Developing Anemia Prevention Interventions for Pregnant Women with the Behavior Change Wheel

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Abstract

Pregnancy anemia is a significant public health issue in Indonesia, requiring effective monitoring of iron tablet use with support from spouses and healthcare workers. Previous interventions often lacked strong theoretical foundations and population-specific approaches. This study documents the systematic development of the ANECMA intervention, integrating the Behavior Change Wheel (BCW) framework based on feedback from target users. The study involved 18 pregnant women, five spouses, and nine healthcare providers (midwives, nutritionists, and general practitioners) from primary healthcare centers in Surakarta, Indonesia, in 2024. Semi-structured interviews and consultation sessions were conducted, and findings were analyzed using deductive and inductive methods within the BCW framework. Behavioral analysis (Steps 1–4) identified nine intervention goals aligned with the COM-B components: Capability, Opportunity, and Motivation. Six intervention functions and 16 behavior change techniques were chosen to drive behavior change. The intervention employs a triadic approach, engaging spouses and healthcare providers to support pregnant women's anemia prevention behaviors, complemented by a mobile app. This study outlines the rationale for selecting intervention components and behavior change techniques. It provides a practical guide to using the BCW framework, emphasizing the active involvement of target groups and stakeholders in designing effective interventions to prevent pregnancy anemia.

Keywords

Anemia prevention; Behaviour Change Wheel; COM-B model; Intervention development study; Pregnancy anemia

Introduction

The World Health Organization (WHO) (2023) estimated the prevalence of anemia in pregnant women is 37%, making it a priority global health problem. Anemia in pregnancy increases the incidence of maternal death and fetal death (Basnet et al., 2022; Means, 2020; Zamané et al., 2019). Anemia in pregnant women is a priority health problem in Indonesia, with a prevalence of 27.7% based on the 2023 Indonesian Health Survey (Ministry of Health, 2024). Surakarta, a city in Central Java, exhibits a disparity in the prevalence of anemia among pregnant women across several health centers within its area. Three healthcare centers continued to have prevalence rates above 20%, indicating a need for immediate attention (BPS-Statistics Surakarta Municipality, 2022).

The WHO (2016, 2024) recommends preventing anemia by routinely giving iron and folic acid (IFA) supplements to pregnant women. The Indonesian government mandates providing a minimum of 90 IFA tablets to pregnant women. Indonesian Health Survey data indicate that only 56.5% of pregnant women received more than 90 tablets during pregnancy, and only 44.2% consumed IFA for more than 90 tablets (Ministry of Health, 2024; Pathirathna et al., 2020). The 2020 Integrated Antenatal Services policy introduced the IFA consumption monitoring form through the KIA book (Ministry of Health, 2020), but this remains unimplemented and lacks program indicators to measure and report on IFA consumption.

The WHO (2016, 2024) likewise advocates nutritional education to promote healthy eating and prevent anemia during pregnancy. However, many pregnant women fail to follow dietary guidelines, doubling their risk (Pathirathna et al., 2020; Rohmatin & Mustikanigrum, 2024). In Indonesia, antenatal care often lacks adequate nutrition counseling, and adherence to IFA supplementation and proper nutritional fulfillment is challenging (Arifah et al., 2024; Rahmawati et al., 2021). Husbands' and health workers' support are critical for adopting sustainable behavioral changes to prevent and manage anemia (Mutalazimah & Rahayu, 2019).

Efforts to improve behavior for preventing pregnancy anemia have gained attention over the past decade (Nahrisah et al., 2020). WhatsApp-based health information packages, incorporating weekly counseling, reminders, and educational messages, improved IFA adherence (Elsharkawy et al., 2022). Direct IFA consumption monitoring involves the support of health workers or family members (Ahamed et al., 2018). Participatory action research involved problem screening, counseling, behavioral change, and evaluation (Shivalli et al., 2015), highlighting the importance of education, engagement, and health worker support, though high workloads often hinder long-term implementation (Darmawati et al., 2020; Widyawati et al., 2015).

The use of mobile health (mHealth) technology offers a sustainable alternative for anemia prevention. By 2022, 57% of Indonesians used mobile health tools, with 83% of adults having interacted with health applications within the past three months (Octavius & Antonio, 2021). Research shows mHealth interventions can improve client empowerment, access to health services, and service quality (Vo et al., 2019). Applications like ANEDOC offer IFA supplementation reminders but rely heavily on health workers, raising sustainability concerns (Andriani et al., 2022; Falah et al., 2022; Fertimah et al., 2022). Government programs like the e-Cohort focus on antenatal care reporting but lack a dedicated application for anemia prevention.

A previous study in Indonesia highlights the crucial role of husbands as key supporters of pregnant women (Arifah et al., 2024). This finding underscores the potential of a new mHealth application that incorporates husband involvement to improve adherence and outcomes, complementing health workers' supervision (Alaiad et al., 2019; Arifah et al., 2024; Morrison et al., 2021). Consistent with the Socio-Ecological Model (SEM), multiple levels of influence, such as organizational factors (e.g., provider engagement) and interpersonal factors (e.g., spousal support), collectively shape individual behavior of anemia prevention (Sedlander et al., 2020). Integrating these perspectives could address sustainability challenges and further enhance the effectiveness of anemia prevention programs.

Previous studies on digital interventions for anemia prevention in pregnant women often lack a theoretical framework, focusing primarily on features like reminders rather than comprehensive behavior change (Fertimah et al., 2022; Firmansyah et al., 2020). These interventions emphasize education or counseling without integrating strategies to empower women for sustainable behavioral shifts (Elsharkawy et al., 2022; Nahrisah et al., 2020). To address these gaps, mobile applications should be grounded in robust theoretical frameworks to incorporate behavior change techniques, ensuring long-term impact. Empowering pregnant women to adopt anemia-prevention behaviors requires addressing their capabilities, opportunities, and motivations (Darmawati et al., 2020, 2022; Mishra et al., 2021).

