that support behavior change based on the Health Belief Model were identified. Based on the results of the needs analysis, a user-friendly user interface and user experience (UI/UX) were designed. Educational modules were systematically organized to cover balanced nutrition during pregnancy, first-trimester nutritional needs, anemia, stunting, and the concept of the First 1,000 Days of Life. The app's features include educational quizzes, daily reminders, behavior tracking, an educational chatbot, and a data visualization dashboard. The app is also designed to be accessible offline to improve user accessibility. Next, three experts including an expert in maternal and child health and an expert in health information systems validated the app's content. The validation assessed the appropriateness of the material, the clarity of the information, and the app's usability. Following the validation process, a pilot test was conducted with five pregnant women to evaluate the app's functionality, ease of navigation, and user experience. Feedback from this stage was used to make improvements and refinements to the app before it was used in the main study. Validity and reliability tests were also conducted on the questionnaire used in the study, specifically to measure the constructs of the Health Belief Model. An instrument is considered valid if the item-total correlation is >0.20 and reliable if Cronbach's alpha is >0.60. This entire process aims to ensure the quality of the app and the research instruments used. Thus, the SIGMA app used in this study has undergone a systematic development and validation process.

The study began with a pre-intervention (pretest) phase for both groups. During this stage, baseline measurements were taken for the study variables, which included knowledge, attitudes, and behaviors related to stunting prevention based on the Health Belief Model. In addition, maternal clinical indicators were measured, including hemoglobin (Hb) levels, upper arm circumference (UAC), and body mass index (BMI). Data on respondent characteristics were also collected through demographic and pregnancy history questionnaires. For the intervention group, initial records of app usage were collected via an initial app log. All measurements were conducted by trained health workers to ensure procedural consistency. The instruments used had previously undergone validity and reliability testing. This phase aimed to establish a baseline before the intervention was implemented.

During the intervention phase, the intervention group was given full access to the SIGMA app and received brief training on how to use it. For four weeks, participants used the app independently to access educational modules, videos, infographics, and interactive features such as quizzes, chatbots, and behavior tracking. The app also provided daily reminders as cues to action to encourage changes in health behaviors. App usage was monitored through a logging system that tracked access frequency, duration of use, and user interactions with app features. Meanwhile, the control group received only standard health education through counseling and informational leaflets provided by healthcare workers. No digital intervention was provided to the control group. The entire intervention process was conducted with minimal supervision to maintain natural conditions for app usage. This phase aimed to evaluate the effectiveness of the digital intervention compared to conventional methods.

After the intervention period ended, a post-intervention (posttest) phase was conducted for both groups. The same variables measured in the pretest phase were reassessed: knowledge, attitudes, stunting prevention behaviors, and maternal clinical indicators (Hb, LILA, and BMI). Changes in scores between the pretest and posttest were analyzed to assess the effectiveness of the intervention. In addition, an evaluation was conducted on the level of user engagement in the intervention group based on app log data. This data was used to identify the relationship between the intensity of app use and behavioral changes. All data were systematically collected and verified to ensure completeness and

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accuracy. This stage is a crucial part of determining the impact of the intervention. The measurement results were then used as the basis for statistical analysis.

Data analysis was conducted in stages using SPSS software. For paired data (pre- and post-intervention), the Wilcoxon signed-rank test was used in this study because some data were non-normal. However, the dependent t-test was used for other data because some were normal. For unpaired data (differences between the intervention group and the control group), the Mann-Whitney U test was used in this study because some data were non-normally distributed. The independent t-test was then used for normally distributed data. All statistical tests used a significance level of $p < 0.05$. The results of the analysis are presented in tables and graphs to facilitate interpretation. With this approach, the study is expected to provide a comprehensive overview of the effectiveness of the SIGMA app in the early prevention of stunting among pregnant women.

