Using new fetal heart rate monitoring technology

Experiences and perceptions among skilled birth attendants and laboring women in Tanzania

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Abbreviations

ANC: Ante Natal Care

bpm: Beats per minute

CS: Caesarean Section

CTG: cardiotocography

DHS: Demographic Health Survey

eFHRM: electronic Fetal Heart-rate Monitoring

ENAP: Every Newborn Action Plan

FGD: Focus-Group Discussion

FHR: Fetal Heart Rate

FHRM: Fetal Heart-Rate Monitoring

FIGO: the International Federation of Gynecology and Obstetrics

HLH: Haydon Lutheran Hospital

HR: Heart Rate

IA: Intermittent Auscultation

MDG: Millennium Development Goal

MNH: Muhimbili National Hospital

MVA: Manual Vacuum Aspiration

RCT: Randomized Control Trial

SBA: Skilled Birth Attendant

SDG: Sustainable Development Goal

TAM: Technology Acceptance Model

TRRH: Temeke Regional Referral Hospital

WHO: World Health Organization

UN: United Nations

UNFPA: United Nations Population Fund

Definitions

Adoption of technology: a sociological model that describes the acceptance of a new product or innovation.

Diffusion: the information exchange through which one individual communicates a new idea to one or several others.

Early neonatal death: a death in the first seven days of life.

Intrapartum stillbirth/fresh stillbirth: a death that occurs after the onset of labor but before birth.

Innovation: the intentional introduction and application within a role, group, or organization, of ideas, processes, products or procedures, new to the relevant unit of adoption, designed to significantly benefit the individual, the group, or wider society.

Health-care worker: all people engaged in actions whose primary intent is to enhance health.

High-/middle-/low-income country: as defined by the World Bank based on gross national income (GNI), low-income country being defined as having a GNI of less than 995$ and high-income of having a GNI of 12 055$.

Low-resource setting: characterized by a lack of funds to cover health-care costs on an individual or societal basis, leading to one or all of the following: limited access to medication, equipment, supplies, and devices; less-developed infrastructure (electrical power, transportation, controlled environment/buildings); fewer or less-trained personnel, limited access to maintenance and parts, limited availability of equipment, supplies, and medication.

Neonatal/newborn period: the first 28 days of life.

New technology: any set of productive techniques that offers a significant improvement over the established technology for a given process in a specific historical context.

Perinatal mortality: a stillbirth of greater than or equal to 28 weeks of gestation and early neonatal deaths at or before seven days of life.

Perinatal period: the fetal period from 28 weeks of gestation age to early neonatal period of seven days of life.

Stillbirth/late fetal death: a newborn with no signs of life at or after 28 weeks of gestation.

Skilled birth attendant: an accredited health professional such as a midwife, doctor, or nurse who has been educated and trained to proficiency in the skills needed to manage normal (uncomplicated) pregnancies, childbirth and the immediate postnatal period, and in the identification, management, and referral of complications in women and newborns.

Quality of care: Defined as the extent to which health-care services provided to individuals and patient populations improve desired health outcomes in terms of them being performed "safely, efficiently, effectively, timely, equitably and people-centered."(WHO)

Technology: the collection of techniques, skills, methods, and processes used in the production of goods or services, or in the accomplishment of objectives such as scientific investigation. Technology can be the knowledge of techniques, processes, and the like, or it can be embedded in machines to allow for operation without detailed knowledge of their workings.

Abstract

Introduction: Each year, an estimated 5.2 million stillbirths and newborn deaths occur globally, primarily in low-resource settings. Regular fetal heart-rate monitoring during labor and the early detection of fetal distress is one method to identify a fetus at risk and to initiate action in order to reduce fresh stillbirth and neonatal mortality. Due to a lack of skilled birth attendants, among other factors, fetal heart-rate monitoring is often not carried out as frequently as recommended. A newly developed electronic fetal heart-rate monitor using Doppler technology, which can be strapped on a woman in labor for continuous fetal heart-rate monitoring, was introduced in Tanzania in 2015. The monitor is called Moyo.

Objective: The main objective of this study was to gain a deeper understanding of the adoption and use of a new technology (Moyo) among skilled birth attendants and laboring women in two urban hospitals in Tanzania.

Methods: Five focus-group discussions and 30 semi-structured in-depth interviews were conducted with skilled birth attendants and women. In total, 53 skilled birth attendants and 20 women participated in the study, which was conducted at two tertiary hospitals in Dar es Salaam, Tanzania. Observation, key-informant interviews, and field notes were used to contextualize findings. Qualitative content analysis was used to analyze the data.

Results: The device was perceived to be useful and highly necessary by all participants. Its use was believed to contribute to reducing maternal and perinatal mortality. Both the skilled birth attendants and the laboring women believed that using the device improved care. For the women, the device also provided much needed information about the status of their child and knowing that their child was doing well, which contributed towards improving their birth experience. Factors that negatively affected adoption of the device included a lack of knowledge about correct use of the device and its limitations. Several women reported not being informed about the purpose of the device. The skilled birth attendants expressed a need for more training on the use of the device, both through practical training and theoretical knowledge, including how to respond to the device's alerts of fetal distress. High staff turnover seemed to impede the diffusion of knowledge about the use of the device in the two labor wards included in the study.

Conclusion: The electronic strap-on continuous fetal heart-rate monitor, Moyo, was perceived as a much needed and highly useful tool to improve fetal heart-rate monitoring for both skilled birth attendants and laboring women. While new technological devices present huge opportunities in low-resource settings in reducing morbidity and mortality, this study indicates that a tailored and long-term approach is needed to ensure that the device and its functions are well understood. This includes comprehensive training and support to users over time.

List of papers

This thesis is based on the following original papers:

Paper 1
Rivenes Lafontan, S.; Sundby, J.; Ersdal, H.L.; Abeid, M.; Kidanto, H.L.; Mbekenga, C.K. *"I Was Relieved to Know That My Baby Was Safe"*: Women's Attitudes and Perceptions on Using a New Electronic Fetal Heart Rate Monitor during Labor in Tanzania. *Int. J. Environ. Res. Public Health* **2018**, *15*, 302

Paper 2
Rivenes Lafontan, S.; Sundby, J.; Kidanto, H.L.; Mbekenga, C.K.; Ersdal, H.L. Acquiring Knowledge about the Use of a Newly Developed Electronic Fetal Heart Rate Monitor: A Qualitative Study Among Birth Attendants in Tanzania. *Int. J. Environ. Res. Public Health* **2018**, *15*, 2863

Paper 3
Rivenes Lafontan S.; Kidanto H.L.; Ersdal H.L.; Mbekenga C.K.; Sundby J. Perceptions and experiences of skilled birth attendants on using a newly developed strap-on electronic fetal heart rate monitor in Tanzania. *BMC Pregnancy Childbirth*. **2019**;19(1):165

Preface

It is 2015 and I am in Liberia managing a project aimed at restoring basic health services after the health system in the country nearly collapsed as a result of the Ebola epidemic. There are widespread reports that the perinatal and maternal mortality rates have spiked in a country where these rates are already among the highest in the world. Working for a UN agency, I am on a field visit to one of the rural health centers in a region outside the capital, Monrovia. I meet with staff and am given a tour of the health facility. As we enter the storage room, I can barely see anything since the only light source in the room is the sun coming in through the window. As my eyes adjust, I start to see boxes stacked against the walls and in a corner, what looks like a CTG machine protected by a plastic cover. I get closer and look at the midwife in charge. "We got it a few months ago from a donor" she says. "No one know how to use it and I don't think it is working properly anymore". We leave the room and close the door.

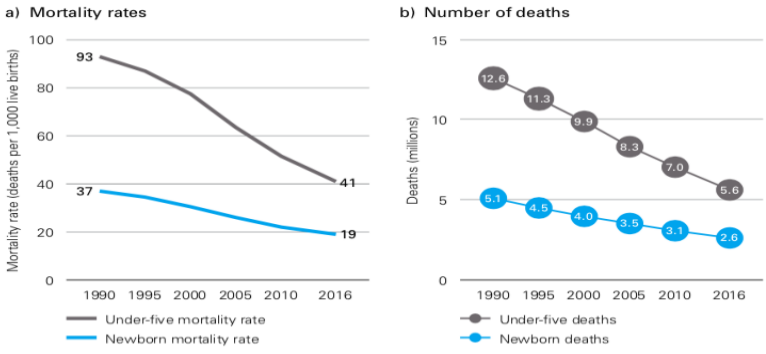
Sitting in the car on my way back to Monrovia, I look out the window and think about all of the times I have experienced this: costly new equipment that should be used to save lives merely gathering dust in a health facility in a low-resource country, unused. *How can we avoid this?* I wonder.

This thesis is an attempt to answer to that question.

1. Introduction

1.1 Global overview and trends in child mortality

The day of birth is the day with the highest mortality risk for both the mother and the baby (1). While there have been global improvements in reducing mortality rates for children under five years of age, mortality during birth until the first month of life- the newborn or neonatal period- has not declined at the same pace (Figure 1). As a result, neonates account for 45% of all deaths under five years of age (2). This amounts to 7000 neonates dying every day, a total of 2.6 million deaths each year (3). In addition, 2.6 million macerated and fresh stillbirths occur annually (4).



Note: The estimates generated by the United Nations Inter-agency Group for Child Mortality Estimation are made following annual consultations with Member States, and may differ from their official statistics because the IGME estimates are standardized, based on all sources of data from the country available in July 2017, and extrapolated forward to the year 2016.

Source: United Nations Inter-agency Group for Child Mortality Estimation, 2017.

Figure 1: Development in mortality and death rates for U5 and newborns 1990–2016 (5)

In an effort to gain global momentum in the fight to reduce neonatal mortality, target 3.2 of the United Nations Sustainable Development Goals (SDGs) is: "By 2030, end preventable deaths of newborn and children under 5 years of age (U5), with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births…" (6). This target can only be met by addressing the three main direct causes of neonatal deaths: prematurity, complications during birth (often defined as birth asphyxia), and infections (3). Unfortunately, a reduction in stillbirths was not included in the SDGs.

Closely linked to a country's income level, the countries in the world with the highest neonatal mortality rates are among the poorest, located in sub-Saharan Africa and South Asia (5). Within countries there are also large differences, with higher rates of neonatal morality among women with low socio-economic status (5). Hence, perinatal and neonatal mortality is a result of global inequalities and a lack of access to affordable, quality health services for the

most marginalized. According to WHO and UNFPA, 80% of all maternal deaths, stillbirths and neonatal deaths could be prevented through a combination of meeting the global unmet need for family planning and educating midwives to international standards (7).

While the successful implementation and scaling-up of vertical programs such as childhood immunization programs have contributed to the overall reduction in U5 mortality, there is a growing understanding that reducing neonatal survival requires broader improvements in overall care (8). Realizing the *unfinished agenda* of the Millennium Development Goals (MDGs), the SDGs and its global targets on neonatal mortality reduction have resulted in renewed efforts and global policy initiatives to spearhead and accelerate progress. The Every Newborn Action Plan (ENAP) initiated by the World Health Organization (WHO) and UNICEF aims to end 80% of all neonatal deaths that are treatable and preventable using cost-effective interventions. Based on recommendations from the Lancet Every Newborn Series, ENAP provides a road map to end stillbirths and neonatal deaths in the SDG era, post-2015, in order to improve the quality of maternal and neonatal care by scaling up a range of evidence-based interventions (9, 10). WHO's framework for quality of care for pregnant women and neonates is closely aligned with ENAP and identifies *essential childbirth care including labor monitoring and action* as one of the areas of high priority in order to reduce neonatal mortality (11).

1.2 Birth asphyxia and fetal distress

Of the 2.6 million neonatal deaths each year, 1 million occur during the first 24 hours of life (5, 12). One third of these are attributed to birth asphyxia (1). This also contributes 40% of the 1.2 million annual stillbirths (9). In one study from rural Tanzania, more than half of the neonatal deaths at term was associated with birth asphyxia (13). Of the neonates who survive, between 1–8 per 1000 develop neurodevelopmental impairments (14). Mortality and morbidity related to birth asphyxia are, to a large degree, preventable using cost-effective interventions associated with quality of care (3, 15, 16).

A fetus is dependent on an adequate supply of oxygen delivered via the placenta and umbilical cord from the maternal circulation. During labor, the placental blood flow is decreased during uterine contractions and therefore, all fetuses experience intermittent lack of

oxygen (17). While tolerated to a certain extent by a healthy fetus, conditions related to the mother, placenta, umbilical cord, or fetus can cause hypoxia during birth, called intrapartum hypoxia. These conditions include obstetric complications such as prolonged and/or obstructed labor, cord compression and/or prolapse, abruption of the placenta, preeclampsia and eclampsia, maternal or fetal bleeding or anemia, infection and/or inflammation, maternal cardiovascular disease among others. Depending on the severity and duration of intrapartum hypoxia, the fetus may die during labor and present as a fresh stillbirth, or be delivered alive with a variable degree of hypoxic-ischemic injury (18). Intrapartum complications such as malpresentation or obstructed labor are associated with the highest risk of birth asphyxia and perinatal death (1).

Birth asphyxia is defined by WHO as the failure to initiate and sustain breathing at birth (19). It is a life-threatening condition during or immediately after birth wherein impaired gas exchange and/or delivery of oxygen to the fetus finally leads to metabolic acidosis and a variable degree of ischemia (17, 18, 20). In high-resource settings, asphyxia is often diagnosed based on umbilical cord arterial pH less than 7 measured by blood gas, which occurs in approximately 3 per 1000 term deliveries in these settings (17, 21). In low-resource settings, the ability to measure umbilical cord pH is limited and an Apgar score below 7 at five minutes after birth is often used as an indicator of asphyxia among neonates (1, 22). Developed by the obstetrical anesthesiologist Virginia Apgar, the Apgar score is a subjective postpartum assessment by the skilled birth attendant (SBA) of a neonate's muscle tone, respiratory effort, heart rate, reflex/irritability and color at 1.5 and 10 minutes. A neonate will receive a zero score if the skin appears pale or blue in color, the heart rate is absent, the neonate does not respond to stimulation, has no movement, and breathing is absent (23). Distinguishing a severely asphyxiated neonate from a fresh stillbirth is clinically difficult in low-resource settings (24), partly due to the subjective nature of the Apgar score, which makes the assessment unreliable (13, 23, 25).

Asphyxial stress produces characteristic fetal heart rate (FHR) patterns such as less baseline variability, late decelerations, variable decelerations, and/or prolonged bradycardia or tachycardia (26). This condition is often described as fetal distress, which is used interchangeably with birth asphyxia. The term *fetal distress* has been criticized for being imprecise and nonspecific, with some suggesting it should be replaced with *non-reassuring fetal status* (1, 27). In low-resource settings where the availability of lactate testing and fetal

blood gas is lacking, the condition is based on the SBA's detection of signs of fetal acidosis, such as abnormal fetal heartbeats between contractions, combined with fresh meconium stained liquor or reduced fetal movement (28).

There are a number of clinical guidelines developed by WHO, the International Federation of Gynecology and Obstetrics (FIGO), and national health entities- and by local adaptations of these- for the diagnosis and management of fetal distress (29–31). Measures to improve fetal oxygenation and avoid the adverse effects of birth asphyxia are called intrauterine resuscitation. These measures include intravenous rehydration, administration of oxygen, repositioning of the mother, review of a senior specialist, and/or interventions to speed up delivery such as the administration of the uterotonic Oxytocin or Misoprostol, or stopping oxytocin (28, 32). By early detection through regular FHR monitoring, most cases of fetal distress can be detected and appropriately diagnosed, and obstetric follow-up action implemented.

1.3 Fetal monitoring and fetal heart rate monitoring

Regular fetal monitoring aims to detect a hypoxic fetus and should trigger obstetric actions to reverse the process that results in organ injury and death due to birth asphyxia (33–35). Fetal monitoring during labor includes a broad range of interventions such as asking the mother about fetal movement during the past 24 hours, assessment of the amniotic fluid and placenta, monitoring duration and frequency of contractions, and the position of the fetus (34). However, one of the most common methods of fetal monitoring is fetal heart-rate monitoring (FHRM). There are a number of national and international guidelines with different recommendations for FHRM based on evidence and consensus among experts in high-income countries, with none adapted to low-resource settings (32). WHO recommends the following intervals and duration of FHR intermittent auscultations:

- Interval: Auscultate every 15–30 minutes in active first stage of labor, and every 5 minutes in the second stage of labor.
- Duration: Each auscultation should last for at least 1 minute; if the FHR is not always in the normal range (i.e. 110–160 bpm), auscultation should be prolonged to cover at least three uterine contractions. Timing: Auscultate during a uterine contraction and continue for at least 30 seconds after the contraction.
- Recording: Record the baseline FHR (as a single counted number in beats per minute) and the presence or absence of accelerations and decelerations.

Box 1: WHO recommendation on intermittent fetal hear rate auscultation during labor (36)

The international recommendations for intrapartum FHRM are based on studies from high-income countries with a substantially higher SBA-to-patient ratio compared to low-resource settings. In one study conducted in a tertiary hospital in Zanzibar where the SBA to patient ratio was 1:6, the actual time spent conducting routine labor monitoring assessments was 33 minutes for each laboring woman per 4 hours of labor. To adhere to WHO guidelines for labor management (Box 1), the first author of the study, Nanna Maaløe, estimated that a SBA would have to spend 110 minutes per 4 hours of active first stage of labor, requiring a 1:1 or 1:2 SBA-to-patient ratio (37). This gap between international guidelines and the reality within which they are implemented in low-resource countries has raised calls for local adaptation of clinical guidelines for intrapartum care (31, 32).

Similar to the lack of international consensus about the criteria for fetal distress and fetal asphyxia, the range for normal FHR is based on limited evidence, and the ranges consequently vary (38, 39). WHO defines normal FHR as 110–160 bpm (32, 36) whereas for others, such as the International Federation of Gynecology and Obstetrics (FIGO), consensus statements define it as 120–160 (30).

1.3.1 Intermittent auscultation

FHRM can be carried out intermittently or continuously. The diversity of FHRM methods has different validity and predictive value.

Globally, intermittent auscultation (IA) has traditionally been carried out using a Pinard fetoscope. Versions of the fetoscope have been in use in labor care since the early 19th century to determine the status of a fetus. It uses sound amplification, through a hollow horn made of wood or plastic, from the fetal heart to the user's ear (Photo 1) (30). While electronic devices have replaced the Pinard fetoscope in high-resource countries, it is the primary tool used for FHRM in low-resource settings. Pinard is reported to be difficult to use, time-consuming, and painful for the mother (30, 40).

Photo 1: Intermittent auscultation using Pinard fetoscope (Photo credit: Allan Gichigi/IRIN)

IA can also be carried out using electronic hand-held tools such as hand-held Doppler devices (Photo 2).

Photo 2: Hand-held Doppler (Photo credit: Colourbox)

Based on ultrasound-detected movements of fetal cardiac structures, the device produces a representation of the sound produced by the fetal heart using the one-crystal Doppler effect (30). Hand-held Doppler devices are commonly used for intermittent FHRM in high-resource settings, but are rarely available in low-resource settings. Hand-held Doppler is believed to cause less pain, and to be both easier to handle and more reliable compared to Pinard (41). With a high risk of false positives, it is unknown if the use of hand-held Doppler reduces neonatal mortality in low-resource settings (42). A study from rural Uganda did not find improved perinatal outcomes when comparing intermittent use of Doppler with the Pinard

fetoscope (43), which is similar to findings from Tanzania (44, 45). In the Tanzanian setting, the midwives also expressed a preference for Pinard to conduct FHRM (46). However, one 1994 study from Harare showed that intermittent use of Doppler was more sensitive in the detection of fetal heart rate abnormalities and reduced adverse perinatal outcome compared to the Pinard (41). Another study from Tanzania found improved perinatal outcomes among neonates delivered vaginally when Doppler was used (44).

According to WHO, IA is a crucial component of intrapartum care regardless of the device used, and is often inadequate (36). Indeed, several studies from low-resource settings found that IA is often not performed or documented as frequently as recommended (33, 37, 45, 47). IA in combination with a fetal stimulation test, use of the partograph, and admission screening of fetuses with particular risk of fetal distress, have all been suggested as the most effective interventions to reduce intrapartum stillbirths in low-resource settings (42).

1.3.2 Continuous fetal heart rate monitoring

Indications for continuous FHRM includes a number of conditions linked to the mother or the fetus that increase the risk of complications during labor, such as hypertension, pre-eclampsia, diabetes, and lack of intrauterine growth during pregnancy (34). Epidural analgesia, meconium-stained liquor, bleeding, induced or augmented labor, or when abnormalities are detected during intermittent auscultation, are other indications for continuous FHRM (38).

Continuous FHRM, or electronic FHRM (eFHRM), was widely introduced in high-income countries in the 1960s using cardiotocography (CTG) (Photo 3). It measures both FHR and uterine contractions using ultrasound technology. Two transducers are strapped to the laboring woman's abdomen for external use. An electrode can also be placed directly on the fetal head after rupture of membranes for continuous FHRM (34, 38). The use of CTG inhibits the laboring woman from moving around freely and makes changing position difficult (48).

Picture 3: CTG in use (Photo credit: Colourbox)

CTG is rarely available in low-income settings, due to the high cost of procuring and maintaining the devices. Described as a complex technology, a study conducted among midwives in Norway found that particularly midwives with less than three years work experience found interpreting CTG results on labor admission *difficult* (49). Several studies have also found poor inter-observer agreement between SBAs when interpreting CTG tracings (50–52). The efficacy and effectiveness of CTG has been heavily scrutinized and remains a contentious area of debate among experts (48, 53). A Cochrane literature review based on studies primarily conducted in high-income countries found that continuous FHRM using CTG is associated with increased caesarian section (CS) delivery rates compared to IA, with no difference in perinatal outcome, while it did reduce the incidence of neonatal seizures (48, 54). FIGO consensus guidelines state that the indications for continuous monitoring using CTG compared to intermittent auscultation in both low- and high-resource settings are *scientifically inconclusive* and describe the use of continuous intrapartum CTG monitoring in low-risk women as *more controversial*, despite occurring in high-income countries (38). A review of literature from low- and middle-income countries concluded that CTG should not be recommended in low-resource settings due to the associated increased CS rates without improvements in perinatal outcomes (42). A review of existing evidence from high-resource settings found that continuous FHRM using CTG on admission, which is commonly carried out, had *no clear benefit when compared to IA in women who do not have any known risks for fetal acidemia at the onset of spontaneous labor at term* (55).

CTG has a low specificity for identification of intrapartum hypoxia (56). In one study from the United States, the use of CTG had a 46% sensitivity and 82% specificity to predict fetal

acidemia (57). CTG also has a high false-positive rate, meaning that the method is less effective in identifying a fetus with abnormal FHR without hypoxia and who therefore do not require intrauterine resuscitation. In high-income countries, new technologies such as fetal electrocardiogram ST segment analysis (STAN) have been introduced in an attempt to diagnose fetal hypoxia more accurately. The STAN method is less invasive compared to fetal blood sampling, and captures changes in the fetal electrocardiogram and reduced oxygenation of the fetus in order to reduce acidosis (58, 59). A meta-analysis comparing CTG to STAN found that while the method did not reduce operative deliveries, Apgar score or mortality rates, using the method did result in a reduction in fetal blood sampling and a reduction in metabolic acidosis (60).

