



Monitoring and Managing Stress during Pregnancy with the ‘Smart Mother’ Information System for Early Detection

Runjati Runjati¹, Sri Rahayu^{2✉}, Arum Budiayati¹, Krisdiana Wijayanti¹, Mundarti¹,
Rr Sri Endang Pujiastuti³, Nur Abadi⁴

¹Department of Midwifery, Poltekkes Kemenkes Semarang

²Department of Midwifery, Poltekkes Kemenkes Denpasar

³Department of Nursing, Poltekkes Kemenkes Semarang

⁴Islamic Education Management Study Program, Universitas Islam Negeri Walisongo, Semarang

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Abstract

Psychological adjustment during pregnancy plays a vital role in maintaining maternal mental health and supporting fetal well-being. This study developed and evaluated Smart Mother, a smartphone-based application designed for early detection and management of stress among pregnant women. The system was developed using the System Development Life Cycle (SDLC) framework and tested through a randomized controlled trial following CONSORT guidelines. A pretest–posttest design was conducted with 120 pregnant women randomly assigned to an intervention group ($n = 60$) and a control group ($n = 60$) from March to October 2023. The intervention group utilized the Smart Mother application, which integrates stress screening and self-management features, while the control group received conventional printed educational materials. Statistical analysis using the Wilcoxon signed-rank test, Mann–Whitney U test, and multivariate analysis showed a significantly greater reduction in stress scores in the intervention group compared with the control group (7.19 ± 5.8 vs. 5.87 ± 4.2 ; $p < 0.01$). Evaluation based on the Technology Acceptance Model (TAM) demonstrated high usability, with an average score of 4.26 (85.2%). These findings suggest that Smart Mother is an effective digital tool for improving stress monitoring and management during pregnancy and supports more comprehensive antenatal mental health care.

Introduction

Pregnancy represents a pivotal developmental period characterized by extensive physiological and psychological transitions (Huizink *et al.*, 2016). Mothers must be able to have coping strategies for maintaining their psychological health during psychological changes (Pangesti, 2018). However, some mothers develop stress, an unpleasant emotion that causes psychological health issues, during pregnancy (Hanifah, 2019). Although global estimates remain inconsistent, evidence from the United States reported that approximately 84% of pregnant women encountered stress, with around 6% experiencing more severe levels

(Corbijn van Willenswaard *et al.*, 2017). Stress is broadly understood as a biopsychological response that emerges when individuals perceive environmental demands as exceeding their adaptive capacity. In the context of pregnancy, this response may be intensified due to overlapping physiological, emotional, and social changes (Valéria *et al.*, 2017).

Findings from an Indonesian investigation indicate that a substantial proportion of pregnant women, approximately 78% of pregnant women, experience stress at mild to moderate levels, while about 6% report stress of a more severe nature. These observations support the broader literature

✉ Correspondence Address:
Department of Midwifery, Poltekkes Kemenkes Denpasar
Email: runjati@poltekkes-smg.ac.id

suggesting that the antenatal period carries a greater susceptibility to psychological distress compared with the postpartum phase. These studies also indicate that a substantial proportion of pregnant women experience psychological stress during pregnancy, particularly at mild to moderate levels, which may affect maternal well-being and pregnancy outcomes (Hasanjanzadeh, 2017; Sari *et al.*, 2019; Pratiwi *et al.*, 2020).

Accumulating evidence has demonstrated that maternal stress during pregnancy is associated with a range of adverse developmental outcomes (Cooney *et al.*, 2019). Elevated stress has been linked to compromised cognitive growth, heightened risks for neurodevelopmental conditions such as autism spectrum disorder and schizophrenia, disruptions in motor development, and increased behavioral difficulties in early childhood. Such consequences underscore the importance of maternal psychological regulation, as unmanaged stress may generate harmful effects for both the mother and her fetus. Mothers could face adverse effects of stress for themselves and their babies if they do not control their psychological health (Rabiepoor *et al.*, 2019).

Evidence from community-based maternal health studies in Indonesia also highlights the importance of psychosocial support and early detection of mental health problems during antenatal care (Rahmawati *et al.*, 2018; Wulandari *et al.*, 2021). Furthermore, to mitigate these risks, antenatal care (ANC) programs have been established as a key public health strategy aimed at safeguarding maternal well-being throughout pregnancy. ANC provides structured monitoring, counseling, and support that can enhance maternal coping capacity and reduce psychological burden. Evidence from previous studies suggests that higher-quality and more comprehensive ANC services are positively associated with improved maternal psychological health, indicating that effective antenatal engagement plays a meaningful role in preventing or minimizing stress-related complications (Runjati *et al.*, 2018; Tsai *et al.*, 2018).

