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"I believe it when there is an expert next to me:" a qualitative analysis on the perceptions and experiences of pregnant women to self-monitor blood pressure in Lombok, Indonesia

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Abstract

Background Hypertensive disorders of pregnancy (HDP) are a leading cause of maternal deaths and require close monitoring of blood pressure (BP) to mitigate potential adverse effects. The World Health Organization (WHO) recommends self-monitoring of blood pressure (SMBP) among women with HDP; however, there is limited research on its acceptability and feasibility in low- and middle-income contexts. We explored pregnant women's perceptions and attitudes towards SMBP, as well as practical considerations for SMBP by leveraging a smartphone-based BP measurement application in Lombok, Indonesia.

Methods Pregnant women with a current or history of HDPs were randomized to participate in focus group discussions (FGDs) regarding their attitudes towards SMBP or provided with a smartphone BP application to provide feedback on conducting SMBP. In-depth interviews (IDIs) were conducted among a subset of FGD participants to further explore perceptions. A second group of participants were provided with a smartphone application to familiarize themselves with SMBP and invited to IDIs to discuss their experiences. Husbands of this second group also participated in separate FGDs. Interviews were double transcribed in Bahasa Indonesia and translated to English for thematic analysis using inductive and deductive approaches.

Results We enrolled a total of 71 pregnant women, across 11 FGDs and conducted 15 IDIs with participants who used the smartphone for SMBP. Themes emerged related to (i) understanding of and experiences related to BP; (ii) facilitators and motivations for SMBP; (iii) barriers and concerns with SMBP; and (iv) experiences of using a smartphone-based BP application. While SMBP was perceived favorably by some women for convenience and

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reassurance in monitoring their BP, participants also expressed their reluctance to self-monitor BP due to factors, such as limited understanding of BP and controlling it, gravity of the consequences for their and fetus' health, self efficacy in conducting SMBP appropriately, trust in BP measurement devices, and being a new diagnosis for some women.

Conclusion For SMBP to be implemented in line with WHO recommendations, efforts are needed to strengthen counselling among women with HDPs, clarify protocols for SMBP and subsequent actions, and provide continued support to pregnant women. Considering varying levels of BP knowledge, future research should examine the implications of introducing SMBP among pregnant women with chronic hypertension versus those with newly onset gestational hypertension, as well as the potential conflation between BP and blood haemoglobin.

Keywords Hypertensive disorders of pregnancy, Self-monitoring of blood pressure, Digital, Smartphone application, Software as a medical device, Self-care interventions, Hypertension, Maternal health, Antenatal care, Pregnancy, Women's health

Background

Hypertensive disorders of pregnancy (HDPs) are amongst the most common complications and leading cause of maternal mortality and morbidity, contributing to 14% of all maternal deaths globally [1–5]. HDPs include chronic hypertension, gestational hypertension, preeclampsia, and chronic hypertension with superimposed preeclampsia [1, 5]. Routine measurement of BP during pregnancy is critical for detecting HDPs and mitigating their debilitating effects [5, 6]. Furthermore, the World Health Organization (WHO) recommends self-monitoring of blood pressure (SMBP) during pregnancy as a supplement to facility-based BP monitoring for individuals with HDPs [7, 8].

Despite low- and middle-income countries (LMICs) bearing the greatest burden of HDPs [2, 3], research on SMBP has been done predominately in high-income settings, primarily in the United Kingdom [9–20] and underscores the need for more context-specific research in LMICs. These studies highlight that SMBP is safe and reassuring for pregnant individuals [8, 11, 20, 21]. In some cases, SMBP was associated with reducing prenatal hospital admissions and improving preeclampsia diagnosis, however with minimal to no effect on clinical maternal and fetal outcomes [8–13, 17, 21–28].

Although SMBP is a relatively nascent intervention in LMICs, emerging studies from these contexts indicate increasing interest among pregnant women in monitoring their BP [29–32]. A qualitative study in a tertiary care facility in Nigeria demonstrated that pregnant women perceived SMBP to be simple and contextually appropriate; however, they cited key barriers including cost, lack of equipment, limited knowledge of HDPs, and inconsistent protocols for management and follow-up actions [29]. As a precursor to SMBP, a study in Ghana compared pregnant women's accuracy in taking their BP against measurements taken by a health worker and showed that after brief training, pregnant women were able to successfully check their BP with similar levels of proficiency as health workers [30]. Considering the critical need for comprehensive approaches to addressing HDPs in LMICs, further research is required to broaden understanding of the feasibility and implementation considerations for SMBP to be conducted with fidelity, contextually appropriate, and integrated into the health system.

The widespread adoption of mobile devices and advancements in digital technology offer a unique opportunity to extend SMBP to resource-limited settings and potentially offset challenges associated with access to information and availability of equipment [29, 33]. For example, the use of digital technologies can facilitate communication and transmission of BP measurements to enable timely action [24, 34–36]. More recently, "software as a medical device" in which software applications powered by algorithms provide clinical and medical functions [37] has emerged as a novel approach to overcome limitations in the availability of medical hardware, such as BP measurement equipment. As one example of software as a medical device for BP, OptiBP™ is an application that runs on Android OS 8.1 and leverages the smartphone camera to record photoplethysmographic (PPG) pulse waves derived from blood flow changes in the fingertips, and applies algorithms to estimate BP values [38, 39]. The OptiBP™ application has received CE certification for use as a BP medical device in Europe [40] and was also assessed for accuracy against international regulatory standards in Tanzania, South Africa, and Bangladesh [41, 42].