1.4 The partograph

The partograph is a tool to monitor and document the progress of labor by providing a continuous pictorial overview. Key events during labor, such as FHR, uterine contractions, and cervical dilatation, are documented against time in hours in order to guide interventions and prevent complications from prolonged labor, such as birth asphyxia (61).

WHO considers the partograph an essential component of routine labor care (29). However, a Cochrane review did not find reductions in CS rates, oxytocin augmentation, or Apgar scores when the tool was used for women in spontaneous labor at term in high-, middle- and low-income countries (61). Being paper-based, the partograph is considered an inexpensive tool to record labor observations and provide a continuous overview of the progress of labor in low-resource settings. While available, the tool is often under-utilized in these settings (62). Studies indicate that the tool is considered time consuming, difficult to fill in, and is often retrospectively completed (63–65). Being based on studies on labor progression from the 1950s, there is a debate both about the accuracy of the pantograph's 1-centimeter-per-hour "rule" for uncomplicated deliveries—particularly before reaching 6 centimeters of cervical dilatation—and the correct obstetric follow-up actions when the alert or action lines are crossed (66, 67).

WHO is currently working on an updated version of the partograph in an attempt to improve the tool. The new partograph will start at 5 centimeters of cervical dilatation, during the first stage of labor, and includes both normal and abnormal values, requiring the SBA to document the actions taken when rates or values are abnormal.

1.5 The electronic fetal heart rate monitor Moyo

Studies from Tanzania reveal that intermittent FHR assessments are not conducted according to guidelines, and that this may cause unnecessary perinatal morbidity and mortality (33, 64, 68, 69). Studies also indicate that fetal distress either goes undiagnosed and/or that interventions are delayed (28, 69–71). In settings with a low midwife-to-patient ratio, it is difficult to assess the FHR as frequently as recommended, and thus the potential benefit of a handheld device (e.g. fetoscope or Doppler) is not fully exploited. One attempt to solve this challenge is the development of new technology to facilitate the process of FHR monitoring, and hopefully detect risks attributable to FHR abnormalities earlier.

Moyo, which means *heart* in Kiswahili, is an electronic FHR monitor that can be used for both intermittent and continuous FHRM (illustration 1 and photo 4) . It was developed by Lærdal Global Health in close collaboration with SBAs at Haydom Lutheran Hospital (HLH) in Northern Tanzania. Based on several visits to the labor ward at the hospital by the designers from Lærdal, labor ward staff provided feedback on several prototypes of the device prior to its finalization. With a 9-crystal Doppler ultrasound, it can accurately detect FHR within 5 seconds. The device has a set of dry electrode electrocardiograms next to the display where the woman can place her fingers in order to differentiate between maternal and fetal HR (called maternal heart-rate pads in illustration 1 below). Moyo displays FHR and stores Doppler signal data for subsequent analysis. The device can also show a 30-minute histogram display of the FHR. The sensor comes with an elastic belt that can be strapped on a woman in labor for continuous monitoring. The color of the FHR indicates whether the FHR is normal (120–160 bpm), shown in green, or abnormal (below 120 bpm or above 160 bpm), shown in orange. If the FHR is below 100 bpm or above 180 bpm for more than 3 minutes, or between 100–110 bpm or 160–180 bpm for more than 10 minutes, Moyo will give an alarm and the FHR will be shown in red on the display. If the probe is displaced, Moyo will also give an alarm and display a question mark. The alarm can be silenced through a button on the display. The device has a rechargeable battery that has the capacity to provide over 10 hours of continuous FHRM before it needs charging. The device comes with a user guide, and an instructional video is available on YouTube (72). The device has won several design awards. The price for one Moyo is $198. This is not-for-profit pricing for countries with the highest maternal and perinatal morality rates (72). The device has been sold to several low-income countries around the world.

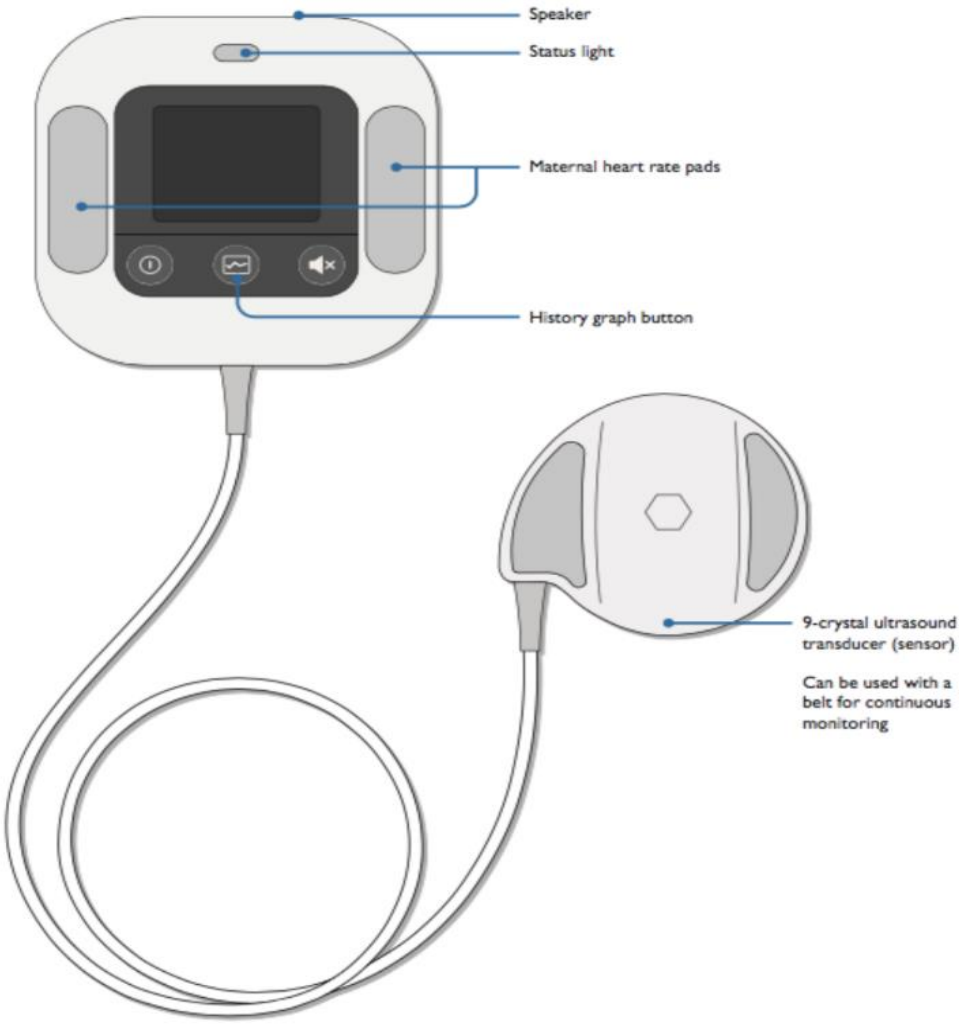


Illustration 1: Moyo

Photo 4: Moyo in use in Tanzania (Photo credit: Lærdal)

1.6 Safer Births project

This PhD study was conducted as part of the research and development project called *Safer Births* (73), implemented from 2013–2018. The project aimed to improve FHRM, newborn resuscitation, and perinatal outcomes by developing innovative products and training methods to better equip and increase the competence of SBAs. Safer Births is a collaboration between several Tanzanian institutions, Stavanger University Hospital, SAFER, Lærdal Global Health, Lærdal Medicals, Weill Cornell Medical College, University of Stavanger, University of Oslo, Norwegian Institute of Public Health, The Arctic University of Norway, University of Bergen, and Trinity College.

Moyo is one of the innovations in the Safer Births project. The device was introduced in 2015 as part of the project by senior labor ward staff at three tertiary hospitals in Tanzania; Haydom Lutheran Hospital (HLH), Muhimbili National Hospital (MNH) and Temeke Regional Referral Hospital (TRRH) for clinical use and research.

The first randomized control study (RCT) as part of Safer Births was conducted at Haydom and found no significant difference in the detection abnormal of FHR when comparing wind-up handheld Doppler to Pinard (45). In the subsequent RCT, Moyo was compared to Pinard, and it was found that abnormal FHR was detected more frequently when Moyo was used (74). At TRRH, a pre/post observational study found that the use of Moyo improved FHRM and timely obstetric actions/referrals, and led to less neonates in need of resuscitation but also an increase in CS when comparing Moyo to Pinard (75). Based on these findings, a subsequent 2-arm RCT was conducted at MNH comparing the continuous use of Moyo to a hand-held Doppler (76). The study found that abnormal FHR were detected more often and earlier when Moyo was used, but the time from detection to birth was longer compared to when Doppler was used. None of the studies were powered to detect difference in perinatal outcomes between the three devices used, and they included only women with a low risk of complications during labor in the study.

The Safer Births project used a mixed-methods approach in order to gain a broader perspective, and the papers included in this thesis are the qualitative component of the evaluation of Moyo. No studies have previously evaluated the use of such a simple strap-on automatic multi-crystal Doppler such as Moyo where the midwives-to-patient ratio is as low as in the three study sites.

At the time of data collection for this PhD study, the quantitative studies were ongoing at MNH and completed at TRRH. The Safer Births project had an office with four staff members at MNH who also provided support for the qualitative data collection.

1.7 New technology and global health challenges

New technological solutions are being increasingly implemented in low- and middle-income countries in order to counter challenges in the health systems which impede access to high-quality health services for many (77). Innovation in technology is considered key to achieving the health-related Sustainable Development Goals (78, 79). From an equity standpoint, access to technology is considered important, as is the belief that those in low- and middle-income countries should also benefit from advances in medical innovation and technology.

As the development of health technologies for low-income countries is picking up pace, there is an increased focus on ensuring that the technology is *acceptable and will be adopted by users* (80). This is partly due to the previous notion, by some, that innovative technology was an "easy fix" which does not take into consideration the resources required to ensure consistent and correct use both from the health-care system and among users. It is argued that while it is fairly easy to introduce new technology into a health care system in low-income countries, it is far more difficult to address barriers to quality of care within the system itself (81). Health care is slow to employ new knowledge, and the dissemination of innovations in these organizations is particularly difficult (82). Additionally, little is known about determinants for successful implementation (82, 83). The fact that more time is spent on the development of a product and less on the adoption of the device by users has been mentioned as one of the reasons why so few health innovations succeed in scaling-up (84).

Most of the literature on the adoption of new technology among SBAs is collected in high-income countries (49, 85–88). These studies indicate that the use of new technology such as hand-held Doppler and CTG is perceived as useful by SBAs. However, challenges related to positive adoption and long-term use include lack of trust in the reliability of the new device, insufficient training and follow-up about correct use, and overestimation of its capacities (46, 89, 90). In addition, little is known about the adoption process of end-users, namely pregnant and laboring women. In the review of literature for this study, only one recent study including the perceptions of pregnant women towards the use of new technology in intrapartum care in low-resource settings was identified (91).

Similar to the results of the quantitative studies about the effect of Moyo, studies conducted in low-resource settings about the use of technology for FHRM to improve neonatal outcomes are inconclusive. While the reasons for these results are multifaceted, it indicates the complexity of translating the integration of new technology in labor care into a reduction in morbidity and mortality.

1.8 Adoption of innovations

Designed to significantly benefit the individual, the group or wider society (92) the characteristics of an innovation typically come in the form of new services, new ways of working, and/or new technologies (93). Adoption of new technology is a commonly used

term to describes the acceptance, of a new product or innovation. Literature from high-income countries indicates that the adoption process is complex and non-linear. Most of the literature on adoption of innovations and how new ideas or technology spread is based on the theories of Everett Rogers, as described in his book *Diffusion of Innovations* (92). He defines an innovation as *an idea, practice or object that is perceived as new by an individual or other unit of adoption* and diffusion as *the process in which an innovation is communicated through certain channels over among the members of a social system*. Rogers's theory describes a five-step innovation-decision process that is initiated by obtaining knowledge about an innovation and establishing an attitude about it, followed by a decision to adopt or reject the innovation, and an implementation and confirmation of this decision.

A systematic review of the diffusion of innovation in health service organizations (94) found the following attributes, as perceived by users, to be key aspects of the adoption process based on Roger's model (92): *relative advantage*—the degree to which a potential user sees an advantage in the innovation; *compatibility*—the degree to which the innovation is compatible with the user's needs, values and norms; *complexity*—innovations that are considered to be simple to use are more easily adopted; *trialability*—innovations that can be tested before use are more easily adopted; *observability*—innovations where the user can see the visible benefits of the innovations are more easily adopted; *reinvention*—innovations that may be modified or adapted by users are more easily adopted; *augmentation/support*—technology that comes with training or a help desk will be more easily adopted. The review highlights that it is the interaction between the innovation, the user, and a particular context that determines the adoption rates. These include individual traits such as tolerance to ambiguity, intellectual ability, motivation, values, and learning style. Berwick (82) supports the notion of an interplay between the innovation and the individual and adds contextual factors such as communication, incentives for use, leadership, and management. The opinion of peers strongly affects the adoption process, particularly in the introduction phase of an innovation (93). This is also pointed out by Rogers (92). He states that interpersonal channels are more effective in persuading an individual to accept a new idea, especially if the individuals are similar in socioeconomic status, education, or other important ways. Interestingly, he also points out that scientific studies are much less important than subjective evaluation from a peer who has already adopted the innovation. Organizational leadership is also highlighted as important, with the fastest rate of adoption occurring when it is stems from authority decisions (92, 95). One study about the introduction of innovation in the

primary health-care service in Sweden found that adoption was more likely when the technology was compatible with existing routines, and that coinciding its introduction with organizational changes and during staff shortages negatively affected the adoption process (96).

1.9 Acquiring knowledge about innovations

Acquiring new knowledge is key to the adoption of new technology. Few studies have been conducted in low-income settings on the process of acquiring knowledge about the use of a new technical device among SBAs. However, studies have evaluated the training of SBAs in the newborn resuscitation protocol and training package called Helping Babies Breathe (HBB) (97). Developed for use in low-resource settings by the American Academy of Pediatrics, the program has been implemented in more than 80 countries with more than 400,000 SBAs trained. Evaluations of the program in Tanzania have found that while the intervention reduced both stillbirths and early neonatal deaths (98), a one-day HBB training session did not facilitate the transfer of skills and knowledge into clinical practice (99). However, frequent "on-site" (or on-the-job) simulation training significantly improved retention of competency in neonatal resuscitation skills and a reduction in neonatal mortality (100). This type of shorter, simulation-based training in teams is often referred to as "low-dose/high-frequency" and is commonly used in low-resource settings (101, 102). Using this method also increased knowledge and skills about locally adapted labor management guidelines among SBAs in Zanzibar and led to a subsequent reduction in neonatal mortality outcomes (103).

1.10 Study context—the United Republic of Tanzania

The country, comprising of mainland Tanzania and the semi-autonomous island of Zanzibar, has a population of 45 million (104). Geographically, it is the largest country in East Africa, illustration 2. Official languages are Kiswahili and English. The country's largest city is Dar es Salaam, with a population of 4.3 million (104).

Illustration 2: Map of Tanzania

Mainland Tanzania is divided into 26 administrative regions, 133 districts, and 162 councils. The country is rated 154 of 189 countries on the Human Development Index and has a gross national income of 920 according to the World Bank, placing it in the low-income country category (105).

Table 1: Overview of selected health indicators (106, 107)

Health indicators	
Total fertility rate	4.8 children
Modern contraceptive use	37 %
Unmet need for family planning	21%
Under-5 mortality rate	67 deaths/1000 live births
Infant mortality (within 1 year)	45 deaths/1000 live births
Perinatal mortality	39 deaths/1000 pregnancies
Neonatal mortality rate	19 deaths/1000 live births
Caesarean section deliveries	6%
Health facility delivery	63%
Maternal mortality	398/100,000 live births
4+ ANC visits during pregnancy	51%

Tanzania has made great improvements in child health in recent decades, particularly in reducing U5 mortality (15, 106). However, neonatal mortality only decreased at half the rate of that of children from 1–59 months old (108). The country was listed as one of the 10 countries in the world with the highest number of neonatal deaths in 2016 (5) and one of the countries with the highest number of stillbirths in the world, totaling 47,000 deaths in 2015 (109). Challenges within the health system that contribute to these numbers include delays in timely referrals, lack of facilities that can provide emergency obstetric care, and issues related to communication and infrastructure. Other challenges include lack of availability of essential drugs and supplies, transport, and financial barriers such as lack of access to insurance schemes and informal payments at health facilities (110, 111). The country also experiences a severe shortage of skilled health-care workers (doctors, nurses and midwives), with only 8 per 10,000 persons compared to the 23 per 10,000 recommended by WHO, and compared to Norway's 218 skilled health-care workers per 10,000 (5, 108). The country's SBA-to-patient ratio is 1:12. It should also be noted that Tanzania has experienced rapid population growth in recent decades leading to a doubling of its population, without the necessary expansion in its health sector (108).

Tanzania is one of the Every Newborn Action Plan (ENAP) focus countries and has made commitments to implement ENAP and monitor progress through the implementation of a

comprehensive, multi-sectoral strategy to reduce neonatal morality. Both the National Road Map Strategic Plan to Improve Reproductive Maternal, Neonatal, Child and Adolescent Health (2016–2020) (112) and the Health Sector Strategic Plan IV (HSSP 2015–2020) (111) address the necessary efforts to strengthen the health system in order to achieve the national targets on reduction of neonatal mortality. These include improving health services along the continuum of care by improving access to family planning, antenatal care (ANC), emergency obstetrics, and newborn care interventions.

1.10.1 Tanzania's health-care system structure

The country's health-care system follows the government administrative structure (110). At the local and village level, public and private dispensaries and health centers provide primarily outpatient curative and preventive services such as ANC and labor care. Council hospitals receive referral patients from the dispensaries and health centers and provide both medical care and basic surgical procedures. Regional referral hospitals provide specialist medical care such as general surgery, cardiology, nephrology, and gynecology. Zonal and National hospitals provide advanced medical care and function as teaching hospitals for medical, paramedical, and nursing schools. Labor care is provided by the following cadres, depending on the facility: nurse/midwives with a certificate (two-year training) titled Enrolled Nurse Midwife (ENM), with a diploma (three-year training) titled Registered Nurse Midwife, or with a Bachelor of Science in nursing or midwifery (four-year training) (113). For complicated cases at tertiary health facilities, Medical Officers (MO) with five years of training or Clinical Officers with three years of training provide support. Similar to nurse/midwifes, doctors have a range of titles based on years of experience and specialization providing labor and obstetric care in the labor ward. In addition to specialists in obstetrics and gynecology, there are residents who are medical doctors conducting a three-year specialist training, registrars who are medical doctors working after completing their internship but before starting specialist training, and interns who are medical graduates working under supervision for a year of practical training. Lastly, there are senior consultants who are specialists with more than ten years of experience.

2. Conceptual/Theoretical framework

Everett Rogers's theory, described in his book *Diffusion of Innovations* (92) and the technology acceptance model (TAM) shown in illustration 3 (114), are the two conceptual frameworks that inspired this thesis. Both are frameworks to help understand user acceptance of innovations such as new technology. Rogers's theory has been described above. The technology acceptance model is a theory that models how users come to accept and use a technology. It was developed with the assumption that knowing the factors shaping a person's intentions to use new technology would allow organizations to manipulate these factors to promote acceptance and increase use. Similar to Rogers, the technology acceptance model includes factors that affect the user's decision to accept or reject the new technology. These are perceived ease of use, perceived usefulness, and attitudes toward the consequences of using the technology. Initially developed to increase acceptance of information technology, the model is perceived as suitable for the health-care sector (114).

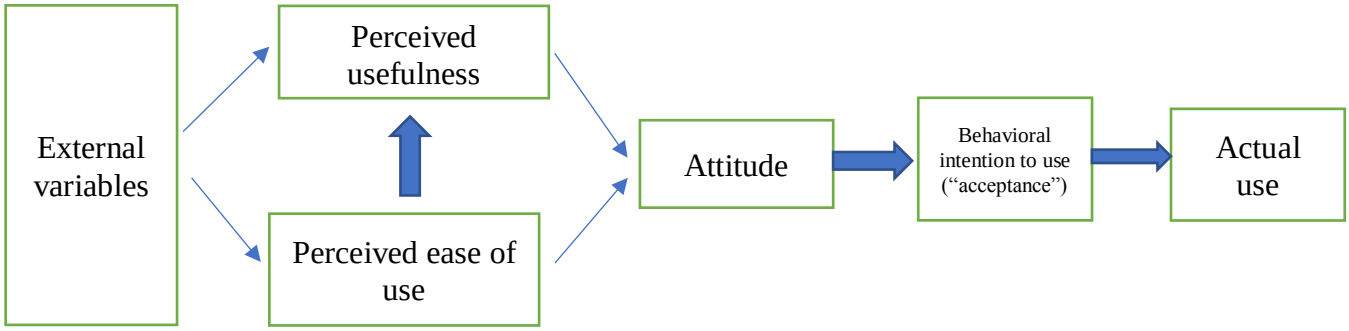


Illustration 3: Technology acceptance model (114)

The model has been criticized for not capturing contextual aspects that affect technology acceptance and adoption (114). While not specifically developed for the health-care context, more recent versions have included external barriers to adoption of technology such as cost and maintenance (114, 115). When used in health-care settings, it has also received criticism for resulting in a limited and generic way of thinking about variables such as usefulness (114, 116).

3. Objectives

Developing new technology solutions is increasingly used to tackle global health challenges, such as neonatal mortality, in low-income countries where most of these deaths occur. The electronic FHR monitor, Moyo, which was developed to improve FHRM and the detection of fetal distress in order to reduce neonatal mortality in Tanzania, is one such example. Acceptance and correct use are essential for new technology to be effective, yet little is known about users experiences and perceptions in low-income countries where new technology has the largest potential to reduce morbidity and mortality.

The main objective of this thesis is to gain a deeper understanding of the adoption and use of new technology (Moyo) among SBAs and women giving birth at two tertiary hospitals in Dar es Salaam, Tanzania.

Secondary objectives:

– To investigate the attitudes and perceptions about Moyo among women who wore Moyo during their most recent delivery (Paper 1).

– To describe how the use of Moyo affects the relationship between the parturient woman and the SBA assisting her during delivery (Papers 1 and 3).

– To describe SBAs' perceptions and experiences while acquiring knowledge about the use of Moyo (Paper 2).

4. Research methods

4.1 Study setting

4.1.1 Temeke Regional Referral Hospital (TRRH)

Temeke Regional Referral Hospital is located in one of the three districts of Dar es Salaam. It has a catchment population of 2 million people, 29% of which are estimated to live in extreme poverty in the primarily high-density area. The hospital receives patients form the district's 135 public health facilities. The maternity ward consists of an antenatal ward where women are admitted, with 12 beds. Here, they are screened for high-risk conditions such as preeclampsia or malaria. Women of high risk received continuous FHRM using Moyo during the period of data collection. The labor ward consists of 18 beds (photo 5). After birth, women are transferred to the post-natal ward, with 30 beds. Here, they receive information about neonatal health, such as breast-feeding, in a joint session before being discharged. The hospital has approximately 17,000 annual deliveries, between 40 and 50 each day. The labor ward does not have an operating theatre exclusively for obstetric surgery, and instead uses the hospital's general operating theatre. There are five nurse/midwives per shift, working in three shifts per day. In addition, two specialists, residents, and interns work in the maternity ward. Pinard was the only method available to monitor fetal heart rate at the time of data collection, in addition to Moyo. The partograph was used to document labor progress. Standard bottle was available for vacuum extraction; forceps were not used.

