Maternal and Child Health in Jimma Zone, Ethiopia: Predictors, Barriers and Strategies for Improvement

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Table of Contents

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Abstract

Reducing maternal and child mortality has been a top global health priority for the past two decades. Through this thesis, I underline some of the strategies, barriers and determinants to optimal maternal and child health (MCH) in three specific districts of Jimma Zone in the southwest of Ethiopia. My first paper has a particular focus on the quality of MCH data collected within the health management information system (HMIS), while the second paper focuses on the utilization of antenatal care (ANC) services, assessments of malaria in pregnancy, and women's access to malaria preventive measures using data from a cross-sectional survey conducted in the three study districts.

The quality of MCH data collected within the HMIS from July 2014 to June 2015 for the 26 primary health care units (PHCUs) located within the three districts was evaluated using the World Health Organization's Data Quality Report Card (DQRC). To complement the methods recommended in the DQRC, Pearson correlation coefficients, intraclass correlation coefficients, and Bland-Altman analysis were used to determine the agreement between MCH indicator coverage estimates derived from the HMIS and a population-based survey conducted with 3,784 women who had a birth outcome within the same time frame. The quality of MCH data collected within the HMIS was determined to be unsatisfactory, with many health facilities located in the three districts not reporting completely, consistently, or accurately MCH key indicators relating specifically to ANC, skilled birth attendance at delivery, and postnatal care. This finding is important since poor data quality can compromise effective decision-making and resource allocation processes aimed at contributing to better health outcomes in mothers and newborns.

To address the objectives set in the second chapter, analysis of cross-sectional survey data from 3,784 women who had a birth outcome in the year preceding the survey was performed through logistic regression models adjusting for clustering of the participants by PHCU. While close to 85% of the women attended at least one ANC visit, less than 50% of the participants received four or more ANC visits. Lack of necessity, distance to health facility and unavailability of transportation were determined as key reasons for not attending ANC. Women who completed secondary or higher education, were from the richest households, were exposed to different media sources, and were able to make decisions about their healthcare by themselves or jointly with their husband were more likely to attend ANC services. Frequent visits by a health extension worker and pregnancy intendedness also influenced ANC attendance. Bed net ownership and utilization during last pregnancy were also relatively low (52% and 26%, respectively). The results also showed that the odds of owning and always using a mosquito net were higher in participants that attended ANC, with odds ratios of 1.98 (95% CI: 1.55-2.53) and 1.62 (95% CI: 1.23 – 2.13), respectively. The prevalence of malaria infection during pregnancy was low in our recruited sample, with 1.45% of the participants reporting suffering from malaria during their last pregnancy. We determined significant negative relationships between malaria infection and maternal age and education level.

This work emphasizes the importance of improving the quality of MCH data within the HMIS in Ethiopia as well as addressing the inequities relating to ANC attendance in Jimma Zone. Given the adverse effects that malaria can have on the progress and outcomes of a pregnancy, the importance of promoting mosquito net ownership and use as part of ANC services is also highlighted.

List of Tables

List of Figures

List of Abbreviations

ANC	Antenatal Care
CI	Confidence Interval
DQRC	Data Quality Report Card
DTP	Diphtheria, Tetanus and Pertussis
EDHS	Ethiopian Demographic Health Survey
FMoH	Federal Ministry of Health
HEP	Health Extension Program
HEW	Health Extension Worker
HIV	Human Immunodeficiency Virus
HMIS	Health Management Information System
ICC	Intraclass Correlation Coefficient
IPTp	Intermittent Preventive Treatment in Pregnancy
IRS	Indoor Residual Spraying
ITN	Insecticide-treated Net
LMIC	Low and Middle-Income Countries
LQAS	Lot Quality Assurance Sampling
MCH	Maternal and Child Health
MDGs	Millennium Development Goals
MMR	Maternal Mortality Ratio
OR	Odds Ratio
PCA	Principal Component Analysis
PHCU	Primary Health Care Unit

PMTCT	Prevention of Mother-to-Child Transmission
PNC	Postnatal Care
SBA	Skilled Birth Attendance
SDGs	Sustainable Development Goals
SES	Socioeconomic Status
WHO	World Health Organization

Chapter 1: General Introduction

Global Status of Maternal and Child Health

A large proportion of women worldwide do not have the opportunity to experience a safe pregnancy and delivery. With an annual estimate of 303,000 women per year, the global number of deaths due to complications occurring during pregnancy and childbirth remains unacceptably high, especially in Sub-Saharan Africa, which accounts for 66% of those deaths.[1]

In addition to being considered one of the key indicators of health equity and socioeconomic development within a country[2], maternal mortality has also been shown to have short- and long-term consequences on children.[3] In countries where the maternal mortality burden is high, adverse outcomes affecting the mental and physiological development or survival of infants and children are generally observed, which have been attributed to, among other reasons, the absence of maternal involvement in the lives of these children, following maternal death.[4] Recent research in Ethiopia demonstrated that children who were orphaned by early maternal death had an 81% chance of also dying, while those who were part of a Tanzanian cohort had a 51% chance of surviving to their first birthday.[3,5] Recognizing the direct and indirect consequences of maternal mortality, the improvement of the health of expecting and recent mothers is one of the key public health priorities to address.

Encouragingly, a 44% decline in the global maternal mortality ratio (MMR) has been noted over the last 15 years.[1] Most of the decline reported has been attributed to the number of initiatives and partnerships established and resources mobilized to reach the fifth target set through the Millennium Development Goals (MDGs), which was to reduce by at least three-

quarters the 1990 global MMR by 2015.[1] In many African countries, the scale-up and delivery of insecticide-treated nets (ITNs) and vaccines for the main vector-borne and vaccine-preventable diseases, respectively, along with the management of Human Immunodeficiency Virus (HIV) infections and the effective prevention of mother-to-child transmission (PMTCT) of HIV through antiretroviral therapy can be held responsible for the non-negligible amelioration in maternal and child health (MCH) status.[6] The notable progress over the last decade in collecting and tracking MCH data through civil registration and surveillance systems, national surveys and censuses have also resulted in an increase in the amount of information generated to support public health policies and interventions that have strong potential to improve MCH outcomes.[1,7] Nonetheless, as of 2015, sub-Saharan Africa remains the area with the highest MMR. For instance, Nigeria accounts for 20% of all maternal deaths observed worldwide, while Sierra Leone and Chad report lifetime risks of maternal mortality of approximately one in 17 and one in 18, respectively.[1]

In 2015, the Sustainable Development Goals (SDGs) were launched to carry forward the progress that occurred under the MDGs and include ambitious targets working towards ending preventable maternal mortality and reducing the global MMR to less than 70 per 100,000 live births by 2030.[1] Achieving the SDG target for maternal health would require reducing the global MMR by a yearly average of 7.5% between 2016 and 2030, which is close to four times greater than the 2.3% annual MMR reduction observed globally under the MDG period.[1] While acknowledging the advancements that have been made collectively during the MDGs era, several sub-Saharan African countries have made insufficient or no progress in reducing their MMR in the past and may therefore fail to achieve this global health goal.[1,6] Ethiopia, a country located in the Eastern part of Africa, has not reached the MDG target for maternal health but has noted a

remarkable reduction in its MMR over the last couple of years and is continuing to make significant progress toward achieving current maternal health goals.[1,8]

Maternal and Child Health and Mortality in Ethiopia: Trends, Causes, and Progress

With an accelerated decline from 204 to 59 deaths per 1,000 live births between 1990 and 2015, Ethiopia has successfully reduced its under-5 mortality rate to levels required to reach the MDG 4th goal target.[4,9] Reductions in maternal and neonatal mortality have, however, been relatively moderate with declines from 1250 to 353 deaths per 100,000 live births and 60 to 28 deaths per 1,000 live births, respectively discerned in the space of 25 years.[1,4]

From the launch of the Health Sector Transformation Plan by the Federal Ministry of Health (FMoH) in 2015, to the SDGs, Ethiopia is striving for better health conditions for newborns and mothers. As mentioned in the 2015/2016 Health Sector Transformation Plan, whose primary objective is to "decentralize the health care system and enhance the health of communities through improving access to and quality of preventive, curative, and rehabilitative health services"[8], the country aims to decrease by more than 50% its MMR (i.e. to 199 deaths per 100,000 live births) in the next five years.[8]

To align with national and global targets, the leading causes of maternal mortality, and reproductive and maternal morbidities in the country have to be addressed. In 2013, abortion related complications, maternal hemorrhage, hypertensive disorders in pregnancy, obstructed labour, and uterine rupture explained the majority of maternal deaths in Ethiopia.[4,10,11] Maternal sepsis and infections such as tuberculosis, malaria, and hepatitis also accounted for a large proportion of maternal deaths.[4] These diseases and related health consequences can occur throughout pregnancy, childbirth, and the postpartum period, and could be avoided or averted if

women had improved access to MCH services of high adequacy.[1,4,8] Yet, as in many developing countries, maternal health service utilization in Ethiopia has been frequently described as suboptimal, with important disparities observed within and between regions of the country.[12]

According to the 2016 Ethiopian Demographic Health Survey (EDHS), the proportion of women who attended at least one antenatal care (ANC) visit on a national scale has increased from 27 to 62% in the last 15 years.[13] The coverage of four ANC visits was lower with a value of 32%.[13] More moderate improvements have been observed in the proportion of births occurring in a health facility, with an increase of 20% from the coverage estimate of 6% observed in 2000.[13] Postnatal care (PNC) coverage remains unacceptably low, however, with only 17% of women who participated in the 2016 EDHS receiving a postpartum checkup within the two days following childbirth.[13]

Variations in the access to essential maternal health services have also been described on a local scale. For instance, Regassa found in Sidama Zone, Southern Ethiopia, that 77% of the recruited women reported attending ANC, while 37% of their newborns received PNC.[14] In a project conducted in Haramaya district, the proportion of women attending ANC was estimated at 74%, institutional delivery at 28% and PNC at 22%.[15] Seifu and Meressa found lower coverage estimates of ANC and delivery attended by a skilled birth attendant (SBA) among pastoral women living in Jigjiga town, with 66% and 16%, respectively.[16]

Reasons for the low utilization of maternal health care services in Ethiopia are considered to be multifactorial, ranging from behavioral and demographic to nutritional and health services related factors.[4] Traditional and cultural beliefs of women in Ethiopia are known to limit their access to the available MCH services.[15,17,18] Seeing pregnancy and childbirth as a natural process

that does not require a visit to a health facility unless complications are present has been frequently mentioned in qualitative studies.[18,19] As noticed by Kaba et al., rituals during and after labour with family members and relatives represent an important aspect of childbirth that women are not willing to give up to deliver in a health facility.[19] In addition to this, education level and economic situation considerably impact women's access to care, with uneducated and poor women less likely to use maternal health services.[17,20–22] Moreover, Gebremeskel et al. determined that women from households prone to food insecurity are less likely to attend MCH services.[23] Finally, the poor state of roads, lack of reliable transportation system along with the long wait time or unavailability of treatment or staff once at the health facility seriously limit women's ability and willingness to seek care when needed.[17,24] These barriers to effective maternal health are often defined as the three "delays", being the delays in deciding to seek care, in reaching a health facility and in receiving quality care once at the health facility.[4]

In response to the first delay, the FMoH launched in 2004 the Health Extension Program (HEP), an important institutional framework for promoting health, preventing diseases and achieving the MDG health targets.[8] As part of this program, pairs of full-time salaried female health extension workers (HEWs) were trained and deployed in health posts, the basic structure for health service delivery at the community level.[4,8] In order to reach all rural communities, it is now estimated that over 19,000 health posts have been built and staffed with over 38,000 trained HEWs.[8,25]

Each pair of HEWs is assigned to one health post to provide basic preventive and curative health services to approximately 5,000 rural community members.[9] They have received, over a period of one year, training based on sixteen packages of interventions, which are grouped under four major areas: 'hygiene and environmental sanitation', 'family health', 'disease prevention and

control' and 'health education and communication'.[8] Accordingly, a large part of their daily activities consists of conducting home visits and raising awareness in their community about hygiene, environmental sanitation, healthy eating habits, and infectious disease prevention.[26] With regards to maternal health, they provide pregnant women and their companions with information on the common danger signs during pregnancy, delivery and the postnatal period.[26,27] Importantly, HEWs also provide education to promote awareness of the importance of going to the health facility for regular checkups and to deliver. As they are not trained in providing safe and clean delivery, they have an important role in assisting women in labour and transferring them to the closest health centre staffed with skilled birth attendants (SBAs).[25,28] Finally, they are in charge of supervising traditional birth attendants.[20] Overall, their role consists of improving access to health services and bridging the gap between their community and the health facilities.[28]

To help HEWs in their functions and activities, networks of health development armies, comprised of community members, were established. Each health development army member is responsible for five households and reports to their assigned HEW.[9] Their scope of work includes ensuring that pregnant women are going for care and attending all follow-up visits.[9] Unlike HEWs, they are able to develop strong links with their assigned community members, giving them the ability to closely follow up on a woman's condition before and after delivery.[8,9] If needed, they can assist in the transfer of birthing women from the community to the health facility by organizing "traditional ambulances" or stretchers to main roads or health posts, where the HEW could call for an ambulance.[28]

The HEP is considered the most important and innovative strategy for addressing poor MCH status in rural communities of Ethiopia.[8] Through the deployment of HEWs and health development army members, the HEP has also resulted in an increased access to and use of key

services relating to family planning and care during and after pregnancy (e.g. ANC).[8] The management and control of main infectious diseases that are known to worsen with pregnancy (e.g. malaria) have also improved. HEWs are also an integral part of the health management information system (HMIS), a system put in place to compile routinely high-quality data from health facilities that will be available at the district, regional, and national levels to inform and guide health programs and initiatives like the HEP. The next sections of the introduction focus on the link between the HEP and the HMIS, as well as on the role of the HEP on ANC utilization during pregnancy and the control of malaria in pregnancy.

1. Health Extension Program and the Health Management Information System

It is well acknowledged that the presence of a health-facility reporting system is essential for healthcare workers and policy-makers to evaluate their community health status and needs and respond to them through effective decision-making.[1,29] Accordingly, in Ethiopia, the HMIS was introduced through the jurisdiction of the FMoH in 1993 in an effort to "support informed strategic decision-making by providing quality data that help managers and health workers plan and manage the health service system".[30] Ethiopia's HMIS has a "top-down bottom-up approach", allowing it "to meet the local health needs within the context of national targets".[31]

The first level of data collection occurs in health posts. There, HEWs maintain folders on each household that is part of their catchment area and keep tally sheets for all the preventive and curative care that they provide to the members of these households.[31] Data from the tally sheets are then transferred onto three HMIS report forms (i.e. the outpatient department disease report, the weekly epidemic summary report and the service delivery report form). Summary reports are subsequently sent on a monthly basis to the affiliated health centre (**Figure 1.1**). Each health

centre maintains a separate register from which a tally sheet is submitted on a weekly or monthly basis to the health centre supervisor.[31] One health centre and five satellite health posts form a primary health care unit (PHCU). A PHCU will then forward its data to the district health office. At this level, data from all PHCUs in the district are summed and sent to the zonal health department.[31] At the zonal health department level, reports are computerized and sent to the regional health bureau that will forward its data to the FMoH. Levels with a reliable internet connection can enter their reports directly into the web-based HMIS, where they are made visible to those with access to the national database.[30]

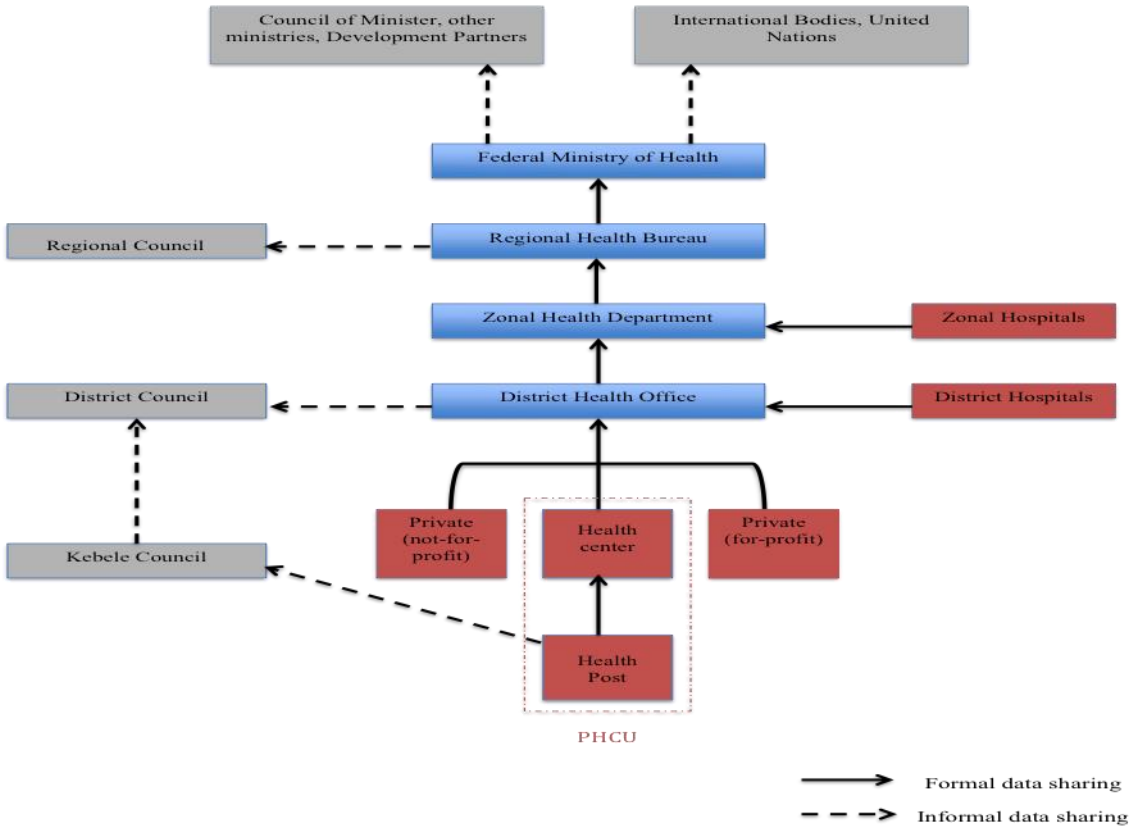

Figure 1. 1 Flow chart representing the organizational structure for the reporting of health information data through the Health Management Information System in Ethiopia[31]

Decision-making processes, resource allocation, and health program development and implementation are shared between the FMoH and the regional health bureaus, which also provide technical support to the zonal health departments. The latter assist the district health offices in the management of health services delivery, while the district health offices are tasked to manage and coordinate the operations of PHCUs.[31] Given the decentralization of the health system, the information forwarded from health posts and health centres to their respective district health office is reviewed during meetings planned between the PHCU supervisor and the district health office head to give feedback on PHCU's performance, assess accomplishments, and inform strategies to enhance the quality of health care services.[31]

As shown in **Figure 1.1**, informal data transmission also happens through councils, which are specific committees at each administrative level that meet to share information and discuss ways to address local health needs.[31] The district council consists of elected community representatives and HEWs from each *kebele* or village. Each council includes members from the agricultural, educational, and health sectors and convenes on a weekly basis to share information and discuss the progress and the development of future agendas focusing on local health issues, and make decisions on the local political administration and service delivery.[31]

The vast majority of data collection occurs at the district level followed by health centres and health posts.[31] Approximately 75% of indicators pertain to service delivery and the remaining to health facility capacity, infrastructure, and expenditure.[31] Services delivery reports include, amongst other elements, data on outpatient and inpatient services, communicable diseases, pharmaceutical supply and services, and healthcare's human capital. Information is also available on more than 30 MCH indicators.

HEWs, being at the lowest level of the health system structure, therefore have an important role in the continuous compilation and transmission of MCH information to their respective health centre and district health office. There, the data can then be utilized to strengthen district planning, monitoring and evaluation of MCH services.[32] The information is also ultimately used by the FMoH to guide national operations for better population health status.