This qualitative study explored perceptions and key considerations for SMBP among pregnant women with HDPs, with the effort to broaden the evidence base to primary healthcare settings in LMIC contexts [43]. The study was conducted in Lombok, Indonesia, and addresses research gaps identified in the WHO guideline on self-care interventions regarding the feasibility of SMBP among pregnant women with HDP [7], including considerations for leveraging a smartphone application, e.g. OptiBP™ to facilitate SMBP [43].

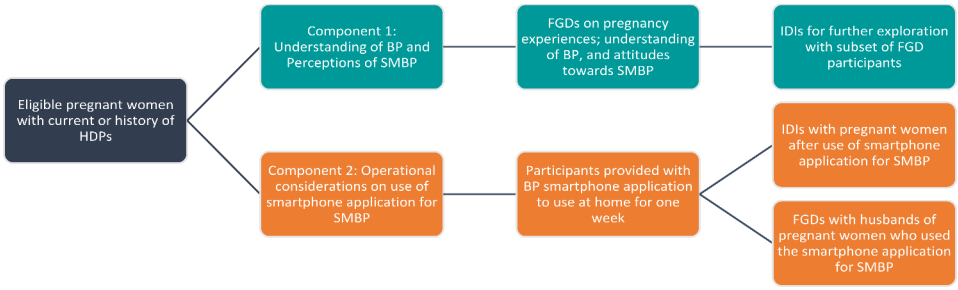

Fig. 1 Assignments to the two study components

Table 1 Sampling of participants across the different components

Component	Activity/Method	Pregnant women with HDP		Husbands of pregnant women
		<30 years	>=30 years	
Component 1	FGD on understanding of BP and perceptions of SMBP	23 participants across 5 FGDs	33 participants across 6 FGDs	N/A
	Follow-up IDIs	8	10	N/A
Component 2	IDIs on use of smartphone application for SMBP	6	9	9 participants across 2 FGDs

**FGD: Focus Group Discussion; IDI: In-depth Interview; HDP: Hypertensive diseases in pregnancy; N/A: Not applicable

Methods

Study design

To examine pregnant women's perceptions and experiences in SMBP, we conducted qualitative research using a grounded theory approach [44] that consisted of focus group discussions (FGDs), in-depth interviews (IDIs), and observations [43, 45]. The study was conducted in West Lombok Regency, Lombok Island, West Nusa Tenggara Province, Indonesia, in communities where the Summit Institute for Development (SID), an Indonesian research and development organization based in Lombok, was conducting digital health interventions to enhance primary health care. This site was also selected as it was one of the areas where a validation study of the smartphone application had been conducted [46].

Pregnant women with current or history of HDPs were recruited following their antenatal care (ANC) consultations and randomly assigned to one of the two study components (Fig. 1). Component 1 consisted of FGDs on general attitudes and perceptions of SMBP, including reflections for support to conduct SMBP. A subset of FGD participants, on average three individuals per FGD, were selected based on their responses or divergent views about pregnancy experiences and perceptions of SMBP for subsequent IDIs for further exploration. To obtain insights on operational considerations for SMBP, pregnant women allocated to Component 2 were provided with a smartphone that contained the BP application, instructed on how to use it, and asked to return for IDIs after a week of using the application. In addition, we invited all husbands of the pregnant women from Component 2 for FGDs.

Participants

Potential participants were selected after a review of both digital records and paper-based ANC registers to identify pregnant women with a history or current HDPs. Research field staff based in the community approached women following their ANC consultations or in their homes to assess their eligibility based on the following criteria: confirmed pregnancy, current or history of HDP, greater than 18 years of age or emancipated minor, living within the catchment area of selected health facilities, able to read and speak Bahasa Indonesia, provision of written informed consent. The sample size was determined based on estimates from similar studies to achieve thematic saturation [35, 36, 47], as well as the availability of pregnant women within the catchment area who fulfilled the eligibility criteria. All eligible pregnant women living in the catchment six primary health centers (*Puskesmas*) in West Lombok (Lingsar, Narmada, Penimbung, Meninting, Jembatan Kembar, and Gerung facilities) were invited to participate in one of the components. For pragmatic reasons related to the purchase and management of smartphones for the study, the number of participants randomly allocated to Component 2 was limited to 15 individuals. Once assigned to the study components, to facilitate homogeneity, we stratified participants into two groups based on their age: greater than/equal to 30 years or less than 30 years) as a proxy for digital literacy and other potential age-related factors, such as parity (see Table 1 for sampling frame).

Procedures

Interviews and observations were conducted over six weeks between March and April 2024 in a

purpose-configured meeting room in a hotel in Mataram, Lombok. Eligible women were given a set of different appointment dates and times to select from for the FGDs and IDIs. The study provided transportation and meal packages to all participants, and some were accompanied by their children, husbands, or family members, but these persons were not present in the meeting room at the time of the interviews. In exceptional circumstances where pregnant women had given birth by the time of the follow-up interview, the study team discussed a convenient date, time and place, including the participants' homes or at the community health post (*posyandu)*, to conduct the IDIs.

For Component 2, the study provided participants with a smartphone containing the BP application, a pictorial guide with screenshots on how to use the BP application, and log sheet to record their experience using the BP application. During this orientation, SID research staff also guided them on measuring BP on their own with the smartphone application. Following this orientation, participants were asked to use the smartphone application to measure their BP in their home setting twice a day for seven days. Participants were also provided with a phone number in case they encountered any issues, and research staff also contacted participants on a daily basis to ensure they did not have challenges with the application.