The Behavior Change Wheel (BCW), rooted in the COM-B model, provides a systematic framework with nine intervention functions and 93 behavior change techniques (Cane et al., 2012; Michie et al., 2014). However, previous interventions have primarily focused on women alone. Incorporating socio-ecological model (SEM) factors, such as the roles of spouses and healthcare providers, can enhance intervention acceptability and sustainability by addressing interpersonal and organizational influences on behavior. End-user participation further ensures that interventions are tailored to real needs and feasible in practice (Leask et al., 2019; Maenhout et al., 2023). Therefore, this study aims to document the systematic development of the ANECMA intervention to support anemia prevention behaviors among pregnant women, detailing the application of the BCW framework while integrating socio-ecological considerations.

Method

Study design

This study represents the first phase of the ANECMA intervention development, guided by the Medical Research Council (MRC) Framework and the Behavior Change Wheel (BCW) (Michie et al., 2013). A qualitative descriptive design, with stakeholder consultation, was used to inform the intervention's initial design.

The development process followed the BCW's eight-step approach through three stages:

1. Understand the problem and behavior (Steps 1–4). In this stage, the research team conducted a qualitative exploration (April 2023–January 2024). Semi-structured interviews with pregnant women, spouses, and health providers to identify barriers, enablers, and support needs for anemia prevention.

2. Identification of intervention option (Steps 5–6) (January–June 2024). Findings were synthesized with literature and theory to define target behaviors, select intervention functions, and outline ANECMA's preliminary components.

3. Identification, intervention content, and implementation (Steps 7–8). Stakeholder consultation was conducted in a workshop with the research team (June–December 2024). Healthcare providers reviewed and refined the proposed intervention to ensure feasibility and contextual relevance.

Study setting

The study was conducted in three primary healthcare centers (Puskesmas) in Surakarta City, Central Java, Indonesia: Sangkrah, Gilingan, and Kratonan. These areas represent diverse urban settings: Sangkrah (Pasar Kliwon Subdistrict) is densely populated with lower socioeconomic conditions; Gilingan (Banjarsari) combines residential and small commercial areas; and Kratonan (Serengan) consists of compact urban housing with accessible primary health services. Most households own at least one smartphone, though internet access varies, particularly among low-income families who rely on prepaid data. The Surakarta City Health Office supervises all three Puskesmas. The sites were selected based on anemia prevalence reported and each Puskesmas's readiness to collaborate in intervention development.

Participants

Participants were recruited from three primary healthcare centers in Surakarta, a city in an urban area. The qualitative phase included 18 pregnant women (nine with anemia and nine without anemia) and five spouses (≥16 weeks of gestation, ≥2 ANC visits), three midwives, three nutritionists, and three general practitioners. Among the 18 pregnant women, eight were in their first pregnancy. Most had completed senior high school (12), most were housewives (10), five were employed, and three were self-employed. The sample included both anemic (9) and non-anemic (9) women, all of whom owned mobile phones with active data plans (Arifah et al., 2024). Participants were recruited purposively to represent key user groups involved in anemia prevention. The sampling aimed to capture a range of experiences and perspectives relevant to the design and feasibility of the ANECMA intervention. Given that the study was formative and aimed at intervention development rather than theory generation, sample adequacy was guided by the concept of information power (Malterud et al., 2016).

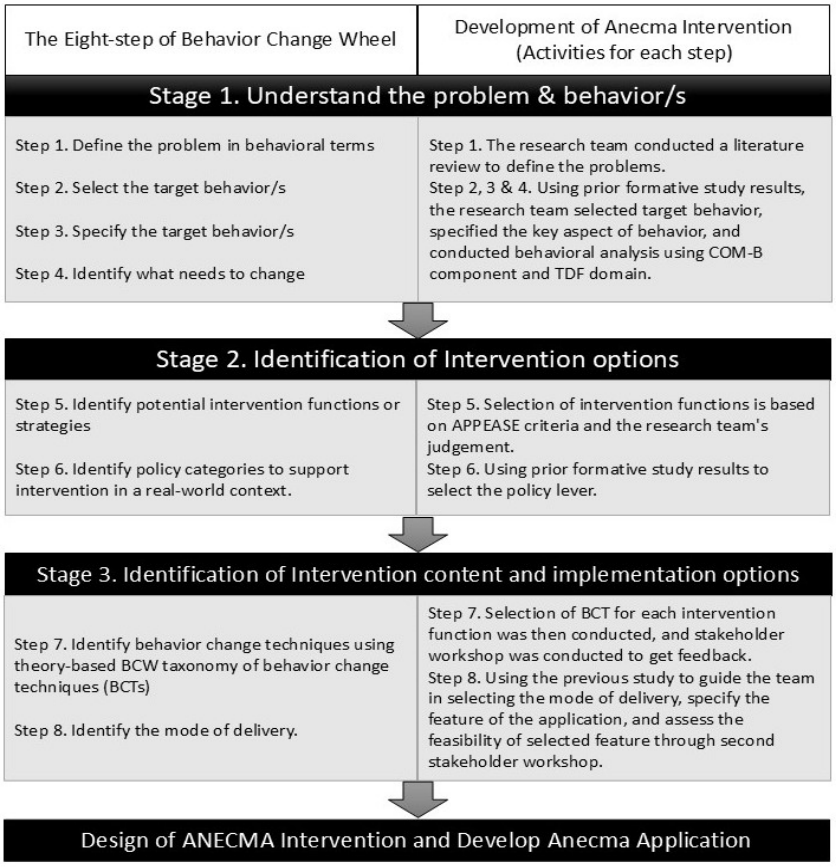
The stakeholder consultation phase involved nine healthcare providers (three midwives, three nutritionists, and three general practitioners) who had been previously interviewed. The group comprises nine female healthcare providers aged 28–59. The stakeholder workshop was held twice, each session lasting about two hours. Data were collected through interviews lasting 45–60 minutes and stakeholder workshops lasting 90–120 minutes, facilitated by the research team and trained assistants. Low-fidelity prototypes of the ANECMA application (paper-based mock-ups) were introduced to gather user feedback on design, functionality, and content. All sessions were conducted in Bahasa Indonesia, audio-recorded, and transcribed verbatim. English translations were prepared by a bilingual researcher and verified for accuracy.

