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The effect of DECO-MOM mobile application for a prenatal environmental health program on environmental health behaviors: a pilot test

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Abstract

Background The DECO-MOM mobile program was developed to enhance prenatal environmental health behaviors among pregnant women, addressing the challenges of climate change and environmental pollution. This pilot study aimed to assess the feasibility and preliminary impacts of the DECO-MOM app on personal and community health behaviors, quality of life, subjective health status, depression, anxiety, and e-learning satisfaction, guided by the revised protection motivation theory.

Methods/Design This non-randomized controlled study employed a pre-post-test design with experimental and control groups. The study analyzed data from 31 participants in the experimental group and 34 in the control group after a four-week mobile application intervention conducted from September 26 to October 24, 2023, in three cities in South Korea.

Results The experimental group demonstrated significant improvements in personal environmental health behaviors ($p = .003$), community environmental health behaviors ($p = .001$), quality of life ($p = .043$), and e-learning satisfaction ($p = .005$) compared to the control group. Significant increases were observed in subcategories such as lifestyle ($p = .005$), dust ($p < .001$), reduction ($p = .011$), involvement ($p = .007$), recycling ($p = .005$), reuse ($p = .035$), content ($p < .001$), and communication ($p = .039$). However, no significant increases were found in subjective health status, depression, or anxiety.

Discussion The DECO-MOM app demonstrated feasibility and potential as a mobile health tool to promote environmental health behaviors among pregnant women. Future studies should explore the long-term effects, scalability, and integration of psychological support features to optimize outcomes.

Trial registration Trial registration Number: KCT0007725, Registered September 22, 2022. Prospectively registered.

Keywords Environmental health, Women, Pregnancy, Health behaviors, Mobile application

Background

The unfolding crisis of climate change presents unprecedented challenges to public health, particularly for vulnerable populations such as pregnant women. The American National Association for Environmental Health has recognized environmental health as encompassing the effects of physical, chemical, biological, and psychosocial factors on human health, a definition that becomes increasingly pertinent as we face escalating

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environmental risks [1]. Pregnant women are of particular concern due to their heightened vulnerability to adverse outcomes from environmental exposures [2, 3].

Climate change exacerbates the spectrum of environmental hazards, from pollution to heatwaves, posing significant threats to maternal and fetal health including neonatal stress and preterm birth [4]. The need for effective interventions is underscored by a growing body of evidence linking environmental pollutants with adverse pregnancy outcomes, including preterm birth, low birth weight, and developmental issues in offspring [2, 3]. Environmental pollution and environmental health factors such as fine particulate matter, air pollution, heavy metals, and chemicals have been shown to contribute to depression, anxiety, and stress in pregnant women [5]. This situation calls for innovative solutions that can empower pregnant women to navigate physical and psychological risks effectively.

Awareness of harmful substances during pregnancy motivates environmental health behaviors [6]. Research on environmental health interventions for pregnant women is scarce. Providing information about exposure to endocrine disruptors in pregnant women's diets increased environmental behaviors [7]. In-person environmental health childbirth classes increased environmental awareness, intention, and behavior among pregnant women [6]. Childbirth education using virtual Zoom meetings and cartoon booklets also increased environmental health vulnerability awareness, self-efficacy, and community health behaviors [8]. It is imperative to consider the potential of mobile health (mHealth) interventions in bridging the gap between environmental health risks and protective health behaviors from environmental hazards. The advent of mHealth offers a promising avenue for enhancing health literacy and facilitating proactive health management, especially in contexts where traditional healthcare access may be limited or where environmental risks are under-recognized [9].

A mobile application, the quintessential mHealth, is needed to leverage the ubiquity and accessibility of mobile technology to educate pregnant women about environmental toxins and promote adaptive health behaviors. However, we could not find any mobile application for pregnant women regarding climate change and environmental health. Therefore, the protocol for a mobile application named Deep ECOlogy MOM application (DECO-MOM app) was developed by drawing upon the revised protection motivation theory (rPTM) as the theoretical foundation [10]. Rogers suggests that perceptions of the severity, susceptibility, response efficacy, self-efficacy, costs, and benefits of health threats can motivate protective health behaviors [11].