2. Health Extension Program and Antenatal Care Attendance

When well implemented, ANC can save lives by providing an opportunity for women to be supported throughout their pregnancy via counseling on healthy lifestyles and the detection, management and control of pre-existing morbidities, obstetrical complications, and infections like HIV, tuberculosis and syphilis.[33] Women who attend ANC are also educated to recognize and act on the common danger signs leading to potentially serious pregnancy complications and can be referred to a maternal health specialist for further health assessments.[33,34] ANC also represents a point of entry for pregnant women within the health system, as women are given information and advice on family planning, safe childbirth and postnatal recovery.[33] This makes them more inclined to give birth in a health facility, seek postnatal care for themselves and their newborns, keep their baby's vaccinations up to date, and use appropriate birth spacing methods.[33] Increasing the proportion of pregnant women who receive ANC may therefore assist with and promote all other aspects of MCH services and thus has been made a priority in countries showing low ANC coverage.[33,35]

Data from a multi-country study published in 2002 by the World Health Organization (WHO) showed that, for women presenting no underlying medical conditions, essential interventions for better pregnancy outcomes could be provided over four ANC visits occurring at

specific time points during pregnancy.[33] A shift from this four-visit model known as focused ANC to a new model increasing the number of visits to eight has however been recommended by the WHO last year and remains to be explored for implementation in countries where achieving the focused ANC strategy is already challenging.[36] The first visit should be scheduled preferably in the first trimester (i.e. gestational age between 8 and 12 weeks) to help recognize women who have specific risk factors for poor pregnancy outcomes and therefore require more attention throughout their pregnancy.[33] The last visit should be near the expected date of birth to ensure that appropriate advice and care are provided prior to childbirth.[33]

In Ethiopia, important variations are observed in the coverage of ANC. The national coverage of receiving at least one ANC visit is reported as exceeding 98% in the HMIS[8], while the 2016 EDHS revealed that 62% of the recruited women sought at least one ANC visit.[13] The proportion of women attending four ANC visits was even lower in the EDHS, with an estimate of 32%.[13] Others studies have also found a low rate of four ANC visits attendance. Wilunda et al. found in Shoa Zone that 45% of pregnant women attended four ANC visits during their pregnancy, compared to Kifle and colleagues who detected that 10% of the women received four visits.[15,21] As noted by many, the majority of women also tend to delay their first visit to the second trimester. Gebremeskel observed that fewer than 20% of pregnant women attended their first visit at the recommended time.[23] This is consistent with the work by Kifle and team who identified that 65% of their participants sought their first visit in the second trimester.[15]

Representing the link between communities and the health system, HEWs are well positioned to identify and encourage women who are unable and/or unwilling to attend a clinic to receive ANC.[8,27,28,37] Through their home visits, they are able to promote early and adequate ANC attendance by explaining its benefits. HEWs also spend a portion of their time providing

ANC at the health post.[37] There, they can also motivate women to attend all the visits by administering good quality care and informing women on the common danger signs and complications in pregnancy.[37] HEWs also refer women with complication to the closest health centre for the subsequent visits. They also review the reports written by the health development army members and identify which women need follow-up visits.

3. Health Extension Program and Malaria in Pregnancy

Malaria represents one of the major global health threats and causes approximately 600,000 deaths annually, with 90% of the deaths occurring in Sub-Saharan Africa.[38] Along with children under the age of five and immunocompromised individuals, pregnant women are considered more vulnerable and bear the heaviest burden of disease.[39] Indeed, it is estimated that approximately 25 million pregnant women are at risk of malaria and 10,000 maternal and 200,000 neonatal deaths can be attributed to this disease yearly worldwide.[39]

Pregnant women are considered more vulnerable to malaria due to the reduced immunity associated with pregnancy.[38,39] Malaria in pregnancy may lead to maternal anemia and death, and greater risk of placental malaria, which may contribute to miscarriage, stillbirth, premature delivery, perinatal mortality, and more commonly low birth weight in the newborn, which may diminish the chances of survival of the infant in the first year of life.[40,41]

Tremendous progress and achievements in terms of malaria prevention, diagnosis, and treatment measures have been made over the past decades, resulting in an important decline in the burden of the disease.[38] As per the WHO recommendations, pregnant women at risk of malaria infection should regularly sleep under insecticide-treated nets (ITNs) and attend scheduled ANC visits, where they may be provided with an ITN and/or receive their intermittent

preventive treatment during pregnancy (IPTp).[38] Moreover, indoor residual spraying (IRS) should be applied inside of the dwellings of high-risk populations in all countries with high malaria transmission.[42] In spite of these recommended preventive practices, malaria during pregnancy continues to be a critical public health matter associated with an important socio-economic burden for the nations of Sub-Saharan Africa.[38]

The malaria parasite prevalence in Ethiopia is lower in contrast to many African countries, yet, nearly 50% of the Ethiopian population is considered at moderate or high risk of malaria infection annually.[43] Approximately 2.5 million clinical malaria cases are reported yearly, causing malaria to be one of the leading causes of morbidity on a national scale.[43] Pregnant women constitute, however, a small proportion of the total number of malaria patients, accounting for 1.7% and 2.9% of all outpatient and inpatient malaria cases, respectively.[43] According to Newman et al., malaria parasitemia in pregnant women in Ethiopia ranged from 7.1% to 2.3%, depending on whether stable and unstable endemicity areas were considered.[44] Comparably, the prevalence of placental malaria was 6.5 % and 2.5% in areas of relatively high and low transmission settings, respectively.[44] Even though the risk of malaria in pregnancy is lower in Ethiopia, relative to some other African countries, the risk of rapid progression to severe malaria and associated consequences among infected individuals, is relatively high, given that pregnant women in Ethiopia are less likely to acquire temporary immunity due to the low malaria parasite exposure in their lifetime.[45]

To ensure good management of malaria infection during pregnancy, the HEP has offered to HEWs training in malaria diagnosis, prevention, and control. HEWs are therefore able to supervise and conduct social and behavior change communication activities and outreach to inform women on the importance of owning and using an ITN.[37] HEWs regularly participate in

mass campaigns to distribute ITNs, keep records of ITN coverage, and track loss and damage through their regular home visits.[43] Moreover, HEWs have become more directly involved in supervising IRS operations and conducting door-to-door mobilizations of IRS.[43] To facilitate the prompt diagnosis and treatment of malaria infection, they are also equipped with multispecies rapid diagnostic tests and antimalarial drugs.

Project Rationale and Objectives

The HEP in Ethiopia has been frequently proven to be a successful strategy for mobilizing efforts within communities and scaling up best health practices.[25,46,47] As part of this program, the expansion of health infrastructure (e.g. health posts) and commodities (e.g. ambulances), and qualified health personnel (e.g. additional trainings given to health centre workers and deployment of HEWs and HDA members) in rural communities would be expected to significantly address the three "delays" resulting in poor maternal health outcomes. Yet, there are currently gaps in our knowledge concerning the HEP's impact on MCH outcomes and service utilization. .

Acknowledging the various roles that HEWs can have on the achievement of the HEP (Figure 1.2), we can further our understanding of the influence of the HEP in improving the maternal health care services in Ethiopia by (**1**) assessing the quality of the data collected and compiled from PHCUs within the HMIS, (**2**) determining women's access to maternal health care services such as ANC, and (**3**) identifying the use of specific prevention strategies for pregnant women that are within the remit of HEWs, such as the use of ITNs (**Figure 1.2**). By focusing on these different aspects, recommendations can be made to facilitate the development and

implementation of policies, strategies and programs that will ultimately lead to an improvement in decision-makings and resource allocations towards improved care for women and children in need.

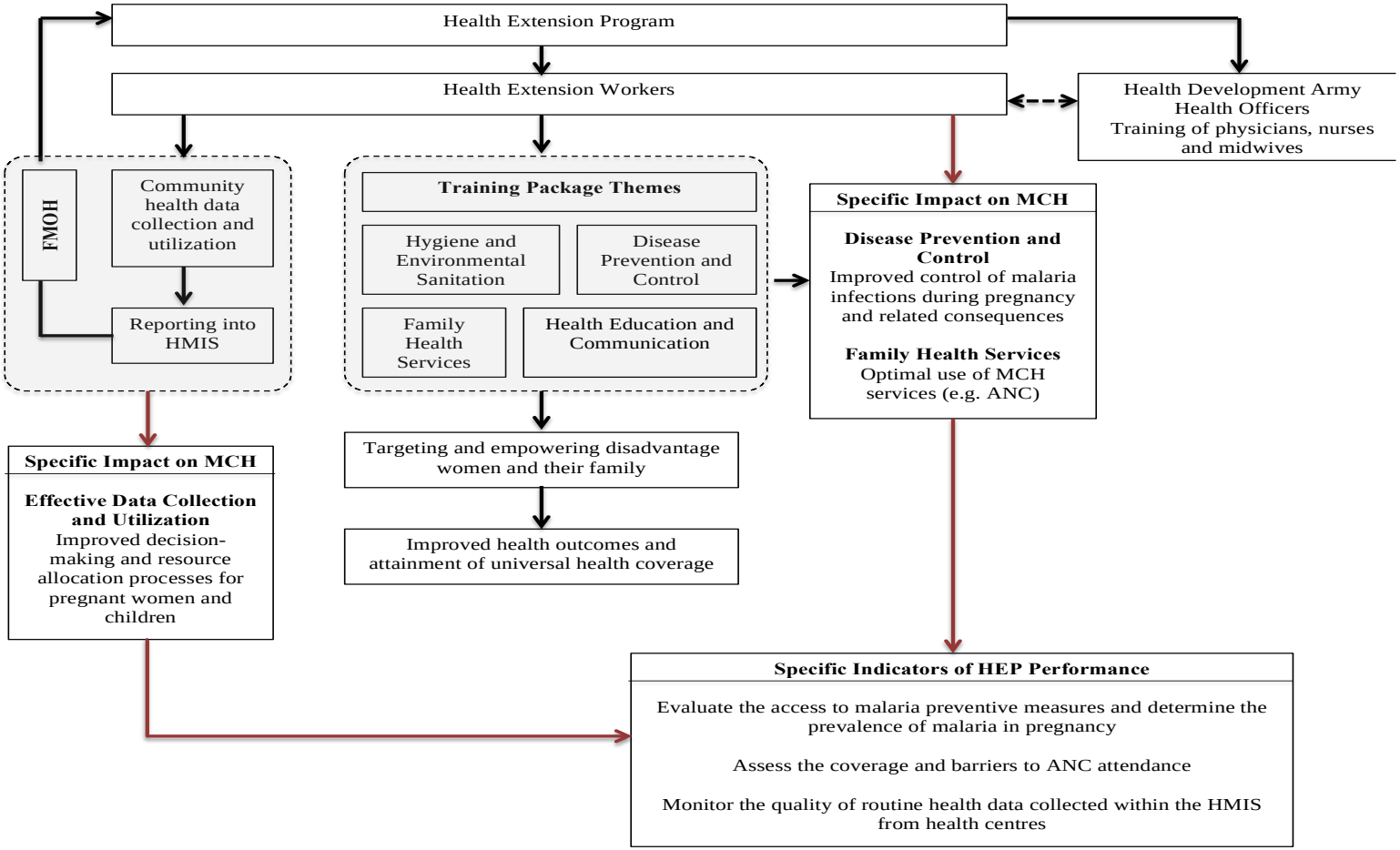

Figure 1. 2 Research framework

Through this thesis, I attempted to expand current knowledge on some of the different determinants and barriers to MCH in Ethiopia with the purpose of generating useful data and recommendations for consideration by the FMoH and other stakeholders, as they seek to improve MCH outcomes through the HEP and related MCH initiatives. I focused attention on three districts of a specific Zone in the southwest of Ethiopia named Jimma, where limited evidence can be found on **(1)** the quality of MCH data within their HMIS, **(2)** the predicting factors of ANC attendance **(3)** the utilization of bed nets for the prevention of malaria, and **(4)** the prevalence and determinants of malaria infection during pregnancy.

Data for this thesis were provided by a collaborative research project between the University of Ottawa and Jimma University, funded by the Canadian Institutes of Health Research (CIHR), International Development Research Centre (IDRC) and Global Affairs Canada through the Innovating for Maternal and Child Health Initiative, and titled: "An Implementation Study of Interventions to Promote Safe Motherhood in Jimma Zone, Ethiopia" (University of Ottawa Sciences and Health Sciences Research Ethics Board Protocol #H 10-15-25B).

This thesis is centered on the following objectives:

1- **To assess the quality of MCH indicators collected through the Ethiopian HMIS from July 2014 to June 2015 in PHCUs located within three districts of Jimma Zone;**

2- **To assess the levels and determinants of mosquito net ownership and use as well as ANC attendance by women within three Jimma Zone's districts and;**

3- **To examine the relationship between mosquito net ownership and use, and self-reported malaria infection in pregnant women living in the three districts of Jimma Zone.**

The objectives covered in this thesis are grouped under two chapters. The first chapter focuses on a quality assessment of HMIS data collected from the PHCUs located within the three districts of interest. The second chapter includes an evaluation of ANC attendance and mosquito net ownership and utilization by women of reproductive age from the three districts of Jimma Zone. In this last chapter, I also characterize the prevalence of malaria in pregnancy in the study population.

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Chapter 2 (Manuscript 1): A Quality Assessment of Health Management Information System Data for Maternal and Child Health in Jimma Zone, Ethiopia

Preface to Manuscript 1

Limited evidence can be found on the quality of the maternal and child health (MCH) data compiled from rural communities into the health management information system (HMIS). It is therefore important to assess whether the quality of MCH data recorded in the HMIS by primary health care units (PHCUs) is satisfactory and can adequately guide MCH resource allocation and decision-making processes at the community level to ultimately produce the intended effect on MCH in rural communities of Ethiopia. Through this work, a data quality assessment was performed using a wide range of MCH indicators, focusing on maternal health service utilization, immunization status of children, and malaria during pregnancy. An established data quality assessment tool developed by the World Health Organization (WHO) was used. We also used data that were collected from a cross-sectional survey conducted with 3,784 women who had a birth outcome in the preceding year. Ethics approval was sought from the Research Ethics and Integrity Board at the University of Ottawa (#H10-15-25C). The certificate of ethical approval is provided in Appendix B. Appendix A contains additional tables and figures for the first manuscript.

Dr. Manisha Kulkarni and Mariame O. Ouedraogo conceived the project. Mariame O. Ouedraogo performed all data preparation and analysis and wrote the manuscript. Dr. Marie-Hélène Roy-Gagnon assisted with the development of the analysis plan and provided guidance on the methodological and statistical aspects. Drs. Manisha Kulkarni, Marie-Hélène Roy-Gagnon, and Beth Potter assisted with interpreting the results and editing the manuscript. All other co-

authors are involved in the large cluster-randomized trial and provided guidance and feedback when needed.

A Quality Assessment of Health Management Information System Data for Maternal and Child Health in Jimma Zone, Ethiopia

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Abstract

Background: Health management information system (HMIS) data in developing regions have often been identified as incomplete and inaccurate, which can jeopardize their usefulness in guiding and reaching sub-national and national health targets. High-quality information is even more important for populations in which the burden of disease and mortality is higher, such as pregnant women, newborns, and children.

Objective: The purpose of this study was to assess the quality of maternal and child health (MCH) data collected through the Ethiopian Ministry of Health's HMIS in three districts of Jimma Zone over a 12-month period.

Methods: The World Health Organization data quality report card was used to appraise the quality of MCH data gathered from July 2014 to June 2015 for the 26 primary health care units (PHCUs) located within three districts of Jimma Zone (Gomma, Seka Chekorsa, Kersa). Eight MCH indicators were considered: antenatal care first (ANC1) and fourth (ANC4) visit, skilled birth attendance (SBA), early postnatal care (PNC), Diphtheria-Tetanus-Pertussis vaccine first

(DTP1) and third (DTP3) dose, malaria in pregnancy and stillbirth rates. Data quality assessments included completeness and timeliness of reporting, zero and missing values, moderate/extreme outliers, and consistency over time. The consistency between indicators expected to be strongly correlated (DTP1/ANC1, ANC4/ANC1, DTP3/DTP1), and of denominators (i.e. official number of expected pregnancies) was also assessed. We further compared MCH data coverage from the HMIS to estimates obtained from a population-based survey conducted with 3,784 women who were pregnant in the preceding year. Health facility- and district-level evaluations were completed. Simple descriptive statistics were obtained for each data quality indicator. The agreement between the two data sources was evaluated using Pearson correlation coefficients, intraclass correlation coefficients (ICC), and Bland-Altman plots.

Results: Completeness and timeliness of facility reporting were highest in Gomma (75% and 70%, respectively) and lowest in Kersa (34% and 32%, respectively). Very few zero/missing values and moderate/extreme outliers were observed for each MCH indicator. Reporting of MCH indicators improved over time for all PHCUs. Large discrepancies between ANC1 and DTP1 coverage were observed in all districts, which may indicate errors in reporting. Five PHCUs reported higher ANC4 visit estimates compared to ANC1, while four PHCUs demonstrated greater number of DTP3 doses administrated than DTP1, which is indicative of data quality issues. Overall, the agreement between MCH estimates obtained from the HMIS and the survey was poor. Pearson's r suggested weak to moderate correlation, while all ICC values were close to zero or even negative. Bland-Altman plots demonstrated similar results, with the agreement being the poorest for ANC4, SBA, and PNC.

Conclusion: The quality of MCH data within the HMIS at the Jimma Zone level could be improved to inform MCH. Training of health workers in rapid data quality assessments and

utilization along with continuous feedback from PHCU and district health office supervisors are recommended to improve the completeness and timeliness of reporting and accuracy of MCH data.

Introduction

In the words of Manya and Nielsen, when health workers, managers, and policy-makers are asked how many deliveries take place in health facilities or how many maternal or perinatal deaths occurred within their communities, their answers must be based on facts and evidence, rather than beliefs and opinions.[1] Through this feedback, the various stakeholders involved in the different levels of the health system should also identify ways to maximize health benefits in their locality and improve the effectiveness of their health system.[2] External donors and aid agencies should also fund projects and interventions based on health indicators that accurately reflect populations' health issues.