All participants provided informed consent, and ethical approval was obtained from the Health Research Ethics Committee at Universitas Muhammadiyah Surakarta (No. 4997/B.2KEPK-FKUMS/VIII/2023).

Designing an intervention using the BCW development process

The eight steps of the Behavior Change Wheel (BCW) framework were applied to develop the intervention, integrating theoretical foundations (COM-B model), researchers' expertise, and participants' experiences (Michie et al., 2014). In Step 1, the Principal Investigator (PI) conducted a literature review to define the problem as "insufficient anemia prevention behavior among pregnant women." Step 2 selected the target behavior, and Step 3 refined it to enhance anemia-prevention behaviors, specifying the population, behavioral changes, and context. In Step 4, behavioral goals were mapped to COM-B components and Theoretical Domains Framework (TDF) domains, supported by a list of barriers and facilitators derived from qualitative data. In Step 5, the research team linked COM-B components to BCW intervention functions, selecting functions based on affordability, practicability, effectiveness, acceptability, safety, and equity. Step 6 identified supporting policies, guided by prior input from healthcare providers. Step 7 focused on selecting Behavior Change Techniques (BCTs) using the BCT taxonomy (Michie et al., 2013). Initially prioritizing commonly used BCTs, the first workshop session explored less common techniques, assessing their feasibility and relevance for pregnant women. Decisions were guided by affordability, practicality, and participant feedback. In Step 8, mHealth was identified as the preferred delivery mode based on evidence. The second workshop session evaluated app features, including monitoring and consultation, for technical feasibility. The flow of the intervention design process is detailed in Figure 1.

Figure 1: Flow Chart of the Intervention's Design Process



Analysis

Stakeholder input was audio-recorded and transcribed verbatim. Data were analyzed using a framework analysis guided by the COM-B model. The coding was conducted primarily by the first author, then reviewed and discussed with another researcher to ensure consistency and accuracy. Coding categories were derived from the COM-B domains, and analytic memos documented reflections.

Results

Step 1. Define the health problem in behavioral terms

Many women face challenges in adopting anemia-prevention behaviors, including regularly taking iron and folic acid (IFA) tablets, avoiding inhibitors of iron absorption, and maintaining a nutritious diet.

Step 2. Select the target behaviors

Previous studies conducted by the research team identified three behaviors that are particularly challenging for pregnant women with anemia: consistent intake of iron and folic acid (IFA) tablets, avoidance of iron absorption inhibitors, and a nutritious diet. Guided by the Behavior Change Wheel (BCW) framework, target behaviors were selected based on specific criteria to ensure clarity and effectiveness. Target behaviors must be clearly defined and actionable (behavioral specificity), while maintaining a focused, straightforward approach. Priority was given to behaviors with high potential to impact anemia prevention and those deemed feasible for adoption by the target population. Additionally, consideration was given to spillover effects, in which a change in one behavior could positively influence others, and to measurability, ensuring that behavioral changes could be easily observed and tracked. These criteria identified two primary target behaviors: (1) regular consumption of IFA tablets and (2) adherence to a nutritious diet.

Step 3. Specify the target behaviors

The selected target behaviors are described in detail, specifying who should perform them, what actions are required, where and when they should be carried out, how frequently they should occur, and with whom they should be performed (see Table 1).

Table 1: Specification of Targeted Behavior

Specification	Target behavior	
	Consuming IFA tablets regularly	**Consuming a nutritious diet**
Who needs to perform the behavior?	Pregnant women, particularly those with low adherence and motivation to consume IFA tablets regularly	Pregnant women, particularly those with low adherence and motivation to consume a nutritious diet

Specification	Target behavior	
	Consuming IFA tablets regularly	**Consuming a nutritious diet**
What does the pregnant woman do differently to achieve the desired change?	Consume IFA tablets consistently and regularly.	Consume nutritious foods in adequate portions, in line with balanced nutritional guidelines for pregnant women.
When do pregnant women need to do it?	Not specified	Every time they eat
Where do pregnant women need to do it?	At home	At home
How often do pregnant women need to do it?	Once a day, every day	Every day
With whom?	Independently, without reliance on others.	Independently, without dependence on others.

Step 4: Identify what needs to change

After selecting and specifying the target behaviors, a behavioral analysis was conducted using the COM-B model and TDF domain to identify the conditions required for each behavior. This analysis examined the necessary changes in capability, opportunity, and motivation related to the target behavior. This analysis was based on qualitative data from pregnant women collected through semi-structured interviews conducted by the research team. The target behavior for the intervention was consistent, regular consumption of IFA tablets during pregnancy.