By situating the DECO-MOM app within the broader discourse on environmental health, climate change, and digital health innovations, this introduction sets the stage for a nuanced exploration of how technology-driven interventions can make a tangible difference in the lives of pregnant women, offering them tools to safeguard their health and that of their fetus in an increasingly complex environmental landscape. This study aimed to assess the feasibility and preliminary impacts of the DECO-MOM app on promoting environmental health behaviors (personal and community), psychological health (quality of life, subjective health status, depression, and anxiety), and e-learning satisfaction among pregnant women. Feasibility was evaluated based on e-learning satisfaction and participants' adherence to the program. By exploring the potential of technology-driven interventions, this research contributes to addressing critical gaps in prenatal environmental health management (Fig. 1).

Methods

Study design

This study employed a non-randomized controlled pilot design with pre- and post-test assessments for experimental and control groups. This study adhered to the Transparent Reporting of Evaluations with Non-randomized Designs (TREND) guidelines [12]. The study protocol was registered in the Korean Clinical Research Information Service on September 22, 2022 (KCT0007725: https://cris.nih.go.kr/cris/search/detailSearch.do?seq=22378&status=5&seq_group=22378&search_page=M. [13].

Setting

Participants were recruited from three public health care centers in Chuncheon, Jeonju, and Gongju cities (in Gangwon, Jeonrabuk, and Chungcheongnam Provinces, respectively) in South Korea. The public centers provided maternal-child healthcare services, offering birth education to pregnant women. Researchers were permitted for study and data collection from the healthcare centers and participated prenatal education as lecturers. Researchers provided a mobile application QR code of the website address for the experimental group after written consent to participate in the study and treatment as usual (TAU) education program for the control group.

Inclusion and exclusion criteria

The participants were included as follows: 1) pregnant women at gestational ages of 4–36 weeks, 2) age over 20 years, 3) ownership of a smart gadget, and 4) Korean language literacy. The exclusion criteria were 1) hospitalization due to physical or psychological health problems

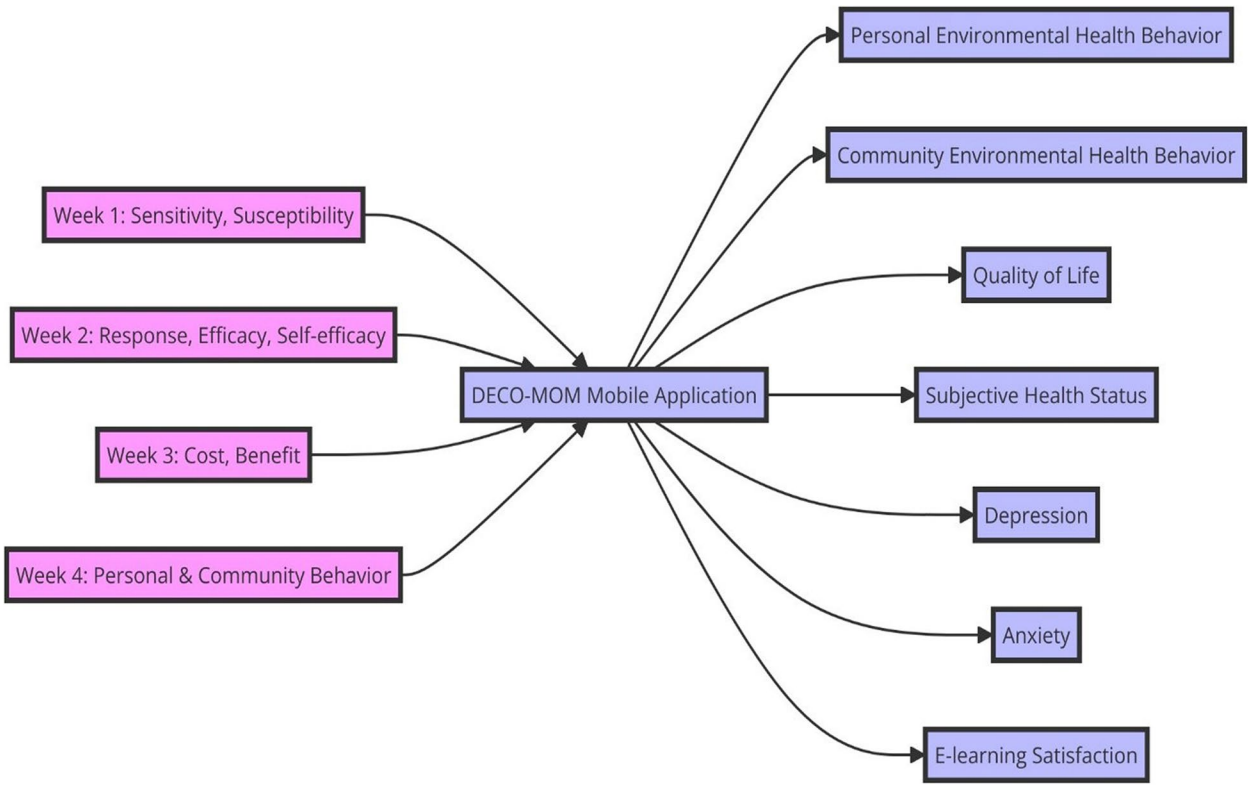


Fig. 1 Theoretical framework of revised protection motivation theory

and 2) currently receiving medical treatment due to fetal or maternal disease.

