# Feasibility of Vital Signs Assessment by Community Health Workers during Antenatal Care Community Outreach in Lusaka, Zambia: A Qualitative Study

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## Abstract

# Introduction

The integration of digital tools in health initiatives marks a pivotal shift in traditional healthcare delivery methods. Technology-supported antenatal care (ANC) interventions have helped healthcare providers and community health workers (CHWs) to choose the course of action for individual patients. This study aimed to explore the suitability, feasibility, and acceptability of a wearable monitor, neoSpot, for measuring vital signs among pregnant women attending routine ANC visits during community outreach in Lusaka, Zambia.

# Methods

This pilot feasibility trial was implemented between March and May 2023 at Kanyama 1st Level Hospital. We conducted 24 in-depth interviews (IDIs) among 12 purposively selected pregnant women and 12 trained CHWs. NeoSpot was placed on a pregnant woman's arm to monitor vital signs and blood pressure. Thematic framework analysis used inductive and deductive reasoning for coding using NVivo and Excel for data organization. Qualitative data was analysed using NVivo. The suitability-feasibility-acceptability (SFA) framework was used to evaluate the potential of neoSpot as a tool for monitoring vital signs during routine ANC community outreach activities.

# Results

The study revealed that neoSpot was accepted by pregnant women and CHWs for its ability to comprehensively assess vital signs, including those not typically assessed at clinics. Participants valued its speed, efficiency, and user-friendliness, believing it could reduce waiting times at antenatal clinics. Initially, pregnant women expressed concerns and apprehension about the new device, fuelled by misinformation and fears of its impact on their unborn babies and their skin.

# Conclusion

Overall, all the study participants found the use of neoSpot to be suitable, feasible, and acceptable, and for use during ANC community outreach, largely due to its time efficiency, ability to simultaneously measure multiple vital signs, comfortable design, portability, and rechargeable battery. Incorporating recommendations could enhance the device's efficiencies and its acceptability by community members and CHWs.

# Trial Registration

# Introduction

Continuous vital sign monitoring is a basic tenet of specialized care in the developed world that is vastly underutilized during inpatient admissions or outpatient routine visits in most low-and-middle-income countries (LMICs). Despite the positive outcomes associated with vital sign monitoring (i.e., increased survival-to-discharge rates, lower complication rates, and shorter length of stay in hospital), the prohibitive costs of conventional patient monitors and the difficulty in maintaining complex medical equipment limit its practice in the developing world (1)(2)(3)(4)(5).

Maternal, neonatal and child health (MNCH) remains a critical challenge in low-resource settings, particularly in regions with limited access to healthcare facilities and professional healthcare providers. The integration of digital tools in MNCH initiatives marks a pivotal shift in traditional healthcare delivery methods. These interventions have been instrumental in enhancing the reach, efficiency, and impact of frontline health workers, particularly in remote and underserved regions. Recent literature has documented the successful integration of technology in community-based antenatal care (ANC) services, illustrating how digital advancements can bridge critical gaps in healthcare accessibility and quality.

The adoption of technology-supported ANC interventions has contributed to health worker training, decision-making support and maintenance of health records, with positive outcomes including, increased ANC attendance, early detection of high-risk pregnancies, management of birth complications, improved collaboration between community health workers (CHWs) and midwives and a perceived source of reassurance for pregnant women at a time when they are most concerned about their health (1)(2). Notably, the rapidly growing field of innovative wearable sensors has also emerged as a pivotal tool in the digital health landscape, providing real-time, non-invasive vital sign monitoring, coupled with the capabilities for digital data storage and remote transmission of vital sign readings (3)(4)(5)(6)(7).

Building upon the promising advancements in innovative vital sign monitors, and their application in MNCH, our study aims to further explore and contribute to this evolving field. The neoGuard v2.0 device (Fig. 1) is a 5-in-1 wearable vital signs monitor designed to measure temperature, pulse rate (PR), respiratory rate (RR), blood oxygen saturation ($SpO_2$) and blood pressure. It is currently under the final stages of development by Neopenda, PBC (Chicago, IL, USA) under international medical device standards and for feasibility in low-resource settings, including: low-power design, safe re-usability, ruggedness, portability, and ease of use. The device weighs approximately 15 grams and measures 42 x 36 x 14 mm. It is made of medical grade polyetherimide plastic and can be worn through an adjustable band.

The bands are made of medical-grade silicone rubber. The devices are wireless and powered by medically certified rechargeable batteries. The pulse rate, respiratory rate, temperature, blood pressure, and oxygen saturation data are recorded and transmitted to an app on a smartphone. Lastly, it contains

two non-invasive sensors: an optical reflectance pulse oximeter and a digital temperature sensor. These sensors measure signals from the surface of the patient's skin, and algorithms within the device calculate the pulse rate, respiratory rate, SpO2, blood pressure, and temperature.