Photo 5: The labor ward at Temeke Regional Referral Hospital (Photo: S.R. Lafontan)

4.1.2 Muhimbili National Hospital (MNH)

Muhimbili is Tanzania's national hospital and a teaching institution for medical and nursing schools. The hospital's catchment population includes the entire city of Dar es Salaam and the neighboring Pwani region. It receives referral patients from TRRH. The hospital has approximately 10,000 annual deliveries and the highest CS rate in the country at 50% (28). The maternity ward consists of five sub-wards, with 19–20 beds each for antenatal and postnatal care, where women stay before and after giving birth. Vital signs, FHR, and vaginal examination are documented on admission in the labor ward register. The labor ward consists of 20 beds. The maternity ward has a separate obstetric operating theatre with two beds. The nurse/midwives works in two shifts, five nurse/midwives and two nursing assistants per shift. There is one consultant, one specialist, two residents, and one intern doctor on call every day. The maternity ward receives both referral patients from the public non-paying system and private patients covered by medical insurance, including scheduled CS. Pinard is the most common way to monitor fetal heart rate at the labor ward. During the period of data collection, Doppler was only sporadically available. CTG had previously been used for continuous FHRM, but was no longer available. The partograph was used to document labor progress of women in the labor ward, and vacuum extraction was carried out. During the period of data collection, there were a number of different studies being conducted at the labor ward.

4.2 The intervention

The quantitative Moyo studies consisted of two RCTs conducted at MNH and one pre/post study conducted at TRRH. Participants were pregnant women in labor. Women with gestational age of less than 28 weeks or women scheduled for elective caesarean section were excluded, as well as women with abnormal or no FHR on admission, multiple pregnancy, or women who were severely ill on admission. As part of the research intervention, each hospital was given 30 Moyo monitors as a donation.

Before the start of data collection, the labor ward staff at both hospitals was trained on using Moyo and procedures for use, in addition to aspects of labor monitoring and management. This included a one-day training of 20 key staff that would be trained as master trainers by senior and management staff from HLH, MNH and TRRH. In addition, a workshop to train the remaining SBAs was conducted during the course of 2015. Using the Training of Trainers

(ToT) cascade model, the master trainers were responsible for conducting shorter training sessions for new staff in addition to refresher sessions for colleagues in the labor ward at the two hospitals.

5. Study design

The choice of method is determined by the one that will yield the richest data based on the research questions of the study (117). As this aimed to gain a deeper understanding of the different perspectives of Moyo users, a qualitative and descriptive approach was chosen. This approach is appropriate when there is limited knowledge about the area of research and to provide contextual information on existing knowledge (118). Qualitative methods are often used to capture experiences, practices and the "lived world" of study participants (119). The interactive design was used to ensure flexible and dynamic research. Different methods of data collection was used to triangulate study findings (120). Table 2 summarizes the three papers and study methods.

Paper	Objective	Data collection methods	Participants	Number of participants
1	To explore the attitudes and perceptions of women who wore Moyo during their most recent delivery about the device and the effects on the care they received	Semi-structured interviews	Women post-labor	20
2	To present skilled birth attendants' perceptions and experiences while acquiring and transferring knowledge about the use of Moyo.	Focus-group discussions	Doctors Nurse/midwives	6 20
3	To explore the attitude and perceptions of skilled birth attendants using Moyo.	Semi-structured interviews and focus-group discussions	Doctors Nurse/midwifes	7 26

Table 2: Summary of the papers comprising the thesis, methods, and participants

5.1 Data collection and Study participants

The study participants included 20 women who had given birth using Moyo and 61 SBAs (doctors and nurse/midwives) who worked in the labor ward at the two facilities and who were using Moyo in their daily work. The data collection took place from November 2016 to March 2017. Two data collection methods were used—semi-structured interviews and focus-group discussions (FGDs)—actively drawing on observations and informal key-informant interviews to contextualize findings.

At both study sites, the FGDs were carried out first, followed by the semi-structured interviews. The interviews and FGDs were conducted in rooms that allowed for privacy. It was believed that bringing the participants together in a setting that was familiar to them and facilitated by a peer would be beneficial in order for the participants to feel at ease to express themselves freely, and for social interaction and socially dominant views to occur naturally.

All the interviews (except one which was conducted in English by the PhD candidate) and FGDs were conducted by a research assistant in Kiswahili, the mother tongue of all the participants. An interview guide was used for all interviews and FGDs (Appendix 14.1-14.4). The theoretical framework and current literature on adoption of technology informed the initial interview guides in order to address the specific objectives of the study. Questions emerging from the preliminary findings from the quantitative Moyo studies were also included. As the study was explorative, the interview guide was adjusted over the course of the data collection. All interviews and FGD were audio recorded and transcribed verbatim.

5.1.1 Semi-structured interviews (study 1 & 3)

Semi-structured interviews are a well-known data collection method in qualitative research. Moen and Middelthon describe the qualitative interview as a *meaning making* process. The interview is perceived as a three-sided relationship between the interviewer, the interviewee and the topic they are engaging with, with the topic being a dynamic part of this process (119). Interviews are therefore not results, but fragments of data that gain meaning when analyzed in a context in view of other data (triangulation). An interview guide was used that included an introduction stating the objective of the interview and open-ended questions. The interview guide started with background questions to make participants feel at ease. Prompts

and follow-up questions would be introduced, hence the semi-structured nature of the interview.

5.1.2 Study 1: participants and data collection

Paper 1 presents the attitudes and perceptions about the device and the effects on the care they received of women who wore Moyo during their most recent delivery. Twenty women were recruited to participate in the study, ten from each study site, upon which it was believed that thematic saturation was reached. It is common to include between 10–15 participants in qualitative studies (121). All participants were interviewed once, often in the morning after giving birth at night and while waiting to be discharged. Recruitment was done through convenience sampling, meaning the participants who agreed to take part in the study and who met the inclusion criteria (122). The women were approached before discharge from the post-natal ward and informed about the study by two members of the research team at both hospitals. All the women who were asked to participate in the study accepted. The recruitment was conducted by the Tanzanian research assistant with assistance from nursing staff at the maternity wards. The inclusion criteria were that Moyo had been used during the most recent delivery, that there was a positive fetal outcome, and that the women were multiparous.

For Paper 1, the interview guide started with background questions such as age, number of children, and occupations, and included questions about experiences wearing Moyo and the information received about the device. Each interview ended by asking the participants if they had any suggestions about how Moyo could be improved and then, lastly, if they had any questions for us (the research assistant and the PhD candidate). The interviews lasted 20–25 minutes. In an effort to verify the collected data with new respondents or to member-check the collected data, additional interviews were carried out after it was believed that thematic saturation was reached. Thematic saturation is achieved when further data collection reveal no new themes (122).

The PhD candidate was present during all interviews and FGDs, working as a note taker, and also observing and taking note of non-verbal communication. During the course of the data collection the candidate's understanding of Kiswahili improved to the extent that she was able to understand in broad terms what the participants were saying. She would at times ask

follow-up questions or request clarifications in English as to what the participants were saying, which was then translated by the research assistant.

5.1.3 Focus-group discussion (study 2 & 3)

Focus-group discussions (FGDs) allow a deeper understanding of social phenomena by obtaining the points of view of many individuals through the exploration of experiences, views, motivations, and beliefs on a specific topic. Focus groups are also useful to capture diversity and difference of perspectives within or between groups (122).

5.1.4 Study 2: participants and data collection

Paper 2 presents the perceptions of SBAs on acquiring knowledge about the use of Moyo. SBAs who were working at the labor ward and using Moyo at the two study sites were invited to participate in the study. All those who were asked to participate accepted. In total, seven medical doctors and 26 nurse midwives participated in the study, of which seven men and 26 women. Despite not making a purposeful effort to sample participants in terms of demographic distribution, the participants ranged in age and years of experience working in labor care.

The participants divided themselves into different FGD groups, with the doctors forming one. This was believed to be beneficial in order to reduce vulnerabilities and the power imbalance between nurse/midwives and medical doctors, and to enhance interaction between group members (122). In total, five FGDs were conducted with 4–6 participants in each group. The most common number of participants in FGDs are 5–8 participants (121). It was believed that it would be beneficial to keep the number of participants in each FGD smaller instead of too large, which could risk some participants being left out of the discussion or becoming passive. The interview guide for the FGDs started by asking the participants why they believed Moyo had been introduced at the facility, and continued with questions about the content of the training and the facilitator. The FGD ended with a closing question asking if the participants had something that they would like to add that they did not get a chance to say during the session.

5.1.5 Study 3: participants and data collection

Paper 3 presents the attitude and perceptions of SBAs using Moyo. It is based on both FGDs and semi-structured interviews with SBAs at the two study sites. The interview guide used for the FGD included questions regarding perceptions and opinions around FHRM, the partograph, and fetal distress. Each FGD lasted 40–90 minutes. After conducting the FGDs, 10 participants selected by the candidate were asked if they would like to take part in semi-structured interviews. In additional to background questions, the interview guide used for the interviews with the SBAs included questions about experiences using Moyo compared to other methods to measure FHR and questions about the last time they experienced fetal distress. The interviews lasted 45–60 minutes. Often the issues raised during the interviews were a follow up to what the participant had said during the FGD. The participants' statements would be paraphrased to ensure that we had understood correctly before asking the participant to elaborate.

5.2 Observation

Actively drawing on ethnographic principles during the fieldwork, observations made during the time spent in the labor ward were included in the daily field notes and used to contextualize the data collected during interviews and FGDs. This included observations of communication between the SBAs and laboring women, work flow in the labor ward, and situations when Moyo was used. Questions about observations made would be brought back to the FGDs for discussion among the participants. Observation is useful not only to experience activities directly and to record one's own perceptions, but also to conceptualize statements and actions with individuals over time (122).

5.3 Field Notes

Field notes were taken at the end of each day of data collection. These included activities, reflections and thoughts about the interviews and FGDs, and observations from the labor ward. In addition to contextualizing findings and identify emerging themes from the data, the field notes helped reflect on what had occurred during the day. Questions for the research assistant or others in the research team the next day would also be included in the field notes.

5.4 Key-informant interviews

To obtain contextual data, the staff in charge of the development and introduction of Moyo was interviewed in English or Norwegian by the PhD candidate. These included staff at Lærdal who was part of the development and distribution of Moyo, and senior labor ward staff who had worked on the introduction of Moyo in Tanzania as part of the Safer Births project. These were staff at TRRH and MNH in Dar es Salaam, and at HLH, where Moyo was also introduced. Questions were prepared beforehand, but the setting was less structured compared to the semi-structured interviews. The interviews were not transcribed, but detailed notes were taken.

5.5 Data analysis

5.5.1 The research assistant

A midwife with a master's degree who was working as a midwifery teacher at the time was recruited as a research assistant. She knew both study sites well, having conducted research and supervised students at the two hospitals. After familiarizing herself with the research protocol and discussing the overall aims of the study, we discussed the interview guides for the FGDs and semi-structured interviews during several meetings before starting the data collection. The research assistant also provided contextual information about the work of a midwife in Tanzania and what we observed in the labor ward each day. After each interview/FGD, we would sit together and discuss the key issues raised under each question of the interview guide, and necessary changes, if any. After each day we would also have a meeting to share and discuss observations—a preliminary analysis of the data. Interview guides were translated to Kiswahili and shared with the research assistant for her input.

5.5.2 Transcriber

The interviews were transcribed by a native Kiswahili speaker who was recommended due to his experience transcribing qualitative data. He was briefed about the project and its objectives prior to starting. During the data collection, Tanzanian members of the research team verified that the transcriptions were correct by listening to the recordings of the interviews while reading the transcribed version. The transcriber was not present during the data collection. He transcribed in an ongoing manner as the data was collected.

5.5.3 Translation

The person translating the transcribed interviews was involved in many aspects of the study throughout the data collection process. She translated interview guides and consent forms and took part in two of the first FGDs conducted, taking notes in English. This also increased her understanding of the context and particularities of the study. She is a Tanzanian who has lived in Ireland for the past 15 years and is fluent in both Kiswahili and English. With her native language skills, she was able to translate not just word for word what was said, but also provided contextual information. She often wrote comments to the translated interviews where she highlighted areas in the interviews where the word for word meaning did not make sense to her and instead explained what she understood as the meaning of a particular quote or statement. She does not have a medical background and her interpretations of unclear sections of the interviews were discussed with the research assistant. Particularly when working on the first interviews, we spent a lot of time discussing context and medical terminology that she was not familiar with. When translating, she often went back to the recorded interviews to listen to make sure she captured the content correctly. Both transcripts and translations were verified and approved by bilingual members of the research team.

5.6 Content analysis

Qualitative content analysis guided the data analysis of all three papers. This type of analysis is considered suitable for descriptive research questions (123). It is a commonly used approach to analyze qualitative data and is particularly useful in order to identify key themes in participants' experiences (122). There are several ways to conduct a qualitative content analysis, all of which include a systematic and structured analysis and interpretation of data (119). Frequently used in nursing research, the process described by Graneheim and Lundman was chosen (124). This particular step-wise process included a familiarization with the collected data, which consisted of the PhD candidate reading and re-reading all transcribed interviews and FGDs. The data relevant to the study objectives was subsequently systematically divided into descriptive codes after analyzing transcripts line-by-line. The software package NVIVO 11 (QSR International) was used to assign codes. A coding list was generated and the codes were subsequently merged into categories. During the process, emphasis was put on keeping the original wording of the participants to the extent possible. Both manifest and latent content was analyzed. Manifest content is what the participants are

saying, while latent content is the underlying meaning. The transcripts, codes, and categories were discussed among supervisors and co-authors.

6. Ethical considerations

The Safer Births project and all its sub-studies are approved by the Norwegian Regional Ethics Committee (REK Vest; Ref: 2013/110/REK vest) and the Tanzanian National Institute for Medical Research (Ref: NIMR/HQ/R.8a/Vol.IX/388). The PhD candidate obtained a research permit to carry out the study from the Tanzania Commission for Science and Technology, COSTECH, (No.2016-396-NA-2016-277) and approval from the Teaching, Research and Consultancy Coordinating Unit at Muhimbili National Hospital (ref MNH/TRC/Research/2017/010), the block manager for the maternity ward at MNH, the District Medical Officer at Temeke Municipality, and from the administration at TRRH. The final manuscript for the three papers obtained permission to publish from the Tanzanian Institute for Medical Research.

Ethical considerations have been a concern throughout the study process, particularly pertaining to issues around informed consent and confidentiality.

6.1 Informed consent

According to the Declaration of Helsinki regarding all research involving human subjects, informed consent should always be obtained for all participants in a study (125). As such, it can be argued that informed consent is a pillar in ethical principles applied to modern research. It implies that all persons taking part in a research project are participating of their own free will, without being persuaded or coerced, and that they are fully aware of the implications of their participation. Informed consent implies that the participants have fully understood the information provided about the research project. This means that the information should be given orally or in writing depending on the literacy level of the participants, and that other communication methods, such as videos or pictures, should also be considered to convey this information (122). When conducting research projects in low-income settings, it can be argued that there is a higher risk of certain participants feeling persuaded or forced to participate due to the power imbalance between the researcher and the participant.

All participants in the PhD study received information about the study in their mother tongue, Kiswahili (see appendix 14.6). The research assistant was trained in how to inform the illiterate and semi-illiterate participants of the study about the content of the consent form in an understandable way. Among the key components of the consent form were: the participants were informed about the purpose of the study, the risk and benefits, their right to withdraw at any time without consequences or to refuse to answer any questions, and to withdraw consent for the use of their data. They were also informed about their right to refuse the use of the digital recorder, that their names would not be written down anywhere, and that the researcher and interpreter would protect their anonymity (125). Contact details were also provided to the research unit at MNH where the participants could raise any complaints related to the study.

6.2 Confidentiality

Several steps were taken to ensure the confidentiality of participants. Their names were not written down anywhere, and references to fellow participants during FGDs were not included in transcripts by name. Instead, each participant received a number to which they would refer to when they spoke. All recorded data was immediately deleted once transcribed. The signed consent forms were kept in a locked box at all times during data collection, and in a safe at the University of Oslo after the candidate's return to Oslo. Due to the sensitive topics discussed, a decision was made not to name the study sites in the published papers in another effort to ensure the participants' confidentiality.

Other ethical considerations included making sure that the questions or issues raised were causing stress or psychological harm to the participants. In addition to reminding participants that they could refuse to answer any question, we also followed up with participants after the interview or FGD was completed. A couple of times the participants expressed that they had appreciated taking part in the discussion, often saying that they had liked that they had been given an opportunity to express their opinions or views. The head of the maternity block at TRRH was also asked if she had received any complaints, which she stated she had not.

7. Results

The main results of the papers included in this PhD thesis indicate that Moyo was perceived as a tool that positively affected the women's labor experience and made work easier for the SBAs. The perception among both SBAs and women was that the device was highly necessary and that its use contributed towards reducing maternal and perinatal mortality (Papers 1 and 3). Also positive was the perception that use of the device improved care (Papers 1 and 3). Factors that negatively affected adoption and use of the device include a lack of knowledge about correct use (Paper 2), and limitations of the device that led to an overestimation of its capabilities (Papers 1 and 2). Other factors that negatively affected adoption and use were a lack of training and practice about how to respond to alerts of fetal distress (Paper 2). The categories for the three papers included are summarized in illustration 4, page 50.

7.1 Summary of results Paper 1

"I was relieved to know that my baby was safe": Women's attitudes and perceptions on using a new electronic fetal heart-rate monitor during labor in Tanzania

The paper is based on 20 semi-structured interviews with women who had recently given birth using Moyo. The objective of Paper 1 was to explore the attitudes and perceptions about the device and the effects on the care they received of women who wore Moyo during their most recent delivery. The attitudes and perceptions of the women participating in the study towards using the device and their perceptions about how the use affected care were divided into four categories: *Understanding Moyo's purpose and functions; Feeling the device had a positive effect on the delivery; Feeling good knowing the baby was safe;* and *Receiving close care.* An additional category was developed to capture the women's suggestions for how the introduction of Moyo could be improved.

The first theme, *Understanding Moyo's purpose and functions* was based on a lack of information about the purpose of the device and its main functions, reported by half of the participants at one of the study sites. Those who said that they had been informed described the purpose of the device, but knew less about its functions, including the alarm function. Many attributed their lack of knowledge to labor pains, which had made it difficult for them to absorb information. Those who reported not being informed seemed more likely to attribute functions to the device and overestimate its diagnostic power. In the second

category, *Feeling the device had a positive effect on the delivery*, the participants described the positive effects of wearing Moyo for both the mother and the child. Some believed that Moyo had helped the labor progress by helping the baby pass through the birth canal. Others said the device had given them strength to push and endure the labor, by making it less painful. The positive effects of wearing Moyo during the delivery was linked to the third category, *Feeling good knowing the baby was safe*, when using Moyo compared to previous deliveries where they had been uncertain about the status of their baby during delivery and in some instances received limited or no information. The women described being able to monitor the status of the fetus themselves when wearing Moyo. Compared to previous deliveries, the care when Moyo was used was described as *close care*. This meant that they felt that the SBA was monitoring the progress of the delivery, even when s/he was not at the bedside. Another point mentioned was that the fact that both the woman and the SBA were monitoring the labor, meaning that the collaboration between them improved. The participants' suggestions for improvements were not related to the functions and characteristics of the device, but rather focused on introducing Moyo during ANC care so that the women had time to familiarize themselves with the device before they arrived in labor.

7.2 Summary of results Paper 2

Perceptions and experiences of acquiring knowledge about the use of a newly developed hand-held strap-on electronic fetal heart rate monitor: A qualitative study among birth attendants in Tanzania

The objective of the paper was to present SBAs' perceptions and experiences while acquiring knowledge about the use of the monitor. Five FGDs were carried out with SBAs who were using Moyo. Four main categories regarding the perceptions and experiences of acquiring knowledge about the use of Moyo were developed. These were: *acquiring knowledge through different approaches*; *challenges of teaching others*; *wanting to learn more*; and *ways in which the Moyo training could be improved.*

The participants in the study had acquired knowledge about how to use Moyo by attending either the ToT training, an in-house training session, through a colleague, or by self-learning. For the participants who had attended the ToT, the main concern was that many of those who had participated and were in turn expected to teach colleagues were no longer working in the

labor ward. It was therefore believed that more staff should have attended the ToT training. Those participants who were tasked with teaching others how to use Moyo described that not everyone was interested in learning about the device and that the *challenges of teaching others* were a concern. The participants pointed out that they could not force those who were not motivated to learn. However, overall the participants in the study expressed a desire *to want to learn more* about Moyo by expanding the duration of the Moyo training, which was believed to be too short. It was mentioned that the *Moyo training could be improved* by spending more time on practical exercises and by including more theory on labor management.