It is by considering these perspectives that health management information systems (HMISs) were structured and introduced in most developing countries. The purpose of a HMIS is to systematically collect and aggregate reliable and valid information that will not only effectively and efficiently capture and monitor the health status and needs of the population but also support decision-makers in their efforts to allocate resources, and prioritize and plan services that would meaningfully impact their communities.[2–4] In addition, high-quality data have to be ensured for estimating the global burden of specific diseases, measuring progress in health and development as well as setting global health priority targets.[2] These data also play a critical role in guiding research studies.[5] Finally, HMIS data should have the ability to inform health professionals on emerging diseases and global health threats.[2]

Most HMIS have been built and organized with a 'bottom-up approach', allowing routine information to reach the higher levels of the health administration to guide health policies.[6] The health information is initially generated from basic health facilities such as health centres, private clinics, and hospitals and transmitted on a weekly, monthly or quarterly basis to the next reporting level. This next level is often a district that acts as the connection between the state and the local health centres.[7] Data are usually collected on paper reports and tally sheets at the primary health care level and sent to the district level to be stored digitally.[8] However, a tremendous shift from paper-based to computer-based records has been observed over the past decades in several low- and middle-income countries (LMIC) [8], enabling health centres to enter their information directly into the electronic HMIS. Ultimately, the data are compiled and made available to the Ministry of Health, which may share them with international bodies such as the World Health Organization (WHO) and the United Nations. Most LMIC have now opted for a decentralized health system allowing the use of data for health planning at the health centre and district levels.[7]

As a comprehensive, disaggregated and comparable source of information about health services in LMIC, HMIS have strong potential to act as the cornerstone for effective public decision-making and thus, significant financial resources have been directed towards the generation and support of health system data.[3,9] Still, several issues related to HMIS data quality, management, analysis, and utilization have been acknowledged, jeopardizing the value of HMIS in tracking progress in health and development. In light of these concerns, a tendency to predominantly rely on indicators measured through population-based surveys such as the Demographic Health Survey and Multiple Indicator Cluster Survey has been observed.[1,3]

Technical infrastructure issues such as unreliable electric power and unstable internet connectivity have been shown to affect the management and utilization of HMIS data.[8,9] In addition, health workers' limited computer skills represent an important barrier to HMIS utilization.[9] In the case where health care units still rely on paper records, problems with data storage and conservation of medical records have often been reported. The latter were found in a Kenyan study to be sometimes lost or torn.[1] Gebrekidan et al. in Ethiopia also found that card rooms, master patient index boxes, and shelves were sometimes unavailable or of limited size.[10] Access to the essential reporting sheets has also been shown to be lacking.[9] In a study conducted in Eastern Rwanda, it was demonstrated that several health facilities did not have proper access to patients' forms or registers for antenatal care, family planning users, and outpatient care.[11] Alternatively, having a web version of the HMIS has often caused an increase in information to manage that does not necessarily translate into an increase in the capacity of HMIS staff.[8] As a consequence, health workers now have to deal with larger amounts of data in addition to their initial role, which has been shown to limit their ability to analyze and interpret the data.[8]

Furthermore, a lack of policies and guidelines and training offered to health personnel has been demonstrated to alter the management of HMIS data.[9] In a Kenyan study, counting from registers and tally sheets represented a challenge for health workers.[1] The study further acknowledged a failure to understand the health indicators.[1] Along with limited knowledge in record filling, health workers were often unable to plot graphics to inform performance and progress in their specific community.[1] Similarly, the absence of supervision and regular feedback from senior levels left health workers unaware of their performance.[9,12] The non-critical use of data, defined by poor-quality data being used to inform health policies, was also reported.[1]

Past research has also identified issues with the quality of the data collected within HMIS in terms of completeness, timeliness, and accuracy, resulting, in some cases, in data contained within these systems contributing very little to decision-making processes.[1,9,13–19] Data completeness was shown to be relatively poor in LMIC with missing data that ranged from 19% in Kenya to 50.3% in South Africa.[20,21] On the other hand, high completeness rates were observed in Rwanda.[11,14] A retrospective data quality audit of immunization data from 41 LMIC conducted in 2009 showed that only nine countries had data of high accuracy.[19] Alternatively, in Mozambique, Gimbel et al. identified relatively high (80%) concordance between health facility clinical registries and monthly facility reports.[18] Through a study of human immunodeficiency virus (HIV) data accuracy, Mate et al. found that only 12.8% of Prevention of Mother-to-Child Transmission (PMTCT) data in South Africa were accurate. In the same study, 19.8% of HIV counseling and testing data and 5.5% of HIV data for babies born to HIV mothers were found to be accurate.[21] Inconsistencies in the use of denominators to generate coverage rates were also found.[19] Over- and under-reporting have also been reported for health indicators for which high and low levels of coverage were desirable, respectively.[15,21,22]

As part of the Federal Ministry of Health (FMoH) "One Plan, One Budget & One Report" policy, Ethiopia contracted the consulting firm John Snow, Inc. in the years 2006-2007 to perform an assessment and redesign of its HMIS, with the aim of improving the management and optimum use of resources for making timely decisions and promoting effective health care system delivery.[23] Through this evaluation, it was found that the burden of data was high, different partners were independently collecting their information, standardized indicator definitions among the different partners and regions were lacking, data were of poor quality, and the use of information was weak and highly centralized.[23,24] Given the paper-based nature of the

HMIS at that time, the project also resulted in the design and deployment of an electronic HMIS in health facilities nationwide.[23]

Following the 2006 reform, another assessment was performed with the sponsorship of the Health Metrics Network. This project highlighted that the HMIS remained "cumbersome and fragmented".[23] The lack of an implementation strategy and guidelines along with the shortage of human capital were some of the additional issues raised by the researchers.[23] Inadequate skills for collecting, analyzing and interpreting the information among the health care staff at the lower levels of the health system and unsatisfactory quality of data in summary reports were also shown to be persistent. The ability to make informed decisions was therefore compromised, the information flow fragmented and the workload increased. This project revealed that the 2006 reform of the HMIS not only failed to address the necessary changes to routine practices in the health system but also to encourage behavioral changes amongst the various contributors of the HMIS.[23]

More recent work also showed that HMIS data quality and utilization remain weak particularly at primary health care unit (PHCU) and district health office levels.[10,24–28]A study conducted by Teklegiorgis et al. in Eastern Ethiopia indicated that completeness and timeliness of data reporting were inadequate with rates of 82% and 77%, respectively.[27] Roughly 70% of the health centres reported having received directives on how to check for data accuracy and submit their reports on time. Eighty-two percent (82%) of the department heads claimed their reports were completely filled while 79% of the reports were considered as being consistent. In the same study, 65% and 42% health facilities used the information gathered for decision-making and observing trends of service delivery, respectively.[29] Another research study in Jimma Zone illustrated that 30% of staff in PHCUs and district health offices complained about their

incomprehension of and ambiguity within their registers given the limited or lack of training obtained. Timeliness was poor with less than 50% of health posts, health centres and district health offices reporting within their given deadline.[26] Thirty-eight percent revealed inconsistencies within their reports. Issues with the quality of data were also noticed in a national report written in 2016 by the Ethiopian Public Health Institute, FMoH, and WHO Ethiopian Office.[24] Even though completeness of reporting was relatively high, private facilities were found to be reporting substantially less to the district health offices than PHCUs managed by the government.[24] The issue of inaccuracies between HMIS and registers kept in PHCUs was also raised by this study. Over-reporting and under-reporting were also observed at all reporting levels.[24,28]

To our knowledge, no study in Ethiopia has focused specifically on the quality of maternal and child health (MCH) data collected within the HMIS, considering a wide range of data quality dimensions and attributes. Recognizing the importance of assessing the quality of data collected on populations in which the burden of morbidity and mortality is higher such as pregnant women, newborns, and children, we aimed to assess the quality of MCH data collected through Ethiopia's HMIS over a 12-month time period (July 2014 to June 2015) in three districts of Jimma Zone, using data quality dimensions proposed by the WHO and MCH indicator estimates from a cross-sectional household survey conducted within the same time frame.

Methods

1. Study Site

Jimma Zone is located in Oromia region, Southwestern Ethiopia, approximately seven hours from Addis Ababa, Ethiopia's capital. The total population of this Zone was estimated at

approximately 2.5 million.[30] Jimma Zone is further divided into 17 *Woredas* or districts. Three of which have been selected for a large cluster-randomized trial designed to address barriers to safe motherhood options[1]: Gomma, Kersa, and Seka Chekorsa. These three districts were selected on the basis of their large population size and the absence of other interventions that could have altered the results and conclusions made through the trial. Gomma has a total of ten health centres, while seven are found in Kersa and nine in Seka Chekorsa. Each health centre is associated to five satellite health posts held by two full-time trained female health extension workers (HEWs).

2. Ethiopia Health Management Information System

The FMoH reformed its HMIS in 2006 to facilitate the decentralization of the health care system and more easily reach rural communities. As a result, the primary level of health service delivery and data collection occurs in PHCUs, which are composed of one health centre and five satellite health posts. Data compiled are then forwarded to the district health offices, which are tasked to manage and collaborate with PHCUs to maximize their operations.[7] Data from the district health offices are subsequently sent to the zonal health departments. The latter support the regional health bureaus and district health offices in the management of health service delivery. Decision-making processes for the implementation of national health programmes are shared between the regional health bureaus and the FMoH. To address the research objective, we used data that were transmitted from the Gomma, Kersa, and Seka Chekorsa PHCUs and district health offices to the Jimma zonal health department.

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[1] This project represents a collaboration between the University of Ottawa, Jimma University with funding received from the Canadian Institutes of Health Research (CIHR), International Development Research Centre (IDRC) and Global Affairs Canada through the Innovating for Maternal and Child Health Initiative

3. Data Sources

(a) HMIS Data

To address our study aim, we first considered monthly service reports that were extracted from the computer-based HMIS at the Jimma zonal health department. We were interested in data gathered from July 2014 to June 2015 in Gomma Kersa and Seka Chekorsa districts and their PHCUs. Monthly reports from the two previous fiscal years (July 2012-June 2013 and July 2013-June 2014) were also retrieved.

(b) Cross-sectional Survey Data

A community-based cross-sectional survey was performed as the baseline evaluation for a large cluster-randomized trial with women from the three districts who had a birth outcome in the preceding year, and, therefore, within the same time frame as the HMIS extracted reports. To attain the sample size for the large trial, a two-stage sampling strategy was used. Twenty-four PHCUs or clusters were first randomly selected from the 26 available PHCUs in the three study districts. From each PHCU catchment area, approximately 160 eligible women were then randomly selected. A total of 3784 women were recruited and provided information on their past use of the MCH services as well as on their experiences when they were pregnant, during childbirth and after delivery. Face-to-face surveys were conducted at the woman's household. After obtaining informed consent, questions were administered by trained interviewers in the local language using a computer tablet-based questionnaire. No replacement was made for women who refused to participate; the refusal rate was less than two percent (i.e. 1.5%).

4. Maternal and Child Health Indicators

We examined key standard maternal health services and immunization indicators recommended by the WHO when conducting data quality assessment of MCH health measures, including antenatal care first (ANC1) and fourth (ANC4) visit coverage, deliveries attended by a skilled birth attendant (SBA) in health facilities, access to early postnatal care (PNC), and Diphtheria, Tetanus, Pertussis vaccine first (DTP1) and third (DTP3) dose coverage.[31] We also included additional indicators, namely, malaria in pregnancy, stillbirth rate.

5. WHO Data Quality Report Card and Data Analysis

Recognizing the need for LMICs to regularly evaluate the quality of their routine health information system, the WHO has developed several tools to assist in the assessment of common data quality dimensions. Among the available tools, we used the WHO's Data Quality Report Card (DQRC), which not only allows the consideration of several data quality dimensions but also represents a relatively easy and quick quantitative method to analyze available health data.[32] Despite the fact that this tool needs to be complemented with other available tools that take into account the need for qualitative assessments in health facilities, the DQRC enables one to identify and highlight inaccuracies and inconsistencies in HMIS data through a series of easy checks and make recommendations regarding the issues found.[32] The simple descriptive statistics provided by the DQRC also make it the most appropriate tool for resource-constrained settings, and it has previously been used in Rwanda, Cambodia, and Uganda.[14,33,34] The tool was initially developed for assessments of health system performance on a national scale but can also be used to look at how a specific district or health facility is performing, which was done in this project.[31] This tool has also been used in the past specifically to assess the quality of MCH indicators.[31]

Four dimensions of data quality are included in the DQRC, which are **(1)** the completeness of reporting, **(2)** the internal consistency of reported data, **(3)** the external consistency of population data and **(4)** the external consistency of coverage rates.[31] These four dimensions are further divided into specific elements or indicators.

(a) Dimension 1: Completeness of reporting

***Completeness of health facility reporting*.** The completeness of PHCU reporting was defined as the percentage of expected monthly health post and health centre reports that were received by the three district health offices. Each health post is expected to send a service report and an outpatient report on a monthly basis, whereas health centres are asked to send in addition to these two reports, an inpatient report to their respective *Woreda* or district health office. The expected number of reports in a given month is thus estimated by using the following formula: *(2* x *number of health posts reporting) + (3* x *number of health centres reporting).*

Given the number of health posts and health centres found in each district (i.e. Gomma: 41 health posts and ten health centres, Seka Chekorsa: 37 health posts and nine health centres, and Kersa: 32 health posts and seven health centres), we expected a total of 112 reports in Gomma, 101 in Seka Chekorsa, and 85 in Kersa in the year of interest.

***Timeliness of health facility reporting*.** Timeliness of health facility reporting corresponded to the percentage of reports from health posts and health centres that were received on time in their respective district, according to the fixed deadline (i.e. by the 26th of the next month). Again, the same expected number of reports per district was used to calculate this indicator.

Completeness of MCH indicator data (zero/missing values). Content completeness was assessed by counting the number of missing and zero values for each MCH indicator in each PHCU and

district service report. Missing entries are very often assigned a value of zero, making it challenging to differentiate between a true zero and a missing value.[31] Still, only MCH indicators for which no true zero values would be expected were assessed. The total number of missing or zero values were then summed across all MCH indicators and divided by the sum of the expected number of reported values for each MCH indicator. The total number of expected indicator values for a specific district for a given year was obtained with the following equation: (*12 months)* x *(number of PHCUs within the district)* x *(number of MCH indicators)*. We thus had 720 total expected MCH values in Gomma, 648 in Seka Chekorsa and 504 in Kersa.

(b) <u>Dimension 2: Internal Consistency of reported data</u>

Accuracy of event reporting: Identification of Outliers. As per the DQRC criteria, two types of outliers were considered: moderate and extreme. Moderate outliers were defined as values that were at least ± two standard deviations from the average value for a specific indicator for a given district at a specified time. Values were considered extreme outliers when they were at least ± three standard deviations from the average value. We then summed the number of outliers per district and calculated the percentage of outliers, using the total annual number of MCH indicator values expected, as described above.

Consistency over time. This indicator looked at the consistency of the values for indicators in the year of analysis compared with the average value of the same indicators for the two previous years combined. As part of our sensitivity analyses, we compared the MCH indicator estimates to the most recent last fiscal year estimates alone (i.e. 2013-2014) rather than using two years of retrospective data, as several missing values were present in the 2012-2013 reports.

Internal consistency between indicators. We evaluated this indicator by looking at the consistency between indicators that have similar patterns of behavior within the health care

system. We first considered the consistency between DTP1 and ANC1 coverage, as both usually represent points of entry into the health system for infants and pregnant women, respectively.[31] Women who seek care will receive at least one ANC visit and are more likely to also seek at least one visit to the health facility for their children after birth.[31] Large discrepancies between ANC1 and DTP1 coverage may indicate reporting errors and problems with data quality. The DTP1/ANC1 ratio obtained for each PHCU was compared to the one obtained for their respective district. This allowed us to identify PHCUs that were more or less contributing to the observed trend, and doing better or worse than their overall district. We also measured the consistency between ANC1 and ANC4, and DTP1 and DTP3, by calculating the percentage difference between the two. While it is possible for ANC4 and DTP3 levels to be greater than ANC1 and DTP1, respectively, such as in areas with frequent in-migration, it is unlikely to happen systematically.[31] We therefore flagged all PHCUs and districts that reported inconsistent ANC4/ANC1 and DTP3/DTP1 ratios.

(c) Dimension 3: External comparison of population data

Consistency of denominator (total number of pregnant women and children under 1 year). For this indicator, we compared the official number of expected pregnancies in each PHCU and district to an alternate one derived from the cross-sectional survey. The official denominators for each PHCU and for the overall district were obtained directly from the Jimma zonal health department. Two pieces of information were required to generate an alternate estimate of the number of expected pregnancies in a district or PHCU: (1) an estimate of ANC1 coverage from survey data and (2) an estimate of the number of women making ANC1 visits from the HMIS for this specific district or PHCU.[31] The alternate denominator was then obtained by dividing the total number total number of ANC1 visit from the HMIS for a specific district or PHCU by the

coverage from the cross-sectional survey for that specific district or PHCU. Calculation of the alternate denominator is limited by the assumptions that the reported number of women seeking ANC1 in the HMIS is accurate and that the survey ANC1 coverage estimate is reliable and free from selection and measurement errors.[31] A ratio of the official to the alternate denominator was then calculated and all PHCUs and districts reporting a large difference between the two denominators were flagged.

A similar comparison is recommended for children under one year[31], using the official denominator estimate of children under one year and an alternate denominator calculated by dividing DTP1 total events reported in the HMIS by DTP1 coverage rate estimated from a recent population-based survey. This assessment was not performed, as the coverage of DTP1 was not collected in the survey.

Two PHCUs (i.e. Meti Koticha in Gomma and Babo Yaya in Seka Chekorsa) were excluded from this evaluation, as women attending these PHCUs were not enrolled in the cross-sectional survey.

(d) <u>Dimension 4: External consistency of coverage rate</u>

The level of discordance between data collected through the HMIS and the estimates obtained from the recent survey conducted with women who had a birth outcome in the preceding year was evaluated for health indicators that could be found in both datasets. We therefore considered ANC1 ANC4, SBA, PNC, malaria in pregnancy and stillbirth rates. As we wanted to compare coverage estimates for the same PHCUs, we excluded participants that reported attending any of these services in a health facility located in another district. Ninety-four women were excluded, representing approximately 2.5% of the total study population.

Scatter plots along with Pearson correlation coefficients and intraclass correlation coefficients (ICCs) were obtained to get a sense of whether coverage rates from HMIS and survey data were related and of the amount of variability between the two methods. The ICCs were calculated using the Deyo's method, as described by Szklo and Nieto.[35]

Bland and Altman analysis was subsequently used. The Bland and Altman technique was proposed as an alternative to correlation coefficients and is now a standard method to assess agreement between two quantitative measurements by estimating the overall mean difference between the two methods of health measurement, and 95% limits of agreement.[36,37] Ninety-five percent (95%) confidence interval limits are also built around the overall mean difference to identify whether the bias between the mean difference and the equality line is statistically significant. This allows distinguishing whether one method is systematically under- or over-reporting a measurement compared to the other method. The limits of agreement represent the range within which most of the difference between the estimates given by the two data sources will be found. The narrower the range between the two limits is, the better the agreement.[37,38] Values outside the limit of agreement are identified as outliers.

An important assumption of the Bland and Altman limits of agreement is that the differences are normally distributed.[39] In some cases, this assumption is not met and it might sometimes be preferable to estimate the limits of agreement using a nonparametric method, as described previously.[39] Given the number of data points in each *Woreda* (i.e. ten, nine and seven PHCUs in Gomma, Seka Chekorsa and Kersa, respectively), adherence to the normal distribution might have been compromised. The median difference was thus used instead of the mean difference, while the 2.5^{th} and 97.5^{th} quartiles were used to create the lower and upper limits of

agreement, respectively. We also added the 95% confidence interval limits of the median difference in order to test for statistically significant differences from equality.

As per the DQRC criteria, all PHCUs with more than 33% difference between the two coverage rates should be identified and flagged. Accordingly, we generated Bland-Altman plots using cutoffs of ±30%. We also included a margin of error of ±10%, which has been used in previous studies.[40] A summary table including how each MCH indicator was evaluated is shown below (**Table 2.1**).

Table 2. 1 List of maternal and child health indicators included in the data quality assessment of health management information system data

Indicators	Level of Assessment	I1	I2	I3	I4	I5	I6
Antenatal care first visit (ANC1)	District and PHCU	✓	✓	✓	✓	✓	✓
Antenatal care fourth visit (ANC4)	District and PHCU	✓	✓	✓	✓		✓
Deliveries by a skilled birth attendant (SBA)	District and PHCU	✓	✓	✓			✓
Diphtheria, Tetanus, Pertussis first dose (DTP1)	District and PHCU	✓	✓	✓	✓		
Diphtheria, Tetanus, Pertussis third dose (DTP3)	District and PHCU	✓	✓	✓	✓		
Access to early postnatal care * (PNC)	District and PHCU	✓	✓	✓			✓
Stillbirth rate	District and PHCU						✓
Malaria in pregnancy	District						✓

Indicator 1 (I1): Missing Data in heath facility reporting; **I2**: Identification of moderate/extreme outliers; **I3**: Consistency over time; **I4**: Internal Consistency between indicators, **I5**: Consistency of denominator; **I6**: External comparison with survey MCH coverage

* PNC in the survey was measured at the mother and newborn levels

Ethics Approval

Approval to use the HMIS data for this assessment was obtained from the Research Ethics and Integrity Board at the University of Ottawa (#H10-15-25C).

Results

1. Completeness and timeliness of reporting

Data completeness was the highest in Gomma with 76% of expected monthly health post and health centre reports received by the district health office, followed by 49% in Seka Chekorsa and 33% in Kersa (**Table 1.1**). Similar patterns were observed for timeliness of PHCU reporting. Gomma district health office received 71% of its expected PHCU reports on time, compared to 33% and 50% in Kersa and Seka Chekorsa, respectively.

2. Completeness of indicators

Kersa had five (0.8%) missing indicator values while Gomma only had three (0.3%) missing values all found in Meti Koticha health centre reports. No zero or missing MCH indicator values were found in Seka Chekorsa reports (**Table 2.2**).

Table 2. 2 Completeness and timeliness of reporting in the three districts of interest, based on an assessment of HMIS data quality for selected MCH indicators, 2014-2015, using WHO data quality report card

	Gomma (%)	Kersa (%)	Seka Chekorsa (%)
Completeness of reporting	75.8	33.5	49.5
Timeliness of reporting	70.9	32.8	49.5
Content completeness	99.6	99.1	100.0

3. Accuracy of event reporting

Gomma had the largest proportion of moderate outliers with 31 (4.3%) of the MCH indicator values being at least two standard deviations from the average value for the respective indicator in this district. Similar proportions were obtained in Kersa (i.e. 24 (3.7%)). Seka Chekorsa had 20 (3.9%) moderate outliers. Across the three districts, SBA and early PNC indicators reported the highest number of moderate outliers; with the majority being above the two standard deviations from the mean. Very few extreme outliers were detected. One was found in Gomma, one found in Seka Chekorsa, and none in Kersa.