Allocation

Convenience sampling was used to allocate 1:1 parallel allocation. The participants recruited from Chuncheon city were allocated to the control group applied only TAU and the participants from Jeonju and Gongju cities in South Korea were allocated to the experimental group applied mobile application. These three cities were middle-sized urban–rural cities with similar socioeconomic and cultural statuses to avoid potential heterogeneous bias. The researcher contacted the pregnant women and explained the study's purpose, procedure, and benefits. The pre-test was performed before the mobile application and TAU, the intervention lasted for 4 weeks, and the post-test was administered just after the intervention between September 26 and October 24, 2023 (Fig. 2).

Sample size

The G*Power 3.1.4.9 [14] calculated the sample size as 32 and 32 in both groups with designated a one-tailed test, the independent t-test, 0.59 effect size (f), 0.75 power, 0.05 significance level, and a 1:1 allocation ratio [15]. The effect size (Cohen's d) was calculated by 18.45 ± 13.13 and 9.68 ± 8.24, resulting in a Cohen's d of 0.59 according to the previous study [6]. The sampling was 35 and 35 participants in both groups considering a conservative rate of 10%. Four participants withdrew from the mobile group due to schedule conflicts involving hospital visits or house chores. In total, 31 participants in the experimental group and 34 in the control group were analyzed. The adherence rates for the experimental and control groups were 88.57% and 97.14%.

Intervention

Intervention group

The DECO-MOM intervention was designed as a four-week program, delivered via a mobile application, aimed at educating pregnant women on environmental toxins and promoting adaptive environmental health behaviors. The Android system was used to develop the application. Grounded in the revised protection motivation theory (rPMT), the program operationalizes the theory's constructs—severity, susceptibility, response efficacy, self-efficacy, costs, and benefits [11]—into weekly themes that progressively aimed to: enhance understanding of environmental risks, motivate protective health behaviors, balance the perceived benefits against costs of such behaviors, and empower both individual and communal

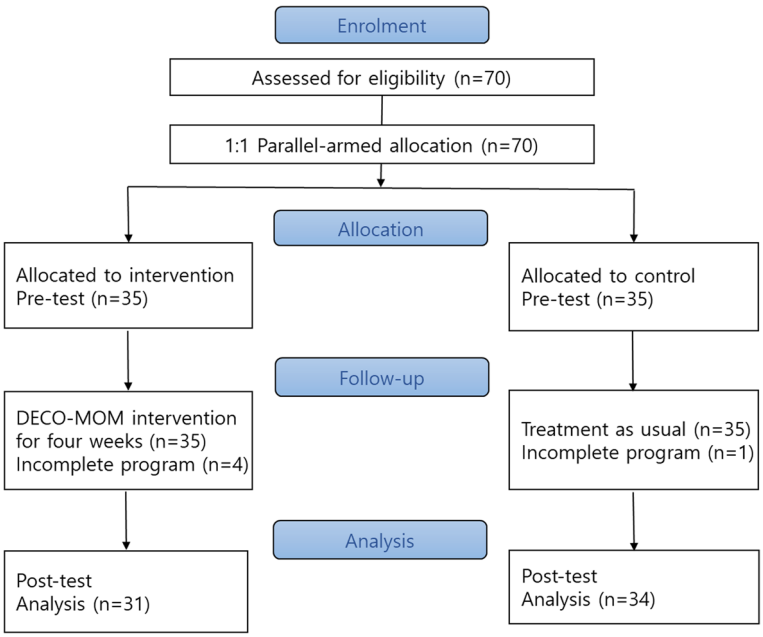


Fig. 2 Flow diagram of the research process

action towards environmental health. This intervention was supported by weekly telephonic follow-ups by a research assistant and facilitated through the widespread KakaoTalk social networking service in Korea, ensuring participant engagement and adherence to the program protocols.

The "DECO-MOM environmental prenatal health program" is structured as a mobile application designed to educate pregnant women on climate change and environmental health over a four-week period. Each week targets different aspects of environmental health through varied educational methods to engage participants.