7.3 Summary of results Paper 3

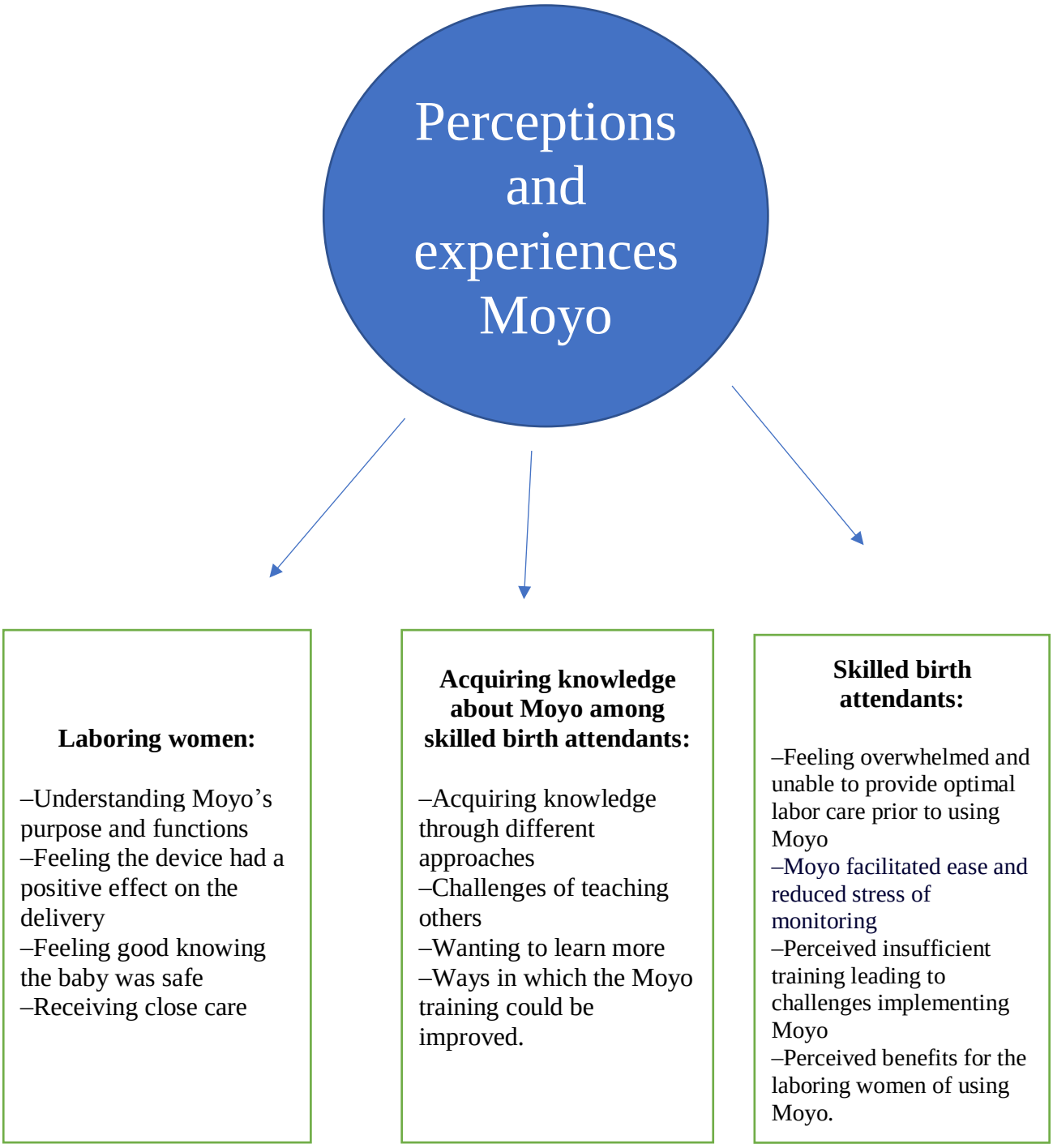
Perceptions and experiences of skilled birth attendants on using a newly developed strap-on electronic fetal heart rate monitor in Tanzania

The aim of Paper 3 was to explore attitudes and perceptions of SBAs using Moyo. Five FGDs were conducted and 10 semi-structured interviews were carried out. The attitude and perceptions of SBAs towards using Moyo were organized in four categories: *Feeling overwhelmed and unable to provide optimal labor care prior to using Moyo*; *Moyo facilitated ease and reduced stress of monitoring*; *Perceived insufficient training leading to challenges implementing Moyo*; and *the perceived benefits for the laboring women of using Moyo.*

Feeling overwhelmed and unable to provide optimal labor care prior to using Moyo included high workload, with the participants describing feeling overwhelmed on a regular basis. The participants expressed the difficulties in monitoring FHR as often as recommended. They also explained how the fear of being blamed for a negative fetal outcome made them work closely together in teams whenever a fetus´ condition worsened. Other challenges included the emotional effects of a poor fetal outcome. The participants believed that *Moyo facilitated ease and reduced stress of monitoring*. This was closely linked to a trust in the accuracy of the device and the objectivity of its FHR reading compared to Pinard. The participants felt they reacted faster to alerts of abnormal FHR and that the overall effect of using Moyo was improved fetal outcomes at the labor ward in both study sites. The participants also believed there were many *benefits of using Moyo for the mother*. This included increased communication between the SBAs and the laboring woman. The participants also recognized that Moyo caused less pain compared to Pinard. However perceived insufficient training lead

to challenges implementing Moyo. These challenges included uncertainties regarding indications for continuous FHRM and not using the device function that measures maternal heart rate in instances of fetal bradycardia. Several participants reported experiences of seeing the FHR on the display but later delivering a stillbirth. It was also mentioned that the waiting time from referral to surgery was often long and that there was no FHRM during this period.

Illustration 4: Summary of categories Papers 1, 2 & 3:



8. Discussion

This PhD study aimed to describe and understand the adoption and use of Moyo among SBAs and laboring women. Both women and SBAs expressed positive experiences of using the device. They also believed it contributed to improved care and better perinatal outcomes. However, among both women and SBAs, gaps were identified in their knowledge about the device and its functions. The SBAs expressed a need for more practice in using the device (Paper 2) while the women suggested introducing Moyo during ANC for more time to familiarize themselves with the device (Paper 1). The use of Moyo was to a large extent affected by external factors and contextual barriers such as weaknesses within the broader health system and a work culture that impeded the potential positive effects of the device (Papers 2 and 3).

8.1 The positive effects of using the device

There was a consensus among participants that there was a need for Moyo (Papers 1, 2, and 3). Believing that a new device positively contributes to improvements in patient outcomes is crucial for the adoption of new technology in health care. The positive effects of using Moyo described by the participants is what Rogers refers to as *relative advantage* (92).
The attitudes and perceptions of the laboring women were largely positive, something that was also mentioned by the SBAs included in the study (Papers 1 and 3). The main reason behind this was the reassurance that the device provided about the well-being of their child. This was also found in a study from Uganda (91). Another reason why Moyo was perceived as positive was that it was linked to technological advancements and improvements in care. Interestingly, Moyo was perceived positively also among women of low socio-economic status who have limited previous exposure to technology. A study from a low-resource setting found more mixed views about the use of ultrasound during ANC visits, with some women being reluctant towards the use of the device (126). In the past 10 years there has been a technological revolution in the use of mobile phones throughout Africa. One can speculate if this has led to an increased acceptance of new technological devices in general, and in particular among women of low-socio economic status who are now also well versed in using a mobile phone.

In his theory, Rogers includes the *characteristics of the people who adopt the innovation*. Both SBAs and the women described a process of feeling unsure about the device and initial hesitation (Papers 1 and 3). When being presented with an innovation, the user balances the risk involved against the potential gain. A person's degree of risk aversion will affect his or her decision. A review of literature about the diffusion of innovations in the health sector in the United Kingdom found that the more people can learn about the expected consequences of an innovation, the more likely they are to adopt it (94). The introduction of Moyo highlights knowledge gaps about the identification of fetal distress/responses and how to avoid misidentification of fetal HR among some of the participants. Papers 2 and 3 point to an insecurity among the SBAs about the consequences of using Moyo, or rather, how to respond to Moyo's alerts and the actions that should follow. Self-efficacy, discussed in Paper 2, was found to be one of the determinants of successful adoption of innovations in a review study (83). The findings from Papers 2 and 3 indicate that Moyo was a highly appreciated tool for the SBAs to determine FHR, but that challenges were related to the lack of clarity and knowledge about how to respond to Moyo's alarms.

Rogers divides adopters of innovations into different groups depending on their willingness to accept new innovations—namely innovators, early adopters, early majority, late majority and laggards (92). Medical professionals are often not early adopters, but rather early and late majority groups (82). However, it is argued that university hospitals are early adopters as they are more results-oriented (95). It is important to identify early adopters who can lead the way for more reluctant colleagues. During the introduction of Moyo, these were identified as master trainers to conduct the ToT about the device at the two hospitals (Paper 2). According to the literature, one-on-one discussions with each professional to address concerns about using the device would have been more effective, and it is perhaps this personal follow-up that lacked during the introduction of Moyo.

8.2 A perceived improvement care

Contrary to the initial assumption that the use of Moyo would create a distance between the woman giving birth and the SBA, findings from Paper 1 and 3 indicate the opposite. Both SBAs and women felt that communication and overall care improved when Moyo was used. For the women, this included a perception about receiving care when wearing Moyo even when the SBA was not present (Paper 1). This finding alludes to previous experiences of

inadequate attention and feeling alone during previous deliveries. Several studies have found labor care in Tanzania to be sub-standard, random, and disrespectful (127–130). In one study among 1,203 rural Tanzanian women, having a respectful and attentive birth attendant was considered the most important factor influencing the choice of giving birth in a health facility (131).

The use of Moyo seemed to give the women a more active role during labor (Paper 1). They were better informed about the status of their child and could take part in the fetal monitoring, which resulted in improved communication with the SBA. This is a largely unexplored area in current literature. The women reported a lack of information regarding the functions and purpose of Moyo that was linked to attributions and overestimation of the capabilities of the device. Women with low socio-economic status, in particular, more frequently reported not being informed or not having understood the purpose and functions of Moyo (Paper 1). For these women, one can wonder if they had a real choice in refusing to use Moyo if they did not wish to. The WHO Quality of Care framework includes the presence of a birth companion for all laboring women, which has shown to improve maternal and perinatal outcomes as well as enhance respectful maternity care (16, 132). If present when Moyo was used, this person could have received information about Moyo together with the laboring woman, which might have enhanced the understanding of the device. WHO's "Recommendations: Intrapartum care for a positive childbirth experience" (16) emphasizes effective communication throughout labor and birth *using simple and culturally acceptable methods* (ibid.). This also highlights the importance of introducing new technological devices as early as possible during ANC to ensure familiarization before the women goes into labor.

8.3 Knowledge about the device and practice using it

Papers 2 and 3 describe how participants felt that there was a need for more training in how to use Moyo, including practical exercises and labor management in general (Paper 2). A Swedish study about the implementation of new tools in primary health care recommends that an assessment of staff expectations, the perceived need for the innovation, and compatibility with existing routines is conducted prior to the introduction of new technology (96). This would have been highly useful prior to the introduction of Moyo and may have prevented obstacles against adopting the device, such as lack of knowledge of correct responses to fetal distress. The findings in Paper 2 point to a need for regular training, instead

of one or two stand-alone sessions in order to ensure that Moyo and its functions were fully understood. This was also a key finding from the evaluation of the national roll-out of Helping Babies Breathe (HBB), an SBA training program in newborn resuscitation in Tanzania (133). In another study from Northern Tanzania, frequent, brief, on-site (also called on-the-job) simulation training was seen as beneficial to improving skills in newborn resuscitation, which resulted in a decrease in neonatal mortality. Here, skills training was conducted for 3–5 minutes per week with 40 minute re-trainings (100). This type of training is often referred to as "low-dose/high-frequency" training. Described by Rogers as *trialability and observability*, the process of learning about a new device through training and observation of colleagues is key to successful adoption of new technology. It is clear that acquiring new skills and knowledge takes time. Studies conducted in high-resource countries have found that repeating training sessions is crucial for successful adoption (95). The circle of learning developed by SAFER (134) and Lærdal Medical can be used to illustrate this process (illustration 5):

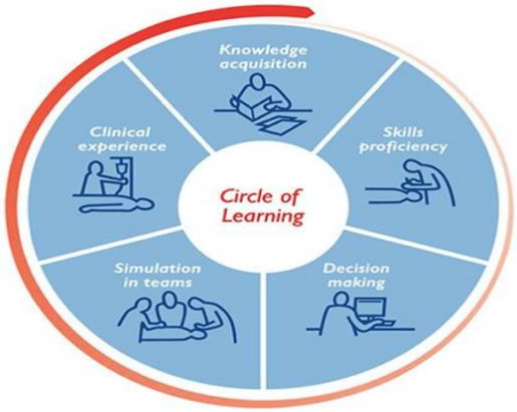


Illustration 5: The circle of learning

Interestingly, the importance of teamwork was mentioned as key when responding to fetal distress by the nurse/midwives in Paper 3, but was not included in the Moyo training. As seen in the circle of learning, simulation in teams is a vital component in acquiring knowledge for any clinical setting.

Moyo was introduced using a ToT training cascade model, commonly used to transfer skills and knowledge among health-care providers in low-resource settings (135). It implies that senior or key staff is trained as so-called "master trainers," who then go on to train his or her colleagues. Paper 2 describes the challenges with this commonly used model to diffuse knowledge, one being that many of the master trainers were no longer working in the ward. This issue was also found in the national HBB evaluation in Tanzania (133). While peer learning can be highly effective, master trainers are not automatically trained in aspects of learning such as motivation, which was considered an issue for the Moyo master trainers. Not knowing how to address a perceived lack of motivation to learn about Moyo among some of their colleagues, they responded by reducing the sessions to include only the absolute minimum. This highlights the pedagogical skills needed to fulfill their "mandate" of ensuring that Moyo and its functions was well understood by colleagues.

The issue of insufficient training prior to using Moyo also raises questions about who should operate the device and the context within which it should be used. Should it be used at a hospital with limited surgical capacity when there is evidence that its use leads to increased CS rates (74, 75)? Should it be used by staff with limited knowledge of how to correctly respond to signs of fetal distress? This lack of knowledge among some of the participants is similar to findings from a study conducted in Zanzibar. Here, some of the staff working in the labor ward at a tertiary hospital on the island lacked the adequate skills to fulfill the definition of an SBA (103). Possible solutions could be to develop a checklist with the required knowledge and competencies needed prior to using the device, or a practical and theoretical test that each SBA/health provider would have to pass in order to become "Moyo certified" and thereby allowed to use the device.

8.4 Contextual factors and barriers against the effective use of Moyo

This PhD study was conducted as part of a mixed-methods design and in part carried out to provide answers to some of the unexpected findings from the quantitative Moyo studies. While a pre/post study showed that the use of Moyo increased early detection of abnormal FHR, the time from detection to delivery was longer when Moyo was used (75). Interestingly, this finding is contrary to the SBAs' perceptions of reacting faster to alerts of fetal distress when Moyo was used (Paper 3). Similarly, both women and SBAs believed that Moyo contributed to improved fetal outcomes (Papers 1 and 3), which so far have not been

found in the quantitative studies that were not powered to do so. This points to several contextual factors that impede Moyo's life-saving potential in the current setting.

Contextual factors, as described by Rogers, are the challenges and opportunities present in the context within which the innovation is introduced (Papers 1, 2 and 3). These include lack of resources, high workload, and societal inequalities. In his theory, Rogers puts less emphasis on contextual factors and a stronger emphasis on the individual factors that determine adoption of a new technological device. In this study, however, the contextual factors were found to be the overarching premise for which the adoption and use of Moyo can be understood. It includes the treatment of women with low socio-economic status in the health system (Paper 1), the role of midwives within a system where they have limited power (Papers 2 and 3), a work culture of fear and blame (Paper 3), and health system weaknesses such as the limited capacity to perform emergency CS, particularly at TRRH.

When viewing the findings of this PhD study in light of the technology acceptance model, (see illustration 2), we find that while the elements of the model are relevant to determining the actual use of Moyo, external factors affected adoption and use at each level during the acceptance process to a far greater extent compared to TAM. Contrary to TAM, the SBAs considered the usefulness of Moyo as separate from the ease of use, meaning that they considered the device as useful while also believing there was a need for more training on how to use it (Papers 2 and 3). Attitudes towards the device were also described as non-linear, with users explaining an initial skepticism that was replaced by appreciation for the device once they felt comfortable using it (Paper 3).

8.5 The role of the skilled birth attendant

Paper 2 points to an expressed need for capacity building among the SBAs. There was *a need to learn Moyo in more detail* that could be interpreted as a perception of having received insufficient training in using the device and a lack of practice in incorporating it into their clinical procedures. It could also be interpreted as a need to learn and practice the correct obstetric responses to signs of fetal distress, namely intrapartum resuscitation. Both of these topics were covered in the training sessions conducted prior to the introduction of Moyo and the subsequent refresher training. While reasons could be the high turnover of staff and long intervals between training sessions, the literature indicates that increasing knowledge through

training does not necessarily lead to better decision making or improvements in care (81, 136). In a study about the lack of adherence to guidelines for the integrated management of childhood illnesses in northern Tanzania, *cognitive overload* or *cognitive absence* resulted in a lack of capacity to concentrate fully on each patient. As a result, the health providers created simpler *rules of thumb* for treatment, instead of adhering to international guidelines (136). Bridging the know-do gap, described as the difference between what health providers know about how a task should be performed and how they actually carry out the task, is considered key to improving maternal and perinatal outcomes (137). In other words, if an SBA knows how to respond to fetal distress when Moyo alerts him/her, why doesn't s/he do it? Here, both individual and contextual factors come into play. While individual factors such as motivation have been raised as a possible explanation (138), an SBA's motivation to perform his or her duties is strongly linked to the environment within which s/he works. Studies have pointed to a naming and blaming culture inside Tanzania's labor wards and nurse/midwives working in fear of being blamed for negative fetal outcomes (127, 139). Paper 3 describes how nurse/midwives would work closely together to avoid individual blame for negative fetal outcomes. This kind of environment will have an effect on how Moyo is adopted and used.

SBAs working in a hierarchical structure, one in which they have limited power and their clinical decisions are heavily scrutinized, will take different follow-up actions to Moyo's alerts compared to an SBA working in an environment where s/he feels supported. It is therefore not surprising that CS rates increased with the introduction of Moyo. Referring a woman with fetal distress to CS shifts the responsibility away from the individual SBA compared to if s/he initiates intrapartum resuscitation.

8.6 Health system weaknesses

Many of the participants expressed a belief that Moyo was beneficial simply because it represented something new and "high-tech" (Papers 1 and 3). In the debate about "too little, too late" and "too much, too soon" (140), when it comes to obstetric care, a device such as Moyo risks falling into the "too much, too soon" category as *interventions that can be lifesaving when used appropriately, but harmful when applied routinely or overused* (140). It is important to highlight the risks of overmedicalization involved in introducing technological devices such as Moyo. The two hospitals where the data was collected have different

characteristics, with MNH having more staff and greater capacity to attend to complicated obstetric cases. Previous studies from hospitals in Tanzania, including MNH, found that CS is made on doubtful indications (70, 141, 142). The quantitative studies of the introduction of Moyo show an increase in CS and delays between referral to the time CS was carried out (75, 76). It should be of concern that the use of Moyo added to the existing problem of overuse of the procedure. A systematic review of maternal and perinatal mortality associated with CS found that women giving birth in sub-Saharan Africa had the highest mortality rates than anywhere else in the world following the procedure (143). The participants in the current PhD study admitted that while forceps was not used, training in manual vacuum aspiration (MVA) was needed to increase rates of vaginal deliveries (Paper 2). Including skills training in MVA could have been beneficial to reducing CS rates after the introduction of Moyo.

The findings of the three papers included in this PhD thesis support the notion that no technological device should be presented as the single solution to the reduction of perinatal morality. Innovative technology has the potential to be one of several tools implemented in an integrated package together with the training of SBAs and strengthening of the overall health system. In line with the Every Newborn Action Plan, adopted by Tanzania, the provision of a package of Essential Obstetric and Newborn care is recommended rather than focusing on individual interventions (144–146).

9. Methodological considerations

9.1 Trustworthiness

Trustworthiness is often used to assess the quality of qualitative research. Lincoln and Guba's four criteria for establishing trustworthiness are commonly used: credibility, transferability, dependability, and conformability (147, 148).

Credibility refers to the ability to capture the multiple realities of those studied.
Several steps were taken to enhance the credibility of this PhD study. Lincoln and Guba (147) describe *prolonged engagement, triangulation, negative case analysis and member-checking* as techniques for establishing credibility. Prolonged engagement meant that as the main researcher on the project, the candidate spent enough time in Tanzania to familiarize herself with the setting within which the data was collected both at the two hospitals and in

Tanzanian society as a whole. This was done not only by being present in the labor ward and informal conversations with staff, but also through conversations with Tanzanian friends, living in Dar es Salaam, learning Kiswahili, and following political developments in the country before, during, and after the data collection. The use of triangulation, which is defined as the examination of a phenomenon from different perspectives (120), was another way in which credibility was enhanced. Three methods of triangulation—triangulation of sources, analyst triangulation, and theory triangulation—were used (147). Data were collected from multiple sources, both SBAs and laboring women, and both FGDs and semi-structured interviews were used to collect data. Data were also collected at two hospitals with quite different characteristics.

During the data collection and data analysis, a continuous discussion occurred between the PhD candidate, the research assistant, supervisors, and others with in-depth knowledge of the study setting to allow for critical reflection and multiple ways of seeing the data in order to reduce researcher bias. To allow for data that did not support patterns emerging from the data analysis, an effort was also made to document opposing views within categories, called negative case analysis. This was included in all three papers, often illustrated by quotes. Member checking was also used during the data collection by bringing back results to the members of the studied group in order to solicit their feedback and in turn enhance the credibility of the study findings (122). This was done both formally during FGDs and semi-structured interviews, but also informally when having conversations with staff at the two study sites. While having been criticized in part because it implies that there is a fixed truth that can be confirmed by a respondent (149), it provides an opportunity to challenge what are perceived as wrong interpretations and to summarize preliminary findings. During the data collection, member checking turned out to be a way to obtain the views of other participants about surprising findings and to obtain additional data about these.

Audiotaping and transcribing verbatim all the data for the analysis to be conducted from written text was also carried out to enhance credibility. Using NVIVO to code the transcribed text was done in an effort to provide consistent coding to large amounts of data and also to enhance credibility.

Transferability refers to how applicable the findings are to other settings or contexts. By providing a detailed description—also called a *thick description*—of the study setting, of the participants, of how the data was collected and analyzed, and of the study findings, readers

are able to make an informed choice about transferability to other contexts. Including SBAs with different characteristics and collecting data at two different study sites was done in an effort to increase transferability to other settings.

Dependability refers to the ability of the researcher to account for the constantly changing conditions over time in data collection and analysis. The use of interview guides allowed for consistency during the data collection. Both transferability and dependability were enhanced through illustrations of how the categories emerged from the data and through illustrative quotes for each category in the three papers.

Confirmability refers to the extent to which the findings presented are drawn from the data and not the researcher's assumptions. Similar to credibility, the daily discussions with the research assistant, supervisors, other members of the research team, and persons familiar with the study setting enhanced confirmability by ensuring a process where data was analyzed using both an outsider and insider perspective. In the initial stage of data analysis, the research assistant was crucial in enhancing the understanding of the collected data. Whenever there were questions about the translated interviews, the candidate would bring them to her for her input. As such, she reduced the subjective bias of the candidate and ensured that the data collected became more balanced (118).

Using triangulation, including research triangulation within a team of both Norwegian and Tanzanian researchers, also enhanced confirmability. Sharing and discussing codes and categories between the researchers reduced researcher bias and enhanced confirmability.

The use of field notes was done in an effort to enhance the study's trustworthiness. Keeping daily notes allowed for reflection on impressions and decisions made during the data collection and analysis.

Reflexivity refers to a researcher's critical reflection both on the research and the researcher herself. It is based on the notion that the perspective or position of the researcher shapes all research and that this self-reflection strengthens the credibility of the study (122). While a number of steps were taken to enhance the credibility of the PhD study, there is no doubt that it would have benefited from the PhD candidate being fluent in Kiswahili and being trained

in obstetrics or midwifery. While she is a registered nurse with experience working in a tertiary hospital in Norway, she is not trained in the skills needed to manage normal (uncomplicated) pregnancies and childbirth. These skills would have allowed for more active participation in the daily work at the labor ward and further enhanced knowledge of the context within which the data was collected. Attempts to counterbalance this weakness were made through the selection of a research assistant with these skills and other mitigating measures as outlined above.

10. Conclusion

In low-resource settings such as Tanzania, there is a need for increased efforts to accelerate the reduction in perinatal deaths. The development and implementation of new technology to improve care is one component of this effort. This study indicates that the introduction of the strap-on electronic FHR monitor called Moyo was largely perceived as positive among SBAs and laboring women in Dar es Salaam. The laboring women felt reassured about the well-being of their unborn child, and the SBAs believed that using Moyo reduced stress and a heavy workload. Challenges related to the introduction of the device include lack of information about the device to laboring women, and a lack of training for SBAs and their consequent uncertainties about how to respond to the device's alerts of fetal distress. This study indicates that a tailored, holistic, and long-term approach is needed when introducing a device such as Moyo in order for it to be used effectively. This includes the need to introduce new technology with a comprehensive and on-going training program, and to support to users over time. To fully reach its potential of reducing perinatal morality, new technological solutions such as Moyo should be introduced within a comprehensive package of activities that strengthen the health system and are aimed at improving both the quality and the availability of care.