4. Consistency over time

The annual mean MCH service coverage for the two preceding years was compared to the MCH coverage obtained for the year of analysis. An increase in the uptake of MCH services over time was observed in all districts and the majority of the PHCUs (**Table 2.3 – 2.5**). PNC was the indicator associated with the most important increase in its coverage. Ratios of 4.8, 7.4 and 3.3 were obtained for Gomma, Kersa and Seka Chekorsa, respectively. In contrast, a consistent coverage rate for ANC1 was observed in the three districts. This was also the case for DTP1 and DTP3 in Gomma and Seka Chekorsa.

The ratios obtained at the district level were then compared to the ones from PHCUs to determine which of the latter performed very differently from their respective district, using an acceptable difference of maximum 10%. We found that all 26 PHCUs had at least one ratio 10% lower or higher than their district ratio. Using the cutoffs established by the WHO, we identified that 8 out of the ten health facilities in Gomma had at least one MCH indicator expressing a 30%

difference from their district ratio. All PHCUs in Kersa showed at least one MCH indicator that had a ratio that was more than 30% different from the district ratio, while this was observed in 8 out of the nine PHCUs in Seka Chekorsa.

As missing values were present in the 2013 reports, we performed a sensitivity analysis assessing the consistency with the 2014 reports (**Table A.1 – A.3**). Increase over time was still important for PNC, which could represent a real increase in PNC service uptake or data quality issues. Other indicators such as ANC1, DTP1, and DTP3 showed a decrease in or constant coverage.

Table 2. 3 Consistency over time ratios in Gomma district, based on an assessment of HMIS data quality for selected MCH indicators, 2012-2015, using WHO data quality report card

	ANC1 ratio	% difference from Gomma ratio*	ANC4 ratio	% difference from Gomma ratio	SBA	% difference from Gomma ratio	PNC	% difference from Gomma ratio	DTP1	% difference from Gomma ratio	DTP3	% difference from Gomma ratio
Ratio for Gomma	1.01		1.87		1.49		4.85		0.96		0.97	
Beshasha	0.90	**-11.19**	1.56	**-16.84**	1.78	**19.46**	5.14	6.41	1.04	8.33	1.43	**47.42**
Chami Chago	1.07	5.11	1.73	-7.78	1.65	**10.74**	5.22	8.07	0.96	0.00	0.88	-9.27
Choche	1.14	**11.98**	1.80	-4.05	1.21	**-18.79**	5.01	3.72	0.57	**-40.62**	0.59	**-39.17**
Dhayi Kechene	0.92	-9.62	1.28	**-31.76**	1.38	-7.38	6.05	**25.25**	0.75	**-21.87**	0.90	-6.70
Gembe	0.99	-2.75	1.91	1.81	1.20	**-19.19**	6.68	**38.30**	1.28	**33.33**	1.24	**27.83**
Kedemassa	1.03	1.17	1.32	**-29.63**	1.19	**-20.13**	4.68	-3.10	0.87	-9.37	0.75	**-22.68**
Limu Shayi	1.31	**28.68**	2.36	**25.79**	1.76	**18.12**	8.08	**67.28**	1.11	**15.62**	1.44	**48.45**
Meti Koticha	0.64	**-37.13**	2.10	**11.94**	1.13	**-24.36**	4.74	-1.86	0.85	**-11.45**	0.83	**-14.43**
Omo Beko	1.85	**81.72**	1.38	**-26.44**	2.76	**85.23**	7.97	**65.01**	3.37	**251.04**	1.82	**87.62**
Yachi	1.15	**12.96**	1.25	**-33.37**	1.28	**-14.09**	4.08	**-15.52**	1.22	**27.08**	1.33	**37.11**

* Ratios are highlighted when the difference was > 10%

Abbreviations: ANC1- antenatal care firs visit, ANC4 – antenatal care fourth visit, SBA – skilled birth attendance, PNC – postnatal care, DTP1 - Diphtheria, Tetanus and Pertussis first dose, DTP3 - Diphtheria, Tetanus and Pertussis third dose

Table 2. 4 Consistency over time ratios in Kersa district, based on an assessment of HMIS data quality for selected MCH indicators, 2012-2015, using WHO data quality report card

	ANC1 ratio	% difference from Kersa ratio	ANC4 ratio	% difference from Kersa ratio	SBA ratio	% difference from Kersa ratio	PNC	% difference from Kersa ratio	DTP1 ratio	% difference from Kersa ratio	DTP3 ratio	% difference from Kersa ratio
Ratio for Kersa	0.96		2.47		1.21		7.74		1.15		1.29	
Adere Dika	0.98	1.03	2.20	**-10.81**	1.58	**30.57**	13.16	**77.83**	1.19	3.47	1.35	4.66
Bale Wajo	1.36	**41.66**	2.69	8.90	1.77	**46.28**	14.10	**90.54**	0.93	**-19.21**	1.01	**-21.70**
Bulbul	0.92	-5.15	0.79	**-68.01**	1.00	**-17.35**	9.15	**23.64**	1.10	-4.00	1.25	-3.10
Kusaye Beru	0.99	2.06	2.99	**21.05**	1.05	**-13.22**	16.25	**118.92**	1.20	4.60	1.38	6.97
Kara Gora	0.51	**-47.30**	1.72	**-30.40**	0.83	**-31.40**	5.16	**-30.27**	0.85	**-25.74**	0.96	**-25.27**
Kellacha	2.19	**125.70**	5.15	**108.30**	2.09	**72.72**	6.24	**-15.67**	2.57	**123.4**	3.27	**153.48**
Serbo	1.14	**17.52**	2.93	**18.62**	1.23	1.65	3.72	**-49.73**	1.22	6.08	1.55	**20.15**

* Ratios are highlighted when the difference was > 10%

Abbreviations: ANC1- antenatal care firs visit, ANC4 – antenatal care fourth visit, SBA – skilled birth attendance, PNC – postnatal care, DTP1 - Diphtheria, Tetanus and Pertussis first dose, DTP3 - Diphtheria, Tetanus and Pertussis third dose

Table 2. 5 Consistency over time ratios in Seka Chekorsa district, based on an assessment of HMIS data quality for selected MCH indicators, 2012-2015, using WHO data quality report card

	ANC1 ratio	% difference from SC ratio*	ANC4 ratio	% difference from SC ratio	SBA ratio	% difference from SC ratio	PNC ratio	% difference from SC ratio	DTP1 ratio	% difference from SC ratio	DTP3 ratio	% difference from SC ratio
Ratio for Seka Chekorsa	**1.00**		**2.06**		**1.35**		**3.33**		**1.00**		**1.08**	
Bake Gudo	1.07	7.00	1.88	-8.50	1.37	1.48	3.41	2.40	1.04	4.00	1.11	2.77
Buyo Kechema	0.75	**-25.00**	1.99	-3.20	1.10	**-18.44**	3.38	1.50	0.78	**-22.00**	0.72	**-33.42**
Dabo Yaya	1.61	**61.00**	2.07	0.68	1.52	**12.59**	4.46	**33.93**	1.60	**60.00**	1.74	**61.11**
Detu Kersu	0.88	**-12.00**	2.29	**11.38**	1.40	4.07	2.93	**-12.01**	1.66	**66.00**	2.37	**119.40**
Geta Bake	1.39	**39.00**	2.06	0.43	1.23	-8.88	2.92	**-12.31**	1.23	**23.00**	1.64	**51.85**
Lilu chaa	1.44	**44.00**	2.24	8.94	1.49	**10.37**	4.46	**33.93**	0.81	**-19.30**	0.97	**-10.09**
Seka	0.76	**-24.00**	1.81	**-11.77**	1.13	**-15.92**	2.74	**-17.71**	0.57	**-43.00**	0.75	**-30.55**
Setemma	1.29	**29.00**	3.52	**71.20**	1.53	**13.33**	3.73	**12.01**	1.06	6.00	1.82	**68.52**
Wokito	1.21	**21.00**	2.89	**40.56**	1.42	5.18	3.25	-2.40	0.99	-1.00	1.38	**27.77**

* Ratios are highlighted when the difference was > 10%

Abbreviations: SC – Seka Chekorsa, ANC1- antenatal care firs visit, ANC4 – antenatal care fourth visit, SBA – skilled birth attendance, PNC – postnatal care, DTP1 - Diphtheria, Tetanus and Pertussis first dose, DTP3 - Diphtheria, Tetanus and Pertussis third dose

5. Internal consistency

Consistency between the number of ANC1 visits and number of DTP1 doses was low in Gomma, with a ratio of 0.58, meaning that roughly 42% more women attended their ANC1 visit than children receiving their first dose of DTP1. The same trend was observed in Kersa and Seka Chekorsa, with 30% and 63% greater ANC1 coverage than DTP1 administration, respectively. Except for Kedamessa PHCU in Gomma, Serbo PHCU in Kersa and Sentemma PHCU in Seka Chekorsa, all PHCUs displayed DTP1-ANC1 ratios at least 10% different from their respective district ratio.

By comparing the number of DTP1 doses to the number of DTP3 doses administrated, we identified that all PHCUs located in Gomma had a negative percentage difference between the two, meaning that a higher administration of DTP1 vaccines compared to DTP3 was reported. In Omo Gurude, for example, 74% of infants who received their first dose did not receive their third one. Similar remarks could be made for Kersa, which showed a negative difference in all PHCUs. In Seka Chekorsa, several PHCUs showed positive differences, meaning that there might be issues with the quality of the data, as we would not expect the number of DTP3 doses number to be higher than DTP1.

Some PHCUs across the three districts showed higher ANC4 uptake compared to ANC1, as indicated by the positive differences. Higher coverage of ANC4 to ANC1 may also be indicative of data quality issues.

6. Consistency of denominator

In general, the alternate denominators estimating the number of pregnant women in each PHCU (i.e. those derived by dividing the total number of ANC1 visits from the HMIS by the ANC1 coverage rate estimated from the survey) were lower than the official denominators (i.e. those used in the HMIS). Gomma reported an overall difference of 81%, signifying a marked potential overestimation of the number of pregnant women in the HMIS for this district, whereas differences of 15% and 6% were observed in Kersa and Seka Chekorsa, respectively. At the PHCU level, ratios of official to alternate denominators ranged from 1.08 to 7.36 in Gomma, 0.62 to 1.30 in Seka Chekorsa, and 0.89 to 2.31 in Kersa.

7. Consistency with survey-derived estimates

MCH service coverage estimates from the cross-sectional survey were generally lower than the ones calculated using the HMIS data, suggesting that MCH services uptake in PHCUs is over-reported within the HMIS. We also found that the stillbirth rate was in general higher in the survey than the HMIS. Interestingly, we noted in Gomma that ANC1 coverage was higher in the survey than the HMIS. We also identified PHCUs such as Yachi in Gomma that consistently had lower MCH service coverage in the HMIS. Some PHCUs, particularly in Seka Chekorsa, had HMIS coverage estimates over 100%, demonstrating data quality problems with either the estimated number of women attending these services or the official estimated number of pregnant women within these PHCU catchment areas. Coverage estimates for SBA and early PNC at the mother and newborn levels appear to be significantly higher in the HMIS than the survey in all PHCUs. The stillbirth rate was low in both the survey and HMIS. In PHCUs such as Sentemma and Wekito, a stillbirth rate of close to the null was obtained with the two data sources. Across all

PHCUs, Gembe PHCU and Yachi reported the highest rates of stillbirth in the survey with 2.3% and 1.9%, respectively. In Kersa, the majority of PHCUs reported slightly higher stillbirth rates in the HMIS compared to the survey. Finally, compared to the HMIS estimates, the cross-sectional survey reported a slightly higher prevalence of malaria infection during pregnancy in the three districts.

Most Pearson correlation coefficients suggested weak or moderate linear associations between HMIS and survey estimates in all three districts (**Table 2.6**). In Gomma, strong correlation coefficients of 0.81 and 0.72 were observed for SBA and early PNC at the newborn level, respectively. Malaria in pregnancy also showed a high level of correlation (R=0.86). Recognizing that correlation coefficients are not necessarily an ideal measure for assessing the concordance between two methods, we also calculated the ICC and determined values close to zero or even negative (**Table 2.6**). This demonstrated that the between-method variability and/or method error was significantly more important than the between-subject (or PHCU) variability. The HMIS and the survey thus seem to have obtained their coverage estimates from two completely different and separate populations, suggesting data quality issues in the HMIS.

Table 2.6 Pearson correlation coefficients and intraclass correlation coefficients for the relationship between HMIS and survey estimates

	Pearson correlation coefficients						
	ANC1	**ANC4**	**SBA**	**PNC (mothers)**	**PNC (newborns)**	**Stillbirth**	**Malaria in pregnancy**
Gomma	0.47	0.48	0.86	0.72	0.75	-0.29	
Seka Chekorsa	-0.58	-0.02	0.37	0.65	0.41	0.48	0.84
Kersa	-0.03	0.42	0.26	0.34	0.28	1.00	

Intraclass correlation coefficients							
Gomma	-0.02	0.17	0.26	0.15	0.02	-0.10	
Seka Chekorsa	-0.54	-0.01	0.03	0.03	0.02	0.15	0.01
Kersa	-0.03	0.24	0.04	-0.004	-0.01	-0.09	

Abbreviations: ANC1- antenatal care firs visit, ANC4 – antenatal care fourth visit, SBA – skilled birth attendance, PNC – postnatal care, DTP1 - Diphtheria, Tetanus and Pertussis first dose, DTP3 - Diphtheria, Tetanus and Pertussis third dose

Bland-Altman plots were subsequently generated to specifically identify MCH indicators and PHCUs that showed poor agreement. All plots can be found in the Appendix A. A summary of the main findings can be found in **Table 2.7**. We also created additional plots using cutoffs of ± 10% and ± 30%. **Table 2.8** specifies the PHCUs that reported levels of discordance greater than these two predefined limits. Malaria infection during pregnancy and stillbirth rates were not included in this table as reported discrepancies between the two methods of data collection in all PHCUs and districts were lower than ± 10% and ± 30%.

Summary of Bland-Altman Analyses

In Gomma, a negative systematic bias of 25.1% (95% CI: - 40.9, -20.7%) was observed for the proportion of women who attended the first ANC visit (ANC1), meaning that on average, ANC1 uptake estimates in the HMIS were lower than the ones obtained from the survey. Kedamess and Omo Gurude PHCUs were identified as potential outliers. In Kersa and Seka Chekorsa, no significant difference was observed between the ANC1 coverage estimate from the HMIS and the one from the survey, with median difference of -0.6% (95% CI: -51.2, 19.1%) and 1.7% (95% CI: -18.3, 41.3%), respectively. While the concordance between the two methods was good for ANC4 in Gomma and Kersa, poor agreement was observed in Seka Chekorsa (median

difference of 47.5% (95% CI: - 32.6, 73.5)). Beke Gudo, Geta Beka and Buyo Kechema PHCUs were identified as potential outliers.

In all three districts, a significant median difference was observed for SBA coverage. Gomma demonstrated a significant median difference of 21% (95% CI: 12.8, 29.4%), while a median difference of 63.7% (95% CI: 52.5, 79.8%) and 39.6% (95% CI: 20.1, 59.0%) were observed in Seka Chekorsa and Kersa, respectively. Similarly, the HMIS was on average reporting higher early PNC services uptake at the mother and newborn levels than the women who participated in the survey in the three districts.

Overall, a good agreement was observed in Gomma between the stillbirth rates reported in the HMIS and the ones from the survey, as shown by the line of equality being within the 95% confidence interval of the median (-0.5% (95% CI: -0.8, 0.4%)). Four out of the nine PHCUs had a difference within the limits of agreement. In Seka Chekorsa and Kersa, The discrepancy in stillbirth rate between the HMIS and the survey was low (median difference of 0% (95% CI: -0.7, 0.2%) for Seka Chekorsa and 0.1% (95% CI: -0.6, 0.7%) in Kersa. The difference in malaria infection rate during pregnancy was also low. No outliers were identified.

When assessing the level of agreement using pre-chosen limits, it was determined that seven out of nine PHCUs in Gomma reported a percentage difference of ± 10% for ANC1. All PHCU demonstrated a percentage difference greater than ± 10% for PNC both at the mother and newborn levels. Similarly, all PHCUs in Kersa and Seka Chekorsa reported PNC estimates at least 10% higher in the HMIS compared to the survey. The majority also reported HMIS coverage estimates that were at least 30% greater than the survey. The same pattern was also observed for SBA.

Table 2.7 Bland-Altman summary statistics for the agreement testing between HMIS and survey data for PHCUs within three districts of Jimma Zone

	Median difference (%) (95% CI)	95% limits of agreement (2.5^{th}, 97.5^{th} percentiles)	Potential Outliers
ANC1			
Gomma	-25.10 (-40.90, -20.70)	-65.60, -5.70	Kedamess, Omo Gurude
Kersa	-0.61 (-51.20, 19.11)	-51.20, 19.11	Kallacha and Wajo
Seka Chekorsa	1.71 (-18.31, 41.32)	-18.31, 41.32	Wokito, Beka
ANC4			
Gomma	-1.50 (-29.03, 8.10)	-32.91, 14.82	Gembe, Omo Gurude
Kersa	15.16 (-16.16, 30.76)	-16.16, 30.76	Kusaye
Seka Chekorsa	47.55 (-32.61, 73.48)	-19.61, 73.48	Kechema, Beka, Gude
SBA			
Gomma	-20.83 (12.80, 29.36)	-3.93, 31.64	Limu Shaye, Omo Gurude
Kersa	39.61 (20.11, 59.05)	20.11, 59.05	Wajo, Serbo
Seka Chekorsa	63.74 (52.56, 79.85)	36.24, 79.85	Beka, Wokito
PNC (mothers)			
Gomma	38.36 (29.37, 48.10)	9.40, 49.22	Limu Shaye, Kechene, Omo Gurude
Kersa	54.01 (20.83, 67.17)	20.83, 67.17	Wajo, Kusaye
Seka Chekorsa	72.54 (68.12, 89.68)	60.71, 69.68	Beka, Gudo, Wekito
PNC (newborns)			
Gomma	44.93 (15.23, 53.16)	15.23, 53.73	Kechene, Omo Gurude

Kersa	55.26 (19.5, 68.08)	19.50, 68.08	Kusaye, Kallacha
Seka Chekorsa	75.09 (67.43, 93.72)	62.34, 93.72	Beka, Kechema, Wekito
Stillbirth Rate			
Gomma	-0.55 (-0.83, 0.46)	-2.01, 0.57	Kedamess
Kersa	0.15 (-0.67, 0.70)	-0.67, 0.70	Bulbul, Kallacha
Seka Chekorsa	0.00 (-0.75, 0.16)	-0.75, 0.16	Seka, Beka
Malaria in Pregnancy	-1.42 (-1.98, -0.81)	-1.98, -0.81	

Abbreviations: ANC1- antenatal care firs visit, ANC4 – antenatal care fourth visit, SBA – skilled birth attendance, PNC – postnatal care, DTP1 - Diphtheria, Tetanus and Pertussis first dose, DTP3 - Diphtheria, Tetanus and Pertussis third dose, CI – confidence interval

Table 2.8 Bland-Altman outliers identified in the agreement analysis between HMIS and survey data within the three districts using pre-defined limits

	Potential Outliers (±10%)	Potential Outliers (±30%)
ANC1		
Gomma	Beshasha, Chami Chago, Choche, Kechene, Limu Shaye, Gembe, Omo Gurude	Beshasha, Kechene, Omo Gurude
Kersa	Bale Wajo, Kara Gora, Kallacha	Kara Gora, Kallacha
Seka Chekorsa	Buyo Kechema, Detu, Geta Beka, Lilu Chaa, Wekito	Geta Beka
ANC4		
Gomma	Beshasha, Omo Gurude, Gembe	Omo Gurude
Kersa	Bale Wajo, Bulbul, Kallacha, Kara Gora, Kusaye Beru, Serbo	Kusaye Beru
Seka Chekorsa	All PHCUs	Geta Beka, Detu Kersu, Buyo Kechema, Lilu Chaa, Seka, Sentemaa, Wekito
SBA		
Gomma	Beshasha, Chami Chago, Choche, Kechene, Gembe, Kedamess, Limu Shaye, Yachi	Limu Shaye

Kersa	All PHCUs	Adere Dika, Bale Wajo, Bulbul, Kara Gora, Kusaye Beru
Seka Chekorsa	All PHCUs	All PHCUs
PNC (mothers)		
Gomma	All PHCUs	Beshasha, Chami Chago, Kechene, Gembe, Limu Shaye, Yachi
Kersa	All PHCUs	Adere Dika, Bale Wajo, Bulbul, Kara Gora, Kusaye Beru
Seka Chekorsa	All PHCUs	All PHCUs
PNC (newborns)		
Gomma	All PHCUs	Beshasha, Chami Chago, Choche, Kechene, Gembe, Kedamess, Limu Shaye, Yachi
Kersa	All PHCUs	Adere Dika, Bale Wajo, Bulbul, Kara Gora, Kusaye Beru
Seka Chekorsa	All PHCUs	All PHCUs

Abbreviations: ANC1- antenatal care firs visit, ANC4 – antenatal care fourth visit, SBA – skilled birth attendance, PNC – postnatal care, DTP1 - Diphtheria, Tetanus and Pertussis first dose, DTP3 - Diphtheria, Tetanus and Pertussis third dose, CI – confidence interval

Discussion

1. Key Findings: Summary and Interpretation

Through the use of an established data quality assessment tool developed by the WHO, we found several issues related to the quality of MCH indicator data collected within the HMIS at the Jimma Zone level. Many PHCUs failed to report to their respective district health office complete and timely reports that reflected the monthly utilization of their MCH services. The observed rates of reporting completeness and timeliness in all districts were lower than the 90% limit sets by the FMoH.[10] Not sending their reports and thus MCH coverage estimates to the next reporting level may indicate that the district health offices only received a partial and incomplete representation of the MCH services provided in their PHCUs. This could have important implications for the health of pregnant women and newborns living in these districts, as information reported by the PHCUs is used by the district health offices to guide future plans and inform accomplishments.[7] Reports that were forwarded to the district health office level displayed, however, few missing or zero values.