Following the one-week use of the smartphone application, participants were invited for a follow-up IDI to share their experiences. In addition to audio recordings, the IDIs in Component 2 were video recorded to document interactions with the smartphone application, such as how participants navigated through the application. The smartphone application was not used by the research team or health workers for any clinical decision-making, and all BP measurements for service provision continued through the standard of care at health facilities.

The interviews with pregnant women were conducted in Bahasa Indonesia by SID women research staff from SID who were trained in qualitative methods and the interview guide, and one had a clinical background as a nonpracticing midwife and lecturer. Prior to the interviews, the study team recorded participants' demographic background and general obstetric history, including age, educational level, marital status, mobile phone access, gestational age, parity, and gravida, and if they were aware or ever told they had high BP in any of their pregnancies. The FGDs with husbands under component 2 were conducted by a male researcher of SID.

Semi-structured interview guides for the FGDs and IDIs were developed jointly between the SID and WHO team in English, and subsequently translated into Bahasa Indonesia. Prior to this study, the interview guides had been piloted with pregnant women in the catchment area who were previously recruited. For Component 1, the interview guide for the FGDs and IDIs consisted of four key sections with several sub-questions: (i) general pregnancy experience and use of mobile phones in pregnancy, (ii) knowledge of BP and experiences in BP measurement, (iii) perception of SMBP, (iv) trust and support requirements to conduct SMBP. The interview guide for Component 2 included all four sections from Component 1 and additional questions on experience using the smartphone application for SMBP, interpretation and trust in the BP measurements, support and guidance requirements for SMBP, including if done via a smartphone application. All interview guides contained probes and prompts to stimulate discussion, such as asking for similar or different experiences. In addition, as part of the structured observation, pregnant women were asked to perform specific tasks, such as turning on the smartphone application, placing their finger on the camera of the smartphone to take their BP measurement, and understanding the result/output from the BP measurement.

Data analysis

Each audio recording was de-identified and transcribed verbatim and independently by two SID research staff under direct supervision. Additional SID research staff then compared the two versions of the Bahasa Indonesia transcripts for quality assurance, and discrepancies were crosschecked against the original recording to revise the transcripts. Each revised transcript was subsequently translated from Bahasa Indonesia to English by two independent and professional translators. The research team subsequently compared the two translated files and reconciled differences against the Bahasa Indonesia transcripts, and original recordings as needed, to obtain the final translated file for analysis. Transcripts were not returned to the study participants.

We analyzed the transcripts using the Ritchie and Lewis (2003) framework for qualitative data management, which consists of (i) familiarization and identification of initial themes, (ii) labeling or tagging the data, and (iii) summarizing or synthesizing the data [48]. A member of the research team (TT) read a subset of the translated transcripts several times to identify themes using both inductive and deductive approaches. These themes were discussed and refined with the broader set of authors to construct the codebook with the initial set of topline codes [49]. Two researchers (TT and NJM) applied these codes to the transcripts using the Atlas.ti software (Web version 24) for thematic analysis. One of the researchers (TT) coded all the transcripts, and another researcher (NJM) coded a subset of six randomly selected transcripts (two from each of the category of activities—FGDs, Component 1 IDIs, and Component 2 IDIs) for consistency in the analysis and interpretation

of findings. The study team, which included a researcher who was involved in conducting the interviews, met on a weekly basis to review extracted quotes and emerging patterns to derive themes, discuss underlying contextual factors, and interpret broader implications of the findings.

Ethical considerations

The study was approved by the Health Research Ethics Committee, Faculty of Medicine, Universitas Mataram in Indonesia (004/UN18/F7/ETIK/2023) and the WHO/HRP Research Review Panel and WHO Ethical Review Committee (Reference number A65932). All eligible participants received an information sheet to review and provided informed written consent before participation, including consent to audio and video recordings. Smartphone ownership was not a requirement as the study provided phones to participants allocated to study component 2. We used the Standards for Reporting Qualitative Research (SRQR) [50] and the COnsolidated criteria for REporting Qualitative research (COREQ) Checklist [51] for reporting and adhering to standards in qualitative research.

Reflexivity statement

There was a diversity of experiences and perspectives that shaped the research and outcomes. The study author team comprised of maternal and digital health researchers from Indonesia working for an institution that had a longstanding community presence in Lombok, as well as researchers from different geographic backgrounds working at the global level or in academia. Three of the co-authors have been pregnant and two of the co-authors had HDP, which could influence the lens in which data was interpreted.

Results

The study enrolled a total of 71 pregnant women: 56 participants for Component 1 and 15 participants for Component 2. We conducted 11 FGDs under Component 1, of which 6 were among women over 30 years old and 5 were women less than 30 years old. Nine of the FGD participants were selected for further exploration through IDIs. For Component 2, we conducted 15 IDIs. Ten women declined to participate in the study, and three dropped out after enrollment due to giving birth by the time of FGD appointment, or scheduling conflict, or dropping out of the study. All participants were married, and the majority owned a smartphone. Across both components, the study included a greater proportion of women greater