11. Recommendations

Policy/national level

- Provide and incorporate on-the-job training for skilled birth attendants.
- Include labor management, including intrapartum resuscitation and MVA, in training programs about use of new technology to monitor FHR.

Health facility level

- Introduce new technological devices at ANC when possible.
- Improve the information provided to laboring women about the status of their fetus.
- Use a "low-dose/high frequency" model when introducing new technology.
- When using the ToT model, include a component on motivation and learning for master trainers.
- Assess the facility's ability to cope with potential effects of introducing a new device (such as an increase in CS referrals).
- Highlight the risks of overmedicalization involved in introducing technological devices such as Moyo.

Community/individual level

- Assess individual suitability to use a technological device.

11.1 Recommendations for future research

- Investigate aspects of empowerment in relation to the introduction of new technology in labor care.
- Investigate further perceived risks by end-users (pregnant and laboring women) of using new technology.
- Investigate if there is a link between inadequate training and blaming user errors on the device.
- The interplay between what is gained and what is lost when introducing new technology (such as the connection with the fetus).
- Increase knowledge about the perceptions of those who do not adopt new technology.

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"I Was Relieved to Know That My Baby Was Safe": Women's Attitudes and Perceptions on Using a New Electronic Fetal Heart Rate Monitor during Labor in Tanzania

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Abstract: To increase labor monitoring and prevent neonatal morbidity and mortality, a new wireless, strap-on electronic fetal heart rate monitor called Moyo was introduced in Tanzania in 2016. As part of the ongoing evaluation of the introduction of the monitor, the aim of this study was to explore the attitudes and perceptions of women who had worn the monitor continuously during their most recent delivery and perceptions about how it affected care. This knowledge is important to identify barriers towards adaptation in order to introduce new technology more effectively. We carried out 20 semi-structured individual interviews post-labor at two hospitals in Tanzania. A thematic content analysis was used to analyze the data. Our results indicated that the use of the monitor positively affected the women's birth experience. It provided much-needed reassurance about the wellbeing of the child. The women considered that wearing Moyo improved care due to an increase in communication and attention from birth attendants. However, the women did not fully understand the purpose and function of the device and overestimated its capabilities. This highlights the need to improve how and when information is conveyed to women in labor.

Keywords: Tanzania; low-resource setting; labor care; laboring women's attitudes; (electronic) fetal heart rate monitoring; labor monitoring; health literacy; informed consent; Moyo; wireless fetal heart rate monitor

1. Introduction

While there have been global improvements in child survival, perinatal mortality remains nearly unchanged [1]. Each year, as many as 2 million babies die during labor (fresh stillbirths) [2–5] and almost 3 million newborn babies die within their first month of life (neonatal deaths). The global target for reducing neonatal mortality as stated by the Sustainable Development Goal 3.2 aims to reduce neonatal mortality to 12 per 1000 live births by 2030 [6]. The countries in the world with the highest neonatal mortality are located in South Asia and Sub-Saharan Africa [7]. While Tanzania has made great improvements in reducing neonatal mortality, 27% of the estimated 8000 newborn

deaths occurring each year in the country are caused by birth asphyxia [7]. Birth asphyxia can be detected through regular fetal heart rate monitoring (FHRM). The most common way to monitor FHR is by using a Pinard fetoscope. However, in low-income settings where there is a lack of skilled birth attendants, such monitoring is often not done according to guidelines [8], partly due to time constraints [9]. FHRM has also been found to be suboptimal as the partogram used for monitoring and documenting the progress of labor through regular FHRM and maternal assessment is considered to be a complex tool [10]. While it provides guidance for obstetric interventions based on the progress of labor, it is often under-utilized or incorrectly completed [11,12].

To improve FHRM, a new strap-on automatic fetal heart rate monitor, Moyo, was developed by Laerdal Global Health (see Appendix A). It helps detect fetal heart rate and alerts the skilled birth attendant in an effort to ensure timely obstetrical actions and prevent birth asphyxia and fresh stillbirths. Acceptance by users is essential for the success of technological devices [8,13]. While investigated in high-income countries, there is limited knowledge about laboring women's views about new technological devices used in maternal care in low-resource settings. We believe it is important to bring forward their perspectives in an effort to improve care. This knowledge is important to identify potential barriers towards adaptation in order to introduce new technology more effectively and ensure long-term use. Through a review of literature, we were unable to identify other studies that investigated laboring women's attitudes and perceptions about a wireless strap-on electronic fetal heart rate monitor in low-resource settings. Research is therefore needed as new technological devices are increasingly introduced in maternal care in low-resource settings. The objective of this present study is to explore the attitudes and perceptions of mothers who wore Moyo during their most recent delivery about the device and its effects on the care they received.

This study is part of the ongoing evaluation of the introduction of Moyo and was conducted in parallel with the quantitative Safer Births Moyo studies in Dar es Salaam. At a tertiary health facility in the city, a 2-arm randomized control study testing the use of Moyo versus a hand-held Doppler for fetal heart rate monitoring was conducted. At a municipal referral hospital, a descriptive study evaluating the use of Moyo and its effects on timely obstetrical actions/referrals and perinatal outcome was carried out.

2. Materials and Methods

2.1. Study Design and Data Collection

As the current study aimed to explore the attitudes and perceptions of laboring women, a qualitative approach was chosen [14]. In order to capture individual experiences, a total of 20 semi-structured individual interviews were carried out [15], ten (10) at each study site. An interview guide was used which included open-ended questions about the information received about the device, opinions about wearing it, and the care received while wearing the device. When necessary, follow-up questions were asked for elaborations or clarifications. Each interview ended by asking the participant if she had any questions for the interviewer. Interviews at both hospitals were conducted in Kiswahili by a research assistant who was a teacher in midwifery with experience in conducting qualitative research. The first author (Sara Rivenes Lafontan) was present during all interviews. Data collection continued until saturation and no new themes arose [15]. Additional interviews were consequently carried out at both study sites in an effort to validate findings with new respondents. This process aims to verify the collected data in order to increase the validity of the findings and is often referred to as respondent validation or member checking [15]. These interviews were part of the total number of interviews carried out. The interviews were conducted 12–24 h post labor at different private locations inside both hospitals to ensure privacy, and lasted 20–25 min. The data collection took place from January to March 2017.

2.2. Recruitment of Participants and Ethics

Twenty mothers were recruited to participate in the study and all participants were interviewed once. Recruitment was done through convenience sampling [15]. The mothers were approached before discharge from the post-natal ward and informed about the study by two members of the research team at both hospitals. All the women who were asked to participate in the study accepted. The recruitment was conducted by the Tanzanian research assistant with assistance from nursing staff at the maternity wards. The inclusion criteria to participate in the study were that Moyo had been used during the most recent delivery, that there had been a positive fetal outcome, and that the women were multiparous.

The study was conducted according to the Declaration of Helsinki [16]. All participants received oral and written information about the purpose of the study before giving their written consent to participate. The Safer Births studies are approved by the Norwegian Regional Ethics Committee (REK Vest; Ref: 2013/110/REK vest) and the Tanzanian National Institute for Medical Research (Ref: NIMR/HQ/R.8a/Vol.IX/388). The first author obtained a research permit to carry out the study from the Tanzania Commission for Science and Technology, COSTECH, (No. 2016-396-NA-2016-277). The study obtained ethical approval from all relevant entities, both at the institutions where the study was carried out and at the local government.

2.3. Study Setting

The study was carried out at two hospitals in Dar es Salaam, Tanzania. Hospital 1 is a tertiary referral hospital with 10,000 annual deliveries. It receives patients referred from both public and private practice and also serves paying private patients. The obstetric department is staffed with a number of obstetric and gynecologic (Ob-Gyn) specialists, resident doctors, intern doctors, and nurses/midwives. The labor ward includes 19 beds and five birth attendants per shift. Hospital 2 is a municipal referral hospital receiving patients from health centers and peripheral hospitals in a primarily high-density area of Dar es Salaam. There are two Ob-Gyn specialists per day working in the obstetrics department in addition to medical doctors, intern doctors, and nurses/midwives. The hospital has approximately 17,000 annual deliveries, between 40 and 50 each day. The labor ward has 12 beds and five birth attendants during the day. Women at the two facilities were monitored using a Pinard prior to the introduction of Moyo (as a trial). Both facilities have the capacity to perform what is described as comprehensive emergency obstetric and newborn care signal functions [17].

2.4. Data Analysis

The interviews were recorded and transcribed verbatim by a transcriber who was trained by the first author (Sara Rivenes Lafontan) and who had previous experience transcribing qualitative interviews in Kiswahili. The transcripts were translated into English by a native speaker fluent in both Kiswahili and English and familiar with the study context. Both transcripts and translated versions of the interviews were verified by members of the research team. The translated interviews were read and re-read to deepen the familiarity with the content. Data organization was undertaken using the software package NVivo 11 (QSR International Pty Ltd., Melbourne, Australia). The data was analyzed using qualitative content analysis which is considered suitable for descriptive research questions [18]. During this stepwise process, the material was systematically divided into codes and categories as described by Graneheim and Lundman [19,20]. Transcripts were analyzed line by line and assigned to relevant codes. A coding list was generated and codes were subsequently merged into categories; see Table 1 below for an example of the coding process. Throughout this process, emphasis was on keeping the original wording of the mothers participating in the study. Condensed meaning units, codes, and categories were discussed and agreed upon among the authors.

Table 1. Example of the analysis process.

Translated Transcribed Interview	Code	Category
I: Okay, great, so can you tell us if this device changed your birth experience compared to your previous deliveries where devices like Pinard were used? R: Yes, I saw the difference because this device allowed the nurse to be closer as opposed to previously where they'd walk around and monitor from afar, they would come to me more often too.	Feels that she received closer and more frequent attention from the nurse compared to previous deliveries due to the device.	Receiving close care [1]

[1] The category was formed by several codes.

3. Results

3.1. Demographic Characteristics

The age range of participants was 23–43 years, median age 32 years. A summary of participant characteristics by age group, occupation, and number of children is presented in Table 2 below.

Table 2. Demographic description of participants by age group, occupation, and number of children.

Variable	Sub-Groups	*n* (20)	%
Age	20–29	6	30
	30–40	13	65
	above 40	1	5
Occupation	Run a small business	7	35
	Maid	1	5
	Teacher	2	10
	Stay at home	5	25
	Farmer	2	10
	Nurse	1	5
	Entrepreneur	1	5
	Business woman	1	5
Number of children	1		
	2	6	30
	3	4	20
	4	8	40
	above 4	1	5

3.2. Categories

The attitudes and perceptions of the women participating in the study towards using the device and their perceptions about how the use affected care were divided into four categories: understanding Moyo's purpose and functions, feeling the device had a positive effect on the delivery, receiving close care, and feeling good knowing the baby was safe. An additional category was developed to capture the women's suggestions for how the introduction of Moyo could be improved.

3.2.1. Understanding Moyo's Purpose and Functions

Half of the participants at Hospital 2 and one participant at Hospital 1 responded that they had not been informed about the purpose of the device and its main functions when it was put on them. All but one of the participants who responded that they had not been informed had asked the health care provider what it was or understood it themselves. This was the only category where there was a clear difference in the responses at the two study sites. Of those who reported that they were informed, the information received and/or retained by the participants seemed to be related to the purpose of the device and less about its functions; they knew that Moyo measured fetal heart rate (purpose), but were unaware of the meaning of the colors on the display and sounds coming from the monitor (functions). None of the participants seemed to have fully understood the functions of the device, including the

alarm function. One woman was unable to see the monitor because it was hung on the IV drip stand with the display away from her:

> *I would like if they could turn the device around so I am able to see and know what's going on, also if they could give us more information about the meaning of colors and what to do if anything ever happens.*
>
> Hospital 1#3

As an explanation for why they did not know certain functions of Moyo or the purpose of the device, six women said that they were unable to absorb information or ask questions about Moyo due to labor pains. One participant indicated that while she had been informed about what the device measured, she had not been informed about its functions but she trusted the health care providers to take the appropriate action if needed. Those who said they had not received information about the purpose of the device did not express more negative attitudes towards the device or about wearing it. However, they more frequently attributed functions to the device; one woman who reported that she had not been initially informed suggested it might be a form of lucky charm since it was worn around her neck. Another thought it was a clock because she saw numbers on the monitor's display. There was also a tendency by some to overestimate the diagnostic power of the device; one woman said she thought that fetal abnormalities would be detected faster when the device was used. Some of the participants also mentioned that they believed the device helped the baby breathe and helped the baby overall to ensure a safe delivery.

One woman at Hospital 2, who also responded that she had not received information, explained that the woman lying in the bed next to her had said that if Moyo did not make a sound it meant that the fetus was dead. Another also expressed fear of the consequences of the device not making a sound:

> *In my mind I was thinking maybe if the device did not produce any sound my baby was no longer alive. So from time to time I pulled the straps of the device and waited for the sound.*
>
> Hospital 2#20

3.2.2. Feeling the Device Had a Positive Effect on the Delivery

All participants in the study delivered vaginally and on term without major complications during their most recent delivery. The women expressed that wearing the device had positive effects during the delivery. Three of the participants at Hospital 2 mentioned that Moyo helped the labor progress due to the belt which some said held the abdomen up, while another said helped the baby progress through the birth canal:

> *Previously when pushing the baby after some time the baby returned inside the womb and I had to push again and again. But this time with the device when pushing the baby did not return inside because there were no room for returning, the device had occupied the remaining space.*
>
> Hospital 2#16

Despite it being a new device, none of the participants expressed any doubt about the accuracy or safety of the device. For some of the women, the use of Moyo seemed to be linked with medical advancement and improvements in care which translated into an easier delivery for the women:

> *A high number of women lost their babies but now when the labor pains start when you attempt to push, the baby arrives with little hustle not like in the past when you would be in labor for six to eight hours.*
>
> Hospital 1#7

None of the participants said the device was painful to wear compared to the Pinard which some said was painful when it was pressed on the abdomen. Some of the women also expressed feeling

that Moyo had given them strength and energy; they had felt less tired and Moyo gave them the strength to push during contractions. There were some conflicting opinions about the effect of Moyo on labor pains. Some participants wondered if wearing Moyo resulted in more labor pain as the pain had become more intense when Moyo was put on. One mother felt that Moyo had contributed to less labor pain. The issue of labor pain and its effects was raised by the mothers and was not part of the interview guide.

3.2.3. Feeling Good Knowing the Baby Was Safe

Several of the mothers at both study sites reported previous negative experiences in childbirth, some having lost a child. Many explained being worried about the wellbeing of the baby and receiving limited information about the progress of the baby during previous deliveries:

I lost a child 2 years ago—they found out that one of the babies I carried died and I only found out after I gave birth to the other baby.

Hospital 2#13

This was compared to the feeling of reassurance about the wellbeing of their unborn child when Moyo was used. The continuous signs from the monitor that the baby was doing well, and being able to hear the heartbeats from the monitor and see the FHR marked on the display enabled the women to experience for themselves that the baby was doing well. One woman, when asked what was different during this delivery compared to previous ones, said:

I: Did you feel anything different?

R: Yes, I felt the difference, the difference is this time I could see how my baby was progressing while I was going through labor, the device gave me hope that the baby was ok.

Hospital 1#9

The main focus for the women interviewed was how Moyo positively affected their unborn child and not about how the women themselves felt about wearing the device. Questions about particular features of the device were often answered with the benefits of using the device for the fetus. When asked what it felt like to wear Moyo during the delivery, one woman simply responded:

I was relieved to know that my baby was safe.

Hospital 2#7

3.2.4. Receiving Close Care

The use of the device seemed to increase the sense of receiving care and being monitored for many of the women in the study. Some of the participants said they felt they had received closer follow-up from the health care provider compared to previous deliveries and said that even if the nurse/midwife was not by the bedside, she was monitoring the progress of the delivery from afar:

Respondent: even though the midwife was away she was able to hear.

Interviewer: she listening when away?

Respondent: Yes.

Hospital 2#7

When comparing Moyo to the Pinard, the increased monitoring was something that was pointed out by some of the women:

I think there's more care and attention given when Moyo device was used, they'd attach it from the beginning until you give birth and they'd monitor it in between whereas with Pinard, they'd only monitor once in a while—when you are first admitted and when you are giving birth.

Hospital 1#8

Moreover, two participants said that they felt they had received more attention from the health care provider when Moyo was used. One of these said that despite receiving less attention, she felt reassured about the progress of her child because she could see it on the device. It could seem as though the use of Moyo gave the health care providers more reason to attend to the mother if only to check on the device. Participants explained how the midwives came to look at the display of the device and left again without taking any other measurements or observations.

When Moyo was used, the mothers felt more actively engaged in the labor monitoring process which they also expressed as positive. Several respondents described how the monitoring of the fetus became a shared responsibility between the mother and the health care providers because the mother could follow the fetal heart rate. One participant said she felt there was an increased collaboration between her, the doctor, and the midwife.

> *I: So how did you feel when you saw that your baby was ok?*
>
> *R: I felt more confident... there was also a lot of cooperation around, compared to the first device (Pinard).*
>
> *I: Why was there no cooperation when the first device was used?*
>
> *R: Because only a doctor/nurse could hear.*
>
> Hospital 2#11

3.2.5. Suggestions for Improvements

None of the participants in the study had suggestions for how the functions and characteristics of the device could be improved. However, it was suggested that Moyo should be introduced during ante-natal care (ANC) visits in order for the mothers to receive adequate information and have time to familiarize themselves with the device before arriving at the labor ward.

> *I would suggest that the patient is educated about the device before coming into the labor ward, we are often in so much pain when we enter the (labor) ward, so it's not easy to listen and take everything in, some may refuse to wear the device because they are worried or in doubt and don't want to add more pain, so it's best that patients are told about the device before they enter the ward.*
>
> Hospital 1#8

Others said that their only suggestion was that Moyo should be available to as many women as possible during labor. It was explained that it would benefit both women and their babies, making the childbirth easier for the women.

4. Discussion

In the present study, we explored the attitudes and perceptions of women using a new electronic fetal heart rate monitor during labor. Our results indicate that the use of the monitor positively affected the women's birth experience by providing much-needed reassurance about the wellbeing of the child. The mothers also believed that the care had improved due to a perceived increase in communication and attention from the health care providers, but also to what the women described as being "monitored from afar".

Expressing that they were being monitored while the health care provider was away suggests that the women felt monitored due to the fact that they were wearing the device. As such, wearing the device became an extended part of the care provided by the birth attendant. Central to perceptions about care is the presence of the provider and by wearing the device the women expressed increased satisfaction with the care received [21]. However, it has been found that women are positive towards any intervention received during ANC or labor, regardless of the efficacy of the intervention [22]. The fact that many expressed that they felt care improved with the use of Moyo could also have to do with possible neglect experienced in the past [23]. Expressed satisfaction with the care received

could also be an indication of low expectations, or not knowing what to expect [24,25]. Often, during labor and delivery, women with low socio-economic status in overburdened public facilities are seemingly quite powerless, passive, and poorly informed, and have low expectations about care and information [26,27]. One could also argue that it might be difficult for the women to judge the quality of care without having experienced good care in the past. Several of the women in the study expressed receiving limited information and labor monitoring during previous deliveries, which could be another reason why the perceptions about care were mainly positive. Studies indicate that receiving medicines or items such as bed nets is described by women as good care while not receiving information from health care providers was not associated with poor care [24].

The reported lack of information by some of the participants about the purpose and functions of Moyo seemed to generate misconceptions and an overestimation of the capabilities of the device. The device was considered by some as almost magical in its abilities and some participants believed that Moyo not only detected but also solved problems by helping the baby to breathe or giving the mother the strength to push during delivery. This finding is similar to a qualitative study about the use of ultrasound in antenatal care in Botswana [28]. The women who reported that they were not informed more frequently reported attributions and an overestimation of the capabilities the device. This indicates an unmet need for information about Moyo and draws on models of health literacy and informed consent. These concepts imply that the patient receives and understands information about purpose, limitations, and procedure and the choice to accept or decline prior to a medical procedure [23]. To increase people's health literacy is an international priority as low health literacy is linked to increased morbidity and mortality [29]. Health literacy is also a critical component of empowerment as limited health literacy reduces autonomy in self-care and decision-making [30].

For the women in our study, the use of Moyo seemed to have strengthened their position during the delivery and the device became a tool of empowerment. In low-income settings, women are perceived as having less access to essential resources and less autonomy and decision-making power compared to men according to studies [31]. Each year, roughly a third of maternal deaths worldwide are directly related to inadequate care during pregnancy [32]. Conversely, empowered women have lower infant mortality and better overall health [31,33]. By wearing the device and monitoring the FHR, the women took on a more active role as they themselves were part of the important task of monitoring the progress of their baby. The combined effect of knowing the status of their unborn child and what they perceived as increased attention from the health care providers created a feeling of confidence, particularly among the participants in the study with the lowest socio-economic status. This contribution to the empowerment of the women in the study is an aspect of technology diffusion in low-income settings that we believe should be investigated further.

To measure FHR, many of the women in the current study preferred Moyo compared to the Pinard fetoscope and did not express concern about Moyo being a new device. It is argued that women have more confidence in information produced by technological devices rather than in their own bodily sensations as technology is often associated with experts and valued over local practices and the intervention-free birth which is perceived as "risky" [28,34,35]. This phenomenon is described as Gizmo idolatry, defined as *the willingness to accept, in fact to prefer, unproven, technologically-oriented medical measures* and that machinery is considered more valuable than a "low-tech" approach [36]. This attitude could explain why none of the participants expressed any fears about the potential harm of using the device which was a surprising finding and contrary to previous studies on the use of ultrasound [23,28].

Many of the respondents expressed a sense of relief knowing that their child was doing well when using Moyo. FHRM seemed to be considered a test to find out if everything was okay, compared to a confirmation that it was. This finding is similar to other studies in Sub-Saharan Africa investigating attitudes toward the use of ultrasound during pregnancy [37]. The anxieties of childbirth, particularly pertaining to uncertainties about the wellbeing of the unborn child, had been largely ignored by health providers during previous deliveries. The need for reassurance due to the risks involved in pregnancy

and childbirth for mothers in low-resource settings is closely linked to the need for information about the labor progress. The fact that some of the women who said they had not been informed either guessed or asked the health care provider about the purpose of the device also indicates a need for control over the labor process, not solely relying on the expertise of the health care providers. Studies from Tanzania indicate that women during ANC and labor receive inadequate information about the status of the fetus and indications, process, and results of medical interventions [23,38]. However, it is argued that most patients are unable to recall information provided to them [39]. As mentioned by some of the women, labor pain makes it difficult to absorb information and the women would most likely have been more susceptible to retaining information provided at an earlier stage of the labor when they were in less pain.