The device evaluated in this study is part of Neopenda's second-generation wearable system, where the neoGuard v2.0 device can be paired with either a continuous monitoring app (neoMonitor) or a spot-checking app (neoSpot). In this study, the spot-checking configuration (Fig. 2) was used, and the system is referred to throughout as neoSpot to reflect this functionality. We report findings from a qualitative evaluation of neoSpot when used during community outreach from the perspectives of pregnant women and CHWs. We describe the feasibility, acceptability, ease of use, and perceived confidence of pregnant women and CHWs to use neoSpot during ANC community outreach in Lusaka, Zambia.

# Methods

# Study Design and Setting

This pilot feasibility trial was implemented at Kanyama 1st Level Hospital and its wider community catchment area in Lusaka, Zambia between March 1st, and May 31st, 2023. The study site, which provides services such as ANC, labor and delivery room, HIV/STI screening, and others, records around 13,000 ANC visits per year. This study was approved by the University of Zambia Biomedical Research Ethics Committee (Ref #: 3109 – 2022) and the National Health Research Authority (NHRA0000008/04/09/2022).

## Study Population and Sample Size

All pregnant women (PW) undergoing an ANC visit during routine community outreach activities and CHWs trained in the use of neoSpot were eligible for study participation. Pregnant women and CHWs who were younger than 18 years of age or did not consent to study participation were excluded from study participation. A total of 24 study participants were enrolled for in-depth interviews (IDIs), pulled from 12 CHWs who had used neoSpot on pregnant women during routine ANC community outreach activities which were supervised by government healthcare providers working at the study site and 12 purposefully selected pregnant women who had consented to be screened using neoSpot during the ANC outreach. A sample size of 12 per participant type has been shown to achieve thematic saturation. The device was synced with a smartphone provided by the study, which was monitored by the CHWs.

## Study Procedures

Research Assistants (RAs) hired by the study approached potential study participants and consented them for study participation. Following enrollment, CHWs and pregnant women underwent In-depth Interviews (IDIs) in a private setting. Pregnant women were purposefully selected from a pool of study

participants who had consented to undergo vital sign and blood pressure assessment using neoSpot. The device was placed on the participant's skin for < 1 minute and data were automatically stored in a smartphone provided by the study. Results of the vital signs and the blood pressure were also shared with the clinical treatment team following screening. The treating clinicians notified the participants of the results and, if required, referred them for appropriate care according to the local standard of care.

## Data Collection

Two IDI guides, one for pregnant women and one for CHWs, were developed specifically for this study to explore the suitability, feasibility, and acceptability of the neoSpot system in the context of ANC community outreach in Zambia. IDIs were conducted in the participants' preferred language: English, Nyanja, or Bemba. English language versions of the IDI guides have been included as Supplementary File 1 and File 2.

Each IDI lasted approximately 1 hour and was audio-recorded. Interviews conducted in Nyanja and Bemba were translated and transcribed into English by a study team member, while those conducted in English were transcribed verbatim. Audio recordings were transcribed, reviewed for completeness, and then permanently deleted to ensure participant confidentiality. Confidentiality of patient identifiers was protected by using a patient identification key that was stored separately from the data set. Each study participant was assigned a unique study identification number. The study database was password-protected, and accessible only to the study Principal Investigator (PI) and data analyst.

# Data Analysis

Following IDI transcription, two qualitative researchers applied thematic framework analysis (8) using NVivo 9.0 (QSR International, Australia) for data analysis. A codebook was developed iteratively using both inductive reasoning to identify emerging themes and deductive reasoning based on the interview guide. All the coders reviewed two transcripts and inductively developed codes. Each coder was initially assigned two transcripts to refine the codes and another two transcripts to achieve consistency. The codebook was used to map the data in Microsoft Excel after which data exploration was done by examining variations and nuances for each participant across the themes. Using the suitability-feasibility-acceptability (SFA) framework, the analysis evaluated the potential of neoSpot as a tool for monitoring vital signs during routine ANC community outreach activities. (9, 10)

## Results

This study aimed to demonstrate the suitability, feasibility, and acceptability of neoSpot when used by CHWs on pregnant women to check vital signs during ANC community outreach activities. We conducted 24 IDIs with a purposive sample of 12 CHWs and 12 pregnant women. Table 1 shows the main themes and sub-themes that captured common, recurring patterns. The results are organized according to each domain area in the SFA framework.

Table 1
Themes and subtitles of common and recurring patterns

| Themes | Sub-themes |
|---|---|
| Suitability | Previous knowledge of and experiences with neoSpot |
| | Perceived advantages and disadvantages of neoSpot |
| | Comprehensive Measuring of Vital Signs |
| | Speed and efficiency of neoSpot |
| Feasibility | Demand for use of neoSpot during ANC community outreach |
| | Integration of neoSpot into routine ANC during community outreach |
| | Practical use of neoSpot for ANC community outreach |
| Acceptability | Ethicality of the use of neoSpot |
| | Opportunity costs incurred due to the use of neoSpot |
| | Perceived effectiveness of neoSpot |
| | Perceived self-efficacy of neoSpot |
| | Practical preferences for neoSpot usage |

**Theme 1: Suitability** During the IDIs, participants were asked to comment on the health system's opportunities and constraints that could impact the use of the digital device during routine ANC community outreach.