In the first week, the focus was on raising awareness regarding the reproductive health problems of maternal, fetus, and child (severity). The potential harms from chemicals, electromagnetic waves, and unsafe foods, along with discussing reproductive and general health issues (susceptibility). This was delivered through an orientation session, cartoons for visual learning, explanations for depth understanding, a 5-min video developed by a researcher, and a question-and-answer segment for interaction, each segment lasting 30 min.

The second week aimed to empower women with knowledge on avoiding environmental toxins and enhancing their health and that of their fetus (response efficacy), addressing topics such as empowering preventive judgment and control (self-efficacy). A 5-min video developed by a researcher, cartoons, and explanations were used, followed by a question-and-answer session, mirroring the first week's duration and teaching methods.

Week three discussed the trade-offs and benefits of making lifestyle adjustments, focusing on the positive (benefits) and negative aspects (costs) of unhealthy environmental behaviors and highlighting the psychological and physical gains from healthier choices. The session used a 5-min video developed by a researcher, cartoons, explanations, and a Q&A format for delivery, each lasting 30 min.

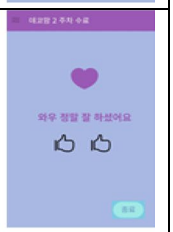
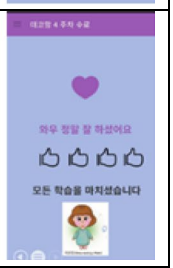
The final week broadens the scope to include changes in personal and community behavior to avoid climate change and exposure to environmental toxins, touching on lifestyle adjustments and community engagement in environmental health practices (motivated health behaviors). It leveraged a 5-min video developed by a researcher, cartoons, explanations, a question-and-answer segment, introduces a trophy system likely for motivation or achievement recognition, and concludes with a wrap-up session. Each method was designed to last for 30 min.

Overall, the program was meticulously designed to educate, engage, and empower pregnant women regarding climate change and environmental health, utilizing a blend of educational methods to cater to different learning preferences and effectively communicate complex information (Table 1).

Control group

For the control group, Treatment As Usual (TAU) was administered through in-person instruction over a four-week period. These sessions took place in the maternity

Table 1 DECO-MOM environmental prenatal health program as a mobile application

Session	Step	Themes	Content	Methods	Duration	Screen shot	
Week 1	Sensitivity Susceptibility	-Chemicals, electromagnetic waves, harmful food -Reproductive & general health problems	30 minutes	Orientation Cartoon Explanation Question and Answer	30 minutes		
Week 2	Response Efficacy Self-efficacy	-Avoid toxicants, pursuit of health -Preventive, judgment, & control efficacy	30 minutes	Animation Cartoon Explanation Question and Answer	30 minutes		
Week 3	Cost Benefit	-Negative atmosphere & burden -Psychological & physical gain	30 minutes	Animation Cartoon Explanation Question and Answer	30 minutes		
Week 4	Personal Behavior Community Behavior	-Lifestyle, personal goods, food, & dust -Reduction, involvement, recycling, & reuse	30 minutes	Animation Cartoon Explanation Question and Answer Trophy Wrap-up	30 minutes		

classroom at the public health center, each lasting two hours and led by two professors specializing in women's health and a midwife. The curriculum covered a range of topics including: 1) comprehension of pregnancy and fetal development; 2) managing pain during childbirth, alongside techniques for relaxation and breathing throughout labor; 3) care after childbirth and breastfeeding practices; and 4) caring for a newborn infant.

Measurements

The questionnaires were distributed via online survey using a Naver Form respectively through the KakaoTalk messenger. The online survey took from 10 to 15 min. Online gift worth 7 dollars was provided to the participants twice after the pre- and post-test. The questionnaire used to measure the primary outcome of this study employed a tool developed and published [16] by the researcher to assess women's environmental health behaviors (see Appendix 1).

Primary outcomes

Personal environmental health behavior Personal environmental health behavior was measured using the Women's Environmental Health Behavior (WEHB) scales [16]. The WEHB consists of four factors: 7 lifestyle, 4 personal hygiene, 3 diet, and 3 dust-related behaviors (total 14 items). The WEHB was measured by a Likert scale, ranging from 1 (not at all) to 5 (strongly agree). Total scores ranged from 14 to 60, the higher score meant the higher personal environmental behavior. The Cronbach's alpha values for internal consistency reliability were 0.90 for the original scale and 0.88 in this study.