Strengths and Limitations

Several steps were taken to increase the validity of the study findings and ensure trustworthiness [20,40,41]. In an effort to increase credibility by shedding light on the research question from different angles, participants in the study varied in socio-economic background, occupation and age. As interviews were conducted in Kiswahili and translated to English, there was a risk that meaning might be lost during the translation process. Translations were therefore verified by members of the research team and the findings were validated with new participants after saturation was reached, in an effort to ensure that concepts were accurately captured. During the data collection, analysis codes were shared, discussed, and agreed upon among authors. The research team was multi-professional with both Tanzanian and Norwegian members, which facilitated interpretation of the data from different angles in order to capture diverse perspectives on the findings. Qualitative findings cannot be generalized due to small and demographically non-representative sample size; however, by describing in detail the context and characteristics of the participants in the current study, we allow the reader to make an informed decision about the transferability of study findings to other contexts [41]. While the women in the study seemed at ease during the interview, they might have felt uncomfortable saying anything negative about the care due to fears of repercussions as they were still admitted to the hospital. A suggestion for future studies is therefore to broaden the group of participants and to interview participants outside of the health care facilities. The women in the current study did not report experiencing severe complications during the most recent delivery and often described it as faster or less painful than previous deliveries. Overall, women with uncomplicated deliveries without unexpected levels of pain and duration of the labor report higher levels of satisfaction with care compared to those who do experience complications. This might be one of the reasons the responses were largely positive, both about the device and about the care received [21,42,43].

5. Conclusions

This study provides an understanding of how the use of a new electronic fetal heart rate monitor had a positive effect on the birth experience of the women in our study. This was largely due to an increased knowledge about the wellbeing of the unborn child and a perceived improvement in care. The study highlights the unacknowledged anxiety of childbirth which should be addressed by both health care providers and policy makers. A lack of understanding of the basic functions and purpose of the device raises the issue of informed consent and health literacy and the need to improve how and when information is conveyed to women in labor. We recommend that information about new devices used in the labor ward is included in the information provided to pregnant women during ante natal care and/or provided in the early stages of labor. This information should also include limitations of a technological device to avoid overestimation of the diagnostic power.

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Author Contributions: Sara Rivenes Lafontan formulated the study design, carried out the data collection and analysis and drafted the paper. Johanne Sundby, Hege L. Ersdal, Columba K. Mbekenga contributed substantially to the design, data collection and analysis and critically revised the paper draft. Muzdalifat Abeid and Hussein L. Kidanto participated substantially in the acquisition of data and in critically revising the paper draft. All authors read and approved the final manuscript.

Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Appendix

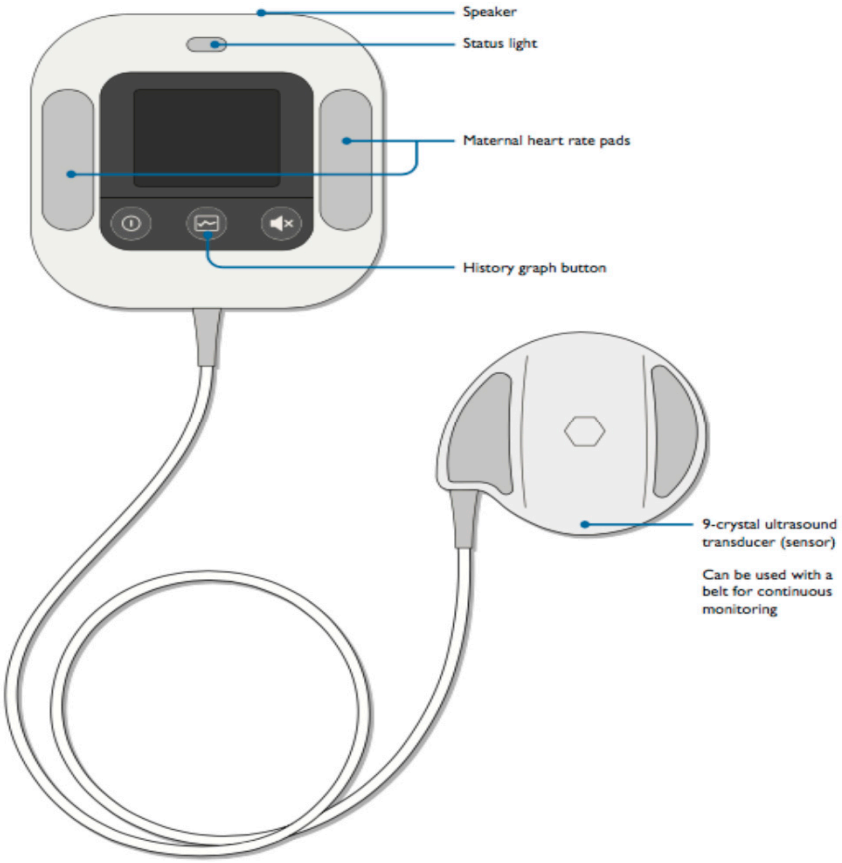

Figure A1. The Fetal Heart Rate (FHR) monitor, Moyo (Laerdal Global Health).

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Acquiring Knowledge about the Use of a Newly Developed Electronic Fetal Heart Rate Monitor: A Qualitative Study Among Birth Attendants in Tanzania

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Abstract: In an effort to reduce newborn mortality, a newly developed strap-on electronic fetal heart rate monitor was introduced at several health facilities in Tanzania in 2015. Training sessions were organized to teach staff how to use the device in clinical settings. This study explores skilled birth attendants' perceptions and experiences acquiring and transferring knowledge about the use of the monitor, also called Moyo. Knowledge about this learning process is crucial to further improve training programs and ensure correct, long-term use. Five Focus group discussions (FGDs) were carried out with doctors and nurse-midwives, who were using the monitor in the labor ward at two health facilities in Tanzania. The FGDs were analyzed using qualitative content analysis. The study revealed that the participants experienced the training about the device as useful but inadequate. Due to high turnover, a frequently mentioned challenge was that many of the birth attendants who were responsible for training others, were no longer working in the labor ward. Many participants expressed a need for refresher trainings, more practical exercises and more theory on labor management. The study highlights the need for frequent trainings sessions over time with focus on increasing overall knowledge in labor management to ensure correct use of the monitor over time.

Keywords: Tanzania; low-resource setting; labor care; (electronic) fetal heart rate monitoring; labor monitoring; health literacy; Moyo; wireless fetal heart rate monitor; birth attendant

1. Introduction

Recently, there has been an explosion in the development and implementation of mobile health solutions and technological devices to diagnose and treat diseases worldwide. Increasingly being used to tackle global health issues, innovation in health technologies is considered an important tool to achieve the health related United Nations Sustainable Development Goals in low- and middle-income countries [1,2]. Here, implementation of new technology is used to counter challenges in the health systems which impedes access to quality health services and by replacing outdated interventions

that are slow and imprecise [3]. The development of an electronic strap-on fetal heart rate monitor, called Moyo (Appendix A) developed by Laerdal Global Health (Stavanger, Norway) is one such example. In an effort to reduce perinatal mortality, the monitor is developed for use in low resource settings, where two million babies die during labor (fresh stillbirths) and almost three million newborn babies die within their first month of life (neonatal deaths), [4]. Strapped on the abdomen of a woman in labor, it uses ultrasound technology to continuously measure fetal heart rate. It alerts the caregiver of fetal distress (i.e., slow heart rate or extremely high rate) by an alarm, to ensure timely interventions to prevent intra-uterine hypoxia leading to fresh stillbirths and birth asphyxia—one of the leading causes of newborn deaths [5,6]. Moyo was introduced in Tanzania in 2015, one of the countries in Sub-Saharan Africa with high newborn mortality rates [4].

A vital component in a successful adaptation of tools such as Moyo, is the complex process of internalizing knowledge about how to use and interpret the technological device. Knowledge about this process is crucial to further improve training programs and ensure long-term use, as many innovative technological solutions initially fail in this endeavor [7,8]. Through a review of literature, we have been unable to identify studies investigating skilled birth attendants' perspectives of acquiring knowledge about the use of a technological device in low resource settings. However, a study from Tanzania about the use of the intermittent electronic fetal monitor, Doppler, found that midwives believed they had insufficient training to use it [9]. Hence, there is a need to better understand the process of learning to use new technology among skilled birth attendants. As part of an ongoing evaluation of the introduction of Moyo in Tanzania, the objective of this paper is to present skilled birth attendants perceptions and experiences acquiring knowledge about the use of the monitor and transferring this knowledge in the labor ward.

2. Materials and Methods

2.1. Study Design and Data Collection

The current study aimed to explore the perceptions and experiences of skilled birth attendants hence a qualitative approach was found to be most suitable. Focus group discussions (FGDs) was selected as data collection method as it allows a deeper understanding of social phenomena such as how people acquire knowledge, by obtaining the points of view of many individuals through a discussion initiated by the interviewer exploring experiences, views, motivations and beliefs on a specific topic [10].

In total, five FGDs were carried out with 4–6 participants in each group (Table 1). The FGDs took place at the hospital premises at both hospitals. An interview guide was used to guide the discussion and included open-ended questions starting with asking the participants how they had learnt to use Moyo, by whom and their motivations to learn about Moyo, probing for the approach used, time allocated and content. The participants were also asked if they had any recommendations for how the training could be improved. The discussions were conducted in Kiswahili by a research assistant who was a university teacher in midwifery with experience in conducting qualitative research. The first author was present during all interviews to observe and take notes. The FGDs lasted 60–80 min and took place at a location that ensured privacy at the two facilities. After each FGD, the facilitator and first author discussed responses to each question in order to make amendments to the interview guide if necessary. Data collection was carried out is until was believed that further data collection revealed no new themes and thematic saturation was reached [10]. The data collection took place from December 2016 to March 2017. The FGDs were audio recorded and transcribed verbatim and translated to English by an experienced transcriber and translator who were both trained by the first author. Transcripts and translated versions were verified by members of the research team.

Table 1. Data collection per study site.

	Data Collection	Medical Doctor	Nurse-Midwife
Study site 1	2 FDGs	0	9
Study site 2	3 FDGs	6	11

2.2. Recruitment of Participants and Ethics

Skilled birth attendants working at the labor ward and who were using Moyo at the two study sites were invited to participate in the study. All those asked to participate accepted. In total, six medical doctors and 20 nurse midwives participated in the study. The medical doctors formed themselves into one FDG group.

The study was conducted following the ethical principles set out in the Declaration of Helsinki [11]. All participants received oral and written information about the purpose of the study before giving their written consent to participate. The Safer Births project has been granted ethical approval by the Norwegian Regional Ethics Committee (REK Vest; Ref: 2013/110/REK vest) and the Tanzanian National Institute for Medical Research (Ref: NIMR/HQ/R.8a/Vol.IX/388). The first author obtained a research permit to carry out the study from the Tanzania Commission for Science and Technology, COSTECH, (No. 2016-396-NA-2016-277). Permission to conduct the study was obtained from all relevant entities, both at the institutions where the study was carried out and the municipality. Permission to publish the final manuscript was obtained from the Tanzanian National Institute for Medical Research.

2.3. Study Setting

The study was conducted at two hospitals in Tanzania's largest city, Dar es Salaam, a city with a population of 4.3 million. Hospital 1 is a tertiary referral hospital which receives patients referred from both public and private practice and also serves paying private patients. It has 10,000 annual deliveries. The obstetric department is staffed with 40 obstetric and gynecologic (Ob-Gyn) medical specialists who rotate on different wards, including the labor ward, resident doctors and intern doctors and 21 registered nurse-midwives and eight nurse attendants. Hospital 2 is a district referral hospital which receives referred patients from 135 surrounding health facilities within its catchment area of 2 million inhabitants. 25 nurse-midwives, five nurse attendants, eight registered doctors and two OB/GYN specialists are employed at the labor ward. There are about 17,000 deliveries taking place at this hospital every year.

2.4. Data Analysis

Data analysis was conducted in an iterative, inductive manner which started during the data collection. After re-reading the translated transcripts repeatedly in their entirety to deepen familiarity with the contents, a qualitative content analysis as described by Graneheim and Lundman [12] was applied to the material. Using the computer software package NVivo 11 (QSR International, Melbourne, Australia), the text was analyzed line by line and condensed into meaning units called codes. A list of codes was developed and the codes were compared to find patterns in the data. The codes were subsequently sorted into categories based on commonalities between codes. Efforts were made when developing codes and categories to maintain the "voice" of the participants. The first author (SRL) coded the data which was later shared and discussed among authors in an effort to reduce researcher bias. Table 2 provides an illustration of how codes, sub-categories and categories were created.

Table 2. Example of the analysis process.

Translated Transcribed Interview	Code	Category
I personally think there is a need to learn Moyo in detail, there are a lot of things such as differentiating maternal heart rate from fetal heart rate which can be easily mixed up, but we could also use other devices like fetoscope to confirm.	There is a need to learn more about Moyo	The need for more training *

Note: * the category was formed by several codes.

2.5. The Moyo Training

The Moyo training was initiated with two comprehensive training workshops organized by senior and management staff at the labor ward at the two hospitals. The first aimed at training master trainers, and the second included skilled birth attendants working in the labor ward at the two hospitals, organized in June and December 2015 respectively. Staff from the two hospitals were trained together in a separate location at one of the hospitals. During the initial Training of Trainers (ToT), the 20 master trainers were selected by senior staff at both maternity wards and were both nurse-midwives and medical doctors. These participants would then be responsible for training their colleagues at the two labor wards about the use of Moyo. The training curriculum included components of fetal heart rate monitoring, labor management and the functions of Moyo. More specifically, this included how to operate the device by correct placement of the probe on the abdomen, the different features of the device such the three buttons on the device namely the on/off button, history button showing the FHR during the past 30 min and the button to silent the alarm which rings during prolonged periods of abnormal fetal heart rate. Other issues included charging and cleaning of the device and instances when the device should not be used such as multi-fetal pregnancies. Flip-charts illustrating correct use of the device and Power Point presentations were used during the training. The workshop also included a demonstration at the labor ward showing how the device is strapped on a pregnant woman's abdomen. The subsequent training of skilled birth attendants included much of the same curriculum as in the ToT, however a training report states that it was of shorter duration as participants by then had a basic understanding of how to use Moyo from the master trainers. In addition, shorter training sessions were carried out in-situ/in-house at the labor ward at the two hospitals during the course of 2016.

3. Results

3.1. Demographic Characteristics

The age range of participants was 22–48 years, average age was 37 years. Median years of experience in labor care was 4 years. Four participants were men and 22 women. A summary of participant characteristics is presented in Table 3 below.

Table 3. Demographic description of participants by age group, gender and number of years of experience.

Characteristics		n (26)	%
Age	20–29	5	19
	30–40	8	31
	above 40	13	50
Gender	Female	22	85
	Male	4	15
Years of experience working in the labor ward	1	2	8
	2	3	12
	3	5	19
	4	7	27
	5	6	23
	above 5	3	11

3.2. Categories

Four main categories regarding the perceptions and experiences acquiring and transferring knowledge about the use of Moyo were identified. These were: (1) learning through different approaches; (2) colleagues motivation to learn; (3) the need for more training and (4) ways in which the Moyo training could be improved.

3.2.1. Learning through Different Approaches

The participants in the study had acquired knowledge about how to use Moyo by attending either the ToT training, an in-house training session, through a colleague or by self-learning. Those who had attended the initial ToT training said the learning tools, such as flip-chart used for the training was reported as being easy to understand and therefore helpful in understanding how to operate the monitor. One issue which was frequently mentioned when discussing the initial ToT was that many of those who had participated in the ToT were no longer working in the labor wards. Many of the participants in the FGDs had not attended the ToT which they felt would have been beneficial. In one of the FGD groups, none of the participants reported having participated in the ToT training and reported knowing only 3 to 4 colleagues who had. At both study sites, it was often mentioned that more staff should have attended the ToT training to receive a more comprehensive training. According to a participant who had not attended the ToT training:

> (The) *training was provided to very few people, so I would suggest that it is allocated to a lot more so that everyone is confident and sure about how to use Moyo.*
>
> (Nurse-midwife, FGD 4)

Those who attended the in-house training said that while it included both a theoretical and a practical component practicing on a laboring woman, it was of shorter duration compared to the ToT training and it was frequently mentioned that it should have been longer. One doctor who attended the in-house training however, felt that the training was sufficient due to the small group, interactive teaching style of the facilitator, and availability of devices for each participant:

> *The mode of teaching was good because we were only a few people, and everyone had the device at hand while the facilitator was teaching, he also had a chart, everyone was able to participate and ask questions.*
>
> (Doctor, FGD 1)

3.2.2. Colleagues Motivation to Learn

Those who had attended the ToT had to acquire knowledge about Moyo while also being responsible for training colleagues in the ward. Not everyone was interested in learning about Moyo

and the participants explained how they evaluated the attitude of the colleagues and their motivation to be trained, before deciding how much details they would include in the training session. When asking one participant how much time she spent teaching each colleague she responded:

It depends on an individual's awareness and willingness to learn.

(Nurse-Midwife, FGD 5)

One participant who had attended the ToT, believed that some colleagues were not interested in learning about Moyo and partly blamed the timing of the ToT training for this:

The ones who wants to learn will come to you and learn but you can't force those who are not interested . . . The problem occurred in the beginning after a few people went to the (ToT) training. Those who didn't attend lost interest and it was too late by the time they received training because they'd already lost interest by then.

(Nurse-Midwife, FGD 4)

3.2.3. The Need for More Training

Some participants stated that they did not feel they had received enough training before starting to use Moyo with one participant stating:

I personally think there is a need to learn Moyo in detail, there are a lot of things such as differentiating maternal heart rate from fetal heart rate which can be easily mixed up . . .

(Nurse-Midwife, FGD 2)

Other participants mentioned that colleagues who did not know how to use the device, blamed the device when it did not function as they wanted it to:

They think that all you have to do is to place the device and it will read the fetal heart rate automatically, they are the ones who complain that Moyo doesn't read properly.

(Nurse-Midwife, FDG 2)

Some of the participants seemed unaware of basic functions of Moyo. One doctor who had learnt about the monitor from a colleague was not aware of the fetal heart rate history function of the device, displayed by pressing one of the three buttons on the device. In one of the groups where several of the participants had attended a ToT training, there was a lengthy discussion about if the device can be used for twin pregnancies or not, an issue covered during the training.

Overall, the participants expressed a desire to spend more time on training. One aspect of this was to expand the duration of the Moyo training. However, it differed between participants if this time should be spent on more theory about labor management or more practice using Moyo. The participants also mentioned other areas of labor management where they would like to strengthen their knowledge. These included: how to detect the baby by pelvic examinations, how to ensure a safe delivery, the management of eclampsia and using ultrasound. One participant, who thought there had been enough theory during the in-house training, would like to learn more about the practical detection of abnormal fetal heart rate:

We need to spend more time with the patients and to learn all steps taken to detect fetal heart rate abnormalities.

(Nurse-Midwife, FGD 3)

3.2.4. Suggestions for Ways in Which the Moyo Training Could Be Improved

When asked how the training about Moyo could be improved, several issues were mentioned. The most common feedback at both study sites was that there was a need for a refresher training.

This was mentioned among participants who had attended both the in-house training and the initial ToT. Another common suggestion was that when practicing using Moyo, this should be done on pregnant women:

> *It is impossible to take in all the theoretical information, practice is necessary if someone wants to learn well.*
>
> (Nurse-Midwife, FDG 5)

One participant who had attended the ToT training said that there should have been more Moyos available during the training so each participant had one they could practice on. It was suggested that brochures, posters and instructional diagrams could be useful teaching aids in addition to the user guide that comes with the device. Two doctors would like to know more about the limitations of Moyo; when the device would provide false results and inaccurate readings.

4. Discussion

This study explored birth attendants' perceptions and experiences acquiring and transferring knowledge about the use of a newly developed fetal heart rate monitor introduced at the labor ward. While the majority of the participants were positive towards the contents of the training they had received, a general perception was a need for additional training in order to become fully confident using the device. Several issues were mentioned regarding the ToT, such as staff turnover which resulted in few master trainers still remaining in the labor ward and lack of motivation to learn about the device among staff who had not been selected to attend the ToT. Among positive aspects mentioned was learning in smaller groups and being able to practice using the device on women in labor.

The participants' desire to practice using Moyo on pregnant women can be interpreted as a wish to learn how to integrate the device into one's current practice. To become an integral part of the way the birth attendants carry out their tasks, training modules about how to use a new technological device should incorporate not only how to operate the device but also practical exercises. We argue that the process of integrating Moyo into their practice requires the same complex learning process as taking up any other new procedure into one's established, well learned and institutionalized practice. Changing behavioral practices takes time. In a study from Zanzibar where birth attendants were trained in locally adapted intrapartum guidelines, four-hour training sessions were conducted on a quarterly basis and were continued after the end of the study [13]. Bandura's social cognitive theory of self-efficacy is often used to understand mechanisms of learning by focusing on personal factors, environmental factors and behavior [14]. Self-efficacy, according to Bandura, is the extent to which a person has confidence that it can perform a task set before him or her and is a prerequisite for learning. It is the result of a multifaceted process which includes previous experience, self-esteem, perception of self and phyco-social factors and overall health. Students who are motivated display greater progress than unmotivated students [15]. Additionally, slow learners are less likely to seek help because it might expose their limitations. One can hypothesize that birth attendants with low self-efficacy were reluctant to learn about Moyo, which might be interpreted by colleagues as a lack of motivation. The reported lack of motivation to learn about the device could also be linked to a lack of confidence in how to respond to signs of fetal distress and or labor management in general. Increasing knowledge in this area might therefore have been beneficial to fully benefit from the advantages of using the device and improve overall care. The fact that several of the participants revealed a desire to learn more about areas of labor management indicates that not all of the participants in the study feel confident in aspects of labor care required to perform their duties. Being considered easy to use, one can wonder if the expressed need to *learn Moyo more in detail* could also be a desire to increase knowledge about labor monitoring and how to respond to fetal distress in particular and not necessarily a need to learn more about how to operate the device. The process of acquiring knowledge about Moyo could have generated a need to strengthen knowledge in other areas of the participants clinical practice. However, with better knowledge about the status of the fetus, also comes a responsibility to carry out the correct

follow-up actions. In low-resource settings, the lack of resources has been found to be an obstacle to implementation of new knowledge. This, combined with a fear of being blamed for negative fetal outcome, might impede the birth attendant from implementing the correct obstetric actions [16,17].

The participants in the study expressed a need for additional training which could be due to the time lapse of a year from the training sessions took place to the time when the FGDs were conducted. However, it is similar to findings from a study conducted among doctors in Rwanda about the use of ultrasound in labor care, which found that many wanted more training to improve ultrasound skills [18]. A review of retention of knowledge of newborn resuscitation and a review of simulation training in post-natal care also found that the participants thought the training should be longer [19,20]. One potential consequence of inadequate training from our results is the potential to blame user errors on the device with participants believing the device provided inaccurate or incorrect results. This is an area we believe should be studied further. It should also be of particular concern to those who introduce new technology, as a lack of understanding of how to use the device make successful adaptation unlikely.

The need for refresher trainings due to high turnover of staff has also been found in studies conducted among birth attendants in Tanzania after simulation training in neonatal resuscitation [9,21]. Evaluations of Helping Babies Breathe found that a one-day training was not sufficient to incorporate new skills into practice, which highlights the need for sustained opportunities to build skills and knowledge through training [22,23]. We therefore recommend using what has been called "low dose/high frequency" training when introducing new technological devices in the labor ward in similar settings. This model, which also relies on training of trainers, has been used for simulation training to improve newborn survival in Tanzania and elsewhere with positive results [20,23–25]. Conducting regular, shorter training sessions in a systematic manner would have allowed staff to regularly practice using Moyo, and also created a forum to discuss any issues experienced using the new device. This type of frequent, short training sessions could also help foster a learning culture and increase motivation to learn while preventing loss of institutional memory about how to use the device being lost due to turnover.