## Previous knowledge of and experiences with neoSpot

Before being trained, the CHWs had never seen or used neoSpot to monitor vital signs. Others thought that the device would not work well for measuring vital signs. Similarly, pregnant women did not know neoSpot and said they had never had their vital signs monitored by such a device.

"Well, according to what I was told, [the device] was actually designed for children but, the study is trying to see how it would work on adults, which is absolutely exciting…So, at first, it looks like a watch but of course, it's not a watch and it works differently from a watch." [CHW IDI_07]

"Yeah, actually, the first time that I heard I never thought this will work." [CHW IDI-04]

"Thoughts are normally there and this is because it's the first time of seeing such a device…so you have that in mind to say what do they want to do to me…?" [PW IDI_01]

"I thought it squeezes very much compared to the BP machine…because of the way it looks. It looks rubbery. It is elasticated. It was just cold." [PW IDI_05]

“I heard of it from the clinic…that’s how we were taught about it. We were told that the device is the same as the old [BP] machine…they want to see how it works on someone’s body…is it the same? Is it fast or slow?” [PW IDI_07]

“I felt good because it is different from the one which they put on the hand because it shocks but with this new one, there is nothing that you will feel such that even if you will get surprised that just now you are done checking for my temperature or BP because results come together.” [PW IDI_10]

## Perceived advantages and disadvantages of neoSpot

There was a general perception that neoSpot could benefit the health system, its end-users, and the recipients of ANC community outreach services. The participants thought that device would complement current practices in ANC provision and improve service delivery turnaround time. When asked about their overall thoughts and feelings about neoSpot, CHWs said,

“This thing made me feel good because like I said, we use the BP machine then after you are done, you need to get the thermometer and measure the woman’s temperature. I am sure it was taking more than 15 minutes but since I started using the device, it only takes a short while then I would get 4 readings within 5 minutes. It saves time.” [CHW IDI_12]

“Some [pregnant women] would be surprised. Others would laugh and say, ‘this technology is changing.’…because they are used to the manual BP machines then what they were seeing is something like watch which was giving readings on a phone.” [CHW IDI_06]

“When we do assessments and find that they (pregnant women) are not okay, we quickly give them a referral to go to the health facility to be assisted. So, we will reduce a lot of complications.” [CHW IDI_06]

“It changed my work because when I measure once time, I will know if the woman’s oxygen is enough for a pregnant woman…I will know how her BP and temperature are at the same time. If it [oxygen] has reduced, I will quickly talk to the people at the hospital and the woman will get help fast.” [CHW IDI_12]

However, some participants also highlighted the disadvantages of using neoSpot for vital signs monitoring during ANC community outreach. A pregnant woman said, “…I noticed it when they are screening you, sometimes what it needed was 15 minutes for one person…Yes, because when they screen you, it will fail to read properly, and it will go back to zero. I noticed that the device doesn’t want you shaking when it’s taking measurements.” PWD IDI_01

Another pregnant woman expressed disappointment because she felt that the device took longer to produce results. She stated that, “…when I entered, I thought that since it’s a new machine, just a push of a button then it reads, and you are on your way out. I found that was taking longer so I was a bit disappointed.” PW IDI_02

Additionally, a CHW thought that even though pregnant women were sensitized about neoSpot, some pregnant women may have been apprehensive about having their vital signs measured by the device for the first time and attributed the malfunctioning of the device to the pregnant woman's uneasiness. Another disadvantage that was highlighted by some participants was the need for internet connectivity to enable the use of the device which they said caused delays if there were network interruptions.

"As I introduced it to her the first time, one was a bit scared and nervous…then I measured her but the results didn't come out well. They were all zeros." [CHW IDI_05]

"Sometimes, you find that it's not connected, or there is a problem with WiFi. So, that causes delays… Everything should be in place until you complete the whole process and ask the woman questions…You don't need to have interruptions with the network because that [causes] delays." [CHW IDI_01]

Another CHW stated that they had experienced challenges with placing the device on a slender pregnant woman while another said they had problems obtaining the readings.

"…the first woman I assessed had a challenge...she was thin. She was so thin that the belt could not be fastened properly until I had to use a pin. So, for that woman, the left arm didn't give good readings." [CHW IDI_06]

Nevertheless, there was a feeling that the use of neoSpot could potentially increase ANC attendance if some of the operational challenges were resolved.