RESEARCH RESULTS

Table 1. Analysis of Data Before and After in the Intervention Group

Variable	Mean Value	Sig (2-tailed)	Assumption
Knowledge			
Before	3.50	0.033	Significance
After	4.64		
Attitude			
Before	44.27	0.002	Significance
After	46.33		
Behavior			
Before	125,00	0.006	Significance
After	129.27		
Hemoglobin Level			
Before	12.09	0.005	Significance
After	12.66		
LILA Measurement			
Before	29.47	0.020	Significance
After	30.04		
IMT Measurement			
Before	27.16	0.005	Significance
After	28.51		

The results in Table 1 show the pre- and post-intervention data analysis for the intervention group. The results of the data analysis indicate that the intervention had a significant effect on improving knowledge (p=0.033), improving attitudes (p=0.002), improving behavior (p=0.006), increasing hemoglobin levels (p=0.005), increasing LILA measurements (p=0.020), and increasing BMI measurements (p=0.005).

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Table 2. Analysis of Data Before and After in the Control Group

Variable	Mean Value	Sig (2-tailed)	Assumption
Knowledge			
Before	3.70	0.084	Significance
After	2.50		
Attitude			
Before	4.50	0.108	Significance
After	9.00		
Behavior			
Before	123.53	0.832	Significance
After	123.80		
Hemoglobin Level			
Before	112.46	0.085	Significance
After	116.40		
LILA Measurement			
Before	27.92	0.334	Significance
After	27.95		
IMT Measurement			
Before	26.38	0.165	Significance
After	26.44		

The results in Table 2 show the pre- and post-intervention data analysis for the control group. The results of the data analysis indicate no significant difference between the pre- and post-measurements in the control group, specifically regarding knowledge (p=0.084), attitude (p=0.108), behavior (p=0.832), hemoglobin levels (p=0.085), LILA measurements (p=0.334), and BMI measurements (p=0.165).

Table 3. Analysis of Data Between Groups

Variable	Group	Mean Rank Value	Sig (2-tailed)	Assumption
Knowledge	Intervention	19.50	0.011	Significance
	Control	11.50		
Attitude	Intervention	21.00	0.000	Significance
	Control	10.00		
Behavior	Intervention	4.26	0.036	Significance
	Control	0.26		
Hemoglobin Level	Intervention	0.57	0.002	Significance
	Control	0.00		
LILA Measurement	Intervention	0.56	0.021	Significance
	Control	0.03		
IMT Measurement	Intervention	1.35	0.004	Significance
	Control	0.05		

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As presented in Table 3, significant differences were observed between the intervention and control groups across all measured outcomes. Knowledge scores were significantly higher among pregnant women in the intervention group than in the control group (mean: 19.50 vs. 11.50; p = 0.011). Similarly, attitudes toward stunting prevention differed significantly between groups, with the intervention group demonstrating higher mean scores (21.00 vs. 10.00; p < 0.001). Stunting prevention behaviors were also significantly improved in the intervention group compared with the control group (mean: 4.26 vs. 0.26; p = 0.036). In addition, pregnant women in the intervention group showed significantly greater increases in hemoglobin levels (0.57 vs. 0.00; p = 0.002), upper arm circumference (MUAC/LILA) measurements (0.56 vs. 0.03; p = 0.021), and body mass index (BMI) (1.35 vs. 0.05; p = 0.004) than those in the control group. These findings indicate that the intervention had a positive effect on knowledge, attitudes, preventive behaviors, and maternal nutritional status.

The SIGMA app evaluates the daily monitoring of pregnant women over 30 consecutive days, covering their routines of taking iron tablets, eating vegetables, consuming protein, drinking enough water, and getting adequate rest. In the intervention group, monitoring was conducted by filling out the app, while in the control group, monitoring was conducted by filling out a daily monitoring sheet.