Similar challenges with the completeness and timeliness of reporting have been evidenced in other studies.[10,41] Gebrekidan et al., for instance, found in their data quality assessment performed in PHCUs from a total of 17 districts across six regions of Ethiopia that service delivery sites had completeness and timeliness rates of 76% and 67%, respectively.[10]Alternatively, an assessment of HMIS data reporting conducted in Addis Ababa showed completeness rate of 100%, while another conducted in Gurage Zone found that approximately 87% PHCUs had a reporting completeness rate of more than 90%.[42,43] The difference between our results and the ones obtained in Addis Ababa and Gurage Zone studies may be explained by the fact that these studies

performed semi-structured interviews with health workers from selected health posts or health centres, which may have been less inclined to indicate poor reporting, which is a theory that has been previously supported.[44]

We also determined issues related to the internal consistency of MCH coverage estimates over time. PNC indicator showed substantial increases over time across the three districts, which may have either represented a real increase in its coverage or data quality issues. When comparing PNC coverage estimates to the 2014-2015 time period estimates, more reasonable increases in coverage over time were observed. This may suggest that PHCUs were under-reporting or not reporting at all their PNC service estimates in the year 2013-2014 and that an improvement has been happening over the last years. Nonetheless, as shown in our agreement analysis, PNC estimates from the HMIS may still be over-reported and thus not reflective of what is the reality in the communities.

Large discrepancies were observed between the official and alternate denominators, with the denominator found in the HMIS generally estimating a higher number of pregnant women in each PHCU catchment area. This finding is in contradiction with the agreement analysis, which suggested that the HMIS over-reports the coverage estimates of MCH indicators. As per the WHO's DQRC, calculations of robust alternate denominators should only be planned when we are confident that the numerator or total number of women attending ANC1 found in the HMIS is accurate.[31] To quantify the discrepancy between the two denominators, the official denominator should also be as accurate as possible.[31] Yet, some PHCUs reported coverage rates for indicators like ANC, SBA, and PNC of over 100%, which is indicative of an inaccurate numerator and/or denominator. As the official denominators for all rural communities are obtained by applying a regional-level conversion factor developed by the FMoH (e.g. conversion factor of 4% for

Oromia region) to population estimates from the most recent census in 2007, we cannot guarantee that the assumptions for calculating the discrepancy between the two denominators are met. We would therefore be cautious about interpreting and making any inferences from this assessment. A more effective way to assess the consistency of denominators may be to compare HMIS denominators with population projections from different reliable sources.[34] Yet, the availability of disaggregated population-based estimates remains limited. The new census, which will be completed in February 2018, may also help to improve the accuracy of future HMIS denominators.

Finally, we found disagreement between the HMIS data and the MCH coverage estimates from the community-based cross-sectional survey, and concluded that ANC, SBA and PNC were the MCH indicators that suggested higher over-reporting in the HMIS across all three districts,, while stillbirth and malaria in pregnancy rates were the least over-reported indicators. While limitations associated with the survey may have caused an under-estimation of the coverage estimates, the findings from the project corroborate with the ones from a national evaluation conducted in 2016. In this report, it was identified that over-reporting of ANC in the HMIS was important, with 43% of PHCUs in Oromia region over-reporting ANC attendance by 10% or more.[24] Both under- and over-reporting of health facility delivery data were also observed.[24] Over-representing the proportion of women attending these services may have a significant impact on women's health outcomes. As they are not actually attending these services, resources may not be going towards improving their access to these health care services. Evidence has also shown that women who attend these services are more inclined to seek health services and the essential vaccinations such as DTP vaccine for their newborns.[31] Babies who receive all their DTP vaccination doses are also more likely to be up-to-date on all their other vaccines.[31]

Improving the quality of MCH coverage estimates as well as identifying and addressing the barriers to the access of these services is thus critically needed to improve MCH.

2. Strengths and Limitations

There are several limitations that constrained the findings of this study. First, we did not perform an exhaustive assessment of MCH indicators collected in the HMIS. Important indicators related to the use of family planning methods or to the PMTCT of HIV were not considered due to time constraints, despite the fact that they represent important data within PHCUs' service reports.[7] Nonetheless, this evaluation was conducted using an established data quality tool recommended by the WHO and appropriate statistical methods. Indeed, we used Bland and Altman plots with nonparametric tests and compared our results with less adequate measures of agreement such as Pearson correlation coefficients. We also considered several dimensions of data quality, which provides a general overview of the quality of MCH indicators in Jimma Zone.

Determining the consistency between information contained in source documents (i.e. health facilities tallies and registers) and the information reported in the HMIS was also beyond the scope of this project but would have still been important to assess. Past work conducted in other areas of Ethiopia highlighted that this may represent an important problem, with PHCUs inaccurately reporting their indicator estimates in the HMIS.[10,24,41,45]

Our study is also limited by the fact that we did not consider private health facilities in our assessments. This was mainly due to time constraints, but also by the fact that studies have demonstrated that private health facilities are less likely to provide the common MCH services to their respective district health office.[7] They also have a tendency to report infrequently their services. We therefore believe that focusing on evaluating the quality of MCH services data

provided in governmental health facilities gives an adequate assessment of the quality of MCH data in Jimma Zone.

Another strength was the use of data from a large household-based cross-sectional survey that recruited women attending the PHCUs of interest to perform the agreement analysis. Yet, women that did not report attending one of the recruited PHCUs were excluded. These participants represented roughly 2.5% of the total study population. We however anticipate that inclusion of these participants would not have substantially changed the MCH coverage estimates. Moreover, we were not able to assess the concordance between the two data sources in two PHCUs (i.e. Meti Koticha in Gomma district and Babo Yaya in Seka Chekorsa), as women attending these health facilities were not recruited.

Self-reporting bias is a possibility that should not be excluded. This may have impacted the coverage estimates obtained in the cross-sectional survey and thus the conclusions made from the agreement analysis. Given the survey eligibility criteria (i.e. women who experienced a pregnancy in the year preceding the survey), the chances of recall bias may have been limited. Interviewer bias may also have occurred although comprehensive training of and field sessions with the recruited interviewers were conducted prior to the actual survey to ensure full understanding and knowledge of the survey. Again, the multiple sources of bias may have resulted in negligible variations in the MCH coverage rates.

3. Implications of Findings

Data from the HMIS in Ethiopia have been previously identified as inaccurate and unreliable.[10,24,29] This can jeopardize the FMoH's and other administrative offices' ability to make decisions that will meaningfully impact communities' health outcomes.[18,46] Even though

there has been a revision of HMIS indicators in 2006 to better support health services, high data quality remains a challenge, as reported in the Ethiopian National Health Care Quality Strategy 2016 report.[47]

Due to resource constraints, it has been challenging for the FMoH to enhance the functionality of the HMIS, especially in health centres and health posts. In 2013, nearly all public hospitals had implemented the HMIS (98%), compared to 87% of health centres.[47] Yet, implementation in health facilities did not necessarily translate into a high data quality or an appropriate utilization of data by health workers and HMIS staff. Recognizing that the HMIS represents the core information needed to inform effective health care system delivery, the scaling up of the HMIS across all PHCUs by 2020 has become a top priority for the FMoH.[47]

Another important target for the FMoH has been to significantly improve maternal, neonatal and child health by 2020, in part through the improvement of access to the essential preventive and curative services for both women and newborns.[47] Along with other data sources such as the Ethiopian Demographic Health Survey (EDHS), information from the HMIS is frequently used to inform on MCH progress and guide research studies and interventions.

Despite acknowledgment of these two priority health areas, minimal evidence can be found on the evaluation of the quality of MCH indicators collected in the Ethiopian FMoH's HMIS with the purpose of determining their appropriateness to inform how pregnant women and newborns access the available health services. To our knowledge, this study was the first study to have focused on conducting a comprehensive quantitative evaluation of the quality of MCH data in Jimma Zone, Ethiopia. Past research has mainly focused on the utilization of HMIS data across all levels of the health system, through qualitative assessments or cross-sectional surveys with

HEW and/or heads of district or zonal health offices. Our findings have therefore not only highlighted some of the issues present in the HMIS at the Jimma Zone level but also stressed the importance of regular data quality assessment within PHCUs and district health offices. Furthermore, the methodology used and findings may assist other researchers in performing an assessment of their HMIS or in designing future observational and intervention studies to improve the quality of MCH services in Jimma Zone.

4. Recommendations for Health Workers and Researchers

It would be essential for those PHCUs with higher quality data to maintain their current level of quality and, importantly, to serve as examples for other PHCUs. In other words, HEWs and supervisors from these high-performing PHCUs could assist other PHCUs that demonstrated unsatisfactory levels of data quality, through reports and meetings. The 2016 Ethiopian National Health Care Quality Strategy report recommended to frequently organize events, workshops or "health summits" that will gather all stakeholders involved in the management and utilization of HMIS to engage them in discussion on the role played by the HMIS within their community as well as their accomplishments and strategies to improve the quality of HMIS data.[47]

The reasons for or determinants of poor or over-reporting in PHCUs were beyond the scope of this project, although it would have been interesting to identify them. In PHCUs that reported frequent data quality issues, qualitative assessments (i.e. focus group discussions, in-depth interviews) with health workers and facility in-charges may allow understanding the contributing factors of poor data quality. It is now well acknowledged that large proportions of health workers still remain unaware of the importance of adequate data collection and use, which can impact the quality of HMIS data.[26,48,49] This has been attributed to the lack or inadequacy of training

provided to the health workers and the absence of feedback from PHCU supervisors or district health office heads.[49] The importance of fully training the individuals collecting and managing the HMIS at the lower levels of the health system cannot be stressed enough. Identifying a focal person in each PHCU, responsible for the daily management of HMIS data may be a solution.[50,51] In Ethiopia, many PHCUs have a focal person, as described by Mesfin et al[10]; however, they often lack the appropriate training to ensure their daily tasks.[42]

Continuous data quality assessments have also been shown in numerous studies to improve the consistency and accuracy of health events reporting. Through continuous data quality self-assessment and basic training on the utilization of data, a specific district in Uganda was able to improve the timeliness of HMIS reports from 61% to 100% and accuracy from 20 to 51%.[52] The trained health workers were also able to discover that the proportions of children who were getting their DTP1 and DTP3 vaccine doses were twice as low as what was reported in the HMIS.[52] Building the capacity of health workers in HMIS data collection, management and utilization has also been demonstrated in other context to be important to ensure high data quality. [11,49,53] Simba and Mwangu in Tanzania found that, regardless of the duration, training and supervision did not influence the quality of HMIS data.[50] This study further raised the importance of implementing strategies that would allow measuring and monitoring the quality of the supervision provided to health workers. As of now, the only way to get a sense of the quality of supervision is verbally or through reports filed by the supervisor in which he or she specifies the number of visits made to that health facility along with his or her comments. It would therefore be essential to not only provide regular interactive training sessions to health workers on the structure of and indicators collected within the HMIS but also on how to conduct frequent data

quality assessments within their PHCUs. Methods are also needed to monitor supervisors' visits and feedback provided to health facilities.

In an effort to assure data quality, some health facilities in Ethiopia have put in place performance monitoring teams, which have been trained in using the Lots Quality Assurance Sampling (LQAS) approach, a quick and reliable technique for comparing the correspondence between data reported in the HMIS and data recorded in registers and patient records.[47] Should the reports be found to be inconsistent, health workers are required to forward another report to the district health office. There, the supervisors repeat the analysis to corroborate the results. Given the LQAS' appropriateness in resource-limited settings, optimizing the utilization of the LQAS among the health workers would be required. With the extended access to the web-based HMIS version in PHCUs, doctors and nurses are now able to enter their data directly within the HMIS and could possibly be instructed to check for accuracy prior entering it in the system. Although they are also required to forward a soft copy to the district health offices, many do not.[26] Supervisors could thus also make sure during their regular visits to PHCUs that health workers not only enter correctly the data in the HMIS but also send a copy of their monthly report to their district health office.

One last point worth noting is that most developing countries including Ethiopia initially had a HMIS with a "top-down" approach when it comes to setting and planning health targets.[7,11] A shift from this concept towards a focus on data use at all levels of the health system is necessary to ensure an improvement of the quality and use of HMIS data. While acknowledging that additional barriers exist and may prevent HEWs from collecting and using MCH data effectively, there may be a need to improve HEWs awareness on the role that they could play in not only collecting the information to forward to the next level, but also in identifying and using indicators

that highlight and address the special health needs of their pregnant women, newborns, and community.

Conclusions

Even though this project did not perform an exhaustive data quality evaluation of all MCH indicators found in the HMIS, we have highlighted certain PHCUs and districts in Jimma Zone that reported MCH indicators incompletely, inconsistently and incorrectly. By comparing the MCH coverage estimates from the HMIS to external data derived from a community based cross-sectional survey, we further highlighted the potential extent of over-reporting within the HMIS.

Planning national and sub-national health budgets that will address communities' health problems and needs more effectively and efficiently requires high quality health data. We hope that the results of this project may not only allow the identification of strategies to encourage HMIS workers to closely evaluate the quality of their HMIS by performing frequent data quality audits but also inform future data quality improvement interventions both at PHCU and district levels.

Past qualitative studies have shown the absence of a culture of information utilization among health workers, which mainly impacts the quality of health data. Although other interventions may be considered, there might be a need to increase the awareness of HEWs on the importance of collecting accurate and valid indicators so that they can be effectively use to inform decision-making that will meaningfully inform and impact MCH outcomes within their community. Health workers might appreciate receiving refresher trainings on HMIS and additional training on basic and quick data quality assessment using tools such as the one used in

this project (i.e. DQRC) or the LQAS technique. Trainings on the use of their health facility's data through summary tables and basic plots could also be considered. Continuous feedback from PHCU and district health office supervisors is finally recommended to improve the completeness and timeliness of reporting and accuracy of MCH data.

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Bridge to chapter 3

In the first manuscript, we identified some of the issues relating to the quality of several key maternal and child health (MCH) indicators in terms of completeness, timeliness, and internal and external consistency. By comparing MCH coverage estimates from the health management information system (HMIS) to the ones derived from a cross-sectional survey conducted with 3,784 women who had a birth outcome within the same time frame, we further highlighted the extent of over-reporting in the HMIS for antenatal care (ANC), skilled birth attendance, and postnatal care. In addition to discussing the implications of this assessment and establishing the strengths and limitations associated with the data quality assessment tool, we made a series of recommendations for health extension workers (HEWs), HMIS supervisors, and researchers to improve the quality of MCH data in the HMIS.

In the following manuscript, we will explore the level and determinants of ANC attendance and insecticide-treated nets (ITNs) ownership and use, and the prevalence of malaria in pregnancy in three districts of Jimma Zone. Through this work, we provide additional evidence on the determinants of ANC utilization and ITNs ownership and utilization, which could be used to guide future Health Extension Program initiatives for MCH by identifying women who are less likely to use ANC and own and use an ITN.

Chapter 3 (Manuscript 2): Utilization of Key Preventive Measures for Pregnancy Complications and Malaria Among Women in Jimma Zone, Ethiopia

Preface to Manuscript 2

This second manuscript adds to the limited literature that can be found on the level and determinants of ANC attendance, the ownership and use of insecticide-treated nets for the prevention of malaria in pregnancy, and the prevalence of malaria in pregnancy in Jimma Zone, Southwest Ethiopia. Data from a large cross-sectional survey performed with a total of 3,784 women living in three districts of Jimma Zone (i.e. Gomma, Kersa, and Seka Chekorsa) were used. Ethics approval was sought from the Research Ethics and Integrity Board at the University of Ottawa (#H10-15-25C). Certificate of ethical approval is provided in Appendix B. Precision and power calculations were performed prior to the analysis to determine whether the fixed sample size of 3,840 women was large enough to address the research objectives. A summary can be found in Appendix C. SAS codes for the logistic regression modeling are presented in Appendix D.

Dr. Manisha Kulkarni and Mariame O. Ouedraogo conceived the project. Mariame O. Ouedraogo performed all data preparation and analysis and wrote the manuscript. Dr. Marie-Hélène Roy-Gagnon assisted with the development of the analysis plan and provided guidance on the methodological and statistical aspects. Drs. Manisha Kulkarni, Marie-Hélène Roy-Gagnon, and Beth Potter assisted with interpreting the results and editing the manuscript. All other co-authors are investigators involved in the large cluster-randomized trial and provided guidance and feedback when needed.

Utilization of Key Preventive Measures for Pregnancy Complications and Malaria Among Women in Jimma Zone, Ethiopia

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Abstract

Background: When well implemented, antenatal care (ANC) can save lives by allowing women to receive health education, counseling and screening for pregnancy complications. ANC also plays a role in the access to insecticide-treated nets (ITNs) and messaging on malaria prevention and treatment. Malaria in pregnancy remains a major public health concern that can possibly result in adverse health outcomes in pregnant women and their infants. In Ethiopia, minimal research has been done to investigate the determinants of ANC and ITN use and the prevalence and predictors of malaria infection among pregnant women.

Objectives: We aimed to assess the level and determinants of ANC attendance, mosquito net ownership and use, and malaria in pregnancy in three districts of Jimma Zone, Ethiopia.

Methods: Data for this study were obtained from a cross-sectional survey conducted in Jimma Zone, Ethiopia with a total of 3,784 women who gave birth in the year preceding the survey. Information was collected on socio-demographic factors, ANC attendance, the possession and utilization of mosquito nets, malaria infection during last pregnancy and various attitudes and practices associated with safe motherhood. Multiple logistic regression models accounting for clustering at the health centre level were used to examine the relationships of interest.

Results: Eighty-five percent of the participants reported having at least one ANC visit, compared to 43% that attended four or more visits. Lack of necessity (48%), distance to health facility (23%) and unavailability of transportation (14%) were determined as key reasons for not attending ANC. The major factors associated with ANC attendance were education, wealth status, media exposure, contact with a health extension worker, the ability to make decisions regarding healthcare, and the intendedness of the last pregnancy. An estimated 52% of women reported owning an ITN during their last pregnancy. Of these, 55% reported to have always slept under it. Women who attended at least one ANC visit showed higher odds of owning and always sleeping under an ITN when compared to women who did not attend ANC (OR=1.98 (95% CI: 1.55-2.53) and OR=1.62 (95% CI: 1.23 – 2.13) respectively).The self-reported prevalence of malaria infection during pregnancy among the participants was low with a value of 1.4%. High maternal age, low education level, and the type of occupation were found to be important predictors of malaria infection in pregnancy.