"I have observed that a lot of women in the community shun coming to the health facility when they are pregnant because they know that it will take very long and most delays are caused by long queues…Okay, neoSpot will help us a lot…if it is worked on and all the issues we experienced are resolved. It [should] start reading the results faster whereby [it starts working] once you connect it… [CHW IDI-08]

# Comprehensive Measuring of Vital Signs

NeoSpot was used to monitor blood pressure, blood oxygen saturation, pulse rate, respiratory rate, and temperature during the study implementation. Both the CHWs and pregnant women expressed their appreciation of the device's comprehensive screening vital signs capabilities, highlighting that it facilitated screening for different parameters including those typically not examined during routine clinic visits:

"This one does not just assess BP and pulse, there are other things. We will assess vital signs on the woman which are also important for the woman to know." [CHW IDI_06]

What I liked the most about this device is that it tests for everything even those things that are not tested at the clinic.

Despite neoSpot ability to screen vital signs at the same time, some of the pregnant women questioned why measurements were being read from the arms and foreheads and expressed fear about its use on their bodies. Nevertheless, some of them were still keen on participating in the study as they believed that the results would be useful for improving ANC.

“What is this device? Why are you taking measurements on three parts of the body?” [CHW IDI_09]

“At first, I was scared…but I felt good when it was put on my head though I don’t know why it was being out there but maybe I had forgotten but we were taught.” [PW IDI_07]

However, some pregnant women also expressed concern about the negative effect of the device on an individual’s health. The pregnant women highlighted the possibilities of experiencing a miscarriage or developing a rash when the device was placed on their tummies or foreheads, respectively.

“…there were people who were explaining, maybe there is an area where they saw it. So, they were the ones who thought they would scare us by saying it is not good and again, if you put in on your stomach, you will have a miscarriage…If it is on your head, you will have a headache and sometimes develop a rash.” [PW IDI_08]

## Speed and efficiency of neoSpot

One favorable aspect of neoSpot was the quick screening process and results turnaround time. Pregnant women were of the view that the device’s efficiency had the potential to reduce waiting times at antenatal clinics, thereby alleviating long queues. The CHWs perhaps expected that the efficiency of neoSpot would free their time and enable them to perform other tasks at the health facility.

“Another thing is that it can be fast. You can help us so that we can be going fast at antenatal and maybe there won’t be long queues because this tests for everything at the same time.” [PW IDI 01]

“The device will quickly give the results and the patient will go back home. So, I was very eager to see this device, and also try to see how it would help people in our community.” [CHW IDI_08]

Some pregnant women were impressed with the availability of more than one device which enabled the CHWs to attend to multiple patients simultaneously.

“My thoughts were that I saw it as a good idea because when they came, they didn’t bring just one device and I believe they will not be using just one device. They will be coming with a lot of them. …looking at the device, it will be fast, and that when tests are done on you, then all are done at once and you don’t have to go elsewhere.” [PW IDI_02]

# Theme 2: Feasibility

The analysis considered Bowen’s feasibility framework (11) and focused on demand, integration, and practicality to assess the feasibility of implementing neoSpot for ANC community outreach.

# Demand for use of neoSpot during ANC community outreach

The study explored the demand for the intervention by enquiring about the actual use of neoSpot during ANC community outreach. Some pregnant women suggested that neoSpot would be feasible to implement and assumed that ANC services would be provided simultaneously at two locations with nurses using the routine vital signs screening tools (i.e. BP machine and thermometer) at the health facility level and the CHWs using neoSpot at the community level.

“What made me happy is that if at least those people will be coming to the community like they did that time, things will be much better. Unlike at the clinic where we are a lot and you find that those nurses start saying that we have run out of time and others [mothers] go back without being checked.” [PW IDI_11]

Some CHWs acknowledged the obvious shortage of equipment for monitoring vital signs at the facility level and thought this inadequacy posed a challenge when teams were split between the health facility and community to provide routine ANC services. They thought introducing neoSpot would alleviate some of the inadequacy challenges and improve the quality of service.

“Well, I thought that because I identify with the challenges that the community goes through because of the shortages in equipment, this idea came in and I was anxious to see some of the challenges being sorted out…and helping to improve our service delivery.” [CHW IDI_07]

"The first thing that came to my mind is that it will be an advantage because you won’t be spending a lot of time measuring for different things as you can be getting the measurements done at once..." [CHW IDI 09]

They also expressed concern about how much time would be required to provide ANC during community outreach and whether there would be enough human resources to provide the services.

“So, when you introduce these devices, even the workers have to increase in number because that thing works with a phone. So, for you to use one phone to attend to one person would take a lot of time. …you can’t leave one worker attending to patients especially that the results also have to be recorded.” [PW IDI_02]

# Integration of neoSpot into routine ANC during community outreach

In discussing the possibility of incorporating neoSpot into routine ANC during community outreach, some CHWs thought that it was vital to provide adequate information about the device to pregnant women before using it to monitor their vital signs.