Table 2 Characteristics of pregnant women participants across component 1 and 2

Characteristics	Component 1 *N* = 56 (%)	Component 2 *N* = 15 (%)
Demographic and obstetric history		
Age		
< 30 years	22 (39.3)	6 (40.0)
≥ 30 years	34 (60.7)	9 (60.0)
Highest level of education		
Primary	15 (26.8)	3 (20.0)
Secondary	37 (66.1)	9 (60.0)
Bachelors and above	4 (7.1)	3 (20.0)
Gestational age		
< 13 weeks	-	-
13–26 weeks	16 (28.6)	5 (33.3)
> 26 weeks	40 (71.4)	10 (66.7)
Number of total pregnancies, including the current one		
1	7 (12.5)	2 (13.3)
2	27 (48.2)	8 (53.3)
3 or more	22 (39.2)	5 (33.3)
Ever told they have or had high blood pressure in pregnancy		
Yes	29 (51.8)	10 (66.7)
No	27 (48.2)	5 (33.3)
Smartphone access		
Owns personal smartphone	34 (60.7)	9 (60.0)
Shared access to a smartphone	16 (28.6)	3 (20.0)
Shared access to a feature/basic phone	1 (1.8)	0
Owns personal feature or basic phone	0	1 (6.67)
Does not own or have access to a phone	5 (8.9)	2 (13.3)

than 30 years old as there were more eligible women in the general sample due to the criteria of having a history or current HDP. The characteristics of the enrolled pregnant women are shown in Table 2.

Husbands of the pregnant women in Component 2 generally had secondary-level education, owned a personal smartphone, and represented the age groups for both greater than and less than 30 years, as shown in Table 3.

Themes derived from the data on the perceptions of and operational considerations for SMBP include the following:

1. Understanding of and experiences related to BP.
2. Facilitators and motivations for SMBP.
3. Barriers and concerns with SMBP.
4. Experiences of using a smartphone-based BP application.

Theme 1: understanding of and experiences related to BP

Participants had varied understanding of the meaning of BP, and awareness of their own BP status varied across participants. Most women understood that BP was a critical factor affecting pregnancy and fetal wellbeing and acknowledged the importance of its measurement in ANC. Variability of BP measurements, not having prior exposure or diagnosis of BP issues, passive roles during BP measurement, and potential conflation between blood hemoglobin levels and BP contributed to differing levels of understanding and experiences with BP.

Knowledge of BP Some participants indicated that they did not have much understanding of BP. For those who had some knowledge of BP, it was often described as an issue of the mind, such as stress, linked to diet, particularly the consumption of meats, or a hereditary condition. Dizziness was often cited as a common symptom of high BP. Some participants also noted low BP as an issue and linked it to physiological symptoms of feeling weak and tired.

> *"I'm not quite sure about blood pressure. I only know about it when it's measured, that's all." (FGD Component 1, younger than 30 years)*

> *"And what does 110 over 70 mean? Because we're not experts. That's probably it. How can the blood pressure readings differ every time we measure it, and even become different?" (FGD, older than 30 years).*

> *"It can cause dizziness. In pregnant women, it can affect the normal delivery of the baby. High blood pressure can prevent a normal delivery, and usually, there will be bleeding." (IDI Component 1, younger than 30 years, primigravida).*

Uncertainty on causes for BP changes While most women knew what BP was, they also expressed uncertainty about the causes behind the fluctuation of their BP measurements. The fluctuation of BP measurements across ANC contacts, facilities, or devices contributed to confusion about the triggers for high BP. Some women mentioned they had not previously experienced issues with their BP in prior pregnancies, and the onset of hypertension in the current pregnancy added to their confusion.

> *"Even though we maintain our diet. So, what's causing it? For example, I never had high blood pressure before. Why now, when I'm pregnant, my blood pressure is high all the time? It's already high at 130. Before, it was never that high." (IDI - Component 2, younger than 30 years, primigravida)*

> *"During the first one, my blood pressure was consistently normal, as expected for a pregnant mother.*

Table 3 Characteristics of husbands of pregnant women in component 2

Characteristics	*N* = 9 (%)
Age	
< 30 years	4 (44.4%)
≥ 30 years	4 (44.4%)
Unknown	1 (1.1%)
Education	
Primary	2 (22.2%)
Secondary	6 (66.6%)
Bachelor and above	1 (1.1%)
Smartphone access	
Owns personal smartphone	66 (66.6%)
Shared access to a smartphone	0
Shared access to a feature/basic phone	3 (33.3%)
Owns personal feature or basic phone	0
Does not own or have access to a phone	0

However, during this second one, it kept going up, sometimes reaching 130–140. I was quite surprised when they checked it at the health clinic, it was unusual. Especially during the ultrasound, the doctor asked me, 'Ma'am, why does your blood pressure keep rising? Why?' And I said, 'I'm also puzzled, doc. Because with this second pregnancy, it's unusual for me like this. (FGD Component 1, older than 30 years)

Concerns related to BP Participants were concerned about how to manage their BP and the impact BP would have on their pregnancy outcome and family's well-being. There was also an understanding of the potential severity of BP-related health issues, with participants noting seizures, bleeding, and negative impact on childbirth and the fetus as potential outcomes of uncontrolled or high BP. Hospital births or requiring a cesarean section due to high BP was a key concern, with women generally indicating preferences for vaginal births.

"I'm afraid that if it keeps going up, our blood vessels might burst, we won't be able to do anything, and might have a stroke…If high blood pressure causes convulsions and puts the child at risk, I'm afraid that the child does not get poisoned." (FGD Component 1, younger than 30 years).