Findings from the qualitative phase revealed that some pregnant women took IFA tablets irregularly, with frequent missed doses due to forgetfulness, side effects, or low awareness of their importance. Therefore, the desired behavioral change is daily and uninterrupted IFA consumption in accordance with national antenatal care guidelines. Readers interested in further details of the previous study are encouraged to refer to the article presented here (Arifah et al., 2024). The analyses and corresponding behavioral diagnoses for both target behaviors are presented in Table 2 (step 4). This process informs the development of targeted interventions to help pregnant women prevent anemia.

Pregnant women face barriers in preventing anemia, including limited knowledge of proper IFA usage and nutritious foods, difficulty in avoiding iron absorption inhibitors like tea, and reluctance to consume IFA tablets or healthy foods due to the side effects. Additionally, limited awareness of affordable, iron-rich foods, forgetfulness, poor time management, insufficient social support, low perception of the health risks of anemia, and the absence of consistent routines further contribute to the challenge. While other barriers may affect some individuals, this study prioritized the most significant obstacles to enhance feasibility and impacts. In integrating with the socio-ecological framework, the COM-B components are influenced by broader socio-ecological factors: *capability* is shaped by provider guidance; *opportunity* is constrained by household decision-making and economic resources; and *motivation* is reinforced through spousal support. This integration highlights how individual behavior change is embedded within and dependent on social and structural contexts.

The PI formulated nine behavioral change goals to improve anemia prevention in pregnant women. These include direct behavior, such as 1) avoid iron absorption inhibitors and 2) establish consistent health habits such as IFA tablet consumption and an iron-rich diet, and

other's supportive determinants, such as 3) learn proper IFA tablet use, 4) increase knowledge of iron-rich foods, 5) overcome aversions to IFA tablets and nutritious food, 6) recognize affordable local food options, 7) improve time management for tablet consumption, 8) receive social support, 9) build positive beliefs about IFA tablets and nutrition. These nine goals were based on the components of COM-B and TDF.

Step 5. Identify intervention functions

The selected COM-B components and TDF domains from step 4 were linked to the intervention functions outlined in the BCW guide, allowing all nine intervention functions to be applied. However, PI prioritized six functions: education, persuasion, incentivization, training, environmental restructuring, and enablement (see Table 2). The remaining three functions were excluded as the restriction was deemed less feasible for a research team, and coercion was considered less acceptable or unlikely to have an impact on pregnant women. Modeling was not included despite its potential effectiveness because it requires substantial time and resources to develop the intervention. Producing videos featuring real pregnant women or providing direct examples is costly and can be substituted with other demonstration formats.

Step 6. Identify policy categories

The next step is to consider the policies that support the delivery of the intervention functions identified in Step 5. PI chose the policy lever to deliver the intervention from among seven policy categories based on BCW's suggestion criteria. The only policy lever available was service provision. Service provision was recommended as a policy lever for intervention functions, such as education, training, persuasion, incentivization, environmental restructuring, and enablement. Therefore, establishing a support service within primary healthcare facilitated by healthcare providers is the most appropriate and effective option.

Step 7. Identify Behavior Change Techniques

A total of 16 Behavior Change Techniques (BCTs) were selected (see Table 2). The PI and the research team have outlined the selection and reasoning for each BCT within the specific intervention function chosen and rejected in Additional file 2. This selection is based on the first stakeholder consultation and the interview with pregnant women and their spouses.

Step 8. Identify the mode of delivery

Most pregnant women preferred receiving the intervention via mobile phones, aligning with literature indicating that digital interventions effectively address anemia and nutrition-related issues during pregnancy (Diamond-Smith et al., 2020). Participants preferred a user-friendly application with a small RAM footprint, a simple interface, and no foreign-language terminology, making it more accessible. They also prioritized features for consulting with healthcare providers and for daily IFA consumption reminders. Health applications should facilitate direct communication between clients and health workers to enhance user engagement and adherence. Additionally, participants emphasized the importance of educational features with photos and videos, as visual media makes complex health

information easier to understand for users with different health literacy levels (Ambarwati & Sulastri, 2023; Carter et al., 2019).

The stakeholder workshop identified that specific BCTs, such as self-monitoring, feedback on behavior and outcomes, and prompts/cues, could be delivered effectively through the application. In contrast, others, such as restructuring the social environment, social support, and reviewing behavior and outcomes, were less effective. As a result, the intervention should involve healthcare providers and spouses as sources of support for pregnant women, creating a more comprehensive support system. The details of selected BCTs and the mode of delivery are explained in Table 2.

Table 2: Behavioral Change Wheel implementation in designing ANECMA intervention and ANECMA Application

COM-B Component	Relevant TDF Component	Requirements for Target Behavior	Need for Change?	Intervention Function	Policy Categories	Goal of intervention	Individual BCT selected	Mode of delivery	ANECMA App Feature based on BCT selected Implementation of BCT in Intervention
		Step 4		Step 5	Step 6	Step 7		Step 8	
Capability									
Psychological Capability	Knowledge	Understand the correct way to consume IFA tablets and the benefits of doing so.	Change is needed, as many pregnant women do not know the correct way to consume the tablets to minimize side effects.	Education	Service Provision	Educate about what to do if experiencing anemia and the correct portion sizes for a balanced diet during pregnancy.	Information on anemia — its consequences, how to prevent it, and how to use IFA tablets effectively — along with improving the daily diet to combat anemia, is provided through posters and videos. *(BCT – Information)*	Distance - Individual Level - Mobile Phone App	Education Feature (husband account and pregnant woman account)
		Know the appropriate portion sizes for pregnant women and foods rich in iron, Vitamin A, Vitamin B9, and Vitamin B12	Change is needed, as many pregnant women lack knowledge about suitable foods and portion sizes to prevent anemia.				Provide information about the health consequences of anemia for both mothers and babies. *(BCT – Information on health consequences)*	Distance - Individual Level - Mobile Phone App	Education Feature (husband account and pregnant woman account)