“I think sensitization is very, very important. Mothers need to be told about the importance of checking their BP, knowing their oxygen levels, pulse rate…[and] you [can] tell the women about the need to be assessed… currently, we have a new device that is easy to use and carry…it’s easy to read the results. It is new but it’s not something scary…[CHW IDI_01]

“Sharing information can help the [pregnant women] become more knowledgeable and could help with acceptability as well as the adoption of the device in other clinics. [CHW IDI_08]

Other CHWs felt that using neoSpot was better than using the manual tools to check vital signs during routine ANC. One CHW said, “Yes, it is a better approach because it is really helpful…I will not bother to say, “pass me that other device, let’s look for the other device to give us the…temperature readings, go and look for a BP machine because it is giving us all the readings…at once. [CHW IDI_02]

While some of the CHWs thought that integrating the device into ANC community outreach was a good suggestion as it would easily be used in the community and minimize the queueing up and long waiting times, others had a feeling that incorporating neoSpot into community activities would not be appropriate because of security concerns. Additionally, some CHWs thought that phones would also be used for personal activities and suggested the use of secure tablets.

“...the other thing I was worried about is the phones. …it can bring some challenges and problems. I think using phones is not very safe. I think there should be some sort of tablet or maybe a tablet that can be designed to be a medical tool that cannot be used for personal things.” [CHW IDI-10]

# Practical use of neoSpot for ANC community outreach

There was a general belief among some of the participants that neoSpot was easy and convenient to use because of the mode of vital signs monitoring and results availability. However, some of them experienced challenges with using the device.

“…neoSpot is easy and it is fast as well. The problem that I was facing was the readings on neoSpot. For some clients, almost four of them, it was reading zeros. And if I try the other neoSpot, it reads. I don’t know if the other machine was not reading properly or we were not positioning it well.” [CHW IDI_11]

Some CHWs attributed the device’s inability to produce consistent vital signs readings to malfunction and connectivity challenges and thought that the operations of neoSpot could be improved if these bottlenecks were resolved. Participants expected the device to be more efficient as compared to the standard of care and expressed frustrations when they were required to wait for longer than usual to get the results.

“Another thing is that neoSpot app, for it to load the questionnaire needs an internet connection but there are scenarios where you may try to connect then the network just breaks down ... and you have to go back into the app and log in again and redo the measurement so like you really can't get that file that was saved and just transfer the information directly. You have to restart the whole procedure.”. [CHW IDI 07]

"The problem I was facing was the readings from neoSpot. For some clients … almost four of them, it was reading zeros. And if I try the other neoSpot, it reads. I don't know if the other machine was not reading properly, or we were not positioning it well." [CHW IDI 11]

"It should be easy to connect to the Internet so that it should be effective…when it's put on a client, it reads immediately than having to repeat." [CHW IDI_11]

Pregnant women also highlighted the connectivity challenges experienced by the CHWs and stated that,

"They were losing I don't know if it's signal. I don't know about the connection but what it was doing is that it starts, then stops." [PW IDI_03]

CHWs found the device's portability a convenience when used both in the community. They indicated that the rechargeable battery allowed them to charge the device once at the health facility for a dedicated period made it possible to use the device for extended periods of time in communities.

"It's perfect because it's portable like phones but for the BP machines, you find that you carry it and develop a fault. Other BP machines need pumping but for neoSpot, it's easy, it's portable and it's fast." [CHW IDI 09]

# Theme 3: Acceptability

The theoretical framework of acceptability guided the exploration of constructs under the acceptability theme. (12) This study focused on constructs that may affect how the device is perceived and received by the various stakeholders (i.e., community health workers and pregnant women) within the health system. The constructs included ethicality, burden, affective attitude, intervention coherence, opportunity costs, perceived effectiveness, and self-efficacy.

# Ethicality of the use of neoSpot

The lack of confidentiality was a concern for some pregnant women. They thought that confidentiality was compromised when the device was used in the community due to the large number of pregnant women who accessed ANC during community outreach. They suggested placing the device in private clinics where ANC services are provided in enclosed spaces and provided for a smaller number of clients or erecting buildings within the community to provide services in enclosed spaces and build people's trust.

"It would be easy if they could introduce them in private clinics or if they open a clinic in the community such that people can trust it because here, you will find a lot of people." PW IDI_12

Pregnant women felt the need to participate in the study because they felt that their participation would help determine if the device could be scaled up for use and consequently, improve ANC service delivery.

"It's the first time I am seeing such a thing and there are people that may be afraid…So, you have that in mind to say what do they want to do to me? And then there are thoughts [that] if we don't help these

people test this device, who else will help them?" [PW IDI_01]

"My decision was based on the fact that I have seen that anything that the hospital brings is helpful and I have witnessed it on my side. They want to see how the machine can work. They need to try so they have to try it on me because that clinic is not for animals but for us human beings." [PW IDI_05]

# Opportunity costs incurred due to the use of neoSpot

When they were initially informed about neoSpot, CHWs reported being curious about it, and sought to obtain first-hand experience of its operations to be able to compare it to the conventional BP machine that is used in health facilities. While they were delighted about the device's efficiency and ease of use, they were concerned about the opportunity costs that would be incurred by the pregnant women when they received care through community outreach and how the costs would impact their families.