Conclusion: ANC and ITN uptake during pregnancy remain relatively low in Jimma Zone, suggesting that research efforts still need to be directed towards improving access to these health services. Reaching ANC non-users and promoting ITN ownership and use as part of ANC services could be emphasized to address these gaps.

Introduction

Despite the known crucial role of antenatal care (ANC) for the detection and management of obstetric complications and promotion of health behaviours during and after pregnancy, ANC services in Ethiopia remain underexploited. As shown in the 2016 Ethiopian Demographic Health Survey (EDHS), there has been an increase in the coverage of ANC from 27% of women receiving any ANC in 2000 to 62% in 2016.[1] However, only 32% of the women had four or more ANC visits in 2016.[1] This is consistent with other work that demonstrated that less than 50% of the women attended four ANC check-ups.[2–4] While it is recommended that women attend ANC during their first trimester, existing evidence also indicates that Ethiopian women tend to initiate their first ANC visit later in their pregnancy[5–7], with a median time of first contact of 4.8 and 5.5 months in urban and rural women, respectively.[5]

Few studies have focused on assessing the different barriers to and determinants of ANC attendance in Ethiopia. We can cite, among others, the study conducted by Yesuf and Calderib-Margalit, looking at trends in ANC usage over a period of 15 years in Ethiopia.[8] Through their nationally representative sample, they found that the odds of ANC use were higher in women who lived in urban areas, had completed secondary or higher education, and were from the richest households, which was defined as possessing various utilities and durable assets.[8] Gebremeskel et al. in Arba Minch Town, southwest Ethiopia, determined that women who were more likely to delay their first ANC visit had a lower monthly income, did not receive any advice on when and where to get their ANC, lived in a household where food insecurity existed and did not intend their pregnancy.[5] In addition to the determinants found above, according to Abosse et al., women whose husband had a positive attitude towards ANC and who lived in household with few children (e.g. less than three children) were more willing to seek ANC.[2] Mekonnen &

Mekonnen also indicated that primiparous women tended to use ANC services more often than women who had more than one child.[9] They also showed that religion could influence ANC utilization. Women who were Muslim, Orthodox or Protestant were more likely to use ANC compared to women who had traditional beliefs.[9] On the other hand, Kifle et al. found that Muslim women were less likely to seek ANC and other maternal health services.[10]

In Jimma Zone, less evidence on the coverage and socio-demographic factors influencing the use of ANC can be found. It was determined in 2006 that the coverage of ANC was roughly 76% in Jimma town.[4] Literacy level, income, gravidity, religion and occupation status were found to be significant determinants of the use of ANC services.[4] Only 6.5% of survey participants attended four visits. In a more recent work, Villadsen et al. found that 60% of the selected women attended their first ANC in the second trimester and close to 44% of them received more than four visits.[11] Women who were from the rural surroundings of Jimma City were also more likely to be unsatisfied about the quality of the ANC services offered within their closest health centre compared to women who attended a health facility in Jimma Town.[11]

In addition to being a cornerstone in the prevention and recognition of pregnancy complications, ANC represents an important opportunity for the diagnosis, management and control of infections, namely, tuberculosis, human immune virus/acquired immune deficiency syndrome (HIV/AIDS), and other sexually transmitted infections.[12] Through ANC services, information on the available preventive measures along with proper diagnosis and treatment of malaria is also offered to pregnant women.[13]

Although the risk of adverse MCH outcomes is known to be higher in expecting mothers infected with malaria, pregnant women in Ethiopia constitute a small proportion of the total

number of malaria patients, accounting for 1.7% and 2.9% of all outpatient and inpatient malaria cases, respectively.[14] The malaria parasitemia in pregnant women in Ethiopia is known to range from 7.1% to 2.3%, depending on whether stable and unstable endemicity areas are considered.[15] Comparably, the prevalence of placental malaria is estimated at 6.5 % and 2.5% in areas of relatively high and low transmission, respectively.[15] On the basis of these circumstances, unlike many countries, intermittent preventive treatment in pregnancy (IPTp) is not included in the Ethiopia national malaria prevention and control strategy.[14]

Insecticide-treated nets (ITNs) and indoor residual spraying (IRS) therefore represent the only malaria prevention tools for pregnant women. A great amount of effort has thus been going towards improving access to ITNs and encouraging their use by pregnant women.[14] In addition to pregnant women and mothers being targeted and prioritized during mass ITN distributions campaigns, ANC health workers are requested to distribute an ITN to every pregnant woman attending a visit.[14,16] ANC workers such as health extension workers (HEWs) and nurses are also expected to engage in a discussion about bed net possession and use at all visits, and the effects that malaria can have on their pregnancy.[16] Women who do not attend ANC may therefore be at a greater risk of malaria, placental malaria, and their associated consequences, given their limited access to ITNs and information regarding the relationship between malaria and adverse obstetric complications.

Few studies have assessed variations in the coverage of ITNs by ANC attendance in sub-Saharan Africa. It was highlighted in a Nigerian study that attendance to ANC was significantly associated with ownership of bed nets.[17] Conversely, no difference in the use of mosquito nets was observed among women who received ANC and those who did not.[17] Another study performed in Gabon identified that bed net coverage did not differ according to the number of

ANC visits and was not associated with ANC attendance.[18] The lack of relationship was attributed to poor bed net availabilities within health facilities, and the absence of routine ITN distribution to pregnant women on their first visit.[18] To our knowledge, no published evidence is available on the link between ANC attendance and use of ITNs in pregnant women in Ethiopia.

Recent evidence suggests that the ownership and utilization of ITNs among pregnant women is also inadequate. The 2015 Ethiopian National Malaria Indicator Survey indicated that 63% of households had at least one ITN. Forty-four percent of the pregnant women reported sleeping under an ITN at night.[14] Birhanu et al. recently assessed the access to and use of ITNs among households in the southwest of Ethiopia and noticed a wide gap between ownership of nets and actual use.[19] Although knowledge of mosquitoes and malaria was relatively high, nearly half of the households did not have access to ITNs, and ownership did not translate necessarily into use by the population. In this study, only 38% of the recruited household heads reported sleeping under an ITN the night before.[19] Belay & Deressa, through their study assessing the use of ITNs by pregnant women in a rural community in Northern Ethiopia, found higher ITN ownership and utilization estimates.[20] Fifty-nine percent of pregnant women stated that their household had at least one ITN. Conversely, Woyessa et al. found that the proportion of households that owned a mosquito net in Butajira areas was less than a quarter.[21] Through this study, the authors also highlighted that the ownership of ITNs varied with the altitude considered. Households located at a low altitude (where malaria transmission is generally more intense) were more likely to possess a mosquito net (54%) than households found in high altitude areas.[21] An overall ITN utilization rate of 83% was estimated among households that owned a bed net. Compared to other studies, Watiro and Awoke found in Gambella region higher rate of ownership of at least one ITN with a proportion of 82%.[22] This may be explained by the fact that

this region is considered a high malaria transmission site.[14,15] Roughly 51% of the pregnant women slept under a mosquito net.

To attain better maternal health outcomes, it is essential to clarify how pregnant women use ANC and ITNs. Furthermore, knowing the impact that malaria could have on the health of both a pregnant woman and her baby, it is not only critical to determine the malaria infection rate in pregnant women but also to assess the various factors related to increased rate of malaria infections during pregnancy. Therefore, in this study we aimed to **(1)** assess the level and determinants of ANC attendance as well as mosquito net access and use within three of Jimma Zone's districts and **(2)** examine the relationship between mosquito net ownership and use, and self-reported malaria infection in pregnant women.

Methods

1. Study Setting

This study was conducted in three *Woredas or* districts of Jimma Zone (i.e. Gomma, Kersa and, Seka Chekorsa), which is situated in Oromia region, approximately seven hours from Ethiopia's capital Addis Ababa. Oromiya was identified as one of the regions in Ethiopia where more moderate progress in the utilization of essential MCH services has been observed.[23] As reported in the National Strategic Plan for Malaria Prevention Control and Elimination in Ethiopia, this region also has one of the smallest percentages of pregnant women who reported the use of bed nets.[16] The primary malaria species of epidemiological importance in Ethiopia are *Plasmodium falciparum* and *Plasmodium vivax*, explaining approximately 70% and 30% of the malaria cases, respectively.[14] The risk of malaria infection depends on the altitude with, the

greatest risk being below 2000 metres.[14] In Gomma district, the altitude varies between 1380 meters and 1680 metres, compared to 1740 and 2660 metres in Kersa district.[19] Similarly, altitude in Seka Chekorsa is ranging from 1580 to 2560 metres. The three chosen areas have similar climatic conditions, with a main rainy season occurring from June to August.[19] A short rainy season is also observable in February and March.[19] The incidence of malaria infection is typically greatest during both the rainy seasons while lower infection is observed during the rest of the year.[14]

2. Data Sources

A baseline community-based cross-sectional survey was conducted as part of a larger cluster-randomized controlled trial[2] between October 2016 and January 2017, and secondary data from the survey were analyzed for the purposes of this study. Only women who had a birth outcome (i.e.live birth, stillbirth, spontaneous or assisted abortion or miscarriage) in the year preceding the survey were eligible to participate. After confirming the eligibility of women through a listing exercise conducted by study staff, HEWs, village leaders and members of the health development army, a two-stage sampling strategy was used. Twenty-four primary health care units (PHCUs) or clusters were first randomly selected from the 26 available in the three study districts. From each PHCU catchment area, approximately 160 eligible women were then randomly selected. Thus, a final total sample size of 3,840 was selected.

[2] This project is aiming at recognizing and addressing the barriers to safe motherhood options. It represents a collaboration between the University of Ottawa, Jimma University with funding received from the Canadian Institutes of Health Research (CIHR), International Development Research Centre (IDRC) and Global Affairs Canada through the Innovating for Maternal and Child Health Initiative

The questionnaire was administered face-to-face at participants' household by trained, local interviewers in the local languages and carried out using Samsung Galaxy Tab 4 tablet computers. When no woman was available for the interview on the first attempt, the household was revisited on a later date. If no respondent was available after two attempts, the household was excluded and not replaced by another. Cross-sectional data collected were synchronized into Open Data Kit and exported as CSV files for data management and analysis.

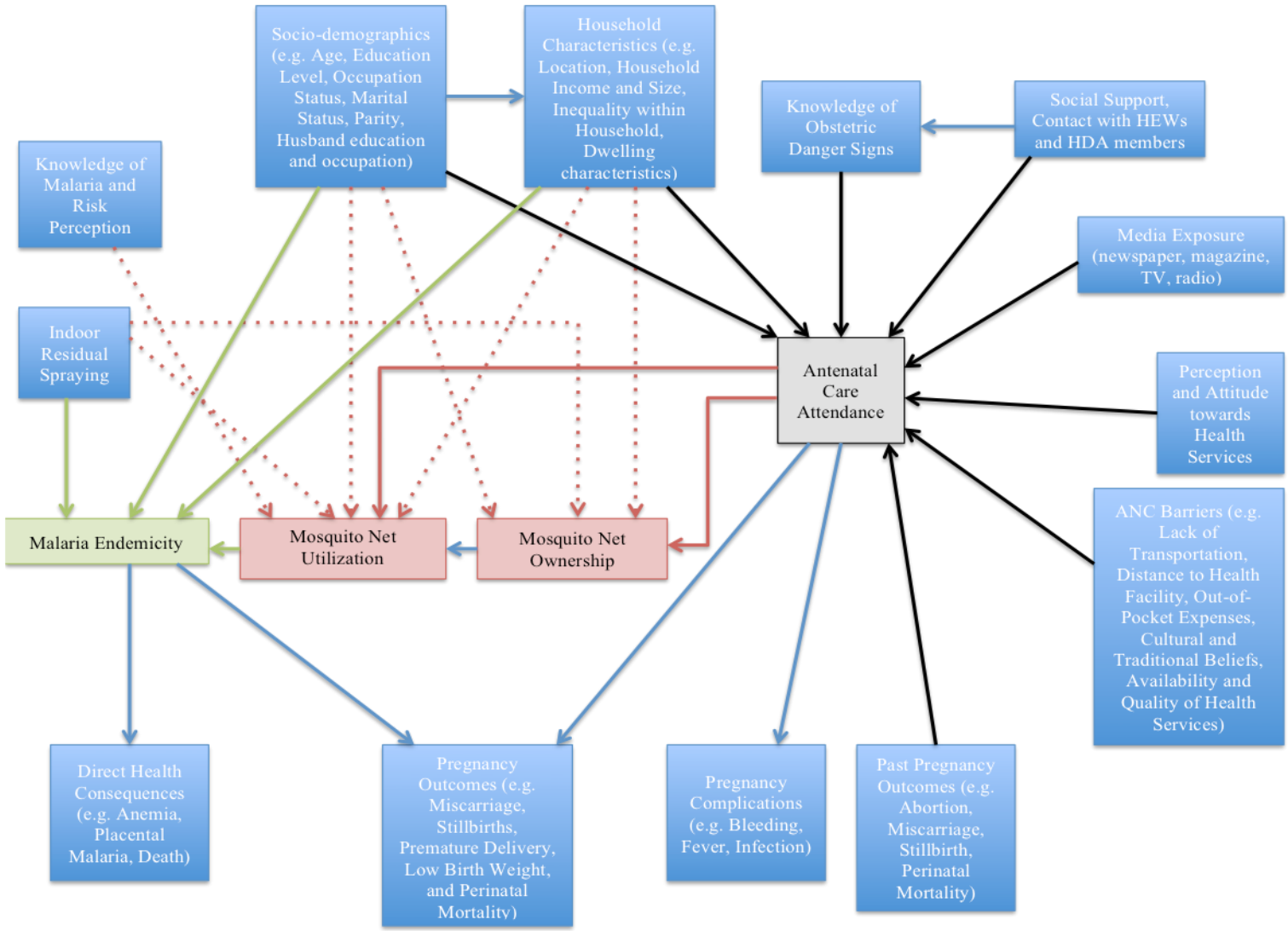
3. Study Variables

Survey questions ascertained socio-demographic characteristics of the study participants in the three districts. Amongst other questions, participants were asked about their age, ethnic group, matrimonial status, education level, and employment status. Household characteristics and data on the participants' reproductive history were also determined.

To assess ANC attendance, women were asked whether they attended ANC during their last pregnancy and how many times they visited a health facility for ANC. Participants who reported not attending ANC were asked the reasons for not attending. Knowing that various social, economic and service availability factors can influence attendance of ANC, we considered the conceptual framework presented in **Figure 3.1** to guide the selection and analysis of potential predictors. Age (15-18, 19-24, 25-34, 35-49), marital status (not married, married), ethnic group (Oromo, Amhara, other), employment status (not employed, self-employed, employed), level of education (no education, primary, secondary, higher), household's wealth (poorest, poorer, middle, richer, richest), whether or not the husband makes the decisions about health care, history of adverse reproductive outcomes (i.e. total number of miscarriage, stillbirths, and neonatal death), and whether the last pregnancy was intended were considered as predictor variables.

In order to determine mosquito net ownership and utilization among our recruited sample, women were asked whether their household owned any mosquito nets during their last pregnancy and how frequently they slept under a mosquito net during their last pregnancy. ANC attendance (no attendance, at least one visit) was considered the main predictor of mosquito net ownership and utilization.

Through the household survey, women were also asked to report whether they suffered from malaria during their last pregnancy. Socio-demographic factors, utilization of mosquito net during pregnancy, and IRS were evaluated for potential association with malaria infection, as described in the conceptual framework (**Figure 3.1**).


Socio-demographics (e.g. Age, Education Level, Occupation Status, Marital Status, Parity, Husband education and occupation)
Household Characteristics (e.g. Location, Household Income and Size, Inequality within Household, Dwelling characteristics)
Knowledge of Obstetric Danger Signs
Social Support, Contact with HEWs and HDA members
Knowledge of Malaria and Risk Perception
Media Exposure (newspaper, magazine, TV, radio)
Indoor Residual Spraying
Antenatal Care Attendance
Perception and Attitude towards Health Services
Malaria Endemicity
Mosquito Net Utilization
Mosquito Net Ownership
ANC Barriers (e.g. Lack of Transportation, Distance to Health Facility, Out-of-Pocket Expenses, Cultural and Traditional Beliefs, Availability and Quality of Health Services)
Direct Health Consequences (e.g. Anemia, Placental Malaria, Death)
Pregnancy Outcomes (e.g. Miscarriage, Stillbirths, Premature Delivery, Low Birth Weight, and Perinatal Mortality)
Pregnancy Complications (e.g. Bleeding, Fever, Infection)
Past Pregnancy Outcomes (e.g. Abortion, Miscarriage, Stillbirth, Perinatal Mortality)

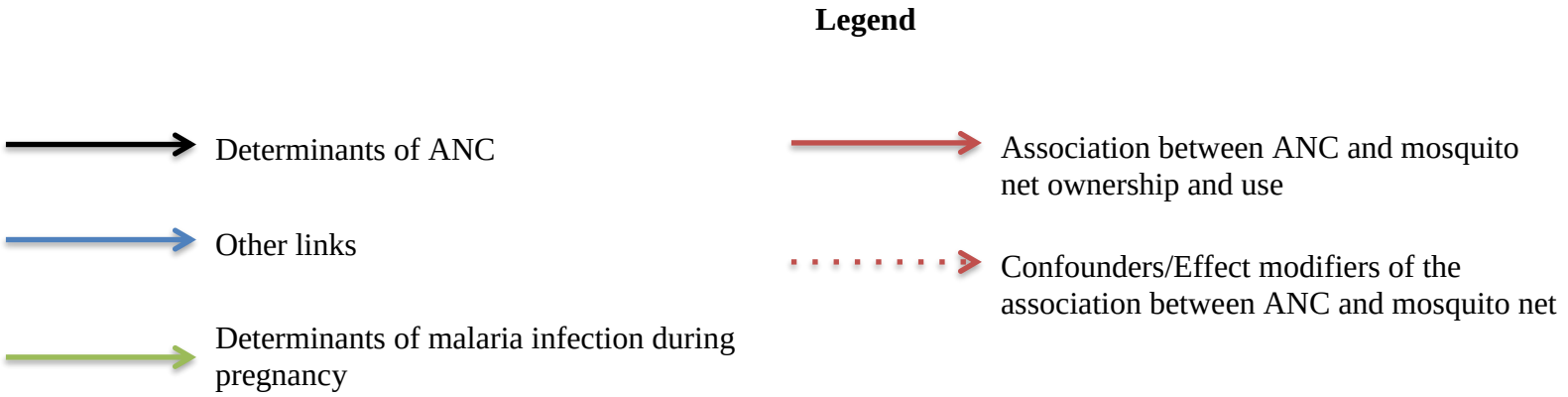


Figure 3. 1 Conceptual framework for the relationship between mosquito nets, antenatal care attendance, malaria transmission, and pregnancy outcomes

4. Wealth Index Creation

Clear measures of household income are generally not available in poor regions and for that reason, wealth indices are generated, using combined data on a household's ownership of assets.[24] The Demographic Health Survey group developed a series of steps to constructing a wealth index, which were followed to build the one for this study.[25] We selected 28 variables collecting information on household sources of water supply, type of toilet facility, type of fuel used for cooking, household size, type of materials used for floor, roof and exterior wall, and ownership of durable assets. We first converted the categorical variables into binary variables, combined variables presenting low counts, and carried out descriptive analyses to obtained frequencies, means, and standard deviations (**Table 3.1)**.[25,26] We subsequently applied principal component analysis (PCA) to the variables.[24,26] The first principal component was extracted and represented a measure of socio-economic status.[26] The eigenvalue for the first principal component had a value of 3.38 and explained 12.07% of the total variance, similar to what was obtained by Vyas and Kumaranayake who developed household wealth indices for Ethiopia using nationally representative survey data on durable asset possession, source of water supply, sanitation facility, and type of floor material.[26] Factors scores from the first principal component were also obtained for each variable. As shown in **Table 3.1**, variables with a positive factor score were associated with higher socio-economic status (SES), and conversely, variables with a negative factor score were associated with a lower SES.