Community environmental health behavior Community environmental health behavior was measured using the Women's Environmental Health Behavior (WEHB) scales [16]. The WEHB consisted of four factors with 5 items on reduction, 5 on involvement, 3 on recycling, and 3 on reuse behaviors (total 16 items). The WEHB was measured by a Likert scale, ranging from 1 (not at all) to 5 (strongly agree). Total scores ranged from 16 to 90, the higher score meant the higher community environmental behavior. The Cronbach's alpha was 0.90 for the original scale and 0.89 in this study.

Secondary outcomes

Quality of life Quality of life was measured using the EuroQol-5D (EQ-5D) [17], and the Korean version of the EQ-5D was used [18]. The EQ-5D consists of 5 items, assessing mobility, self-care, usual activity, pain/discomfort, anxiety/depression. The EQ-5D was measured using a Likert scale, ranging from 1 (not at all) to 4 (nearly every day). Total scores ranged from 5 to 20, with higher scores indicating lower quality of life. Cronbach's alpha was 0.61 for the original scale and 0.75 in this study.

Subjective health status

Subjective health status was measured using the EQ-VAS [17], and the Korean version of the EQ-VAS was used [18]. EQ-VAS had one question of 'The worst health you can imagine' and numbered from 0 (the worst health respondent can imagine) to 100 (the best health respondent can imagine). When presenting data with the central tendency, the mean value and the standard deviation could be used or, if the data are skewed, it may be preferable to present the median values and the interquartile range (IQR).

Depression

Depression was measured using the ultra-short depression screener Patient Health Questionnaire (PHQ-2) [19], and the Korean version of the PHQ-2 was used [20]. A total score of 3 or greater should prompt administration of the full PHQ-9, as well as a clinical interview to determine whether a mental disorder is present. The PHQ-2 was measured using a Likert scale, ranging from 1 (not at all) to 4 (nearly every day). Total scores ranged from 4 to 8, with higher scores indicating higher depression. Cronbach's alpha was 0.61 for the original scale and 0.82 in this study.

Anxiety

Anxiety was measured using the General Anxiety Disorder-7 (GAD-7) [21] and the Korean version of the GAD-7 will be used [22]. The GAD-7 had seven items using a Likert scale, ranging from 1 (not at all) to 4 (nearly every day). Total scores ranged from 7 to 28, with higher scores indicating higher anxiety. Cronbach's alpha was 0.97 for the original scale and 0.85 in this study.

E-learning satisfaction

E-learning satisfaction was measured using the E-Learning Satisfaction Scale (eLSS) (17 items) [23]. The eLSS consisted of three factors with 8 content, 5 interface, and 4 communication items (total 17 items). The eLSS was measured by a Likert scale, ranging from 1 (not at all) to 5 (strongly agree). Total scores ranged from 8 to 40, with higher scores indicating greater content satisfaction. Cronbach's alpha for internal consistency reliability was 0.93 for the original scale and 0.95 in this study.

General and obstetric characteristics

The general characteristics were elicited self-reported information, including age, present disease, and employment status. The obstetric characteristics included gestational age and number of children.

Ethical consideration

This study was approved by the Institutional Review Board of Jeonju University (jjIRB-231214-HR-2023–1014) and adhered to the Declaration of Helsinki. Informed consent was obtained from all participants in the study.

Statistical analysis

This study used SPSS for Windows version 27.0 (IBM Corp., Armonk, NY, USA). The homogeneity test was performed using t-test and chi-square test between the two groups. Shapiro–Wilk test was used to test normality, linearity, and residual independence. The independent t-test was used to test the study hypothesis.

Hypothesis 1: The mobile group would have higher scores for personal and community environmental health behaviors than the TAU group.
Hypothesis 2: The mobile group would have higher scores for quality of life, subjective health status than the TAU group.
Hypothesis 3: The mobile group would have lower scores for depression and anxiety than the TAU group.
Hypothesis 4: The mobile group would have higher scores for e-learning satisfaction than the TAU group.

Results

Homogeneity between groups

The characteristics compared include age, gestational age, number of children, present disease, employment status, personal environmental health behavior (with subcategories: lifestyle, personal goods, diet, dust), community environmental health behavior (with subcategories: reduction, involvement, recycle, reuse), quality of life, subjective health status, depression, anxiety, and e-learning satisfaction. The results indicate no significant differences between the control and experimental groups across most variables, suggesting homogeneity in terms of demographics and baseline measures (Table 2).