"Within a short time, we help the women so that they also go and attend to other things because the way life is currently, women are busy. Some run businesses, others are working. So when they come here and you keep them the whole day, it means her day has been wasted. Some of them are single mothers and families depend on them. If you keep them for only a short while, they will proceed with the things they usually do [CHW IDI-06]

The CHWs were concerned about how much time was required to take vital sign readings as spending and whether the device would be acceptable among pregnant women.

"My thoughts were, "How this thing can manage to do four things at once!" I thought to myself that, "Then how long does it take to do all these four things at once." That's what I thought since I have worked with pregnant women for a long time. I wondered, "Would a pregnant woman accept it or not?" [CHW IDI 12]

# Perceived effectiveness of neoSpot

Both the pregnant women and CHWs valued neoSpot citing its capacity to simultaneously measure multiple vital signs, its inclusion of oxygen saturation measurement (stated as not routine in ANC), and consistently report the results of individual pregnant women via a phone:

"…when I saw it, I wondered how a small thing like that would be able to read the measurements and give results correctly. I had an exciting experience using the device. [CHW IDI_08]

"I think there are some who have used the gadgets…so…they always measure the steps. I am quite sure that with this device, the readings are correct because it is reading from the blood of the body. It is taking measurements and temperature of the body so some results are fine. [CHW IDI-09]

They felt confident because the readings were the same. It is not the first one. They say that technology changes so obviously, even this one can work…

Some pregnant women reported a favorable attitude towards adopting neoSpot, a sign of their willingness to embrace novelty and advancements in healthcare technology:

“The reason why I accepted is because I wanted to take part because technology is changing nowadays so I wanted to take part. So, I accepted because I wanted us to be using new things.” (PW IDI 10)

“They were so happy when they saw it to say it’s new, it’s small. It’s different. And how is it even working? They were so interested in knowing.” [CHW IDI 02]

# Perceived self-efficacy of neoSpot

There was a perceived belief among pregnant women that if neoSpot was used to check their vital signs, they would experience some negative effects. They were apprehensive about its use because of the rumours suggesting that allowing the placement of the device on their head, skin or abdomen could potentially lead to a headache, skin rash, or miscarriage, respectively. This apprehension also stemmed from the lack of familiarity with the device as the pregnant women had neither seen nor used the device before the study outreach activities.

“They would scare us saying it is not good and again if it will be put on your stomach, you will have a miscarriage…If you out it on your head, you will have a headache and sometimes develop a rash.” [PW IDI 01]

“I was scared ... I didn’t know what it was and what it’d do, but those testing me encouraged me that, “Do not be scared”.” [PW IDI 7]

After experiencing neoSpot, some pregnant women felt that the device offered a less restrictive and more comfortable experience when compared to the traditional BP machines which often felt like they squeezed the arm during the measurement process.

“I feel good because it (neoSpot) doesn’t squeeze, like for example the old one, it squeezes and feels like it’s draining your blood but this one doesn’t. This one is good because you will feel flexible even after it’s put on you.” (PW IDI 4)

“Like I said that the BP machine makes my heartbeat faster but when the device is put on you, it is quiet, it does not feel like it hurts or doing anything. It is not tight or hold on to you such that it makes you feel uncomfortable. You can have that device or not, but your hand still feels the same.” (PW IDI 5)

Some pregnant women were pleased with the operations of neoSpot and highlighted its capacity to take various vital signs at the same time. One pregnant woman said, “What I like about this thing [neoSpot] is that it’ll be reading everything at once and you are done. There won’t be things like this is not there, wait for it. It will be reading everything at one time at once”. [PW IDI 02]

# Practical preferences for NeoSpot usage

CHWs suggested that neoSpot should be used to measure vital signs on only one part of the body as opposed to the three parts (left arm, right arm, and forehead) to streamline the measuring process and save additional time. Most pregnant women preferred to have neoSpot placed on their arms to check their BP reading like it is done with the conventional method.

“It should be made to measure vital signs on one part of the body and not all three – left, right arms and forehead to save time for the patients and providers.” [CHW IDI 12]

“Testing should be on my hand. The hand is where I felt comfortable. It is what I am used to. Even when checking for BP, it’s where they check from.” [PW IDI 06]

Some pregnant women recommended that the device should feature adjustable belts to accommodate people of varying body sizes to enhance its practical usability.

“The belts should be made such that you can tune because there are very different people, some very slim people. I noticed that if not tuned very much it can’t read.” [PW IDI 01]

# Discussion

This study explored the suitability, feasibility, and acceptability of a wearable monitor, neoSpot, for measuring vital signs among pregnant women attending routine ANC visits during community outreach in Lusaka, Zambia. The study findings show that generally, the device could be used to monitor the vital signs of pregnant women during ANC community outreach. Pregnant women and CHWs experienced measuring vital signs using neoSpot including the ones that would typically not be monitored at the health facility due to inadequate tools.