Table 3. 1 Descriptive statistics and factor scores obtained from principal component analysis

Variables	N (%)	Mean (Std. dev.)	Factor score
Sources of water supply			
Piped into dwelling/ Piped into yard/plot			
Yes	93 (2.4)	0.025 (0.008)	0.435
No	3691 (97.5)		
Protected spring/well			
Yes	2047 (54.1)	0.54 (0.008)	-0.075
No	1737 (45.9)		
Borehole/ Public tap/standpipe			
Yes	818 (21.7)	0.22 (0.022)	0.135
No	2966 (78.4)		
Unprotected spring/well			
Yes	826 (21.8)	0.22 (0.025)	-0.207
No	2958 (78.2)		
Toilet facility			
Use bush			
Yes	84 (2.2)	0.022 (0.002)	-0.106
No	3700 (97.8)		
Flush to pit latrine/ Flush to septic tank/ Flush don't know			
Yes	179 (4.7)	0.047 (0.003)	0.055
No	3605 (95.3)		
Open pit			
Yes	1227 (32.4)	0.324 (0.007)	-0.290
No	2557 (67.6)		
Pit latrine with slab			
Yes	2077 (54.9)	0.548 (0.008)	0.218
No	1707 (45.1)		
Ventilated improved pit latrine			
Yes	217 (5.7)	0.057 (0.003)	0.136
No	3567 (94.3)		
Type of fuel used for cooking			
Charcoal			
Yes	25 (0.6)	0.006 (0.002)	0.357
No	3759 (99.3)		
Electricity			
Yes	32 (0.8)	0.008 (0.003)	0.461
No	3752 (99.1)		
Wood			
Yes	3720 (98.3)	0.983 (0.004)	-0.564

No	64 (1.7)		
Number of rooms for sleeping		1.86 (0.0265)	0.171
Assets ownership			
Electricity in the house			
Yes	1028 (27.2)	0.271 (0.057)	0.508
No	2756 (72.8)		
Radio			
Yes	1986 (52.5)	0.525 (0.022)	0.210
No	1798 (47.5)		
Television			
Yes	279 (7.4)	0.073 (0.018)	0.633
No	3505 (92.6)		
Refrigerator			
Yes	53 (1.4)	0.014 (0.003)	0.508
No	3731 (98.6)		
Car/truck			
Yes	16 (0.42)	0.004 (0.002)	0.376
No	3768 (99.6)		
Bicycle			
Yes	26 (0.7)	0.007 (0.002)	0.282
No	3758 (99.3)		
Motorcycle			
Yes	65 (1.7)	0.017 (0.003)	0.355
No	3719 (98.3)		
Mobile phone			
Yes	242 (6.4)	0.064 (0.012)	0.412
No	3542 (93.6)		
Dwelling characteristics			
Floor			
Cement/ Wood planks/ Polished wood/Plastic parquet			
Yes	112 (2.9)	0.0296 (0.007)	0.377
No	3672 (97.0)		
Dung/Earth			
Yes	3672 (97.0)	0.970 (0.007)	-0.377
No	112 (2.9)		
Roof			
Corrugated iron			
Yes	2936 (77.6)	0.776 (0.032)	0.472
No	848 (22.4)		
Thatch/Wood			
Yes	846 (22.3)	0.223 (0.032)	-0.472
No	2938 (77.6)		
Exterior walls			

Cement/Stone/Wood			
Yes	68 (1.8)	0.0179 (0.003)	0.113
No	3716 (98.2)		
Mud			
Yes	3715 (98.2)	0.982 (0.003)	-0.111
No	69 (1.8)		
Health insurance			
Yes	383 (10.1)	0.101 (0.015)	0.192
No	3401 (89.9)		

Using these factor scores as weights for each variable, an overall score for each household was subsequently obtained, which can be interpreted as the household's socio-economic score.[26] In accordance with the Demographic Health Survey's methodology to construct a wealth index, we then divided the households into five equal quintiles (e.g. <20%, <40%, <60%, and <80%).[25] Frequency distributions on the quintile variables were subsequently calculated to verify that the percent for each quintile value was close to 20%. We also looked at whether the developed index was internally coherent by comparing the mean value for each asset variable by the SES quintiles. As expected and shown in **Table 3.2**, the wealthiest households were more likely to have piped drinking water, pit latrine with slab or ventilated improved pit latrine as toilet facilities, charcoal or electricity as types of fuel for cooking, and own various assets such as a mobile phone, television, refrigerator and a motorcycle. They were also more likely to have health insurance and their dwelling made of iron, stone or cement. The majority of the poorest households obtained their water supply from an unprotected spring or well, had either no or low-quality sanitation facility, and did not possess any durable assets.

Table 3. 2 Ownership of durable assets and housing characteristics by socio-economic status quintile

	Poorest	Second	Middle	Fourth	Richest
Source of water supply					
Piped into dwelling/ Piped into yard/plot	0.000	0.003	0.000	0.006	0.112
Protected Spring or Well	0.504	0.586	0.589	0.573	0.451
Borehole/ Public tap/standpipe	0.113	0.099	0.218	0.293	0.363
Unprotected Spring or Well	0.382	0.310	0.192	0.126	0.072
Toilet facility					
Use bush	0.056	0.028	0.012	0.010	0.001
Flush to pit latrine/ Flush to septic tank/ Flush don't know	0.027	0.051	0.066	0.044	0.047
Open pit	0.484	0.643	0.258	0.128	0.082
Pit latrine with slab	0.399	0.267	0.605	0.743	0.750
Ventilated improved pit latrine	0.032	0.009	0.056	0.072	0.118
Type of fuel used for cooking					
Electricity	0.000	0.000	0.000	0.000	0.042
Wood	0.998	0.998	0.997	0.998	0.922
Charcoal	0.000	0.000	0.001	0.000	0.031
Asset ownership					
Electricity in the house	0.033	0.067	0.129	0.338	0.793
Radio	0.332	0.380	0.443	0.730	0.741
Television	0.001	0.001	0.001	0.003	0.360
Refrigerator	0.000	0.000	0.001	0.002	0.066
Car/truck	0.000	0.000	0.000	0.000	0.021
Bicycle	0.001	0.000	0.001	0.001	0.030
Motorcycle	0.000	0.002	0.003	0.007	0.072
Phone	0.003	0.023	0.018	0.041	0.234
Health Insurance	0.043	0.057	0.069	0.122	0.214
Number of rooms for sleeping	1.529	1.632	1.903	2.036	2.196
Dwelling characteristics					
Floor					
Cement/ Wood planks/ Polished wood/Plastic parquet	0.000	0.005	0.004	0.010	0.128
Dung/Earth	1.000	0.995	0.995	0.989	0.871
Roof					
Iron	0.030	0.875	0.988	0.996	0.997
Wood/ Thatch	0.969	0.121	0.011	0.004	0.002
Exterior walls					
Cement/Stone/Wood	0.021	0.012	0.007	0.013	0.035
Mud	0.978	0.986	0.992	0.986	0.964

5. Data Analysis

All analyses were performed using SAS 9.4. The distribution of each variable was assessed through frequency tables. Chi-square and Fisher's exact tests were used to explore associations between the variables and determine differences in proportions. Differences in means were assessed through T-tests. A P-value of 0.05 was considered the level of significance.

Using unadjusted and adjusted multivariable logistic regression models, we generated odds ratio (ORs) and corresponding 95% confidence intervals to identify significant predictors of attending at least one ANC visit. A sub-group analysis was also performed to identify whether the participants that attended four ANC visits were different from the women that attended three or fewer ANC visits.

Multivariable logistic regression analyses were also undertaken to establish the relationship between ANC attendance and bed net ownership and utilization. In accordance with what was included in the conceptual framework, we considered age, marital and occupation status, highest education level, household wealth, and whether the dwelling was sprayed with insecticide in the last year as potential confounders and effect modifiers. Effect modification was investigated by introducing interaction terms between main predictors and potential effect modifier into the regression models.

The main predictors of malaria infection during pregnancy were also determined through logistic regression models. As showed in the conceptual framework, we considered socio-demographic factors, bed net utilization and IRS as potential predictors.

In the cross-sectional survey sampling frame, women were clustered within PHCUs, thus failure to account for the sampling design can lead to incorrect inferences.[27] As a result, clustering of the data was acknowledged in all the analyses through logistic regressions with random intercept models, using the PROC GLIMMIX function in SAS 9.4 software. Model diagnostics included assessing the distribution of the residuals and random effects.

Ethics Approval

Ethical clearance for the secondary use of the cross-sectional survey data was obtained the Research Ethics and Integrity Board at the University of Ottawa (# H10-15-25C).

Results

1. Participant's Characteristics

A total of 3,784 women agreed to take part in the cross-sectional survey (**Table 3.3**). Similar numbers of respondents participated in each district, with 1402, 1110, and 1272 participants found in Gomma, Kersa and Seka Chekorsa, respectively.

We identified that half of the participating women in each district were aged between 25 and 34 years (50.5%) (**Table 3.3**). Women within the 19 to 24 years of age group followed with an overall proportion of 25%. Oromo was the most dominant ethnic group, with an overall proportion of 94% across the districts. Ethnic groups other than Oromo and Amhara were combined given the low count found in all three districts. These included among others Yem, Keffa and Dawuro ethnic groups.

Nearly all participating women were married (97.7%) and unemployed (78.2%). Roughly 20% of the respondent were self-employed working as traders or farmers. Kersa district had the highest proportion of women that were uneducated (67.9%) followed by Seka Chekorsa (53.9%) and Gomma (47.2%). With regards to healthcare decisions, the majority of women decided jointly with their husband (59.2%). In all three districts, most households comprised between five and eight individuals with three or fewer children.

Through the wealth index, we determined that Kersa had the largest proportion of participants of the poorest wealth quintile (35.9%) compared to 6% of households in Gomma. Seventy percent of richest households were found in Gomma.

Table 3. 3 Characteristics of the women who participated in the cross-sectional survey conducted in three districts of Jimma Zone from October 2016 to January 2016

	Total (N=3784)		Gomma (N=1402)		Kersa (N=1110)		Seka Chekorsa (N=1272)	
	%	N	%	N	%	N	%	
Maternal age (years)								
15 -18	7.5	95	6.8	80	7.2	110	8.6	
19-24	25.5	345	24.6	264	23.8	356	27.9	
25-34	50.5	736	52.5	559	50.4	615	48.3	
35 - 49	16.5	226	16.1	207	18.6	191	15.0	
Ethnic group								
Oromo	93.7	1262	90.0	1065	95.9	1220	95.9	
Amhara	1.9	58	4.1	4	0.4	11	0.9	
Other	4.3	82	5.8	41	3.7	41	3.2	
Education level								
No education	55.5	661	47.2	754	67.9	686	53.9	
Primary[1]	31.0	470	33.5	273	24.6	430	33.8	
Secondary[2]	12.7	259	18.5	77	6.9	146	11.5	
Higher	0.7	12	0.9	6	0.5	10	0.8	
Marital Status								
Married	97.7	1348	96.2	1098	98.9	1252	98.5	
Not married	2.3	54	3.8	12	1.1	19	1.5	
Employment status								
Not Employed[3]	78.2	1132	80.7	845	76.1	981	77.1	
Self-employed	19.2	211	15.1	255	22.9	260	20.4	
Employed	2.6	59	4.2	10	0.9	31	2.4	
Wealth								
Poorest	20.0	89	6.3	399	35.9	270	21.2	

Poorer	21.3	252	17.9	227	20.4	326	25.6
Middle	18.6	222	15.8	213	19.2	269	21.1
Richer	20.1	309	22.0	186	16.7	265	20.8
Richest	20.0	530	37.8	85	7.66	142	11.2
Frequency of reading newspaper/ magazine							
Not at all	92.8	1268	90.4	1065	95.9	1180	92.7
At least once a week	5.8	114	8.1	35	3.1	73	5.7
More than once a week	1.3	20	1.4	10	0.9	19	1.5
Frequency of listening to the radio							
Not at all	45.6	622	44.4	534	48.1	569	44.7
At least once a week	26.5	422	30.1	272	24.5	309	24.3
More than once a week	27.9	358	25.5	304	27.4	394	30.9
Frequency of watching the TV							
Not at all	88.8	1070	76.3	1066	96.0	1226	96.4
At least once a week	5.2	150	10.7	26	2.3	22	1.7
More than once a week	5.9	182	12.9	18	1.6	24	1.9
Frequency of contact with HEW							
Not at all	66.4	856	61.0	856	77.1	802	63.0
Less than once a month	23.0	348	24.8	200	18.0	323	25.4
One or more times a month	10.5	198	14.1	54	4.8	147	11.5

Decision Making about healthcare							
Self	12.2	170	12.1	120	10.8	171	13.4
Jointly	59.2	883	62.9	628	56.6	728	57.2
Husband	27.9	336	23.9	355	31.9	366	28.7
Family member	0.7	13	0.9	7	0.6	7	0.2
Household size							
≤ 4	34.0	504	35.9	329	29.6	454	36.7
5 - 8	56.2	794	56.6	629	56.7	702	55.2
≥ 9	9.8	104	7.4	152	13.7	116	9.1
Number of children per household							
≤ 3	56.2	848	60.5	553	49.8	725	57.0
4-6	38.7	506	36.1	465	41.9	493	38.7
≥ 7	5.1	48	3.4	92	8.3	54	4.25

Notes: [1]considers women who completed all or some primary school years; [2] considers women who completed all or some secondary school years; [3] the unemployed category contains women who were unemployed, housewives or students

2. Participants' Reproductive History

Analysis of the reproductive history of the participants revealed that, on average, the number of pregnancies per woman was three to four (**Table 3.4**). In Gomma, 7.6% of the women had at least one induced abortion, compared to 4% in Kersa and 5% in Seka Chekorsa. The proportion of women with a history of prior miscarriage in each district were low, with the highest being of 3.9% in Gomma. Finally, we found across the three districts that 4.5% of the women had history of at least one stillbirth.

Table 3. 4 Reproductive history of the women who participated in the cross-sectional conducted in three districts of Jimma Zone from October 2016 to January 2017

	Total (%)	**Gomma**		**Kersa**		**Seka Chekorsa**	
		N	**%**	**N**	**%**	**N**	**%**
Gravidity (mean ± SD)*	3.70 (± 2.34)	3.51 (±2.25)		4.15 (±2.47)		3.52 (±2.27)	
Live birth							
1	1.6	32	2.3	7	0.6	21	1.6
> 1	98.4	1370	97.7	1103	99.4	1251	98.3
Induced abortion							
0	94.1	1295	92.4	1058	95.3	1210	95.1
≥ 1	5.9	107	7.6	52	4.7	62	4.9
Miscarriage							
0	97.4	1347	96.1	1088	98.0	1250	98.3
≥ 1	2.6	55	3.9	22	2.0	22	1.7
Stillbirth							
0	95.5	1314	93.7	1066	96.0	1234	97.0
≥ 1	4.5	88	6.3	44	3.9	38	2.9

* Defined as the number of times a woman has been pregnant

3. Antenatal Care Attendance

Of the 3,784 women who participated in the survey, 84.2% received ANC during their last pregnancy. ANC attendance among the participants was the highest in Gomma with 90.3%, compared to 85.2% in Seka Chekorsa and 75.5% in Kersa (**Table 3.5**). A larger proportion of women reported attending four ANC visits in Gomma (54.2%), while Kersa and Seka Chekorsa had estimates of approximately 38% and 46%, respectively.

As shown in **Table 2.3**, we also found that the majority of women were more likely to initiate their antenatal care visit in the second trimester. Women who were living in Gomma were more likely to report receiving ANC during their first trimester, compared to the two neighboring districts.

Table 3. 5 Descriptive information on antenatal care utilization in three districts of Jimma Zone

	Total	**Gomma (N=1402)**	**Kersa (N=1110)**	**Seka Chekorsa (N=1272)**
Number of ANC visits				
0	15.8	137 (9.7)	272 (24.5)	188 (14.8)
1	2.0	22 (1.6)	28 (2.5)	26 (2.0)
2	8.6	87 (6.2)	115 (10.4)	126 (9.9)
3	26.6	395 (28.2)	272 (24.5)	341 (26.8)
4	34.2	571 (40.7)	315 (28.4)	407 (32.0)
≥ 5	12.7	190 (13.5)	108 (9.7)	184 (14.4)
Timing of ANC				
First trimester	13.2	226 (17.9)	82 (9.8)	114 (10.5)
Second trimester	82.9	1000 (79.0)	709 (84.6)	934 (86.1)
Third trimester	3.8	39 (3.1)	47 (5.6)	36 (3.3)

4. Barriers to Antenatal Care Attendance

We identified that 597 participants, corresponding to approximately 16% of the total number of women recruited, reported not attending ANC. These participants were asked about the reasons for not attending ANC (**Table 3.6**). The main barriers to attending ANC were a perceived lack of necessity (45%) or time (14%), the distance to the closest health centre (22%), and the absence of transportation to the closest delivery site (13%). Other non-negligible barriers included the absence of husband's support (8%), or of sickness or complications related to pregnancy (7%), poor service within the health facility (5%) and the unavailability of childcare (5%). Thirty-two participants did not provide an explanation for not seeking ANC.

Table 3. 6 Reasons for not attending antenatal care in three districs of Jimma Zone

Reasons for not attending ANC	N	%
Not necessary	273	45.7
Closest health facility is too far	134	22.4
No time	82	13.7
No transport available	81	13.5
Husband	49	8.2
Felt healthy	44	7.4
No childcare	32	5.4
Reason not provided	32	5.4
Don't know	31	5.2
Poor services	28	4.7
Wait time	21	3.5
Did not know where to go	13	2.2
Other	12	2.0
Sickness	7	1.2
Fear	7	1.2
Inconvenient hours	6	1.0
Home remedy	5	0.8
Abortion	4	0.7

5. Determinants of Attending at least one Antenatal Care Visit (ANC1)

In the multivariable analysis (**Table 3.7**), women who were of an ethnic group different than Oromo or Ahmara were approximately 40% less likely to attend at least one ANC visit (OR: 0.58 (95% CI: 0.38 – 0.89)) compared to women who were part of the largest ethnic group (i.e. Oromo).

Education and wealth were also identified as important predictors of attending at least one ANC visit. In fact, we found that participants who completed some primary school education were 50% (OR: 1.47 (95% CI: 1.16 – 1.87)) more likely to attend at least one ANC visit, while the odds of ANC1 were 2.4 (95% CI: 1.49 – 4.09) times higher in women that had completed some secondary or higher education, compared with women who had no education. Considering women living in the poorest households as the reference category, we found that women who were in the poorer wealth quintile were roughly 50% (OR: 1.53 (95% CI: 1.17 – 1.99)) more likely to attend ANC1. Women who were classified in the richest wealth quintile had 4.3 times the odds of attending ANC1 than participants from the poorest wealth quintile.

Women who were exposed to difference sources of media (i.e. newspapers, magazine, radio and/or TV) at least once a week were more likely to attend at least one ANC visit compared to women who had no exposure. Similarly, frequent contacts with an HEW improve ANC1 attendance.

Women who were able to decide for their healthcare themselves were 10% more likely to attend ANC1 compared to women who let their husband or family member take decisions about their health care. Women who were deciding jointly with their partner had also better odds of receiving ANC1 (OR: 1.26 (95% CI: 1.02 – 1.56)) than women whose husband or family

member take the decisions about their health care. Attendance to at least one ANC visit was also more likely among women who experienced health problems during their last pregnancy (OR: 1.58 (95% CI: 1.22 – 2.05)). Finally, women who had wanted their last pregnancy were approximately 70% more likely to seek an ANC1 visit.