In certain situations, pregnant women encounter barriers to accessing healthcare

and treatment due to factors such as time constraints, cost, geographical distance from healthcare facilities, and limited transportation options. (Lukoff *et al.*, 2018). Thus, innovations are needed for mothers to access health services from anywhere and at any time. Digital health interventions, including mobile-based monitoring systems, have been increasingly explored in public health services in Indonesia to improve accessibility, early detection, and continuity of care (Hidayat *et al.*, 2022; Lestari *et al.*, 2020). Therefore, there is a pressing need for innovative solutions allowing mothers to access health services anytime and anywhere. Previous research has examined the feasibility, acceptability, and clinical effectiveness of e-screening compared to traditional paper-based methods for assessing psychological health in Indonesia. These studies highlight the importance of identifying digital tools that are both accessible and acceptable to women and healthcare providers, as well as establishing effective early detection methods. The use of information technology, particularly through smartphones, has been suggested as a way to address challenges in the early identification of psychological health issues. Research found that evaluating the practicality and effectiveness of smartphone-based early detection systems can lead to quicker identification of mental health concerns at various stages of pregnancy (Lukoff *et al.*, 2018; Nicholson *et al.*, 2018). Consequently, it is crucial to explore the effectiveness of smartphone-based information systems in detecting maternal stress during pregnancy.

Method

The study design employed the System Development Life Cycle (SDLC) methodology, which is a structured approach to software development that involves stages such as planning, analysis, design, implementation, testing, and maintenance. In this study, an experimental randomized controlled trial with a pre-test and post-test design was utilized. The study adhered to the CONSORT 2010 guidelines for reporting trials (Figure 1). The research was conducted at the Semarang City Primary Healthcare Center. Participants of the study used probability sampling from