"Well, hearing that my blood pressure was rising, it stressed me out. I started to worry about what I ate, even though it was normal. They said I should reduce salt intake, and I did, but it still kept rising. They said it might be stress, as the doctor mentioned, so I was tense during this second pregnancy, while the first one was normal, and the delivery was also normal for the first one… Because of this, you know, the blood pressure fluctuated between 160–180, so I was scared because I've never had surgery before, and now they said I needed a cesarean section." (FGD Component 1, older than 30 years).

"I'm afraid there will be bleeding later [and] have to give birth in the hospital, but hopefully it's here at the midwife. I am afraid." (IDI Component 1, younger than 30 years old, multigravida).

Linkage between blood hemoglobin and blood pressure There was often a link made between abnormal BP and the need for "blood boosters" indicating a perceived association between BP and anemia. In some cases, there was a conflation between the two and uncertainty about whether to continue with nutritional supplements such as iron and folic acid, provided to prevent anemia during pregnancy, if their BP was high. While some participants made the distinction between blood hemoglobin and BP, others indicated concerns that increasing blood [hemoglobin] levels could worsen their BP.

"Sometimes I'm afraid to ask for a blood booster. Just from the name, it's a blood enhancer. It's already high blood pressure when you add blood, right? [laugh]. But I once asked the midwife, if it's okay if it's 130 if we take the blood booster tablet…" (IDI Component 1–older than 30 years old, multigravida).

"I asked the midwife, 'Could I skip taking the blood-boosting tablet? My blood pressure is already high, and I'm afraid it might increase further. I'm worried that I might get more anxious.' She said, 'Oh no, it doesn't affect your anxiety. It affects the baby inside.'" (FGD Component 1, younger than 30 years old).

"At first my husband forbade drinking [the blood booster] …but I said, 'this is not for blood pressure boosters'…maybe he saw the blood booster writing so he thought the drug was to increase blood pressure." (IDI Component 1, younger than 30 years old, multigravida).

Engagement in BP measuring during ANC Pregnant women understood BP to be an indication of pregnancy outcomes and recognized the importance of its measurement. However, the level of involvement in understanding their BP when it was taken during ANC varied across women. Some participants perceived BP to be something managed by health workers or due to how ANC is provided/patient flow. Whereas some pregnant women, particularly those with a history of hypertension, were proactive in understanding their BP status.

"We don't think about it. We're just satisfied with being examined and asked about the numbers. Because we know there are others waiting in line." (FGD Component 1, older than 30 years).

"Um, it's directly measured by the midwife. Usually, the experience is that when they find out, they just inform me that everything is normal and good, that's what they say. But when there was this activity, and I found out that my blood pressure was almost reaching a high level, they said." (IDI Component 1,younger than 30 years old, primigravida).

"Sometimes I'm directly informed, sometimes I look at the device, you know…the measuring device…In my case, during each health check-up, it sometimes goes up and down. However, during the last health check-up, it was 130/89, which is high. Later, when I visited the health center, the doctor said it was

within the normal range, around 120." (FGD Component 1, younger than 30 years).

Online resources as supplements for understanding BP Online resources, particularly YouTube and Google, often supplemented information gaps and questions from participants. Pregnant women used smartphones to access these resources to understand issues concerning their pregnancy, including their BP, diet, and others.

"I haven't been explained about high blood pressure or anything by the midwife, so I don't know. I saw on, what's it called, YouTube on my phone, that it's dangerous if your feet swell, and you have to do a urine test first so that everything can be delivered normally, but I don't really know clearly what high blood pressure is." (IDI Component 1,- older than 30 years old, multigravida).

"I don't think it's [blood booster] to increase blood pressure but for the baby's needs I think to my knowledge and I saw it in the book and I've heard it where I don't know…I saw it on my cell phone." (IDI Component 1- younger than 30 years old, multigravida).

"I wanted to know how to lower it because they said that if our blood pressure rises, it's dangerous for the baby. It could lead to premature birth. So, I searched on my phone, on YouTube, how to lower blood pressure." (IDI Component 1, older than 30 years old, primigravida).

Theme 2: Facilitators and motivations for SMBP

The concept of SMBP was relatively new to most participants, though some women, primarily those with hereditary or chronic BP issues prior to the pregnancy, were aware of what SMBP entailed or had done it before. Some participants perceived benefits from SMBP, such as convenience, reassurance, and empowerment in their ability to control their health. Participants who had an interest in SMBP often expressed this as something they would do in emergencies or feeling dizzy or to gauge their health without having to go to a facility.

Convenience Participants who expressed interest and willingness to SMBP indicated reasons related to the convenience of doing it in a home setting, including avoiding queues, wait time, and distance to facilities. Although FGD participants noted the potential convenience of SMBP related to geographic constraints in accessing health facilities, those who were exposed to the smartphone application (Component 2) emphasized aspects related to being able to have control of their time.

"It's also because of the difficulty, like when measuring it, for example, going to the midwife is far [hmm], it's uphill, there's a high slope [uphill]… If we have our equipment, then it's alright, you know, it's usable, we can measure it ourselves." (FGD Component 1, less than 30 years).

"With the midwife, it's once a month. With this, we can measure it every day. So, I prefer the application." (IDI Component 2, older than 30 years old, multigravida).

"Because of my condition with a baby, sometimes I feel weak. So, it's good to have the freedom to use it whenever we want, even at home, without having to rely on other people." (IDI Component 2, younger than 30 years old, multigravida).