The findings from this study resonate with the broader literature on the suitability, feasibility, and acceptability of wearable vital sign monitoring technologies, particularly in low-resource settings. A key aspect of our study was the integration of neoSpot in ANC community outreach by CHWs, which aligns with the growing trend of employing digital health interventions in the delivery of MNCH services (1)(2)(13)(14). Our acceptability findings highlighted the initial apprehension among pregnant women towards neoSpot, a sentiment also observed in other studies where new health technologies were introduced (18)(19). The apprehensions regarding the use of neoSpot due to community misconceptions (such as the perceived onset of headaches, skin rashes and possible miscarriages) and unfamiliarity underscore the need for culturally sensitive education and community engagement.

Both the CHWs and pregnant women appreciated the device and its use in the community but expressed concerns about the seemingly extended time to attend to individuals particularly when there was an error in the readings. However, while some CHWs were anxious about the opportunity costs to be incurred by the pregnant women due to the extended waiting times, the pregnant women were more cognizant of the possibility that this community-led approach would help eliminate the need to access ANC services at congested health facilities. They were also curious about the possibility of using the

device at home in the absence of a CHW if there was a need to continue monitoring abnormal vital signs readings.

The CHWs were also concerned about the security of the phones when they were returned to the health facility for safekeeping and possible personal use of the phones. Similar to challenges reported from projects in Rwanda (14), Uganda (16)(17), and Burkina Faso (1), our study encountered obstacles related to logistical aspects of implementing technology-based interventions in low-resource settings, such as device malfunctions and connectivity issues. These challenges underscore the need for robust support systems and infrastructure to ensure the efficacy of technological interventions in similar settings. Recommendations for improving neoSpot, such as addressing connectivity issues and adjusting the device for different body sizes, are consistent with the literature emphasizing the importance of user-friendly design in wearable health technologies (7)(18)(22)(16)(21).

The CHWs and pregnant women were optimistic that the scaleup of neoSpot for vital signs monitoring during ANC community outreach has the potential to decongest the health facility and facilitate the identification of pregnant women needing emergency care and referral to the health facility for further management, thereby improving ANC service delivery. In North Carolina, physicians perceived the top benefits of wearable health technologies as real-time monitoring of chronic disease management, improved patient communication and care coordination, remote monitoring, and off-site diagnosis. They, however, noted that adding another device would increase the data to be collected and strain the already hectic workflow. (15)

Regarding the device's suitability and feasibility, both pregnant women and CHWs appreciated the device's comprehensive measuring capability and efficiency in providing results, contributing to reduced waiting times. This aligns with the reported benefits of wearable devices in other healthcare settings (20) (21). However, challenges related to device malfunctions and connectivity issues are common concerns in the deployment of digital health tools, especially in low-resource settings (1)(14)(16)(17).

Overall, our study suggests that the integration of neoSpot in community health settings can enhance the efficiency and reach of CHW-led ANC services. This is in line with the growing evidence supporting the use of wearable sensors for vital signs monitoring in various healthcare settings, offering the potential to improve patient outcomes (22)(23)(14)(20)(24). To maximize the benefits of multifunctional healthcare technologies in low-resource settings, innovators should consider strategies for overcoming technological barriers, ensuring community engagement and providing training to healthcare workers (5)(23)(25)(26)(27). Future research should focus on long-term impact assessments, scalability and integration of such interventions within existing healthcare systems.

# Limitations

We acknowledge that there were some limitations to our study. First, interviewing CHWs may have introduced desirability bias leading to highlighting the positive features of this digital vital signs monitoring tool. However, their extensive involvement in routine community ANC outreach activities

allows them to objectively compare both approaches. Secondly, while the device was used by CHWs, it was utilized in an urban setting in Lusaka, thus our findings may not be generalizable to rural settings within Zambia where CHWs may not be exposed to such digital tools. Additionally, urban settings may be more favorable for the use of digital monitoring tools that require internet connectivity as compared to rural settings with possible less connectivity. Further research would help to clarify the usability of this device in rural settings with different challenges revolving around community ANC activities.

# Conclusion

The findings of this study suggest that neoSpot is a useful digital tool for vital signs monitoring during community outreach. The device has the potential to improve the monitoring of vital signs during pregnancy, mitigate the inadequate availability of vital signs monitoring tools at health facilities, and facilitate the provision of improved care for women in need. Even though there was some apprehension about the use of the device in the community, both the CHWs and pregnant women appreciated the benefits of monitoring several vital signs simultaneously. Recommendations to improve the functionality of the device should be considered. While stakeholder engagement is a critical component to ensuring high acceptance of the device, adopting a patient-centered approach should be prioritized to achieve patient satisfaction and improved health outcomes.