COM-B Component	Relevant TDF Component	Requirements for Target Behavior	Need for Change?	Intervention Function	Policy Categories	Goal of intervention	Individual BCT selected	Mode of delivery	ANECMA App Feature based on BCT selected Implementation of BCT in Intervention
		Step 4		Step 5	Step 6	Step 7		Step 8	
		to combat anemia.							
	Behavioral Regulation	Develop the willingness and ability to avoid habits that inhibit iron absorption.	Change is needed, as many pregnant women know that drinking tea inhibits iron absorption but struggle to resist it.	Training		Educate on substituting or modifying the timing of tea consumption.	Provide detailed instructions on consuming IFA daily while minimizing side effects and consuming meals in the correct portions for pregnant women. *(BCT – Instruction on how to perform behavior)*	Distance - Individual Level - Mobile Phone App	Education Feature (husband account and pregnant woman account)
						Train proper IFA tablet intake and understanding inhibitors.	Encourage self-monitoring of IFA tablet intake with Vitamin C. *(BCT – Self-monitor behavior)*	Distance - Individual Level - Mobile Phone App	Record of daily IFA tablet consumption feature
		Develop the willingness to consume nutritious food in	Change is needed, as many pregnant women know			Train balanced dietary habits to prevent anemia.	Provide instructions on combining a variety of foods to help prevent	Distance - Individual Level - Mobile	Education Feature (husband account and

COM-B Component	Relevant TDF Component	Requirements for Target Behavior	Need for Change?	Intervention Function	Policy Categories	Goal of intervention	Individual BCT selected	Mode of delivery	ANECMA App Feature based on BCT selected Implementation of BCT in Intervention
		Step 4		Step 5	Step 6	Step 7		Step 8	
		appropriate portions.	the importance of nutritious food, but cannot overcome nausea.				anemia. *(BCT – Instruction on how to perform behavior)*	Phone App	pregnant woman account)
						Train balanced dietary habits to prevent anemia.	Promote self-monitoring of balanced and nutritious diets. *(BCT – Self-monitor behavior)*	Distance - Individual Level - Mobile Phone App	Daily Meal Journal Feature
Opportunity									
Physical Opportunity	Environmental Context and Resources	Have a variety of nutritious foods available at home.	Change is needed, as many women lack awareness of affordable iron-rich food sources, often due to socioeconomic factors.	Training	Service Provision	Train balanced dietary habits to prevent anemia.	Provide instructions on combining a variety of foods to help prevent anemia. *(BCT – Instruction on how to perform behavior)*	Distance - Individual Level - Mobile Phone App	Education Feature (husband account and pregnant woman account)
		Have the time and remember to	Change is needed, as forgetfulness is a common	Restructuring environment		Restructure the environment by providing	Offer individualized reminders timed to the pregnant	Distance - Individual Level - Mobile	Reminder of the daily IFA consumption feature

COM-B Component	Relevant TDF Component	Requirements for Target Behavior	Need for Change?	Intervention Function	Policy Categories	Goal of intervention	Individual BCT selected	Mode of delivery	ANECMA App Feature based on BCT selected Implementation of BCT in Intervention
		Step 4		Step 5	Step 6	Step 7		Step 8	
		consume IFA tablets.	reason for not taking the tablets.			cues and prompts to remind pregnant women to take IFA supplements.	woman's daily routine (e.g., before bedtime or after meals). The frequency is set based on healthcare providers' advice, tailored to anemia status and tablet dosage. *(BCT – Prompt/cues)*	Phone App	
Social Opportunity	Social Influences	Receive support from husbands and healthcare providers to remind them to take IFA tablets and eat nutritious food.	Change is needed, as not all pregnant women receive adequate support.			Restructure the social environment to remind and support IFA supplement consumption.	Educate spouses about the importance of their wife's adherence to IFA intake and her anemia status. Encourage spouses to support this behavior by providing nutritious food, purchasing IFA tablets, or ensuring ANC visits when	face-to-face - Individual level	Supported by Partner Education Feature

COM-B Component	Relevant TDF Component	Requirements for Target Behavior	Need for Change?	Intervention Function	Policy Categories	Goal of intervention	Individual BCT selected	Mode of delivery	ANECMA App Feature based on BCT selected Implementation of BCT in Intervention
		Step 4		Step 5	Step 6	Step 7		Step 8	
							supplies run out. *(BCT – Restructure social environment; Social support (emotional, practical))*		
							Healthcare providers are encouraged to educate patients about adherence to IFA consumption and anemia status. Encourage providers to offer direct instructions on adequate IFA intake and provide nutrition counseling during Antenatal Care. *(BCT – Restructure social environment;*	face-to-face - Individual level	Supported by the Healthcare provider admin feature and the counselling feature