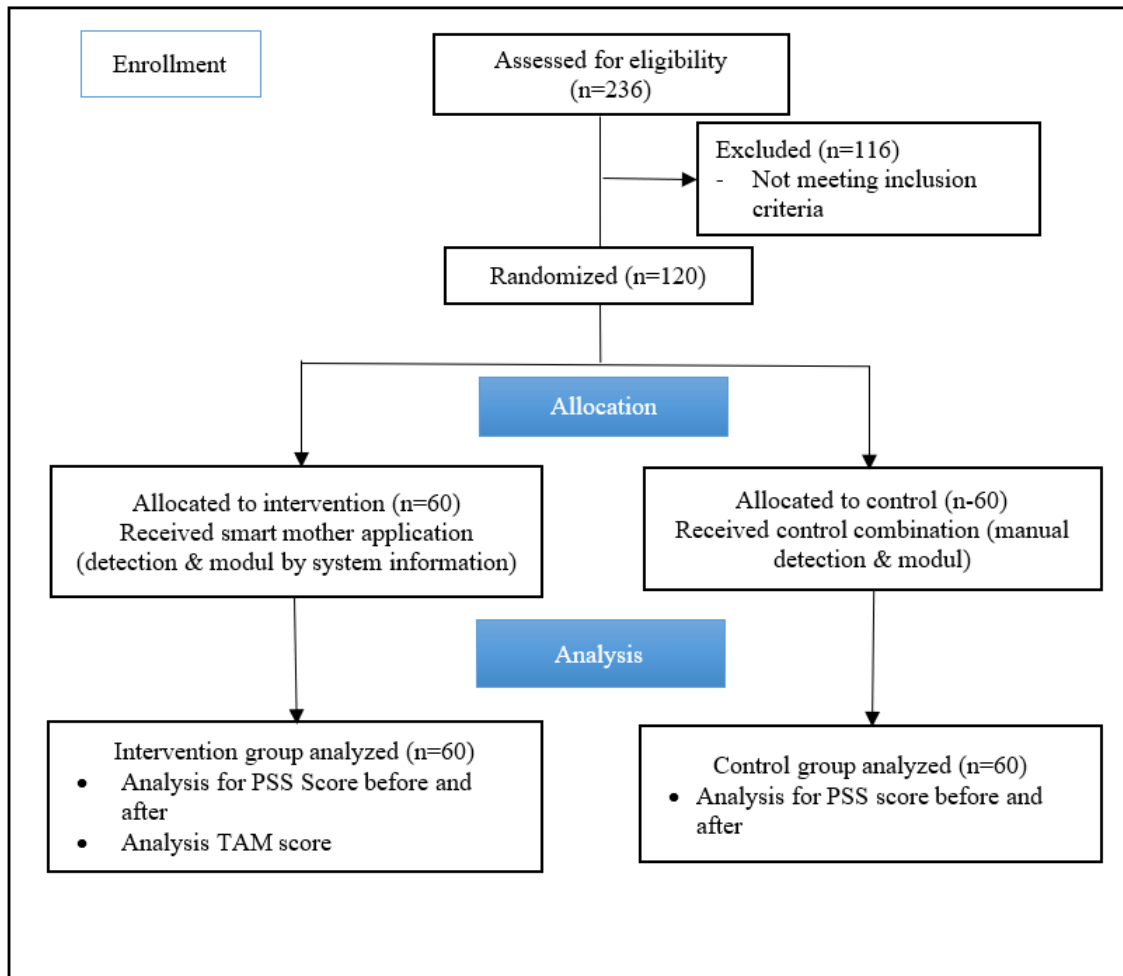


Figure 1. Consolidation Standards of Reporting Trials Flow Diagram

230 assessed for eligibility. Participants who met the inclusion criteria were selected, 120 mothers in total, consisting of 60 mothers in the intervention group and 60 mothers in the control group. The intervention group was given the Smart Mother application, a smartphone-based information system. In the application system, mothers registered by filling in their identity, pregnancy, education, and work status. After that, they answered the stress detection questionnaire. They received the score once they finished the questionnaire. The system had three sections of stress management, which contained educational videos and modules about stress detection and management. In the control group, stress levels were identified manually, and it was given modules to learn and practice stress management. The control group was given a month to study the module, as well as the intervention group. Mother's stress levels

were measured with a perceived stress scale (PSS) (Chan & La Greca, 2020; Kashanian *et al.*, 2021). This study recruited pregnant mothers who owned and could operate a smartphone, were willing to use information systems, were not illiterate, were willing to be respondents, and had no history of mental health disorders or pregnancy complications.

The research instrument employed in this study consisted of two main questionnaires: the Perceived Stress Scale (PSS) to assess the stress levels of participants, and the Technology Acceptance Model (TAM) questionnaire to evaluate the effectiveness of the information system. The effectiveness of the information system was measured through several constructs within the TAM framework, including perceived usefulness, perceived ease of use, user attitudes, behavioral intentions to use the application, and actual usage behaviors

(Sayekti & Putarta, 2016; Scherer, 2018). The responses from the questionnaires were analyzed to determine the differences in stress levels experienced by pregnant women before and after utilizing the Smart Mother application and its associated modules. Statistical analyses were conducted using the Wilcoxon signed-rank test and the Mann-Whitney U test to evaluate pre- and post-usage differences. Ethical approval for this study was obtained from the Health Research Ethics Committee at Semarang State Health Polytechnic (approval number: 0623/EA/KEPK/2022). Prior to participation, all participants provided informed consent, ensuring voluntary and ethical participation in the study.

Results and Discussion

According to Table 1, there is a diversity in the characteristics of pregnant women across both groups. The majority of participants had attained higher education, with 93.3% in the

intervention group and 83.3% in the control group. Employment was common among respondents, with 53.3% in the intervention group and 56.7% in the control group holding jobs. In terms of parity, 55% of the respondents in the intervention group and 38% in the control group were primiparous. Both groups of respondents received social support. Regarding gestational age, 50% of those in the intervention group and 38.3% in the control group were in their third trimester. To explore potential causal relationships between the respondents' characteristics, a multivariate linear regression analysis was conducted.

As shown in Table 2, the analysis revealed that none of the respondents' characteristics, either individually or collectively, had a significant effect on pregnancy-related stress ($p > 0.05$). Therefore, it can be concluded that the characteristics of pregnant women do not influence their stress levels. The distribution of respondent characteristics demonstrated variability between the intervention and control

Table 1 Characteristics of Respondents

Characteristics of Respondents	Intervention		Control	
	N	%	N	%
Education				
Tertiary	56	93.3	50	83.3
Secondary	3	5.0	7	11.7
Primary	1	1.7	3	5.0
Work				
Working	32	53.3	34	56.7
Does not work	28	46.7	26	43.3
parity				
Primipara	33	55	22	36.7
Multipara	27	45	38	63.3
Social Support				
Support	60	100	60	100
Does not support	0	0	0	0
Gestational Age				
Trimester 1	12	20	16	26.7
Trimester 2	18	30	23	38.3
Trimester 3	30	50	21	35.0