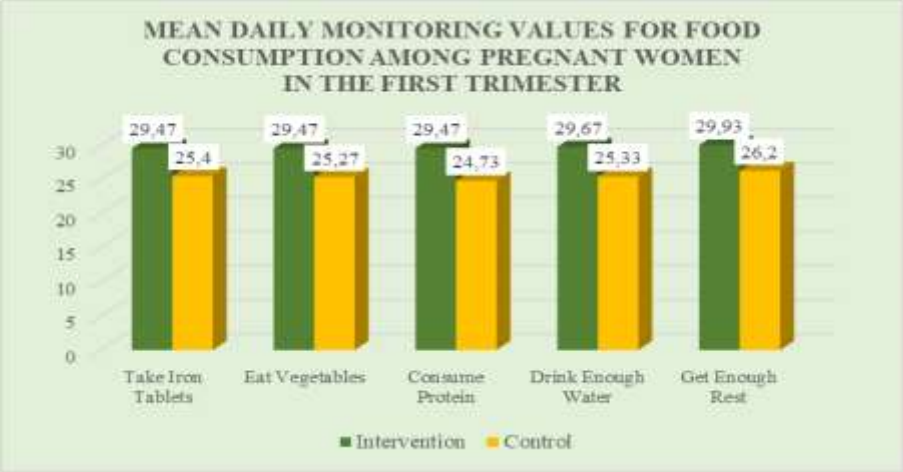


Figure 1: Mean Daily Intake Values for Pregnant Women in the First Trimester

Daily monitoring of first-trimester pregnant women's dietary intake revealed differences in mean values between the intervention and control groups. The mean value for iron tablet intake over 30 days in the intervention group was higher than that in the control group by 4.07. The mean value for vegetable intake over 30 days in the intervention group was higher than that in the control group by 4.20. Protein intake over 30 days in the intervention group had a higher mean value than in the control group, with a difference of 4.68. Adequate water intake over 30 days in the intervention group had a higher mean value than in the control group, with a difference of 4.34. Adequate rest over 30 days in the intervention group had a higher mean value than in the control group, with a difference of 3.73.

DISCUSSION

The study results show that the use of the SIGMA app significantly improved knowledge, attitudes, and behaviors related to stunting prevention among pregnant women compared to the control group. These findings indicate that digital technology-based interventions are more effective than conventional education, which is generally one way and limited to the duration of a visit. The significant improvements in these three aspects strengthen the evidence that an interactive and sustained educational approach is more effective at promoting positive changes in health behaviors (Wang et al., 2023). In addition, there was a trend toward improvement in clinical indicators such as hemoglobin (Hb), upper arm circumference (UAC), and body mass index (BMI), although not all showed

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significant differences between groups. This suggests that the behavioral changes that have occurred are beginning to have a physiological impact, although it will take longer to produce significant clinical changes. Overall, these results support the effectiveness of the SIGMA app as a digital health intervention for the early prevention of stunting. These findings align with global trends showing an increase in the use of mobile health in maternal and child health interventions. Thus, SIGMA has the potential to serve as an innovative solution for improving the quality of technology-based health services.

The improvement in knowledge, attitudes, and behaviors among the intervention group can be explained through the Health Belief Model (HBM), which served as the basis for the development of the SIGMA app. The HBM emphasizes that behavioral change is influenced by an individual's perceptions of susceptibility, severity, benefits, barriers, cues to action, and self-efficacy (Alyafei & Easton-Carr, 2024). The SIGMA app is designed to address all of these constructs through educational modules, reminder features, interactive quizzes, and behavior tracking. As individuals' perceptions of risks and benefits increase, they become more motivated to adopt healthy behaviors. In addition, self-monitoring features and visual feedback via the dashboard boost users' confidence in managing their health. This demonstrates that integrating behavioral theory into digital technology can enhance the effectiveness of interventions. This approach is superior to conventional education, which often focuses solely on increasing knowledge without considering users' psychological aspects. Therefore, the application of the Health Belief Model (HBM) in the SIGMA app is one of the key strengths of this study.