Effects of the "DECO-MOM" prenatal mobile program

The total score of personal environmental health behavior was significantly increased from 55.85 (SD = 6.48) in the control group to 62.32 (SD = 10.38) in the experimental group ($p = 0.003$). Subcategories as lifestyle ($p = 0.005$) and dust ($p < 0.001$) also showed significant improvements. Total scores of community environmental health behavior significantly improved from 54.18 (SD = 5.58) in the control group to 60.48 (SD = 9.27) in the experimental group ($p = 0.001$). Improvements were noted across all subcategories; reduction ($p = 0.011$), involvement ($p = 0.007$), recycle ($p = 0.005$), and reuse ($p = 0.035$).

Score of quality of life was increased in the experimental group (M = 7.53, SD = 2.03) compared to the control group (M = 6.55, SD = 1.76) ($p = 0.043$). Total score of e-learning satisfaction increased from 57.76 (SD = 11.71) to 65.10 (SD = 8.13) significantly ($p = 0.005$). Subcategories as content satisfaction ($p < 0.001$) and communication satisfaction ($p = 0.039$) increased significantly in the experimental group compared to the control group. There were no significant results for subjective health status, depression, and anxiety (Table 3).

Table 2 Analysis of homogeneity between groups ($N = 65$)

Characteristics	Control group ($n = 34$) n (%) / M (SD)	Experimental group ($n = 31$) n (%) / M (SD)	t/χ^2	*p*
Age (years)	34.35 (4.22)	33.06 (4.36)	1.20	.231
Gestational age (weeks)	24.35 (7.45)	28.03 (7.79)	−1.94	.057
Number of children	0.50 (0.62)	0.77 (0.96)	−1.38	.170
Present disease				
Yes[a]	9	11	0.84	.772
No	22	23		
Employment				
Employed	14	14	0.11	.746
Unemployed	17	20		
Personal environmental health behavior				
Total	55.74 (13.47)	57.10 (8.35)	−0.48	.629
Lifestyle	22.56 (5.36)	23.58 (3.68)	−0.88	.378
Personal good	14.21 (4.72)	13.94 (3.49)	0.26	.759
Diet	7.53 (2.57)	7.81 (2.12)	−0.47	.639
Dust	11.44 (3.21)	11.77 (1.27)	−0.51	.609
Community environmental health behavior				
Total	51.50 (12.01)	55.74 (10.12)	0.38	.705
Reduction	14.08 (3.88)	16.39 (3.93)	0.86	.389
Involvement	14.88 (4.10)	15.84 (3.89)	0.75	.452
Recycle	10.82 (3.81)	12.06 (2.11)	−0.62	.537
Reuse	10.26 (2.64)	11.45 (2.16)	−0.14	.888
Quality of life	7.51 (1.79)	6.65 (1.47)	1.22	.225
Subjective health status	73.12 (11.51)	67.42 (17.02)	1.36	.176
Depression	10.32 (3.85)	10.45 (3.50)	−0.14	.889
Anxiety	2.76 (0.92)	3.10 (1.32)	−1.18	.242
E-learning satisfaction	32.15 (6.40)	29.90 (6.08)	1.44	.153

M mean, *SD* Standard deviation

[a] Anemia, cystitis, cough, gestational diabetes, headache, hemorrhoid, hyperthyroidism, hypothyroidism, hypertension, hypotension, rhinitis

Table 3 Effects of "DECO-MOM" prenatal mobile program on environmental health behaviors, quality of life, depression, anxiety, and satisfaction ($N=65$)

Characteristics	Control group ($n=34$) n (%) / M (SD)	Experimental group ($n=31$) n (%) / M (SD)	t/χ^2	*p*
Personal environmental health behavior				
Total	55.85 (6.48)	62.32 (10.38)	−3.04	.003
Lifestyle	22.68 (3.96)	25.82 (4.77)	−0.82	.005
Personal good	14.35 (2.76)	15.00 (3.52)	0.26	.411
Diet	8.24 (1.72)	9.03 (2.47)	−1.51	.134
Dust	10.59 (1.50)	12.48 (1.98)	−4.37	< .001
Community environmental health behavior				
Total	54.18 (5.58)	60.48 (9.27)	−3.38	.001
Reduction	16.03 (1.56)	17.71 (3.35)	−2.62	.011
Involvement	15.74 (2.71)	18.00 (3.82)	−2.77	.007
Recycle	11.38 (1.81)	12.81 (2.12)	−2.92	.005
Reuse	11.03 (1.66)	11.97 (1.85)	−2.15	.035
Quality of life	6.55 (1.76)	7.53 (2.03)	−2.06	.043
Subjective health status	71.29 (20.54)	77.42 (21.12)	−1.18	.241
Depression	10.85 (3.06)	9.77 (2.85)	1.45	.151
Anxiety	2.62 (0.95)	2.97 (1.27)	−2.25	.213
E-learning satisfaction				
Total	57.76 (11.71)	65.10 (8.13)	−2.90	.005
Content	26.35 (5.62)	31.10 (3.78)	−3.94	< .001
Interface	17.85 (4.40)	18.97 (3.06)	−1.17	.245
Communication	13.56 (3.11)	15.03 (2.44)	−2.11	.039