Reassurance and empowerment Other factors included curiosity and having a perceived source of reassurance in between scheduled ANC contacts and for checking BP when women were feeling unwell. SMBP was often cited as something that they would want to do in emergencies or when they have doubts about their health, such as when feeling tired or dizzy. Linked to reassurance and convenience, participants also indicated the benefits of SMBP in helping to manage and have control over their health.

"In situations when we feel dizzy, like an emergency situation, that's when we'd need to do it ourselves if we have the equipment. If we have it, we'd want to do that. That's the main reason." (FGD Component 1, younger than 30 years old).

"When we're tired, dizzy, sometimes experiencing blurred vision, we want to know if maybe the blood pressure is dropping or rising. It would be helpful if there's a device at home like a blood pressure monitor, it can help us find solutions, like if the blood pressure is low, we can find out the solution, or if it's high, we can find medication." (FGD Component 1, older than 30 years old).

Theme 3: barriers and concerns for SMBP

Across both study components, pregnant women's reasons for not wanting to self-monitor BP or preference to measure BP exclusively at a health facility included concerns related to trusting BP devices, uncertainty on whether they would be doing SMBP correctly, and how to manage the results and follow-up actions. Participants also indicated that the lack of a health worker's presence made them unsure of what actions to take. For participants who were provided with the smartphone application, trust and accuracy in the BP results were the key

issues affecting women's attitudes toward SMBP, and some pregnant women noted that digital applications could be unreliable. Although to a lesser degree, pregnant women also questioned the reliability of the BP readings if they were to do it themselves as they had observed variability in BP measurements across the different devices (e.g. manual versus automated cuff) that health workers used and health facilities, such as between hospitals, health centers, and health posts (*posyandu)*. For participants who had not been introduced to the smartphone application, access to equipment or devices was cited as one of the barriers.

Trust and accuracy of BP measurements Participants mentioned issues related to trusting the BP measurements if they were to SMBP, particularly as they had experienced variations with devices used across different facilities and health workers over the course of their ANC contacts. Participants often cited the presence of health workers or the similarity of measurements to that of what they had when done with health workers led them to trust the results. For participants who had used the smartphone application, they emphasized their concerns about the accuracy of the BP measurements, particularly if the BP measurements differed from what they expected.

"Because the results differ between measuring at the doctor's and measuring on your own, that's why there's a concern about accuracy. I'm also afraid of the results, whether they are accurate or not. We're not experts, we're just assisted by the device, who knows if there could be errors right? Afraid of the results, that's it." (FGD Component 1, older than 30 years).

"Well, in terms of its accuracy, how can we know that when we use it at the Posyandu (health post) compared to using it manually, how can we know about its accuracy, so that we're not hesitant about the blood pressure results on the phone if they are not too far off from the manual results."(IDI Component 2, older than 30 years, multigravida).

Limited self-efficacy Some participants were concerned about their ability to appropriately self-monitor BP and felt they lacked the skills or educational background to do it. For these participants, BP measurement was something that should be managed by "experts" or people perceived to be more qualified, including their husbands and other family members.

"Not sure yet, because we lack experience, lack education, well, I'm just not confident for myself [small laugh], I need to be accompanied by a midwife. I'm afraid that I won't understand it or something like that." (FGD Component 1, younger than 30 years)

"I believe it when there's an expert next to me. After I measure it myself, and someone else measures it too, and the results are the same, then I believe…if I do it alone, I might have some doubts…It's better to do it directly with the midwife, or maybe with the husband or someone knowledgeable, so we can be reassured…We're afraid of making mistakes." (FGD Component 1, older than 30 years).

"The difference is, well, when you do it yourself, but personally, I've never done it alone, never. When you go to the hospital or the midwife, you can also ask about the causes of high blood pressure, like what might be causing it, for example, a lack of blood or whatever we might feel, we can ask about it at the same time." (IDI Component 1, younger than 30 years old, multigravida).

Anxiety and desire for immediate follow-up Participants expressed anxiety about SMBP and not having the support of a health worker to counsel them. The lack of immediate access to a health worker for managing BP or being alone when identifying high BP values was a concern for some women, and indicated the need for guidance on appropriate action.

"When our blood is normal, low, or high. Like when we go to the midwife and they say 'No, no, no, everything is fine,' for example. But this is a mobile app. Who do we ask? (IDI Component 2, younger than 30 years, primigravida)

"I don't want to measure my blood pressure myself and then have it spike like that. I don't want to think about it and get more worried. I don't want to think too much about it. I don't want to stress too much, especially because I'm pregnant." (IDI Component 2, older than 30 years, multigravida).

"… what do the numbers mean, so that when we see the numbers, we don't just look at them without knowing…Maybe there should be a follow-up included, like if our measurement indicates hypertension, there should be advice or suggestions below it… how to proceed with it." (FGD Component 1, older than 30 years).

"So that it doesn't get high all the time, the blood pressure. Then, I need information like that, how to do it, how to deal with it. So, because I'm afraid if I say the blood pressure keeps going up, I'm afraid it

will be like this again, in the next day." (IDI Component 1, older than 30 years old, multigravida).

Access to devices for SMBP Participants who indicated an interest in SMBP mentioned the lack of devices or tools as a limiting factor. These individuals also demonstrated seeking support from health workers or neighbors to access devices to be able to SMBP.

"I want to, but don't have the tools. But if someone gives then we learn from those with more experience. For example, with the midwife, I'll ask for help later on how to do it. If there is one… if there isn't, I'll wait until posyandu, or I'll go to the hospital, that's it." (IDI Component 1, older than 30 years, multigravida).