Source: Primary Data, 2023

Table 2. Characteristics of Respondents

Characteristics of Respondents	Sig	Stress level		
		R- Square	R	p-value
Education	0.874			
Work	0.880			
parity	0.424	0.029	0.171	0.489
Gestational Age	0.109			

Source: Primary Data, 2023

groups. Most participants had completed higher education, and more than half were employed in both groups. Previous studies conducted in Indonesia suggest that higher educational attainment may increase awareness of psychological health issues, although it does not necessarily protect against antenatal stress (Andhavarapu *et al.*, 2021; Kusumawati *et al.*, 2023). Employment status showed no meaningful difference between groups, supporting earlier findings that occupational engagement alone is not a decisive determinant of stress during pregnancy when adequate social support is present (Simanjuntak & Simanjuntak, 2023).

Primiparity was more common in the intervention group; however, multivariate regression analysis indicated that parity, gestational age, education level, employment status, and social support were not significantly associated with stress levels ($p > 0.05$). These findings are consistent with previous KEMAS studies reporting that antenatal stress is shaped by complex psychosocial interactions rather than isolated demographic factors (Andhavarapu *et al.*, 2021; Nashih *et al.*, 2024). International evidence similarly emphasizes that perceived stress during pregnancy is more strongly influenced by coping mechanisms and psychological resilience than by baseline sociodemographic characteristics (Kashanian *et al.*, 2021; Cooney *et al.*, 2019). Pregnancy involves a phased process, starting from ovulation, migration of sperm and egg cells, conception, the growth of the zygote, implantation in the uterine wall, the formation process of the placenta, and the growth and development of the fetus. During pregnancy, a mother's body changes and adapts due to the presence of a fetus in the womb. Pregnancy

involves the fertilization of the sperm and egg cells until the fetus develops at term in the womb, physically and psychologically.

Physiological and psychological adaptations last throughout gestation as a result of the physiological response given by the fetus. During the psychological adaptation of pregnancy, mothers have psychological needs, including support from family and health workers, and a sense of security and comfort. The need for others to give decision-making support and confidence is faced by expectants.

¹⁶ Otherwise, mothers will develop stress if this need is not met. In this study, 60 mothers in the intervention group were detected as experiencing stress (10 respondents with mild stress, 47 with moderate stress, and 3 respondents with severe stress). Meanwhile, in the control group, 8 respondents experienced moderate stress, and 52 respondents experienced severe stress. After being given the intervention, the number of respondents who experienced stress decreased to 46 respondents with mild stress and 14 respondents with moderate stress. A similar thing happened to the control group, where 9 respondents experienced mild stress, 27 respondents experienced moderate stress, and 24 respondents experienced severe stress.

Pregnancy involves continuous physiological and psychological adaptation. During this period, women require reassurance, emotional security, and guidance from both family members and healthcare providers. When these psychological needs are unmet, stress responses may intensify (Kusumawati *et al.*, 2023). Educational and supportive interventions implemented during antenatal care have been shown to reduce psychological vulnerability, as demonstrated in previous KEMAS publications focusing on health education and non-

pharmacological approaches (Kusumawati *et al.*, 2023; Değirmenci *et al.*, 2025). Prior to the intervention, all participants exhibited varying degrees of stress. Following the intervention period, the proportion of women experiencing moderate to severe stress declined markedly in the intervention group, whereas reductions in the control group were less pronounced. This pattern supports earlier research indicating that early identification of stress combined with structured management strategies can significantly improve maternal psychological outcomes (Tsai *et al.*, 2018; Rabiepoor *et al.*, 2019). From a biological perspective, psychological stress during pregnancy activates neuroendocrine pathways, leading to increased secretion of stress hormones such as cortisol. These hormones may cross the placental barrier and interfere with fetal growth and development (Smith *et al.*, 2019; Taylor *et al.*, 2020). Evidence from Indonesian studies published in KEMAS further confirms that stress-related hormonal changes are measurable among pregnant women, reinforcing the clinical importance of early stress monitoring (Sari *et al.*, 2025).