M Mean, *SD* Standard deviation

Discussion

In this study, the DECO-MOM app demonstrated potential in promoting environmental health behaviors in personal and community aspects, improving quality of life, and increasing satisfaction with the app. However, no statistically significant changes were observed in psychological health outcomes, such as subjective health status, depression, and anxiety. As a result, hypotheses 1 and 4 were preliminarily supported, while hypotheses 2 and 3 were not. These findings suggest the feasibility of using technology to disseminate critical health information and encourage behavioral change at personal and community levels. Furthermore, the insights gained from e-learning satisfaction highlight the elements that may increase user engagement and satisfaction in digital health education contexts. Larger, randomized studies with extended follow-up periods are necessary to further explore the efficacy and long-term impact of the DECO-MOM app.

The effectiveness of this study is attributed to the rPMT, which recognizes that pregnant women are vulnerable to climate change and environmental pollution and perceive real risks to their health [11]. Personal lifestyle and health behaviors to prevent microdust triggered health behavior response efficacy, and community environmental health behaviors of reducing, engaging, recycling, and reusing stimulated self-efficacy to respond to climate change [11]. Climate change encompasses a broad spectrum of environmental alterations, including rising temperatures, increased exposure to pollutants, and the proliferation of vector-borne diseases, all of which pose significant health risks. For pregnant women, these environmental stressors can lead to adverse pregnancy outcomes, such as preterm birth, low birth weight, birth defects [24], and developmental issues in children [25]. The susceptibility of pregnant women to these environmental factors was attributed to physiological changes during pregnancy that can alter their response to heat, pollutants, and infectious agents. The intrauterine environment, crucial for fetal development, was sensitive to external environmental conditions, making it imperative to protect maternal health from the adverse effects of climate change [25].

The feasibility of this intervention was demonstrated to a moderate extent through acceptable levels of adherence and participant satisfaction. This study's adherence rates for the experimental and control groups were

88.57% and 97.14%, respectively, which are attributed to the short intervention duration and small number of participants. Adherence to internet-based interventions is often challenging, with dropout rates ranging from 18.0% to 87.5% and typically increasing with longer intervention durations [26]. Strategies such as coaching, social support, and notifications can help improve participant engagement and consistency [26]. The results of positive e-learning satisfaction reported by participants further validate the design and content delivery approach of the DECO-MOM program. The satisfaction is indicative of the program's ability to engage users effectively, a critical factor in the success of any health intervention [27]. This study showed that content satisfaction and communication satisfaction were effective, but interface satisfaction was not, suggesting that it is necessary to use more convenient and attractive technologies for users when developing environmental health apps. Gamification strategies, such as personalized avatars, progress tracking, interactive features, and visual rewards like badges and leaderboards, can significantly improve user engagement and motivation. Additionally, incorporating aesthetic elements, such as an intuitive and visually appealing design, dynamic feedback mechanisms, and customizable user interfaces, could address the low satisfaction with the interface of the DECO-MOM app. Leveraging these gamification techniques can create a more immersive and enjoyable user experience, enhancing both satisfaction and adherence [28].

While previous studies in digital healthcare for pregnant women have shown benefits for depression [29], anxiety [29, 30], and subjective well-being [31], this study did not show significant psychological effects. In a meta-analysis of internet-based prenatal education to reduce depression and anxiety, delivering an intervention more times was associated with a greater effect, and the number of times the intervention was delivered ranged from 12 to 39 sessions and 5 to 18 weeks prenatally. Therefore, it is necessary to increase the number and duration of interventions in this study to over 12 and add a booster intervention [26]. The lack of effect on psychological health outcomes in this study could be attributed to the lack of social support during app use. Communication was noted as a key factor affecting the sustainability of mobile apps, so future research should incorporate this factor into the design and evaluation of tools [29]. Mental health experts ought to be strategically involved in mitigating the adverse effects of climate change by delivering essential psychological assistance and incorporating mental health aspects into the broader framework of climate resilience strategies [32]. The low levels of subjective well-being and happiness globally were linked to exposure to environmental factors during pregnancy [33]. Implementing mobile health interventions that focus on environmental health during pregnancy could enhance healthcare quality. Additionally, these interventions can encourage women to take a more active role in managing their own health, ultimately leading to empowered attitudes, healthier environmental health behaviors [32].