"If we have it, yes, by ourselves [together - answered simultaneously], but if we don't have it, we have to go to the midwife." (FGD Component 1, younger than 30 years).

Theme 4: experiences of using a smartphone-based BP application

The smartphone BP application was perceived as a convenient approach to SMBP, but participants also questioned its accuracy in comparison to current methods of BP measurement particularly for detecting high BP. The ability to measure BP with a smartphone drew interest from other household members to also use the application, and participants wanted to understand the implications of phone sharing on ensuring consistency and reliability of BP measurements. Participants also highlighted considerations for the usability, including simplifying the finger placement and incorporating features for fetal heart monitoring.

Reliability of the smartphone application

Pregnant women expressed confidence in the measurements if it was within the range they obtained with health workers. However, some participants questioned the reliability of the smartphone application measurements, particularly for detecting high BP. In addition, women noted interest from household members and friends to use the smartphone application but were unsure of the implications of phone sharing on the consistency of BP results.

"Because my blood pressure is always around that range. 100, 110. It never goes higher or lower. That's why I believe." (IDI Component 2, older than 30 years, multigravida).

"I don't know because I don't know about apps like this…Because many apps have been proven to be unreliable." (IDI Component 2, younger than 30 years, multigravida).

"In some cases, when the blood pressure is high, it's okay. However, there will always be issues, like in the manual, uh, the digital one, it might not be detected if the blood pressure is in the 200s." (IDI Component 2, older than 30 years, multigravida)

"This is what I want to ask. For example, if we use the application now, or our spouse uses it. It will mix the results, right? So, we don't know whose result it is. How do we differentiate our results from others?" (IDI Component 2, older than 30 years, multigravida).

Usability of the smartphone application

Participants appreciated the possibility of monitoring BP on a smartphone and the efficiency in obtaining their measurements. However, some women also reported initial challenges of the with the appropriate finger placement on the smartphone camera to detect BP readings, especially if fingers were wet or cold. In addition, pregnant women expressed the desire for additional functionalities to enhance the smartphone application, such as incorporating fetal heart rate.

"It measures as soon as you place your finger on it. You can't move too much. We have to be still and not talk too much." (IDI Component 2, younger than 30 years, primigravida).

"So far I've been using it alone. But sometimes my fingerprint isn't accurate, so that's the only obstacle. And it's slippery, it moves, and I have to repeat it again." (IDI Component 2, older than 30 years, multigravida).

"The benefit of this application can be used anywhere and anytime. So, it makes it easier for me to measure my blood pressure." (IDI Component 2, older than 30 years, multigravida).

"Oh, why only blood pressure? There is an application for this, so why not directly into the heart of the baby?" (IDI Component 2, younger than 30 years, multigravida).

Findings from husbands' perspectives

Husbands' of the pregnant women who used the smartphone application (Component 2) generally understood BP as a diet-related issue and a reason for hospital birth.

From the perspectives of the husbands, the main driver for SMBP was convenience, and their key concern was trust and accuracy of BP measurements, particularly when using a smartphone application as it is a new tool (see Table 4 for emerging findings from husbands' perspectives).

Discussion

This study examined pregnant women's perception of SMBP in Indonesia, including through introduction of a smartphone-based BP application, to inform implementation considerations for conducting SMBP in resource-constrained primary healthcare settings. Understanding of BP varied across pregnant women, which influenced attitudes towards SMBP. SMBP was perceived favorably by some women as a tool to provide flexibility and reassurance in monitoring their BP. However, participants also indicated reluctance and potential challenges with SMBP. The fluctuating nature of BP, lack of clarity on how to control their BP, the gravity of consequences on their health and baby, accessibility of and trust in devices, and being a newly diagnosed condition for some women, were contributing factors for not wanting to take on the responsibility of SMBP. The novelty of using a smartphone application for SMBP in Component 2 emphasized concerns related to the accuracy of BP readings, as well as the need for concrete guidance on follow-up actions. Furthermore, the use of a smartphone application will also require addressing considerations for phone sharing and equity in accessibility to smartphones.

These findings resonate with qualitative studies on perceptions of HDPs among pregnant women, in which understanding of BP was found to be variable and limited, but also a source of anxiety [20, 29, 52–57]. Pregnant women's BP-related concerns included the well-being of the fetus and their health, as well as the possibility of requiring a cesarean section. While age and gravida did not seem to be as big of a differentiator in mediating understanding of BP, women with a history of hypertension in prior pregnancy or chronic hypertension may have been more well-versed in discussing BP and have greater self-efficacy for SMBP, compared to

Table 4 Emerging findings from husbands' perspectives

Understanding of BP: Husbands' understanding of BP in pregnant women was often linked to diet, particularly salty foods. Referral for hospital birth was also another aspect of high BP in pregnancy.

> *"Yes, it's the same as nutrition what's the name, what food is good for you, when we measure the blood pressure, we have to eat this, don't do this." (Husband of pregnant women older than 30 years)*

> *"According to the information I got, if she has hypertension, she can't usually give birth at the health center, if you have high blood pressure, you have to go to the hospital. Food intake must be managed, such as salty, sweet foods." (Husband of pregnant women older than 30 years)*

Convenience as a motivator for SMBP: The ability for SMBP with a smartphone was noted as something that would allow for greater flexibility and convenience in checking BP, especially when feeling unwell.