# Abbreviations

ANC
Antenatal care
IDI
In depth interview
PW
Pregnant women
SFA
Suitability-feasibility-acceptability
CHWs
Community health workers
LMICs
Low-and middle-income countries
MNCH
Maternal, neonatal and child health
PR
Pulse rate
RR
Respiratory rate
SPO2
Blood oxygen saturation

BP
Blood pressure
HIV
Human Immunodeficiency virus
STI
Sexually transmitted infection
RAs
Research assistant
PI
Principal investigator

# Declarations

Ethics approval and consent to participate

This study was approved by the University of Zambia Biomedical Research Ethics Committee (Ref #: 3109-2022) and the National Health Research Authority (NHRA0000008/04/09/2022). All study procedures were conducted in accordance with the Declaration of Helsinki and relevant local guidelines and regulations. Written informed consent was obtained from all participants prior to their involvement in the study.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

Teresa Cauvel and Sona Shah are co-founders and current employees of Neopenda, the innovator of NeoSpot. Assumpta Nantume was previously affiliated with Neopenda as the Research and Evaluation Lead. The remaining authors declare that they have no competing interests.

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Authors' contributions

TT – interpreted the data and completed the first draft of the manuscript

NM – conducted the statistical analysis, developed the results section, and reviewed the manuscript.

AM – co-developed the study protocol, oversaw the study implementation, data collection, interpreted the results, and drafting of this manuscript.

CM – conducted the high-level data analysis and reviewed the manuscript.

KM – oversaw the data collection

HN – conducted the translations and transcriptions of the IDIs

TZ – conducted the translations and transcriptions of the IDIs

EH – conducted the translations and transcriptions of the IDIs

AS – assisted with development of the interview guides, data interpretation, and provided feedback on the manuscript

TC – co-developed the study protocol and provided feedback on the manuscript

SS – co-developed the study protocol and provided feedback on the manuscript

AN – co-developed the study protocol, oversaw the study implementation, data collection, interpreted the results, and drafting of this manuscript.

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# Figures


**Figure 1**

The neoGuard v2.0 wearable device developed by Neopenda

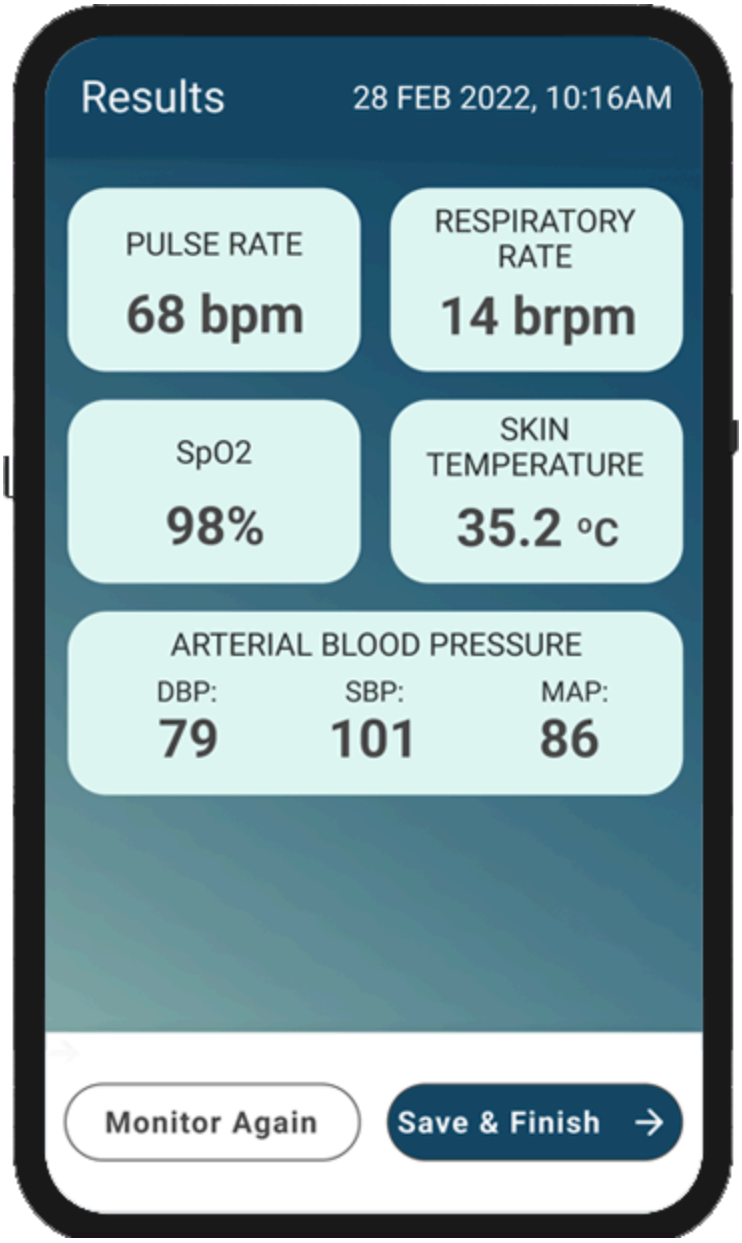


**Figure 2**

The neoSpot mobile application displaying vital signs readings

## Supplementary Files

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- NeoSpotCHWsIDIGuideV1.0Final.docx
- NeoSpotPregnantWomanIDIGuideV1.0Final.docx