Stress is the way the body reacts to dangerous, unusual, and disturbing situations. Such situations can make a person frustrated, nervous, or even angry. Under stress, the body responds by making physical and chemical changes. However, the response can be different for each person. A situation sometimes can be stressful for one person but not for others (Kołomańska, Zarawski & Mazur-Biały, 2019). If pregnant women experience stress, they may develop negative thoughts and feelings of fear. Stress during pregnancy will hamper the physiological and psychological development of the baby. What a pregnant woman thinks has a direct physical relationship to the development of the child in the womb (Ramos *et al.*, 2019). Studies have shown that stress in pregnancy is associated with low birth weight, and cognitive, behavioral, emotional, and neurodevelopmental problems, especially among premature babies (Monk *et al.*, 2020).

The impact of smartphones on the early detection of stress in pregnant women is detailed in Tables 3 and 4. Based on the data, which were not normally distributed, the Wilcoxon test results revealed that the average

stress level in the control group decreased from 18.17 before the treatment to 10.98 after the intervention. In contrast, the intervention group showed a change in average stress level of 7.19. The information system's effect on the intervention group was statistically significant, with a p-value of 0.000, indicating that the Smart Mother app had a substantial impact on early stress detection. For the control group, the average stress level decreased from 32.13 before treatment to 26.35 after treatment, showing a difference of 5.87 compared to the intervention group. In other words, the intervention group experienced lower stress levels than the control group. The control group also exhibited a p-value of 0.000, suggesting that the treatment had a significant effect on stress reduction. Furthermore, the Mann-Whitney test results demonstrated a significant difference in the treatment effects between the intervention and control groups ($p = 0.000$).

This study, as shown in Table 3, demonstrates that the smartphone-based information system was effective in the early detection of stress in pregnant women ($p = 0.000$). The findings indicate that the average reduction in stress levels for the intervention group, which used the Smart Mother application and modules as stress management tools, was 7.19. In comparison, the control group, which only used the module, showed a difference of 5.87. This suggests that the intervention group experienced a greater reduction in stress levels than the control group. The results presented in Tables 3 and 4 also indicate that the *Smart Mother* application produced a greater reduction in stress levels compared with conventional printed modules. The statistically significant differences observed between groups demonstrate that smartphone-based interventions can enhance the effectiveness of stress management during pregnancy. These findings are consistent with previous studies highlighting the benefits of mobile health (mHealth) platforms in supporting maternal mental health (Tsai *et al.*, 2018; Nicholson *et al.*, 2018).

Stress during pregnancy is often linked to negative thoughts and feelings of fear, which can impact fetal development. The first exposure to stress results in hormone transmission to

Table 3. The Effect of Smart Mother Application for Early Detection of Stress in Pregnant Women to Reduce Stress

Variables	Data	Groups		P-Value
		Intervention	Control	
		Mean $\pm$ SD	Mean $\pm$ SD	
stress	Pre	18.17 $\pm$ 5.6	32.13 $\pm$ 6.0	
	Post	10.98 $\pm$ 4.6	26.25 $\pm$ 3.8	
p-value		0.000	0.000	
	Difference	7.19 $\pm$ 5.8	5.87 $\pm$ 4.2	0.000

Source: Primary Data, 2023

Table 4. The Effectiveness Score of Mother Application

No	Variables	Number of Respondents	Score Average	Percentage (%)
1.	Perceived Ease of Use	60	4.21	84.3
2.	Perceived Usefulness	60	4.21	84.3
3.	Attitude toward Usage	60	4.23	84.5
4.	Behavioral Intention	60	4.35	87.0
5.	Actual Usage	60	4.32	86.0
	Overall Average		4.26	85.2

Source: Primary Data, 2023

the fetus via the placenta. While the placenta typically acts as a barrier to harmful substances, the hormone cortisol, released during maternal stress, can pass through and potentially cause intrauterine growth restrictions (Smith *et al.*, 2019; Johnson & Lee, 2020). This exposure could lead to premature birth and hinder fetal development. Additionally, stress can impair the mother's immune system, making her more susceptible to infections and complications during pregnancy (Davis *et al.*, 2021). Pregnancy-related diseases not only affect maternal health but can also influence the mother's behavior, physical activity, nutritional intake, and sleep patterns (Miller *et al.*, 2022). Typically, the body attempts to maintain homeostasis when stressed. Stress activates the immune system by altering the production of pro-inflammatory cytokines, which then stimulate neurons in the hypothalamus to release corticotropin-releasing hormone (CRH). Elevated CRH levels can increase the production of stress hormones such as cortisol (Kumar & Singh, 2023).