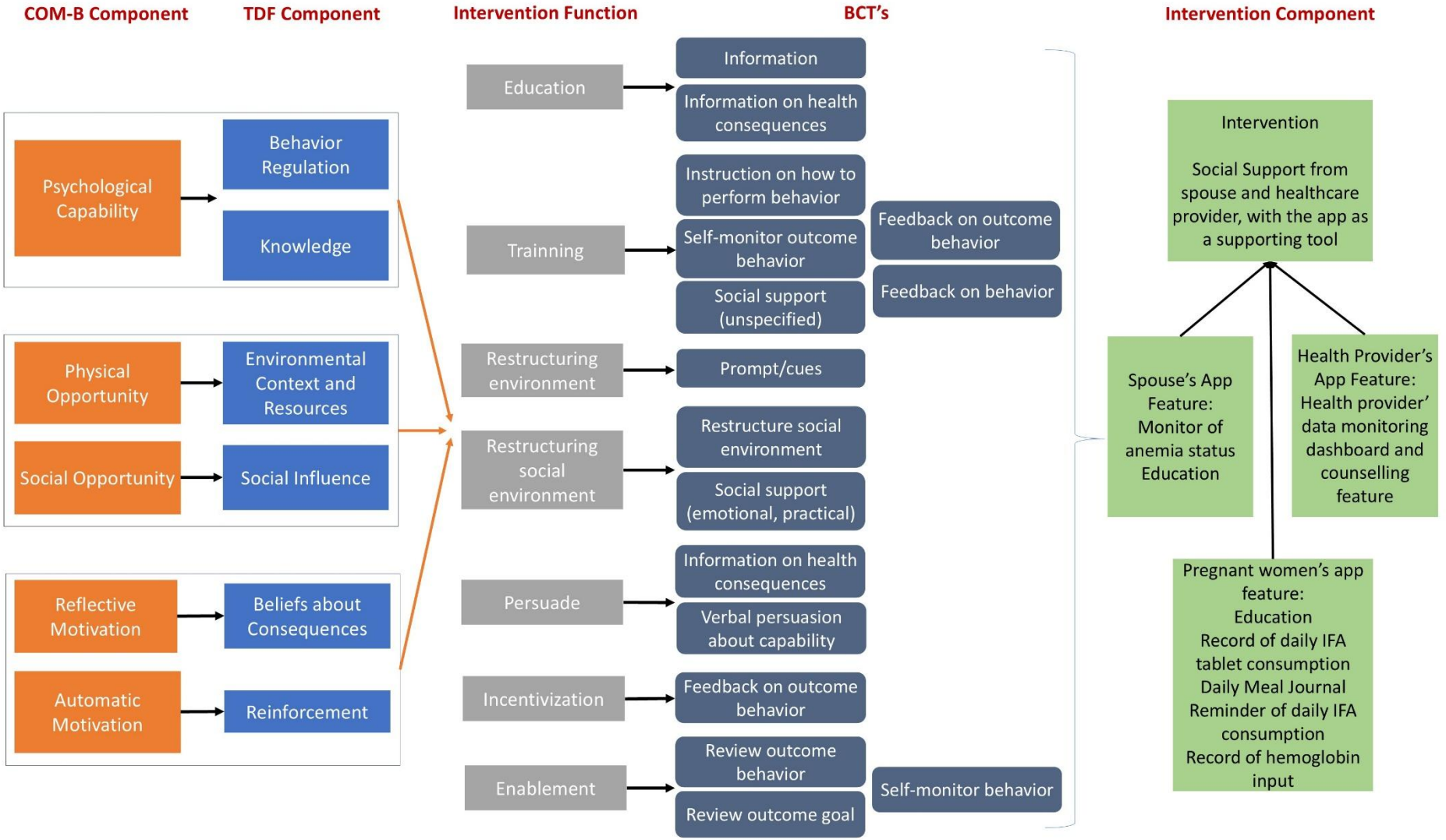
COM-B Component	Relevant TDF Component	Requirements for Target Behavior	Need for Change?	Intervention Function	Policy Categories	Goal of intervention	Individual BCT selected	Mode of delivery	ANECMA App Feature based on BCT selected Implementation of BCT in Intervention
		Step 4		**Step 5**	**Step 6**		**Step 7**	**Step 8**	
							Social support (unspecified)		
Motivation									
Reflective Motivation	Beliefs about Consequences	Believe that daily consumption of IFA tablets and nutritious food reduces anemia and positively impacts maternal and child health.	Change is needed, as not all pregnant women believe in the health benefits for themselves and their babies.	Persuade	Service Provision	Persuade women to view daily IFA tablet consumption positively and feel discouraged when they skip it.	Educate pregnant women on the health consequences of anemia for both mothers and babies. *(BCT – Information about health consequences)*	Distance - Individual Level - Mobile Phone App	Education Feature
							Use motivational verbal messages and visual reminders (e.g., posters with relevant imagery) to encourage daily use of the IFA tablet. *(BCT – Verbal persuasion about capability)*	Distance - Individual Level - Mobile Phone App	Reminder of the daily IFA consumption feature

COM-B Component	Relevant TDF Component	Requirements for Target Behavior	Need for Change?	Intervention Function	Policy Categories	Goal of intervention	Individual BCT selected	Mode of delivery	ANECMA App Feature based on BCT selected Implementation of BCT in Intervention
		Step 4		Step 5	Step 6	Step 7		Step 8	
				Incentivization		Incentivize improvement in hemoglobin levels.	Provide individualized feedback and an appraisal when women enter their hemoglobin results and are no longer anemic. *(BCT – Feedback on outcome behavior)*	Distance - Individual Level - Mobile Phone App	record of the hemoglobin input feature
Automatic Motivation	Reinforcement	Establish routines and habits for consuming IFA tablets and eating the right portion of nutritious food.	Change is needed, as not all women have established consistent routines for these behaviors.	Education Training	Service Provision	Educate and train to plan self-monitoring of IFA intake, check hemoglobin levels, and ensure a balanced diet.	Encourage pregnant women to self-monitor daily IFA tablet intake and dietary habits by keeping a behavior record. *(BCT – Self-monitor behavior)*	Distance - Individual Level - Mobile Phone App	Record of daily IFA tablet consumption feature
							Pregnant women are encouraged to input their hemoglobin examination results. *(BCT – Self-monitor outcome behavior)*	Distance - Individual Level - Mobile Phone App	record of the hemoglobin input feature