The SIGMA app offers unique benefits through the integration of maternal clinical data with an adaptive digital education system. Unlike most health apps that only provide general information, SIGMA utilizes clinical data such as Hb, LILA, and BMI to generate more personalized risk assessments. This approach enables the delivery of more relevant educational content tailored to each user's specific condition. Additionally, the "triggered education" feature delivers content gradually based on user needs, thereby enhancing learning effectiveness. The daily reminder feature serves as a cue to action, helping users maintain consistent healthy behaviors. Meanwhile, the educational chatbot provides more flexible and responsive access to information. The app's ability to function offline is also a key advantage in reaching users in areas with limited internet access. With this combination of features, SIGMA serves not only as an educational tool but also as a means of monitoring and reinforcing healthy behaviors. This demonstrates that the integration of technology and clinical approaches can result in more comprehensive interventions.

Daily monitoring such as taking iron tablets, eating vegetables, consuming protein, drinking enough water, and getting adequate rest is an effort made to bring about physiological changes, such as an increase in Hb levels or nutritional status; however, this takes longer than changes in knowledge or behavior. In addition, other factors such as daily nutrient intake, individual health status, and adherence to the intervention also influence clinical outcomes. Therefore, a four-week intervention period may not be sufficient to produce optimal clinical changes. These findings are consistent with previous studies showing that nutritional interventions require at least several months to produce significant effects. Consequently, further research with a longer duration is needed to evaluate clinical impacts more comprehensively. Furthermore, integrating digital interventions with direct support from healthcare professionals can also enhance the effectiveness of clinical outcomes. This is an important consideration for future program development.

The SIGMA app has great potential for integration into maternal and child health (MCH) services, particularly in antenatal care (ANC). Using the app can help healthcare workers provide more systematic, data-driven education. Additionally, the app can reduce the workload of healthcare workers in providing repetitive education, since some of the information is already available in digital form. For pregnant women, the app provides more flexible access to information that can be used at any time. This increases user engagement in managing their own health. However, implementing the app also requires infrastructure support, such as the availability of devices and internet access. Furthermore, users' digital literacy is a critical factor that must be considered. Therefore, training and guidance on using

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the app are essential components of the implementation process. With the right support, SIGMA can play a role in the digital transformation of healthcare services.

The policy implications of this study suggest that the integration of digital health applications based on clinical data and behavioral theory should be considered in national strategies for stunting prevention. This approach aligns with the direction of health system transformation, which emphasizes the use of digital technology. The use of applications such as SIGMA can improve the efficiency and effectiveness of health programs, particularly in the education and monitoring of pregnant women. Additionally, the data generated by the application can be utilized as a source of information for evidence-based decision-making. However, widespread implementation requires regulatory support, interoperability standards, and data security guarantees. The government and stakeholders need to collaborate in developing an integrated digital health ecosystem. In this way, innovations like SIGMA will not remain confined to research but can be widely implemented within the health system. This will have a greater impact on efforts to reduce stunting in Indonesia.

This study makes an important contribution to the development of digital health interventions grounded in theory and clinical data. The SIGMA app proved effective in improving literacy and behaviors related to stunting prevention among pregnant women. The integration of technological approaches, behavioral theory, and clinical data is the key strength that distinguishes this study from previous research. Although there were limitations regarding the duration of the intervention and the sample size, the results of this study provide a strong foundation for further development. Future research is recommended to include a larger sample size and a longer intervention duration. Additionally, an evaluation of the long-term impact on the nutritional status of mothers and infants is also necessary. With continued development, the SIGMA app has the potential to become a model of innovation in maternal and child health services. Therefore, the use of digital technologies such as SIGMA should continue to be promoted as part of a sustainable public health strategy.

CONCLUSION

This study shows that the SIGMA app, which is based on clinical data and the Health Belief Model, is effective in improving knowledge, attitudes, and behaviors related to stunting prevention among pregnant women compared to conventional education. The integration of maternal clinical indicators such as hemoglobin (Hb), upper arm circumference (UAC), and body mass index (BMI) with a behavior change approach enables interventions that are more personalized, targeted, and adaptive to users' needs. There is a trend toward improvement, indicating the potential for long-term physiological effects. These findings confirm that digital health interventions based on theory and clinical data have advantages over conventional educational methods in promoting changes in health behavior.

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