Our findings indicate it would have been beneficial to include a component of motivation and learning theory in the ToT module. This cascade training program where master trainers are given the responsibility to ensure that colleagues are trained, is a commonly used, cost-effective way of diffusing knowledge in organizations. While its usefulness has been documented [26], it does require effective supervisory and pedagogical skills by the master trainers. If these skills are lacking, the master trainers might be unable to effectively approach colleagues perceived to be less motivated. However, increasing birth attendants' motivation to learn should not only be a priority during training sessions. Lack of overall motivation has been found among birth attendants in Tanzania and should be of concern [27]. One way to improve both practice and motivation conducive to learning, is through supportive supervision. A review paper from Sub- Saharan Africa on the effects of supportive supervision, found that it can increase job satisfaction and health worker motivation [15]. In addition, it was found that providers who received training on quality improvement tools such as new technological devices, were motivated compared to those who did not, which is similar to our findings [28]. Through supportive supervision, participants would also be able to receive feedback and discuss the way in which Moyo was used after attending training sessions. This could in turn facilitate a continued learning process where the device, and the correct follow-up actions to its alerts of fetal distress, became integrated into the birth attendants' clinical practice.

Strengths and Limitations

Strengths of the study include the use of FGD as a data collection method which was suitable, allowing for interaction between participants and gathering of different perspectives and views about the study objective. A broad range of study participants including both doctors and nurse/midwives, males and females, with a various degree of experience in labor care and from two health facilities at different levels of the healthcare system were included in the study to increase credibility of the study findings. Since the discussions were conducted in Kiswahili, the participants were able to express themselves with ease during the discussions in their native tongue. The study was conducted by a multi professional and multi- cultural team which brought both insider and outsider perspectives to the process and also increased credibility of the study findings. The fact that the first author, although not fluent in Kiswahili, attended and took notes during all FGDs strengthened the analytical process. Limitations of the study include the possible recall bias as some of the participants had undergone training one year before the study was carried out. Meanings might also have been lost during the process of transcribing and translating the FGDs, despite efforts made to counter this by training the transcriber and translator and verifying both transcripts and translations by other members of the research team.

5. Conclusions

The participants in this study expressed a need to strengthen their knowledge about the use of a new electronic fetal heart rate monitor, despite most participants having participated in organized training sessions about how to use the device. More time spent on training birth attendants about the use of the electronic fetal heart rate monitor would have been beneficial. Specifically shorter and more frequent training sessions is recommended to increase learning output. The participants in the study also expressed a need to obtain further training in other areas of labor management, which indicates an unmet need for knowledge in aspects of their practice which should be addressed to ensure a skilled and motivated workforce.

Author Contributions: S.R.L. formulated the study design, carried out the data collection and analysis and drafted the paper. J.S., H.L.E., C.K.M. contributed substantially to the design, data collection and analysis and critically revised the paper draft. H.L.K. participated substantially in the acquisition of data and in critically revising the paper draft. All authors read and approved the final manuscript.

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Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Appendix A

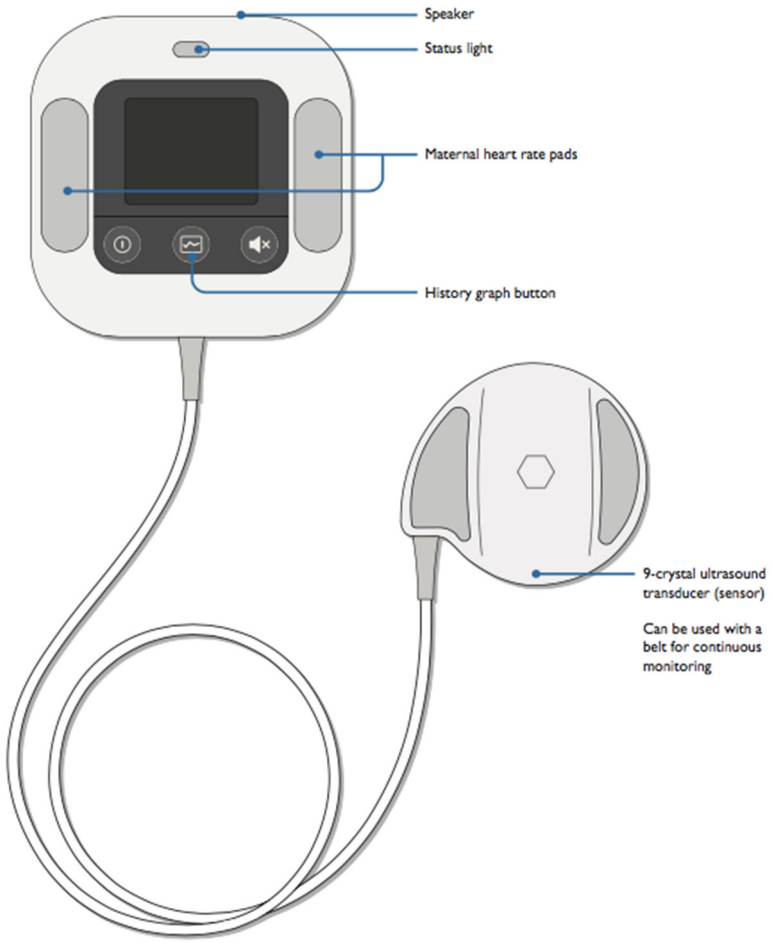

Figure A1. The Fetal Heart Rate (FHR) monitor, Moyo (Laerdal Global Health).

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RESEARCH ARTICLE Open Access

Perceptions and experiences of skilled birth attendants on using a newly developed strap-on electronic fetal heart rate monitor in Tanzania

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Abstract

Background: Regular fetal heart rate monitoring during labor can drastically reduce fresh stillbirths and neonatal mortality through early detection and management of fetal distress. Fetal monitoring in low-resource settings is often inadequate. An electronic strap-on fetal heart rate monitor called Moyo was introduced in Tanzania to improve intrapartum fetal heart rate monitoring. There is limited knowledge about how skilled birth attendants in low-resource settings perceive using new technology in routine labor care. This study aimed to explore the attitude and perceptions of skilled birth attendants using Moyo in Dar es Salaam, Tanzania.

Methods: A qualitative design was used to collect data. Five focus group discussions and 10 semi-structured in-depth interviews were carried out. In total, 28 medical doctors and nurse/midwives participated in the study. The data was analyzed using qualitative content analysis.

Results: The participants in the study perceived that the device was a useful tool that made it possible to monitor several laboring women at the same time and to react faster to fetal distress alerts. It was also perceived to improve the care provided to the laboring women. Prior to the introduction of Moyo, the participants described feeling overwhelmed by the high workload, an inability to adequately monitor each laboring woman, and a fear of being blamed for negative fetal outcomes. Challenges related to use of the device included a lack of adherence to routines for use, a lack of clarity about which laboring women should be monitored continuously with the device, and misidentification of maternal heart rate as fetal heart rate.

Conclusion: The electronic strap-on fetal heart rate monitor, Moyo, was considered to make labor monitoring easier and to reduce stress. The study findings highlight the importance of ensuring that the device's functions, its limitations and its procedures for use are well understood by users.

Keywords: Health care providers, Fetoscope, Doppler, Fetal heart rate, Labor, Moyo, Tanzania, Low-resource setting, Newborn health, Midwives

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Background

Globally, an estimated 2.6 million macerated and fresh stillbirths (FSB), and 2.7 million newborn deaths (28 days) occur each year [1, 2]. Approximately 40% of stillbirths and early newborn deaths occur in relation to birth, with 1.3 million FSB and 1 million newborn deaths annually [1, 2]. Most of these deaths share a common hypoxic-ischemic pathway (birth asphyxia) and are preventable by early recognition of fetal heart rate abnormalities coupled with timely obstetric interventions and deliveries [3]. Fetal heart rate monitoring (FHRM) is considered a key component of intrapartum care in order to detect signs of fetal distress and a potentially hypoxic fetus [4, 5]. However, studies from Tanzania revealed that FHRM is not conducted as frequently as recommended, which may cause unnecessary perinatal morbidity and mortality [6–8]. FHRM can be carried out intermittently or continuously.

Intermittent auscultation (IA) is the recommended method of FHRM for women with a low risk of complications during labor. In low-resource settings IA is commonly carried out using a Pinard fetoscope. However, Pinard is reported to be difficult to use, time-consuming, and painful for the mother [9, 10]. An alternative electronic solution is the hand-held Doppler ultrasound that is believed to cause less pain, be easier to handle and more reliable [11, 12]. According to international guidelines IA should be performed every 15–30 min during first stage of labor and every 5–15 min during the second stage [13, 14]. This requires a ratio of skilled birth attendant to laboring woman of 1:1 or 1:2, which is rarely the case in most low-resource settings, characterized by a lack of skilled birth attendants to adequately monitor each fetus [15]. While there remains a debate about the efficacy of continuous FHRM by cardiotocography (CTG) to prevent adverse perinatal outcome, it is recommended for use in high-risk pregnancies and is commonly performed in high resource settings [16]. Due to a variety of challenges related to price, access to electricity, maintenance and training of staff in the interpretation of CTG traces, it is rarely used in labor wards in low-resource settings.

In an effort to improve FHRM in low-resource settings and to enable more timely responses to detection of an hypoxic fetus, Laerdal Global Health developed a new automatic FHR monitor with a nine-crystal Doppler ultrasound sensor, called Moyo (Fig. 1). It can be strapped to the women's abdomen and detect FHR intermittently or continuously. It alerts the birth attendant when detecting an abnormal FHR and stores Doppler signal for subsequent analysis. Moyo was introduced in Tanzania in 2015 and was associated with improved FHRM and abnormal FHR detection in quantitative studies [12, 17]. There is limited knowledge about the views of health care providers using electronic FHRM devices in low-resource settings. One qualitative study conducted among midwives in Tanzania found that while electronic FHRM was considered to have many advantages, challenges were related to insufficient training and follow-up concerning the correct use of the device, and a lack of trust in its reliability compared to Pinard [18]. In another qualitative study from Tanzania, skilled birth attendants perceived both the training received prior to using Moyo and in particular training concerning the correct follow-up actions to the device's abnormal FHR alerts to be inadequate [19]. Increased knowledge about the experiences of skilled birth attendants about the use of new technology in labor care is important in order to ensure successful adoption in low-resource settings which in turn may lead to a reduction in morbidity and mortality. The objective of the present study was to explore the attitude and perceptions of birth attendants using Moyo. This study is the qualitative component of an evaluation of the introduction of Moyo in two urban hospitals in Dar es Salaam, Tanzania [12].

Methods

Study design

The study employed a qualitative design drawing on semi-structured in-depth interviews (IDIs) and focus-group discussions (FGDs) with skilled birth attendants to explore attitudes toward labor monitoring and experiences using different methods of fetal heart rate monitoring.

Setting

The study was performed at two tertiary health care facilities in Dar es Salaam. This is the largest city in Tanzania and has a population of approximately 3,4 million. The maternity ward at Hospital 1 receives both public and private patients. The hospital receives referral patients from the entire city of Dar es Salaam and neighboring regions. About 10,000 deliveries take place annually, of which 50% are caesarean sections (CS) according to one study [20], the highest rate in the country. The maternal mortality rate at the hospital averaged 301/100,000 live births from 2013 to 2015 and the stillbirth rate was 78/1000 live births at the facility [21]. The obstetric department is staffed with a number of obstetric and gynecologic specialists, resident doctors, intern doctors and nurse/midwives. The labor ward includes 19 beds and five nurse/midwives per shift in addition to specialists in obstetrics, resident doctors and intern doctors. Hospital 2 receives obstetric referrals from facilities within its catchment area, which covers one of three districts of Dar es Salaam. About 17,000 deliveries are performed annually, with a CS rate of 6.5% [22]. Two specialists in obstetrics work in the maternity ward in

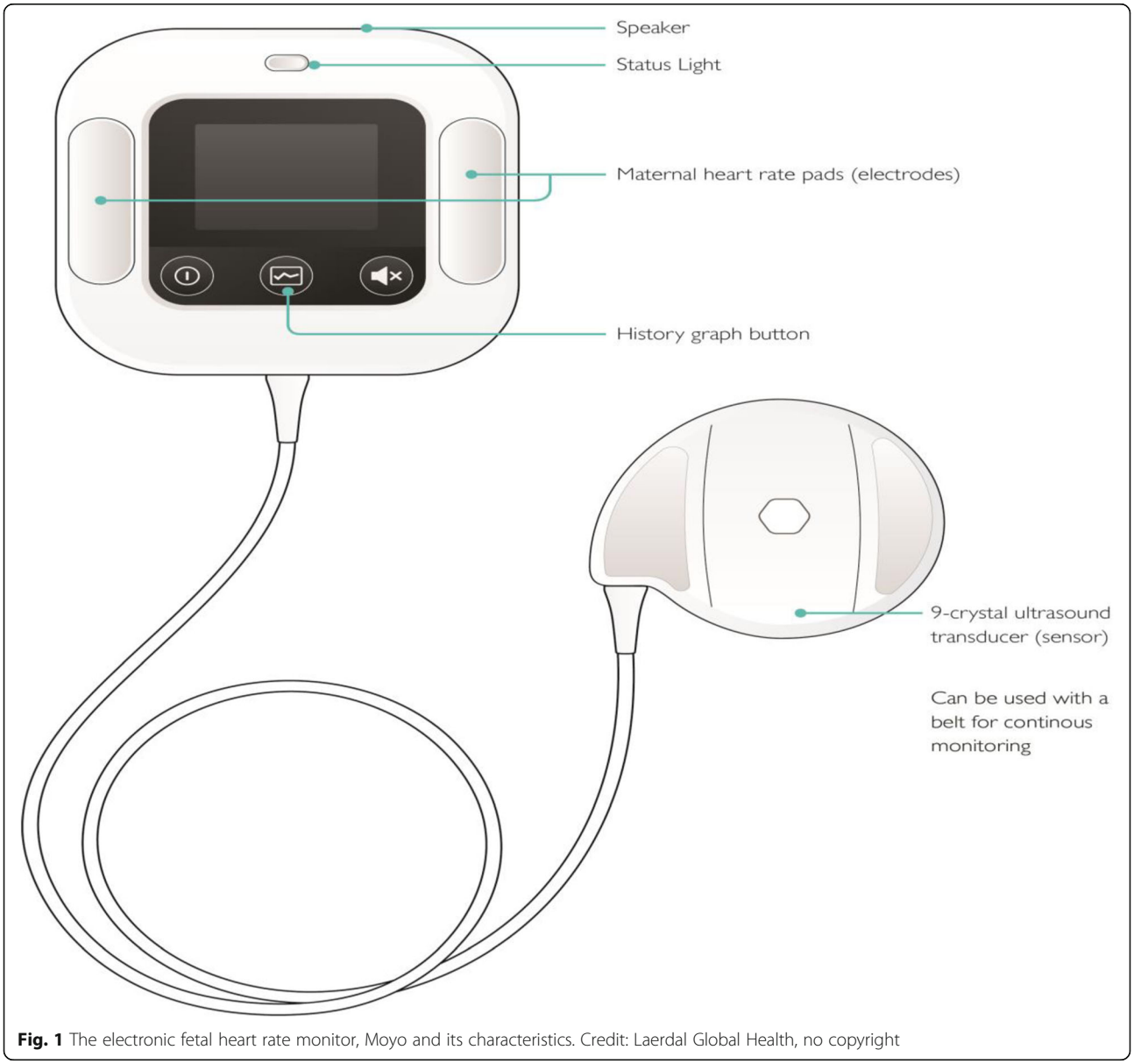

Fig. 1 The electronic fetal heart rate monitor, Moyo and its characteristics. Credit: Laerdal Global Health, no copyright

addition to medical doctors, intern doctors and nurse/midwives. The labor ward has 12 beds and five nurse/midwives working during the day.

Participants and data collection

The data collection was conducted between January and March 2017. Invitations to participate in the study were issued to both nurse/midwives and medical doctors working in the maternity ward at the two hospitals and who had used Moyo. Efforts were made to include participants who varied in age, gender and number of years they had worked at the labor ward in order to capture a broad spectrum of perspectives on the study objective. In total, five FGDs were conducted and 10 semi-structured interviews were carried out. All interviews and FGDs were conducted in Kiswahili by a research assistant who is also a midwifery teacher, in the presence of the first author. Three semi-structured interviews were conducted in English by the first author. The five FGDs were conducted prior to the interviews and were arranged by cadre, with one FGD composed of all the medical doctors who participated in the study. Participants from the FGDs were then selected for an additional semi-structured in-depth interview. An interview guide was used for each FGD and IDI (Additional files 1 and 2 respectively). This included the objective, and open-ended questions regarding fetal heart rate monitoring, collaboration between staff at the labor ward and instances when Moyo was used. When it was believed that thematic saturation was reached and no new themes

arose, an additional FGD and IDI was carried out in order to validate findings with new respondents- a process often referred to as respondent validation or member checking [23]. These IDIs and FGDs were part of the total number carried out. Each interview or FGD took place at the health facility in an area where privacy could be ensured. Each FGD lasted approximately 60–90 min; the IDIs approximately 40–60 min. All were audio-recorded.

Data analysis

Data were transcribed on an on-going basis by a transcriber with experience in transcribing qualitative data and who had also been trained by the first author. The transcripts were then translated into English by a bi-lingual Kiswahili/English speaker. Translations were discussed with the first author for clarity. The first author transcribed the interviews conducted in English. Field notes were taken during the entire data collection and included in subsequent analysis. A qualitative content analysis was used to analyze the data. The analytical process included assigning descriptive codes to the transcribed material using NVivo 11 Software by the first author. The codes were subsequently merged into categories as described by Graneheim and Lundman [24, 25]. The transcribed material, including codes and categories was discussed and agreed among authors. Table 1 illustrates how the transcribed text was condensed into codes and categories.

Intervention

Moyo was introduced at the two study sites in Dar es Salaam in 2015. Each study site received approximately 35 devices each. Training sessions concerning the functions of the device and indications for use were organized for staff. Details of the training have been described elsewhere [19]. Randomized control trials comparing the device to other methods of FHRM were also conducted at each study site. After the completion of the trials, the devices are currently used in the labor wards.

Results

Participants' characteristics

In total, 28 nurse/midwives and doctors participated in the study: 24 females and four males. The mean age was 37 and the median time of working in the labor ward was 4.8 years, with a range of 1–12 years.See Table 2 for overview of data collection and participants profession by study site.

Table 2 Overview of data collection and participants profession by study site

	Data Collection	Medical Doctor	Nurse/midwife[a]
Study site 1	3 FGDs 5 IDIs	0	12
Study site 2	2 FGDs 5 IDIs	7	14

[a]Five of the nurse/midwives from each study site participated in semi-structured in-depth interviews (IDIs) in addition to the focus group discussions (FGDs)

The attitudes and perceptions of skilled birth attendants towards using Moyo were organized in four categories: 1) Feeling overwhelmed and unable to provide optimal labor care prior to using Moyo, 2) Moyo facilitated ease and reduced stress of monitoring; 3) Perceived insufficient training leading to challenges implementing Moyo; and 4) the perceived benefits for the laboring women of using Moyo.

Feeling overwhelmed and unable to provide optimal labor care prior to using Moyo

The context within which Moyo was introduced was described as both challenging and characterized by a high workload, which left the nurse/midwives feeling overwhelmed on a regular basis. In particular, the number of laboring women who required monitoring and the lack of resources to provide good care were frequently mentioned. It was also mentioned that it was difficult to conduct FHRM as frequently as recommended:

> Participant: *You become lazy when using Pinard, having to listen to the fetal heartbeat every half an hour. I must tell the truth, we never used to do that often.*
>
> Interviewer: *What was the problem?*
>
> Participant: *Not enough time, had a lot of patients to see.*
>
> (Nurse/Midwife 3, IDI, Hospital 2)

Table 1 Example of the analytical process

Transcribed text	Code	Category
When you decide there is a fetal distress and you decide to do a C-section, the time for preparation is too long. You might say this is fetal distress then pass half an hour, forty- five minutes and still they are in the labor ward.	Delays	Feeling overwhelmed and unable to provide optimal labor care prior to using Moyo

The difficulties of documenting the FHRM of each patient in the partogram before the introduction of Moyo was also mentioned as an issue:

Sometimes we only examine…and only record if the contractions are severe. Recording every half hour is not realistic.

(Nurse/Midwife 4, FGD 1, Hospital 2)

During instances of fetal distress, the collaboration between the midwives was highlighted as crucial both to assist in the situation and to avoid blame for a potentially negative outcome. This was not a topic included in the interview guide but mentioned by both doctors and nurse/midwives:

If there is a fresh stillbirth or early neonatal death, you're in trouble. We tell each other "whenever you face a difficulty when conducting deliveries, if you see a patient is changing condition, just shout." Somebody will call someone else. Three people will be there. You help each other so if something bad happens, all of you guys are there. So three heads can't miss out things. So if something bad happens, it was unavoidable.

(Nurse/Midwife 3, IDI, Hospital 1)

Coping with the emotional effects of poor fetal outcomes were also an issue raised by the participants. One participant described being heartbroken after the delivery of a FSB:

The baby was very fragile when she came out. I felt bad because the fetal heart rate wasn't normal from the beginning to the end and then on top of all that all those other problems developed. It broke my heart.

(Nurse/Midwife 5, IDI, Hospital 2)

Moyo facilitated ease and reduced stress of monitoring

Some of the participants described a process of going from feeling uncertain about Moyo and its benefits when it was first introduced, towards a gradual appreciation of its benefits after becoming more comfortable with the device.

Now I trust Moyo very much, although in the beginning I did not know how to operate it properly. Now after being conversant with it, I trust it so much and it is so accurate.

(Nurse/Midwife 2, IDI, Hospital 2)

One participant felt she was missing the connection with the fetus that was provided by the Pinard fetoscope when using Moyo, a connection she described as being developed by staying and listening to the FHR:

You feel a connection to the baby because once you listen, it's like magical. You stay and listen and after some time the baby is out. There is some sort of connection. With Moyo you just put it on and you hear. So you don't feel like you are really connected.

(Nurse/midwife 3, IDI, Hospital 1)

Overall, Moyo was considered an advantage to the majority of participants, both doctors and nurse/midwifes. One of the positive aspects most commonly mentioned was that Moyo made their work easier by making it possible to monitor several women at the same time. The knowledge that they would be alerted in cases of fetal distress was mentioned by several of them as reducing the stress of monitoring a number of laboring women at the same time:

The alarm function makes you relaxed. Once the alarm goes off you go and check. If anything causes stress it is Pinard because it takes time to locate the pulse and the results are not always accurate.

(Nurse/midwife 5, FGD 3, Hospital 1)

Participants reported reacting faster to alerts of abnormal FHR alerts when using Moyo compared to Pinard. There were two reasons for this; The first was the fact that all staff were alerted to instances of fetal distress at the same time, and would rush to the mother because of the alarm; the second reason was that as everyone was able to see the FHR on the device's display, and considered it to be both more reliable and less subjective than Pinard where only one person at a time can hear the FHR. This latter point was often mentioned by the doctors who experienced more difficulties hearing the FHR when using Pinard:

When I use Pinard my actions are slower than when I use Moyo because Moyo gives me the exact reading. When I use Pinard I may hear and say maybe I did not hear well and I will call a colleague to come and hear. So delays in making a decision. Because I will call the midwife to come and listen. But with Moyo, you make a decision straight away.