> *"Can know every day, for example, every day or not, every week, we check on that handphone, right? In that application, so we know, what it's called, like low blood pressure." (Husband of pregnant women younger than 30 years)*

> *"Yes, it's easy for us to know what causes us to get sick, sometimes we have a headache, guess no tension, we download nice app, it let's us know how we do know. Once I'll try it first." (Husband of pregnant women older than 30 years)*

Trust and accuracy as a concern for SMBP: Husbands also questioned the reliability of BP measurements due to the fluctuating nature of BP generally, which was also compounded by the newness of measuring BP via a smartphone application.

> *"When I check it, I have to check it using normal blood pressure [device], so that I know whether it's true or not so that the application is certain.... The problem is that there are so many applications like that, like that too but I don't think that is ever accurate." (Husband of pregnant women younger than 30 years)*

> *"At that hour, the blood[pressure] can go down or up, it's impossible, right, from that pressure, maybe something from the device might be damaged or maybe it's lacking, maybe it's right." (Husband of pregnant women younger than 30 years)*

pregnant women where BP issues were diagnosed during the current pregnancy. However, this would need to be confirmed with a larger study and stratified sampling between pregnant women with a history of HDP and those where it is newly onset. Additionally, we observed a conflation between blood hemoglobin and BP, in which pregnant women questioned the consumption of iron folic acid due to fears it would elevate their already high BP. Considering the risk for anaemia in pregnancy [58–60], this perceived linkage would need to be addressed through targeted health information and education [61]. To our knowledge, this conflation in pregnant women's understanding of BP versus blood haemoglobin and anemia has not been extensively documented in other studies. Future research conducted should explore whether this finding is specific to the study context, such as due to packaging iron-folic acid supplements as "blood boosters," and the implications of this potential misconception.

Although findings of reassurance and empowerment have emerged in other SMBP studies [8, 11, 20, 22], we observed critical impediments related to self-efficacy and lack of clarity in managing BP results, similar to that of a study conducted among minority populations in the United States [18]. These issues of women's acceptability and feasibility of SMBP point to a need to strengthen counseling among pregnant women during antenatal care to facilitate SMBP to be a more equitable and effective strategy for addressing HDPs [18, 29, 62]. The variability in women's understanding and not receiving adequate explanation also points to opportunities to improve quality of ANC [63]. Notably, participants highlighted the use of online tools to supplement knowledge gaps and expand their health literacy during pregnancy. With the increasing use of digital tools among individuals [64], mobile devices can play a dual role as enablers for understanding BP, and as an actual tool to conduct SMBP, as explored in this study.

A key strength of this study is that it goes beyond a theoretical understanding of SMBP in LMIC contexts and obtain feedback from women who had exposure to SMBP using a smartphone application. This corroborated the findings from the FGDs and underscored the practical concerns of pregnant women conducting SMBP. The experience of conducting SMBP with a smartphone also added a dimension for examining emerging innovations of "software as a medical device" [37], flagging the need for building trust among users of digital tools. Furthermore, this study responds to a direct research gap identified in the WHO guidelines on self-care interventions [7] and contributes to the nascent body of literature on SMBP in LMIC settings, where comprehensive approaches to managing HDPs are needed most. Limitations of the study comprise the exclusion of women who were not literate, which could affect the digital divide and introduce a bias in recruiting women with great health literacy. Lastly, the interviews were conducted in Bahasa Indonesia with the analysis conducted in English; however, this was mitigated through quality assurance in double transcription and double translation, as well as collective discussions with authors from the local contexts on the key themes.

Conclusions

Our study provides key considerations for introducing SMBP among women with HDPs in primary healthcare contexts. For SMBP to be implemented in line with WHO recommendations [7], efforts are needed to ensure linkages with the health system, including strengthening counselling among women with HDPs, clarifying protocols for SMBP and subsequent actions, and providing continued support to pregnant women. In the absence of this integration within the broader health ecosystem and understanding of pregnant women's self-efficacy, SMBP may risk being perceived as an additional burden and a source of anxiety on women and families [57]. Considering the varying levels of knowledge about blood pressure, future research should also examine the implications of introducing SMBP among pregnant women with chronic hypertension versus those with newly onset gestational hypertension, as well as exploring the potential conflation between blood pressure and blood haemoglobin. Furthermore, it will be important to account for health workers' perspectives as part of the broader considerations for integrating SMBP into the health system [15, 29, 31].

Abbreviations

BP	Blood pressure
FGD	Focus group discussion
HDP	Hypertensive diseases in pregnancy
IDI	In-depth interview
N/A	Not applicable
SMBP	Self-monitoring of blood pressure

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Author contributions

Conception and design of the work: TT, YDS, MB, OT, AHS, AG; Analysis and interpretation of data: TT, YDS, MB, NJM, OT, AHS; Drafting of the manuscript: TT; Revision and feedback: YDS, MB, AHS, OT, AG. All authors reviewed and approved the submitted version.

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Data availability
The data and materials that support the findings of this study are available from the Summit Institute for Development, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Summit Institute of Development.

Declarations

Ethics approval and consent to participate
The study was approved by the Health Research Ethics Committee, Faculty of Medicine, Universitas Mataram in Indonesia (004/UN18/F7/ETIK/2023) and the WHO/HRP Research Review Panel and WHO Ethical Review Committee (Reference number A65932). All eligible participants received an information sheet and were requested to provide informed written consent before participation and for audio and video recordings.

Consent for publication
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Competing interests
The authors declare no competing interests.

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