COM-B Component	Relevant TDF Component	Requirements for Target Behavior	Need for Change?	Intervention Function	Policy Categories	Goal of intervention	Individual BCT selected	Mode of delivery	ANECMA App Feature based on BCT selected Implementation of BCT in Intervention
		Step 4		Step 5	Step 6	Step 7		Step 8	
							Provide personalized feedback on whether dietary intake meets recommendations and suggestions for improvement. *(BCT – Self-monitor behavior; Feedback on behavior)*	Distance - Individual Level - Mobile Phone App	Daily Meal Journal Feature
							Provide feedback based on hemoglobin results, explaining anemia status and necessary next steps. *(BCT – Feedback on outcome behavior)*	Distance - Individual Level - Mobile Phone App	record of the hemoglobin input feature
				Training Enablement		Train and enable consistent IFA tablet consumption through reminders and	Encourage women to develop a daily habit of taking IFA tablets by maintaining records of their consumption and	Distance - Individual Level - Mobile Phone App	Record of daily IFA tablet consumption feature; Daily Meal Journal Feature

COM-B Component	Relevant TDF Component	Requirements for Target Behavior	Need for Change?	Intervention Function	Policy Categories	Goal of intervention	Individual BCT selected	Mode of delivery	ANECMA App Feature based on BCT selected Implementation of BCT in Intervention
		Step 4		Step 5	Step 6	Step 7		Step 8	
						self-evaluation records.	hemoglobin levels. *(BCT – Self-monitor behavior)*		
							Allow healthcare providers to monitor input from pregnant women and provide feedback on adherence to IFA intake and achieving anemia-free outcomes during Antenatal Care. *(BCT – Review outcome goal; Review outcome behavior)*	face-to-face - Individual level	Supported by the Healthcare provider admin feature

Figure 2: The development process of ANECMA intervention and ANECMA Application feature based on the COM-B component, TDF domain, and the selection of behavior change techniques (BCTs)



ANECMA Intervention

The ANECMA (Anemia Control and Monitoring for Pregnant Women) intervention was systematically developed using the BCW 8-step and implemented in Indonesia. Figure 2 illustrates the development process, detailing how COM-B components, intervention functions, and BCTs interconnect within the intervention design. ANECMA introduces features to support the Capability, Opportunity, and Motivation components of the COM-B model.

The application features include an Education tool, a Record of Daily IFA Tablet Consumption, and a Daily Meal Journal Feature to enhance the Capability. These tools aim to improve pregnant women's knowledge and skills in adhering to anemia prevention practices. The Opportunity component is addressed through a daily IFA reminder that serves as a cue to action. Additionally, the app fosters a supportive environment by engaging healthcare providers and spouses. A dedicated Husband's Account enables spouses to monitor IFA consumption, hemoglobin input, and meal journal entries, thereby promoting partner involvement —a key factor in adherence.

Motivation is reinforced through features such as the Record of Daily IFA Tablet Consumption, Hemoglobin Input, and Daily Meal Journal. These encourage self-monitoring and provide pregnant women with a sense of progress and achievement. By tracking their progress, users are more likely to stay motivated and adhere to recommended health practices. ANECMA's innovative features align with the COM-B model to empower pregnant women and support anemia prevention.

The application also supports healthcare providers by offering a Documentation and Recapitulation Feature that consolidates pregnant women's IFA consumption records, hemoglobin inputs, and meal journal data. This feature allows healthcare providers to monitor progress more effectively during antenatal visits and tailor their guidance accordingly. Notably, this functionality addresses a gap in existing applications by operationalizing the Opportunity component of the COM-B model, specifically by creating a supportive environment for pregnant women and their support network (Gomes et al., 2020; Michie et al., 2014). Moreover, the recapitulated IFA consumption data can serve as an indicator for monitoring IFA adherence at the Puskesmas (primary healthcare center) level. This type of data has not been collected nationally, but it holds the potential to inform regional policy innovations for anemia control programs, particularly in Surakarta. By providing a mechanism to monitor IFA adherence at both the individual and regional levels, this application introduces a novel approach to strengthening anemia prevention efforts.

Discussion

This paper explains the systematic development of the ANECMA intervention to help pregnant women prevent and manage anemia using the eight steps of the BCW and the COM-B model. It is currently undergoing testing for validity, usability, and effectiveness compared to standard antenatal care. A key lesson is that, although the BCW is resource-intensive and time-consuming, it enables interventions tailored to local target needs. Following BCW's systematic steps, the research team conducted a rigorous problem analysis using components of the COM-B model and TDF, supported by qualitative research with pregnant women,

spouses, and stakeholders, and further input from the researcher and healthcare providers. The BCW framework guided the selection of intervention functions, BCTs, and delivery modes. This paper provides a transparent rationale for selecting BCTs, sets explicit goals for each intervention component, and describes the intervention using standardized terminology.