(Doctor 2, FGD, Hospital 2)

Overall, it was felt that Moyo had contributed to improved fetal outcomes at the labor wards. The device was said to be particularly useful in instances of complicated cases and when the FHR was not found using Pinard. Several participants told stories of how they believed the fetus had survived because Moyo was used:

I attached Moyo which indicated that there was fetal distress. I told the patient that her fetal heart rate was abnormal and that we would do our best to save the baby, so I gave her Ringer lactate but the fetal heart rate was still abnormal after half an hour so I called the doctor. He told me to look for a doctor who would perform an operation but I wanted to try once more, so I continued to monitor the fetal heart rate and gave another dose of Ringer lactate and within one hour the fetal heart rate went back to normal. When I examined her she was in second stage of labor so I encouraged her to push. She delivered the baby, though the baby was born with the cord around the neck but I said to myself that without Moyo the baby would not have survived.

(Nurse/Midwife 4, IDI, Hospital 2)

Perceived insufficient training leading to challenges implementing Moyo

There was a lack of clarity concerning when and how Moyo should be used. The nurse/midwives gave different answers to questions about indications for continuous FHRM, with some believing that all mothers should wear the device for continuous monitoring.

Another issue frequently mentioned issue was related to the function of the device in measuring the maternal heart rate. The participants admitted that it was rarely used, even in instances when the device indicated an abnormally low FHR. During one FGD with six participants, one participant said she believed it was not used often enough, and then went on to ask each of the other participants how many times they had used it. Of the six, one admitted never having used the function and two reported using it only once.

Both nurse/midwives and doctors had experienced seeing the FHR on the display but later delivering a stillbirth. One participant raised it as a possible explanation as to why some colleagues were reluctant to use Moyo. Variations of the following account were told by several participants both in FGDs and during IDIs at both study sites:

I got a fetal heart rate from Moyo and convinced myself that the fetal heart rate was there. The woman was having a ruptured placenta so I rushed her for CS but on delivery the fetus was not alive.

(Doctor 5, FGD, Hospital 2)

One issue that was mentioned in relation to this account, was the lack of monitoring when the mother left the labor ward for surgery, and the waiting time from between referral until the procedure was carried out. One midwife explained how Moyo was removed before leaving the ward to go to the operating theatre for CS:

When the mother is having a Cesarean and on the way to the theatre for operation, we normally remove Moyo, patients don't take them to the theatre.

(Nurse/Midwife 4, FGD 2, hospital 1)

While stating that the device was easy to use, the participants also believed there should have been more training concerning how to use Moyo. It was often mentioned that the device was not turned off between patients and that procedures for cleaning and charging the device were not followed resulting in insufficient availability of devices at any given time.

The perceived benefits for the laboring women of using Moyo

Moyo was believed to contribute positively to the provision of care. Some participants mentioned that it increased communication between the midwife and the laboring woman.

Moyo was also perceived to be more comfortable for the woman compared to Pinard. Despite some reports of complaints from mothers that it was uncomfortable to wear the belt, the participants seemed to perceive Moyo as being something positive for the women:

We tell the mothers that we use Moyo because it is more efficient. They are generally happy to be able to see the progress of their baby on the screen.

(Nurse/Midwife 2, IDI, Hospital 1)

One participant also believed it attracted more women to deliver at the hospital:

Moyo is a new device, we only saw it for the first time when we were trained. Now the word is out on the street that there is a new device at ... [Hospital 2] and therefore people come to this hospital because of this new device.

(Nurse/midwife 4, FGD 2, hospital 2)

Discussion

The present study explored the perceptions and experiences of skilled birth attendants using an electronic FHRM monitor called Moyo. The participants in the study considered Moyo a useful tool to improve FHRM. Issues related to the use of Moyo included a lack of clarity about the correct use of the device. The context in which Moyo was implemented also seemed to affect adoption of the device.

Prior to the introduction of Moyo, participants in the study described being unable to provide adequate labor monitoring and documentation due to a lack of resources. They also described a strong sense of collaboration and support between each other in order to avoid being blamed for poor fetal outcomes and the associated consequences. We hypothesize that the combination of a lack of resources to provide adequate labor care and a fear of being blamed for-and coping with-negative fetal outcome might cause high levels of stress, which in turn affect patient care. A systematic review among health care providers in low-and middle-income countries found burnout to be highly prevalent [26]. However, the participants in the study described both feeling more relaxed when Moyo was used knowing that the alarm would alert the birth attendants of fetal distress, and an overall feeling that the device made the work easier. This aspect of electronic continuous FHRM was also mentioned in a mixed-methods study from Uganda about perceptions of a prototype CTG used on non-laboring pregnant women at term [27]. Thus, the use of what the participants in the present study perceived to be a crucial tool in performing their duties seemed to reduce stress, which could lead to increased job satisfaction; similar to findings from a study investigating the effects of new technology among health care providers in South Africa [28].

Both nurse/midwives and doctors experienced fear of the consequences of being blamed for negative maternal or fetal outcome, in line with findings from a qualitative study from Tanzania [29]. In the present study the nurse-midwives described ways in which they would try to avoid this blame by always working as a team of midwives if the condition of the laboring woman or fetus worsened. Quantitative studies from Tanzania comparing the continuous use of Moyo to intermittent use of Pinard fetoscope, did not find an improvement in perinatal outcome despite an increased identification of abnormal FHR, in part due to delays in obstetric follow-up actions [12, 30]. Additionally, a qualitative study among birth attendants in Tanzania about the training they received prior to using Moyo found uncertainties among the nurse/midwives concerning how to respond to alerts of fetal distress [19]. The fear of being blamed for negative outcomes, stress and uncertainties about how to respond to fetal distress alerts combined with systemic context barriers, could explain why increased detection of fetal distress through electronic FHRM have not so far been shown to result in reduced mortality rates [31].

Several participants, both nurse/midwives and doctors, told similar accounts of how Moyo had indicated a FHR but the fetus was delivered as a FSB. These accounts illustrates some of the challenges using Moyo raised, such as lack of a clarity about procedures for use and insufficient training. The fear of being held responsible for poor outcomes could explain instances of blame avoidance and dislocating responsibility to Moyo not working properly. While a culture of "naming and blaming" [32] is difficult to change, it might have been beneficial to analyze and discuss these events in an early phase of Moyo's introduction. Using the account as a topic of discussion could also have increased awareness about the limitations of the device and reinforced procedures for use.

The account of the fresh stillbirth was mentioned by some participants in relation to the issues of occurring after referral to surgery. At both hospitals, Moyo was removed when the patient left the labor ward for cesarean-section (CS) and delays after CS referral were reported as common, with limited FHRM during the waiting time. This could lead to a poor outcome of severely asphyxiated fetuses. At the time of data collection, Hospital 1 had a surgical theatre used exclusively for obstetric emergencies, whereas Hospital 2 did not; there, obstetric emergencies were dealt with in the general surgical theatre and were dependent on capacity. Studies from Tanzania indicate that unnecessary CS is already a challenge in tertiary health facilities in the country [21, 29, 33]. As quantitative studies found an increase in CS after the introduction of Moyo [17], addressing the factors contributing to the overuse of CS is becoming paramount.

The participants felt using Moyo made their work easier, allowing for several women to be monitored at the same time and knowing that they would be alerted in case the device detected an abnormal FHR. While continuous FHRM is not recommended for low-risk pregnancies due to adverse effects such as the increase in CS, calls have been made for innovative alternatives to CTG such as Moyo to improve "intermittent prolonged" FHRM in low-resource settings, in part due to a "substantial mismatch.. between international guidelines and what is locally achievable" [15]. Indeed, it is difficult to imagine how the five skilled birth attendants working per shift at Hospital 2, are able to perform IA every 15–30 min on each of the 46 women delivering at the hospital every day. This reality highlights the urgent need to increase the number of skilled birth attendants and address other systemic barriers [34, 35]. It also illustrates the need for locally adapted, context-specific solutions developed in close collaboration with users. In Zanzibar, locally adapted intrapartum guidelines which were

developed and implemented in a participatory process with skilled birth attendants resulted in significant improvements in newborn survival [36, 37].

Several participants reported how the maternal heart rate was not always measured during detection of abnormal FHR. Intrapartum misidentification of maternal heart rate as FHR is well known, particularly when the maternal HR is above 100 beats/minute [38, 39]. The International Federation of Obstetrics and Gynaecology (FIGO) recommends simultaneous evaluation of the maternal pulse when using handheld Doppler and reviewing the sound from the device [39]. Furthermore, when using any Doppler device there is a slight risk that the device may sporadically indicate a number that could be interpreted as FHR due to movement by the mother or abdominal movements such as fluids or muscles. FIGO guidelines recommend that users listen for the rhythmic sound mimicking the fetal heart, described in the guidelines as a *galloping horse* to avoid misidentification. Misidentification could be another possible explanation for the account of the FSB and further illustrates the importance of using the story as a topic for discussing the device's procedures for use. We recommend that steps to avoid misidentification of FHR should be emphasized in training birth attendants about the use of Doppler devices. Due to the lack of knowledge of this issue in similar settings, we believe it could be an area for further investigation.

The process of becoming conversant in using Moyo was described by some as one of initial skepticism towards the device with a growing trust in it after becoming confident in its use.

Some of the participants believed Moyo was more accurate and less subjective than Pinard; which was expressed as an almost blind trust in the device and its ability to detect fetal distress. This might be one of the reasons why procedures such as verification the FHR with Pinard and using the maternal HR function were reported as often being ignored. A study from Tanzania investigating perceptions among birth attendants about ultrasound use, found an overestimation of the benefits of ultrasound during labor and a possible reduction in attention to other methods of FHRM [40]. Thus, there seems to be a risk that the adoption of a new device may result in the reduced use of current tools, such as the Pinard fetoscope. Conversely, some participants described missing the connection they gained with the fetus when using the familiar Pinard which is similar to a finding from a study investigating perceptions about a FreePlay wind-up Doppler among midwives north in Tanzania [18]. This indicates the complexity of the adoption of new technology in labor care that we believe should be investigated further.

Limitations

The findings of the study need to be considered in relation to its limitations. Those who agreed to participate in the study were overall positive towards the device and thus might have been more motivated to participate in the study than those with negative experiences who did not want to use Moyo. While participants were informed before consenting to agree to take part in the study that raising negative perceptions or experiences of using Moyo would have no repercussions - an assurance that was also repeated during the data collection - there is a risk that participants may have expressed more positive views for fear of repercussion if they did not. An attempt to mitigate this issue was to interview some of the participants twice by inviting them to take part in a semi-structured interview after the FGD. This was carried out in order to build trust with the participants, to allow for further reflection on the issues discussed and to improve the quality of the data [41]. Further investigations are needed into the perspectives of skilled birth attendants who reject devices such as Moyo. The participants worked at two tertiary facilities with more exposure to new technology than skilled birth attendants working in smaller primary health care facilities who might be more hesitant towards using Moyo.

Conclusion

The electronic strap-on FHRM Moyo was perceived to make labor monitoring easier and to reduce stress among birth attendants, who, prior to the introduction of the device, described feeling overwhelmed by a high workload and an inability to adequately monitor each laboring woman. Challenges associated with its use included a lack of clarity concerning procedures and indications for use. The study findings highlight the importance of ensuring that the functions of the device, its limitations and its procedures for use are well understood by users to ensure correct use and to reduce risks of the adverse effects of continuous FHRM.

Additional files

Additional file 1: Interview guide focus group discussions. (PDF 84 kb)
Additional file 2: Interview guide semi-structured interviews. (PDF 292 kb)

Abbreviations

CS: Cesarean-section; CTG: Cardiotocography; FGD: Focus group discussion; FHR: Fetal heart rate; FHRM: Fetal heart rate monitoring; FIGO: International federation of obstetrics and gynaecology; IA: Intermittent auscultation; IDI: in-depth interview

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request. The interview guides are available as Additional files 1 and 2.

Authors' contributions
SRL formulated the study design, carried out the data collection and analysis and drafted the paper. JS, HLE, CKM contributed substantially to the design, data collection and analysis and critically revised the paper draft. HK participated substantially in the acquisition of data and in critically revising the paper draft. All authors read and approved the final manuscript.

Ethics approval and consent to participate
The study was conducted according to the Declaration of Helsinki [42]. All participants received oral and written information about the purpose of the study before giving their written consent to participate. The Safer Births studies are approved by the Norwegian Regional Ethics Committee (REK Vest; Ref: 2013/110/REK vest) and the Tanzanian National Institute for Medical Research (Ref: NIMR/HQ/R.8a/Vol.IX/388). The first author obtained a research permit to carry out the study from the Tanzania Commission for Science and Technology, COSTECH, (No. 2016–396-NA-2016-277). The study obtained ethical approval from all relevant entities, both at the institutions where the study was carried out and at the local government. Permission to publish the final manuscript was obtained from the Tanzanian National Institute for Medical Research.

Consent for publication
Not applicable.

Competing interests
The authors declare no conflict of interest. Hussein Kidanto is an Associate Editor for BMC Pregnancy and Childbirth.

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14. Appendices

14.1 In-depth interview guide—Skilled birth attendants

Objectives:

– Capture participants' experiences using Moyo
– Capture how the participants feel that using the device affects patient care.
– Capture suggestions for improvements/changes to the device.

Introduction to the session:

This session is to discuss your experience using Moyo. Please note that there are no right and wrong answers. We will be asking you ten questions. Before we start, do you have any objections to the session being recorded?

1. Can you tell me about a regular day at work?
2. Moyo has been introduced at this facility, what would you say are the reasons it has been introduced?
3. In your work, what do you consider the indications to put Moyo on, for how long do you leave it on, what are the indications to take it off?
4. Would you say that any of your actions to alerts from Moyo of abnormal fetal heart rate are different from when you detect an abnormal FHR using other monitoring techniques such as Pinard or Doppler?
5. In what way do you feel using Moyo affects your workload and stress level?
6. Compared to using other methods of fetal heart rate monitoring, do you feel using Moyo changes the way you interact with your patients?
7. If there is anything you would like to change about Moyo, what would it be?
8. What are the challenges associated with the use of Moyo?
9. There is a function on Moyo measuring maternal fetal heart rate. Could you tell me when you last used the function and what was the reason you wanted to know the mother's pulse?
10. What are the comments you have heard from the mothers about Moyo?

To close the session:

As we are coming to the end of this session, is there something that you would you like to say that you did not get a chance to say during the session? (pause) *We thank you for taking the time to participate, and please do not hesitate to contact us.*

14.2 Focus-group discussion—Fetal heart-rate monitoring

– Capture health-care workers attitudes about labor monitoring and the different methods used.

Introduction to the session: *This session is to discuss labor monitoring and the different methods used. Please note that there are no right and wrong answers. We will be asking you nine questions. Before we start, does anyone have any objections to the session being recorded?*

1. In your opinion, is it important to measure fetal heart rate? (why?)
2. When is it important to measure fetal heart rate?
3. What are the other ways to monitor a labor except from measuring the fetal heart rate?
4. Which method would you say you use the most frequently to monitor a labor?
5. What do you trust the most to determine FHR—Pinard or Moyo/Doppler? Why?
6. What are some of the positive and negative aspects of using the partograph?
7. How do you define fetal distress?
8. There is a function on Moyo measuring maternal fetal heart rate. Could you tell me when you last used the function and what was the reason you wanted to know the mother's pulse?
9. What are the comments you have heard from the mothers about Moyo?

To close the session:

As we are coming to the end of this session, is there something that you would you like to say that you did not get a chance to say during the session or do you have any questions? (pause) *We thank you for taking the time to participate, and please do not hesitate to contact us.*

14.3 Interview Guide—FGD Moyo

Objectives:
– Capture participants' views on the training received before starting to use Moyo.
– Capture participants' experiences using Moyo and how they feel using the device affects patient care.
– Capture suggestions for improvements/changes to training or the device.

Introduction to the session: *This session is to discuss your experiences using Moyo and the training you received about the device. Please note that there are no right and wrong answers. We will be asking you nine questions. Before we start, does anyone have any objections to the session being recorded?*

1. Moyo has been introduced at this facility, what would you say are the reasons it has been introduced?
2. Before starting to use Moyo, you participated in training about the device. Would you say the training was adequate to familiarize yourself with the device (in terms of the approach used, the time allocated and content)?
3. Now that you have used Moyo for a while, are there additional components that you can think of that you recommend to be included in the training, or any changes you would recommend to the training module? (more or less time to familiarize themselves with the device, more or less training time)
4. The training was conducted by a medical doctor, and doctors and nurses were trained together. Would you have preferred a nurse/midwife to have conducted the training and for training to have been only with other nurses/midwives, or would you say that is not important? (why)
5. Has there been any refresher training? (when and duration)
6. If there is anything you would like to change about Moyo, what would it be? (measure contractions, remove the function measuring the mothers pulse, changes to the sound?)
7. What are the challenges associated with the use of Moyo?
8. Do you feel that you have been able to give feedback about Moyo that has been taken into consideration?
9. In your opinion, is there a need for a device like Moyo? (why, changes in maternal or fetal outcomes attributed to the use of the device)

To close the session:
As we are coming to the end of this session, is there something that you would you like to say that you did not get a chance to say during the session? (pause) *We thank you for taking the time to participate, and please do not hesitate to contact us.*

14.4 Interview guide semi-structured interviews women

Objectives:
– Capture the attitudes of mothers giving birth about Moyo.
– Understand how the use of Moyo affects the relationship between the woman giving birth and the health care provider assisting her.

Introduction to the session: *This session is to discuss your experiences giving birth. Please note that there are no right and wrong answers. We will be asking you seven questions. Before we start, does anyone have any objections to the session being recorded?*

Background

1. How old are you?
2. How many children do you have?
3. What is your occupation?
4. How many years have you gone to school?

Experience of Moyo

5. During your delivery, was a device put on your abdomen?
6. Did anyone explain to you what it was? If yes, what was said?
7. Compared to previous deliveries, what was it like to have the device around your neck during the delivery?
8. Compared to other deliveries, what was it like to have the device attached to your abdomen? (in the way or painful)
9. Sometimes the device made a sound, what did you think about this sound? (annoying, too loud, comforting). Did anyone tell you what was that sound for?
10. In your opinion, did the care that you received change because of the device that was used on you? (did the midwives attend to you more or less often?)
11. Would you say it changed your birthing experience compared to previous deliveries without this device?
12. Did the device make you feel more worried or more safe about the delivery?
13. Is there anything you would change with the device?
14. Do you have any additional questions for me or is there something you have not said?

14.5 Consent form
Request for participation

Consent can be given orally with one witness present.

My name is Sara Rivenes Lafontan and I am a PhD student at the University of Oslo, Norway. This research is part of my PhD project and is the qualitative component of the Moyo study that has been implemented at your work place. The study has approval from Tanzania National Institute of Medical Research (NIMR), the Tanzania Commission of Science and Technology (COSTECH), the Executive Director at Temeke Municipality and the research unit at Muhimbili National Hospital.

I would like to ask you some questions about your work as a health-care provider, fetal heart-rate monitoring, using Moyo and the training you received to familiarize yourself with the device. This information may be used to improve training modules and technology used to measure fetal heart rate. I am an independent researcher, employed by the University of Oslo.

The interview may last approximately one hour. I am interested in your personal point of view based on your experience as a health-care provider. There are no right or wrong answers. You do not have to discuss issues that you do not want to and you may end this interview at any time. You may withdraw for the study at any time and do not have to give reasons for doing so. There will be no consequences of doing so. You may also refuse the use of a recorder, and we will take notes instead. If a recorder is used, the file of the recorded interview will be discarded at the end of the study. The information that you provide will be used for the purpose of this study only. Your name will not be written anywhere and will never be used in connection with any of the information you tell me.

Contacts:
Should you have any further questions or comments, please do not hesitate to contact me by email: s.r.lafontan@medisi.uio.no or mobile: +255 674948222
You can also contact the research unit at Muhimbili National Hospital should you have any complaints or comments regarding your participation in the study :
+255 222151367-9

By signing this form, I agree to take part in the study.

Signature

14.6 Consent form in Kiswahili

Ombi la kushiriki katika utafiti

Hiari yako kushiriki au kutoshiriki katika utafiti inaweza pia kutolewa kwa mdomo ukiwa na shahidi. Ridhaa inaweza kutolewa kwa mdomo kukiwa au bila shahidi

Jina langu ni Sara Rivenes Lafontan na ni mwanafunzi wa shahada ya uzamivu (PhD) katika cho kikuu cha Oslo, Norway Utafiti huu ni sehemu ya utafiti wangu wa shahada ya uzamivu kwa kutumia usaili kwa njia ya kupata taarifa zenye sifa kulingana na vigezo vya utafiti wa "Moyo"ambao umekuwa ukitekelezwa hivi sasa kazini kwako.

Utafiti huu umeidhinishwa na Tanzania National Institute of Medical Research (NIMR), Comisheni ya Sayansi na Tekinologia ya Tanzania (COSTECH), Mkurugenzi Mtendaqji wa Manispaa ya Temeke na kitengo cha utafiti cha ya Hospitali ya Taifa ya Muhimbili. Ningependa kukuuliza maswali kuhusu kazi yako kama mtoa huduma ya afya hususani kuhusu kufuatilia mapigo ya moyo ya watoto tumboni mwa mama, kwa kutumia kifaa cha Moyo na pia mafunzo uliyopata kutokana na kifaa hicho. Taarifa hiyo itasaidia kuboresha mafunzo na tekinolojia ya kupima mapigo ya moyo ya mtoto aliye tumboni, nikiwa kama mtafiti huru niliye ajiriwa na chuo kikuu cha Oslo.

Usaili utachukua muda wa saa moja. Ninavutiwa zaidi na maoni yako kuzingatia sifa na ujuzi wako kama mtoa huduma ya afya. Hakuna majibu sahihi au makosa.
Pia hulazimiki kuzungumzia masuala ambayo hutopenda kuyazungumzia, na unaweza kusitisha usaili huu wakati wowote . Pia unaweza kujiondoa kwenye ushiriki huu wakati wowote na hulazimiki kutoa sababu bila athari dhidi yako. Unaweza kukataa kutumia chombo cha kurekodia na hivyo watafiti watachukua maandishi badala yake. Kama chombo cha kurekodia sauti kitatumiwa taarifa iliyorekodiwa itafutwa baada ya utafiti. Taarifa zote za usaili zitatumika kwa nia ya utafiti tu. Jina lako halitaandikwa sehemu yeyote na wala kutumika kwa namna yoyote kuhusika na taarifa utakazokuwa unanipa.

Mawasiliano:
Kwa maswali maelezo ya ziada wasiliana name kupitia barua pepe email:
s.r.lafontan@medisi.uio.no au simu yangu ya mkononi: +255 674948222
Pia unawaza kuwasiliana na kitengo cha utafiti cha Hospitali ya Taifa ya Muhimbili kama una tatizo lolote kuhusu ushiriki wako katika utafiti huu kwa simu:
+255 222151367-9

Kwa kusaini fomu hii nakubali kushiriki katika utafiti huu:

Saini yako: _____