This study had several limitations. First, the non-randomized controlled design introduced potential biases, limiting the internal validity of the findings. The lack of randomization, due to challenges in recruiting participants as planned in the protocol, raises concerns about selection bias. Future studies should consider employing randomized designs to improve the reliability of results and minimize bias. Second, the small sample size of pregnant women in three Korean cities further restricts the generalizability of the findings. The conclusions of this study should be regarded as preliminary and not applicable to broader populations without further research involving larger and more diverse samples. Third, the study did not address health equity, as it excluded individuals with limited digital literacy or migrant women, focusing only on participants fluent in Korean and proficient in using digital devices. Fourth, while the researchers provided a mobile app and encouraged participation through social networking services, the lack of individualized social support may have contributed to the lack of significant improvements in mental health outcomes. While the app focused on education and behavioral change, it did not include structured psychological or social support, such as peer interaction or counseling services. This omission could explain the lack of significant improvements in depression, anxiety, or subjective health status. Fifth, the study measured outcomes immediately after the four-week intervention, without assessing the long-term effects of the app. The lack of long-term follow-up data limits the ability to assess the sustainability of the observed behavioral changes and whether the app's benefits persist over time. Future research with extended follow-up periods is necessary to evaluate the sustained impact of the intervention. Lastly, participant feedback indicated lower satisfaction with the app's interface, suggesting that technical limitations or usability issues may have affected engagement and adherence. Future iterations of the app should integrate user-centered design principles, including gamification elements, intuitive navigation, and personalized features to enhance user experience.

The DECO-MOM study, which explored the use of a mobile application for prenatal environmental health education, provides preliminary insights with potential implications for public health strategies and future research in environmental health and mHealth

interventions. The study highlights the importance of integrating environmental health education into prenatal care to address the unique vulnerabilities of pregnant women. While the findings indicate the feasibility of using mobile technology to promote environmental health behaviors, they should be interpreted with caution due to the study's design and scope limitations. Tailoring interventions to individual needs and carefully considering the physical and psychological circumstances of pregnant women could enhance the effectiveness and acceptability of such programs. Future research should focus on evaluating the long-term impacts, scalability, and integration of supportive features, including social support mechanisms such as peer interactions or counseling, to optimize outcomes. Ensuring that interventions remain accessible, equitable, and socially engaging is essential for fostering sustained participation and improving health outcomes.

The DECO-MOM study lays the groundwork for future research in key areas. There is a need for further studies to explore the long-term effects of prenatal environmental health interventions on maternal and neonatal outcomes. Such research could provide deeper insights into the potential for mHealth tools to contribute to reducing adverse birth outcomes associated with environmental exposures. In conclusion, the DECO-MOM study not only demonstrates the effectiveness of a mobile application in improving environmental health behaviors and e-learning satisfaction among pregnant women but also reflects the potential of digital health interventions in enhancing environmental health outcomes.

Trial status

Registered before recruiting.

Abbreviations

DECO-MOM	DEep Ecology-MOM
GAD-7	General anxiety disease
e-LSS	E-learning satisfaction scale
EQ-5D	European quality of life 5-dimension
EQ-VAS	European quality of life Visual Analogue Scale
PHQ-2	Patient Health Questionnaire-2
QR	Quick response
rPMT	The revised protection motivation theory
TAU	Treatment As Usual
TREND	Transparent Reporting of Evaluations with Nonrandomized Designs
WEHB	Women's environmental health behavior

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12884-025-07361-1.

Supplementary Material 1. Appendix 1. Women's Environmental Health Behavior scales.

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Authors' contributions
HKK participated in the conception and design of the study. HKK and JHK acquired data and drafted the first and final versions of the manuscript.

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Data availability
The data that support the findings of this study are available on request from the corresponding author.

Declarations

Ethics approval and consent to participate
This study was reviewed by the Institutional Review Board of Institutional Review Board of Jeonju University (jjIRB-231214-HR-2023–1014) and adhered to the Declaration of Helsinki. Participants completed written consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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