The elevation of cortisol and

corticotropin-releasing hormone (CRH) in response to stress results in a reduction in progesterone levels, a hormone crucial for maintaining pregnancy. This imbalance can trigger uterine contractions and intensify their frequency, potentially resulting in preterm labor. During stress, cortisol's negative feedback mechanism is vital for maintaining homeostasis. However, if the stress response disrupts this balance, it can impair the sensitivity of the hypothalamic-pituitary-adrenal (HPA) axis. The hypothalamus plays a key role in processing external stimuli and regulates the body's responses through both the nervous system and hormone release. The brain, in turn, influences the secretion of hormones from the pituitary and adrenal glands, leading to an increase in cortisol production (Taylor *et al.*, 2020).

Table 4 demonstrates the perceived use of the system. The data of the intervention group showed that overall, the average value of this variable is 4.26, found in 85.2% of the intervention group. So, the smartphone-based information system is highly effective and easy to use by pregnant women in the third

trimester. The results of the intervention group also showed that the question about perceived ease of use obtained an average of 4.21 with a percentage of 84.3. In the question about perceived usefulness, the average value was 4.21 with a percentage of 84.3. Regarding the attitude, the value was 4.23 found among 84.5 of the intervention group. In behavioral questions, the intention variable had an average value of 4.35, shown by 87.0% of the respondents. In the actual use question, the variable showed an average value of 4.32 in 86.0% of the intervention group. It can be concluded that the smartphone information system for early detection of stress in pregnant women is very effective.

The effectiveness of a smartphone-based information system for early stress detection in the intervention group was demonstrated in Table 5, where a significant difference between the intervention and control groups was observed ($p = 0.000$). The intervention proved more effective than the control, likely due to the smartphone's ability to serve as an integrated tool that collects (inputs), processes, stores, distributes (outputs) information, and provides feedback to meet specific goals (Jones *et al.*, 2021). The smartphone app functions similarly to a personal computer, offering a versatile platform for gathering data and providing feedback on psychological health, even without internet access. It can store data locally, which helps reduce costs and time, ensures privacy, and allows for access anywhere and anytime. According to previous studies, 72% of psychiatric patients in teaching hospitals owned smartphones, with 50% expressing interest in using them to track their mental health (Smith & Lee, 2020). The results of this study indicate that smartphone-based information systems are effective in early stress detection among pregnant women, as reflected by their perceived ease of use and perceived usefulness. The Technology Acceptance Model (TAM) questionnaire, which evaluates user perceptions through two key variables, which are ease of use (Perceived Ease of Use) and benefit (Perceived Usefulness), enabled the researchers to predict the acceptance of information technology by users (Wu & Chen, 2017; Al-Emran *et al.*, 2018). The simplicity and adaptability of TAM make it a popular model for assessing the acceptance of

information systems.

User evaluation based on the Technology Acceptance Model (TAM) revealed high scores across all domains, including perceived ease of use, perceived usefulness, attitude toward usage, behavioral intention, and actual use. These results align with KEMAS studies, reporting favorable acceptance of digital and video-based educational interventions among pregnant women (Kusumawati *et al.*, 2023; Oktaviani & Hariteluna, 2021). High usability and perceived benefit are critical factors influencing sustained engagement with digital health technologies (Wu & Chen, 2017; Al-Emran *et al.*, 2018). Smartphone-based systems offer several advantages, including portability, immediate feedback, and the ability to function without continuous internet connectivity. These features make such systems particularly suitable for maternal health services in settings with limited access to conventional care (Jones *et al.*, 2021). Integrating digital stress screening and management tools into routine antenatal services may therefore improve early detection of psychological distress and support more comprehensive, patient-centered maternal care (Kusumawati *et al.*, 2023; Tsai *et al.*, 2018).

Conclusion

This study demonstrates that smartphone-based information systems can effectively support early detection and management of stress among pregnant women. The findings indicate that integrating such digital tools into midwifery care enables more systematic monitoring of maternal psychological well-being and facilitates timely, self-directed stress management. The observed improvements in stress outcomes and high user acceptance provide a strong empirical basis for adopting mobile health solutions as a complementary component of routine antenatal services. Incorporating smartphone-based systems may enhance the accessibility and continuity of psychosocial support for expectant mothers. Future studies should examine the sustainability of these interventions over longer periods and evaluate their applicability across diverse healthcare settings to optimize their broader implementation.

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