Previous studies have reported similar benefits of using the BCW's eight steps and the COM-B model. For instance, the Move It, Move ID! intervention was developed to enhance physical activity among individuals with intellectual disabilities. Moreover, interventions targeting pregnant women include the ICAN QUIT program for smoking cessation among pregnant smokers and the behavior change intervention for gestational diabetes management (IINDIAGO) (Gould et al., 2017; Maenhout et al., 2024; Murphy et al., 2023). The COM-B model has also been employed to understand behaviors during pregnancy. A South Wales, UK study used COM-B to explore multiple health behaviors among low-income pregnant women (Grant et al., 2019). Similarly, research in Cork, Ireland, identified enablers and barriers to physical activity among overweight and obese pregnant women using the COM-B model and Theoretical Domains Framework (TDF) (Flannery et al., 2018). Additionally, a study in India utilized the COM-B model to investigate barriers and opportunities influencing maternal nutrition behaviors (Jhaveri et al., 2023). These diverse applications demonstrate the model's utility for understanding pregnancy-related behaviors and for developing interventions that effectively support behavior change.

This study identified barriers to preventing anemia within psychological capability, physical and social opportunity, and reflective and automatic motivation. These findings align with a study in India that found psychological factors were significant barriers to dietary diversity among pregnant women. In contrast, opportunity factors were critical for IFA intake (Jhaveri et al., 2023). The study proposed six intervention functions linked to 12 BCTs: education, persuasion, incentivization, training, environmental restructuring, and enablement. This approach aligns with a systematic review in sub-Saharan Africa, which found that combining functions such as incentivization, persuasion, and environmental restructuring improved maternal and child nutrition and psychosocial outcomes, as these functions effectively addressed participants' motivation and enhanced the impact of behavior change interventions (Watson et al., 2023). The review demonstrated that studies that addressed multiple intervention functions were more effective than those that relied on a single function. However, these findings do not suggest that more intervention functions yield better results. This highlights the need for a multifaceted approach tailored to the target population's specific barriers and enablers.

The findings from this study informed the development of an anemia prevention intervention grounded in behavioral theory and contextual understanding. Behavior change among pregnant women does not occur in isolation but within broader socio-ecological systems that influence the COM-B components. At the individual level, ANECMA enhances capability and motivation through tailored education and digital self-monitoring. However, opportunities for sustained behavior are shaped by interpersonal and structural contexts such as household decision-making dynamics, spousal support, provider workload, and economic constraints (Sedlander et al., 2020). These contextual factors indicate that the app alone cannot address structural barriers.

This study further highlights that triadic collaboration between pregnant women, spouses, and healthcare providers can strengthen mothers' motivation to prevent anemia (Morrison et al., 2021). Previous studies have shown that poor adherence to iron supplementation and dietary recommendations is often hindered by limited knowledge and a lack of family support

(Williams et al., 2020). Thus, addressing anemia requires synergistic engagement among healthcare workers, families, and communities (Morrison et al., 2021). The mHealth intervention developed in this study cannot function as a standalone solution but can complement and enhance stakeholder support, improving the efficiency and reach of anemia prevention efforts (Vo et al., 2019). Integrating user input was crucial to ensuring alignment with pregnant women's needs and to improving usability within routine care. Prior evidence suggests that user readiness and provider willingness are key to developing feasible, acceptable, and practical solutions (Alaiad et al., 2019). By prioritizing user-centered design, this study emphasizes the role of technology as a facilitator rather than a replacement for human interaction. Future dissemination and pilot testing should explore strategies to engage families and providers within the system to ensure sustainable adoption and integration of ANECMA alongside existing health information platforms.

Strengths and limitations

This study's primary strength lies in its systematic use of the Behavior Change Wheel (BCW) framework, supported by stakeholder feedback, to develop an anemia prevention intervention for pregnant women. The integration of behavioral theory and contextual insights helped address key gaps in previous interventions, particularly the limited use of theory and the lack of population-specific adaptation. Although the process emphasized stakeholder consultation rather than complete co-creation, feedback from healthcare providers, pregnant women, and their spouses was instrumental in refining the intervention design to ensure cultural and practical relevance. Moreover, the development of the ANECMA mHealth application represents the first structured attempt to create a behaviorally informed digital tool to prevent pregnancy anemia in Indonesia. Its innovative feature of monitoring iron-folic acid (IFA) tablet consumption provides a potential complement to existing nutritional surveillance systems.

Despite these strengths, several limitations should be acknowledged. Stakeholder participation was limited mainly to the later BCW steps due to time constraints and the need for a specialized understanding of formative data and behavioral frameworks. Husbands' specific barriers and support needs were not explored in depth, restricting insights into their role in behavior change. Importantly, this paper focuses on the intervention's development phase; the ongoing testing phase will be reported separately. Future studies should extend stakeholder engagement across all stages, incorporating iterative co-design, pilot testing, and evaluation within routine antenatal services. Incorporating husbands' perspectives, addressing provider workload, and exploring practical mechanisms for digital integration are also essential. The next crucial step involves disseminating ANECMA to the Surakarta District Health Office and relevant partners to promote adoption and explore financial and policy support for sustainable implementation.

Conclusion

The ANECMA intervention was developed using the BCW, alongside stakeholder feedback. The research team considered this approach beneficial; therefore, it is strongly advised that sufficient time, budget, and skilled scientific personnel be invested in developing interventions. By methodically analyzing the requirements of pregnant women and incrementally correlating them with theoretical notions, identification with pregnant women

underscored the importance of support from spouses and healthcare providers, indicating that reliance solely on a mHealth application is insufficient. The intervention will employ a triadic strategy involving the husband and healthcare provider to monitor pregnant women's progress in effecting behavioral change, supported by an application. Strategies are required to effectively implement and engage both families and providers actively in the system. Therefore, dissemination and pilot testing are needed to explore practical mechanisms for integrating these actors into the system, ensuring that ANECMA can be sustainably adopted and utilized alongside existing health information systems. A comprehensive, transparent development framework can help practitioners incorporate the BCW and its related BCTs and engage the target group to prevent pregnancy anemia.

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