Table 3. 7 Association between maternal characteristics and attending at least one antenatal care visit

	Attended at least one ANC visit N (%)	Did not attend ANC N (%)	P value for the overall difference among the categories	Factors associated with attending at least one antenatal care visit, univariate analysis OR (95% CI)	Factors associated with attending at least one antenatal care visit, multivariable analysis AOR (95% CI)
Maternal age (years)					
15 -18	231 (7.2)	54 (9.0)		Reference	Reference
19-24	864 (27.1)	101 (16.9)	**<0.0001**	1.83 (1.25 – 2.67)	1.27 (0.84 – 1.91)
25-34	1594 (50.0)	316 (52.9)		1.01 (0.72 – 1.42)	1.26 (0.85 – 1.88)
35-49	498 (15.6)	126 (21.1)		0.884 (0.58 – 1.23)	1.33 (0.84 – 2.10)
Ethnic group					
Oromo	2995 (93.9)	552 (92.5)		Reference	Reference
Amhara	66 (2.1)	7 (1.2)	**0.0113**	1.11 (0.49 – 2.50)	0.85 (0.35 – 1.95)
Other	126 (3.9)	38 (6.4)		0.56 (0.37 – 0.84)	0.58 (0.38 – 0.89)
Education level					
No education	1660 (52.1)	441 (73.8)		Reference	Reference
Primary[1]	1041 (32.6)	132 (22.1)	**<0.0001**	1.92 (1.55 – 2.39)	1.47 (1.16 – 1.87)
Secondary[2] or Higher[3]	486 (15.2)	24 (4.0)		4.57 (2.96 – 7.05)	2.38 (1.49 – 3.82)
Employment Status					
Not Employed[4]	2510 (78.7)	448 (75.0)		Reference	Reference
Self-employed	583 (18.3)	143 (23.9)	**0.0004**	0.78 (0.63 – 0.97)	0.79 (0.63 – 1.01)
Employed	94 (2.9)	6 (1.0)		2.74 (1.16 – 6.45)	1.68 (0.69 – 4.09)
Wealth					
Poorest	544 (17.1)	214 (35.8)		Reference	Reference
Poorer	649 (20.4)	156 (26.1)	**<0.0001**	1.45 (1.13 – 1.87)	1.53 (1.17 – 1.99)
Middle	614 (19.3)	90 (15.1)		2.319 (1.74 – 3.08)	2.52 (1.87 – 3.39)
Richer	665 (20.8)	95 (15.9		2.27 (1.71 – 3.03)	2.37 (1.76 – 3.19)
Richest	715 (22.4)	42 (7.0)		4.96 (3.39 – 7.23)	4.29 (2.89 – 6.35)
Frequency of reading newspaper/ magazine					
Not at all	2936 (92.1)	577 (96.6)		Reference	Reference
At least once a week	203 (6.4)	19 (3.2)	**0.0006**	1.84 (1.12 – 3.00)	0.67 (0.38 – 1.18)
More than once a week	48 (1.51)	1 (0.2)		11.64 (1.58 – 85.81)	2.48 (0.31 – 19.56)

Frequency of listening to the radio					
Not at all	1373 (43.1)	352 (58.9)		Reference	Reference
At least once a week	879 (27.6)	124 (20.8)	**<0.0001**	1.76 (1.39 – 2.22)	1.27 (0.99 – 1.64)
More than once a week	935 (29.3)	121 (20.3)		1.97 (1.56 – 2.49)	1.28 (1.00 – 1.66)
Frequency of watching the TV					
Not at all	2783 (87.3)	579 (96.9)		Reference	Reference
At least once a week	185 (5.8)	13 (2.2)	**<0.0001**	2.30 (1.29 – 4.21)	1.39 (0.74 – 2.62)
More than once a week	219 (6.9)	5 (0.8)		6.18 (2.50 – 15.28)	2.98 (1.15 – 7.74)
Frequency of contact with HEW					
Not at all	2053 (64.4)	461 (77.2)		Reference	Reference
Less than once a month	773 (24.2)	98 (16.4)	**<0.0001**	1.61 (1.26 – 2.05)	1.69 (1.15 – 2.48)
One or more times a month	361 (11.3)	38 (6.4)		1.86 (1.29 – 2.67)	1.66 (1.27 – 2.13)
Decision-making about healthcare					
Husband or family member	874 (23.1)	210 (5.5)		Reference	Reference
Self	385 (12.1)	76 (12.7)		1.16 (0.86 – 1.57)	1.10 (0.81 – 1.51)
Jointly with husband	1928 (60.5)	311 (52.1)	**0.0086**	1.45 (1.21 – 1.81)	1.26 (1.02 – 1.56)
Household size					
≤ 4	1155 (36.2)	132 (22.1)		Reference	Reference
5 - 8	1751 (54.9)	374 (62.6)	**<0.0001**	0.54 (0.44 – 0.67)	0.87 (0.63 – 1.19)
≥ 9	281 (8.8)	91 (15.2)		0.43 (0.31 – 0.58)	0.75 (0.45 – 1.26)
Number of children per household					
≤ 3	1882 (59.0)	244 (40.9)		Reference	Reference
4-6	1159 (36.4)	305 (51.1)	**<0.0001**	0.51 (0.42 – 0.62)	0.74 (0.55 – 1.00)
≥ 7	146 (4.6)	48 (8.0)		0.47 (0.33 – 0.68)	0.76 (0.41 – 1.39)
Health problems during last pregnancy					
No	2491 (78.2)	509 (85.2)	**0.0050**	Reference	Reference
Yes	694 (21.8)	88 (14.7)		1.57 (1.22 – 2.02)	1.58 (1.22 – 2.05)
Number of live birth					
0-1	742 (23.7)	79 (13.4)		Reference	Reference
2-4	1424 (45.4)	229 (38.8)	**<0.0001**	0.67 (0.52 – 0.88)	0.97 (0.70 – 1.36)
≥ 5	968 (30.9)	282 (47.8)		0.40 (0.31 – 0.53)	0.84 (0.55 – 1.29)
Number of child-deaths					
None	2734 (85.8)	485 (82.1)	**0.0059**	Reference	Reference
≥1	453 (14.2)	112 (18.8)		0.78 (0.61 – 0.98)	1.04 (0.79 – 1.35)
Intended pregnancy					

No	967 (30.3)	309 (51.7)	**< 0.0001**	Reference	Reference
Yes	2220 (69.6)	288 (48.2)		2.18 (1.81 – 2.63)	1.68 (1.38 – 2.06)

Abbreviations: CI – Confidence interval; OR – Odds ratio; AOR – Adjusted odds ratio

Notes: [1]considers women who completed all or some primary school years; [2] considers women who completed all or some secondary school years; [3] secondary and higher education were combined given model conversion issues; [4] the unemployed category contains women who were unemployed, housewives or students

6. Determinants of Attending four or more Antenatal Care Visits (ANC4)

Of the women who received any ANC, respondents had higher odds of attending four or more visits if they had completed some secondary (OR: 1.90 (95% CI: 1.46 -2.47)) or higher (OR: 5.24 (95% CI: 1.53 – 17.95)) education (**Table 3.8**). Wealth was still identified as an important determinant of ANC4. Yet, only the odds ratios for respondents that were from the richest quintile were significantly different from the poorest group. The odds of ANC4 attendance were also significantly higher in women who watched TV at least once a week (OR: 1.60 (95% CI: 1.12 – 2.30)) and were visited by a HEW even less than once a month (OR: 1.37 (95% CI: 1.15 – 1.64)). Women who took decisions about their health by themselves or with their partner were approximately 30% more likely to attend ANC4. Women who were part of a household with more than seven children were 46% less likely to attend four or more ANC visits than women who had three or fewer children part of their household. Wanting the last pregnancy was also a significant predictor, with an adjusted OR of 1.37 (95% CI: 1.17 – 1.62). Interestingly, we found that women who had a prior stillbirth were 35% less likely to attend four visits.

Table 3. 8 Association between maternal characteristics and attending four antenatal care visits

	Attended four antenatal care visits N (%)	Did not attend four antenatal care visits N (%)	P value for the overall difference among the categories	Factors associated with attending four antenatal care visits, univariate analysis OR (95% CI)	Factors associated with attending four antenatal care visits, multivariable analysis AOR (95% CI)
Maternal age (years)					
15-18	123 (6.9)	108 (7.6)		Reference	Reference
19-24	530 (29.8)	334 (23.6)	**0.0037**	1.41 (1.05 – 1.89)	1.24 (0.91 – 1.68)
25-34	863 (48.6)	731 (51.7)		1.01 (0.78 – 1.36)	1.04 (0.76 – 1.42)
35-49	259 (14.6)	239 (16.9)		0.96 (0.69 – 1.31)	1.01 (0.69 – 1.46)
Education level					
No education	854 (48.1)	806 (57.1)		Reference	Reference
Primary[1]	564 (31.8)	477 (33.8)	**<0.0001**	1.11 (0.95 – 1.30)	0.99 (0.83 – 1.18)
Secondary[2]	332 (18.7)	126 (8.9)		2.47 (1.96 – 3.11)	1.90 (1.46 -2.47)
Higher	25 (1.4)	3 (0.2)		8.38 (2.50 – 28.07)	5.24 (1.53 – 17.95)
Wealth					
Poorest	268 (15.1)	276 (19.5)		Reference	Reference
Poorer	312 (17.6)	337 (23.8)		0.92 (0.73 – 1.16)	0.92 (0.73 – 1.17)
Middle	344 (19.4)	270 (19.1)	**<0.0001**	1.27 (1.00 – 1.61)	1.27 (0.99 – 1.61)
Richer	371 (20.9)	294 (20.8)		1.26 (1.00 – 1.59)	1.19 (0.94 – 1.51)
Richest	480 (27.0)	235 (16.6)		2.01 (1.58 – 2.56)	1.64 (1.27 – 2.12)
Frequency of reading newspaper/ magazine					
Not at all	1618 (91.1)	1318 (93.3)		Reference	Reference
At least once a week	128 (7.2)	75 (5.3)	**0.0278**	1.37 (1.01 – 1.84)	0.76 (0.54 – 1.07)
More than once a week	29 (1.6)	19 (1.3)		1.28 (0.71 – 2.32)	0.38 (0.18 – 0.75)
Frequency of watching the TV					
Not at all	1490 (83.9)	1293 (91.6)		Reference	Reference
At least once a week	133 (7.5)	52 (3.7)	**<0.0001**	2.15 (1.53 – 3.00)	1.60 (1.12 – 2.30)
More than once a week	152 (8.5)	67 (4.7)		1.91 (1.41 – 2.59)	1.25 (0.88 – 1.79)
Frequency of contact with HEW					

Not at all	1098 (61.8)	955 (67.6)		Reference	Reference
Less than once a month	483 (27.2)	290 (20.5)		1.42 (1.19 – 1.68)	1.37 (1.15 – 1.64)
One or more times a month	194 (10.9)	167 (11.8)	**0.0027**	0.95 (0.76 – 1.20)	0.88 (0.69 – 1.11)
Decision-making about healthcare					
Husband or family member	426 (24.0)	448 (31.7)		Reference	Reference
Self	221 (12.4)	164 (11.6)		1.39 (1.09 – 1.77)	1.33 (1.03 – 1.70)
Jointly	1128 (63.5)	800 (56.6)	**0.0002**	1.46 (1.24 – 1.72)	1.32 (1.11 – 1.55)
Household size					
≤ 4	692 (38.9)	463 (32.8)		Reference	Reference
5 - 8	936 (52.7)	815 (57.7)	**0.0021**	0.77 (0.66 – 0.89)	0.94 (0.76 – 1.16)
≥ 9	147 (8.3)	134 (9.5)		0.74 (0.57 – 0.97)	1.24 (0.81 – 1.92)
Number of children per household					
≤ 3	1097 (61.8)	785 (55.6)		Reference	Reference
4-6	612 (34.5)	547 (38.7)	**0.0009**	0.80 (0.69 – 0.93)	0.91 (0.72 – 1.14)
≥ 7	66 (3.7)	80 (5.6)		0.61 (0.43 – 0.85)	0.54 (0.31 – 0.92)
Health problems during last pregnancy					
No	1368 (77.1)	1125 (79.7)	**0.0385**	Reference	Reference
Yes	407 (22.9)	287 (20.3)		1.18 (1.00 – 1.41)	1.17 (0.98 – 1.40)
Number of live birth					
0-1	479 (26.9)	316 (22.4)		Reference	Reference
2-4	789 (44.4)	635 (44.9)	**0.0147**	0.73 (0.59 – 0.88)	1.08 (0.87 – 1.36)
≥ 5	507 (28.5)	461 (32.6)		0.81 (0.68 – 0.97)	1.29 (0.87 – 1.36)
Prior stillbirth					
No	1708 (96.2)	1330 (94.2)		Reference	Reference
Yes	67 (3.8)	82 (5.8)	**0.0217**	0.63 (0.45 – 0.88)	0.65 (0.46 – 0.92)
Intended pregnancy					
No	467 (26.31)	500 (35.41)	**<0.0001**	Reference	Reference
Yes	1308 (73.69)	912 (64.58)		1.54 (1.32 – 1.79)	1.37 (1.17 – 1.62)

Abbreviations: CI – confidence interval, OR – Odds ratio, AOR – Adjusted odds ratio

Notes: [1]considers women who completed all or some primary school years; [2] considers women who completed all or some secondary school years

7. Malaria Infection and Mosquito Net Ownership and Utilization During Pregnancy

We observed very low rates of malaria infection during pregnancy in our sampled group, with infection rates of 2.0%, 0.8%, and 1.4% found in Gomma, Kersa, and Seka Chekorsa, respectively. Fifty-one percent (51%) of all cases were found in Gomma (**Table 3.9**). The difference in malaria prevalence across the three districts was not significant.

Bed net ownership was relatively low with 62.3% of participating women in Gomma, 43.6% in Kersa, and 34.9% in Seka Chekorsa reporting that they possessed a bed net. The utilization of mosquito nets was also low in the three districts; fifty-nine percent of the women living in Gomma who owned a net said that they always slept under it during their last pregnancy compared to 50.7% in Kersa and 51.2% in Seka Chekorsa. With proportions ranging from 15.9% in Seka Chekorsa to 33.9% in Kersa, relatively low proportions of women reported that their house had been sprayed within the 12 months prior to the survey.

Table 3. 9 Malaria variables per district

	Total N (%)	**Gomma (N=1402)**	**Kersa (N=1110)**	**Seka Chekorsa (N=1272)**
		N (%)	N (%)	N (%)
Malaria infection during pregnancy				
Yes	55 (1.4)	28 (2.0)	9 (0.8)	18 (1.4)
No	3729 (98.5)	1374 (98.0)	1101 (99.2)	1254 (98.6)
Bed net ownership				
Yes	1802 (47.6)	874 (62.3)	484 (43.6)	444 (34.9)
No	1982 (52.4)	528 (37.6)	626 (56.4)	828 (65.1)
Bed net use*				
Never	34 (1.8)	18 (2.0)	9 (1.8)	7 (1.6)
Sometimes	323 (17.9)	154 (17.6)	83 (17.1)	86 (19.4)

Often	448 (24.8)	182 (20.8)	147 (30.4)	119 (26.8)
Always	997 (55.3)	520 (59.5)	245 (50.7)	232 (51.2)
Indoor Residual Spraying				
Yes	960 (25.4)	382 (27.2)	377 (33.9)	202 (15.9)
No	2824 (74.6)	1020 (72.7)	733 (66.0)	1070 (84.1)

* Bed net use among women who owned a mosquito net

8. Association between Antenatal Care Attendance and Ownership and Use of Mosquito Net

Based on the univariate analysis, participants who attended at least one ANC visit had 2.1 (95% CI: 1.68 – 2.68) times the odds of owning a net relative to those who reported not attending ANC (**Table 3.10**). Their odds of always utilizing a net during their pregnancy were also 86% higher (OR: 1.86 (95% CI 1.43 – 2.43)) (**Table 3.11**).

After adjusting for the main potential confounders and considering effect modifiers such as maternal age, education level, occupation status, wealth, and IRS, we found that participants who attended at least one ANC were 1.98 (95% CI: 1.55 – 2.53) more likely to have owned a net. Similarly, we found that women who attended at least one ANC visit were 62% more likely to have always used a net during their last pregnancy. None of the covariates considered were identified as effect modifiers (i.e. p-values for the interaction terms were not significant).

We also considered district in an interaction term to assess whether the association between attending at least one ANC visit and bed net ownership and use differ by district. It was found that there was no significant modification of the association between ANC attendance and bed net ownership by district.

Table 3. 10 Association between antenatal care attendance and the ownership of bed nets

	Owned a net N (%)	Did not own a net N (%)	P value for the overall difference among the categories	Factors associated with owning a mosquito net, univariate analysis OR (95% CI)	Factors associated with owning a mosquito net, multivariable analysis AOR (95% CI) *
Antenatal care attendance					
No	177 (9.8)	420 (21.2)	**< 0.0001**	Reference	Reference
At least once	1625 (90.2)	1562 (78.8)		2.13 (1.68, 2.68)	1.98 (1.55 -2.53)

* Adjusting for main confounders - maternal age, ethnicity, education level, wealth, household size and indoor residual spraying
Abbreviations: CI – confidence interval, OR – Odds ratio, AOR – Adjusted odds ratio

Table 3. 11 Association between antenatal care attendance and the utilization of bed nets

	Always used a net N (%)	Did not always use a net N (%)	P value for the overall difference among the categories	Factors associated with always using a mosquito net, univariate analysis OR (95% CI)	Factors associated with always using a mosquito net, multivariable analysis AOR (95% CI)*
Antenatal care attendance					
None	85 (8.5)	512 (18.4)	**<0.0001**	Reference	Reference
At least once	912 (91.5)	2275 (81.6)		1.86 (1.43 – 2.43)	1.62 (1.23 – 2.13)

* Adjusting for main confounders - maternal age, ethnicity, education level, wealth, household size, indoor residual spraying
Abbreviations: CI – confidence interval, OR – Odds ratio, AOR – Adjusted odds ratio

9. Risk Factors of Malaria in Pregnancy

Participants who used a mosquito net were less likely to have a malaria infection although the odds ratio was not significant (OR: 0.87 (95% CI: 0.44 – 1.72)) (**Table 3.12**). High maternal age and low education level were significantly associated with lower odds of malaria infection during pregnancy. Women who were self-employed were 2.8 times more likely to have a malaria infection than their unemployed counterpart. Other risk factors such as IRS were not found to be significant.

Table 3. 12 Association between maternal characteristics and malaria infection during last pregnancy

	Malaria infection during last pregnancy N (%)	No malaria infection during last pregnancy N (%)	P value for the overall difference among the categories	Factors associated with malaria infection during last pregnancy, univariate analysis OR (95% CI)	Factors associated with malaria infection during last pregnancy, multivariable analysis AOR (95% CI)
Maternal age (years)					
15 -18	11 (20.0)	274 (7.3)	**0.0088**	Reference	Reference
19 - 24	14 (25.4)	951 (25.5)		0.36 (0.16 – 0.80)	0.48 (0.19 – 1.18)
25 - 34	23 (41.8)	1887 (50.6)		0.29 (0.14 – 0.62)	0.25 (0.11 – 0.58)
35 - 49	7 (12.7)	617 (16.5)		0.28 (0.11 – 0.73)	0.21 (0.07 – 0.65)
Employment status					
Not Employed	31 (56.4)	2927 (78.5)	**0.0007**	Reference	Reference
Self-employed	21 (38.2)	705 (18.9)		2.97 (1.68 -5.22)	2.81 (1.55 – 5.11)
Employed[1]	3 (5.4)	97 (2.6)		2.99 (0.87 – 10.17)	3.50 (0.99 – 12.38)
Education level					
No education	39 (70.9)	2062 (55.3)	0.0790	Reference	Reference
Primary[2]	11 (20.0)	1162 (31.2)		0.48 (0.24 – 0.95)	0.42 (0.20 – 0.88)
Secondary[3] or higher[4]	5 (9.1)	505 (13.5)		0.48 (0.19 – 1.25)	0.42 (0.15 – 1.21)
Bed net utilization during pregnancy					
No	42 (76.3)	2745 (73.6)	0.6999	Reference	Reference
Yes	13 (23.6)	984 (26.4)		0.83 (0.43 – 1.58)	0.87 (0.44 – 1.72)
Indoor Residual Spraying					
No	39 (70.9)	2784 (74.6)	0.5260	Reference	Reference
Yes	16 (29.1)	945 (25.3)		1.17 (0.62 – 2.23)	1.45 (0.73 – 2.90)

Abbreviations: CI – confidence interval, OR – Odds ratio, AOR – Adjusted odds ratio

Notes: [1] the unemployed category contains women who were unemployed, housewives or students; [2] considers women who completed all or some primary school years; [3]considers women who completed all or some secondary school years; [4]secondary and higher education were combined given model conversion issues

Discussion

1. Summary of Findings and Interpretation

Using data from a cross-sectional survey conducted with women who had a birth outcome in the preceding year, we found that the coverage of ANC1 was 84% across the three districts of Jimma Zone, Ethiopia. This is similar to what was observed by Abosse and colleagues in Hadiya Zone (86%) but higher than what was reported in studies conducted in the eastern and southern parts of Ethiopia.[2,10,28,29] On the other hand, this ANC1 coverage estimate is lower than the 97% reported in the recent 2014/15 Ethiopia Health Sector Development Program IV Annual Performance Report.[14] The overall level of ANC4 was determined to be poor with only 46% of the participants saying that they attended four or more visits. In another study conducted in Jimma Zone ten years ago, about 76% of the women attended one visit, while 6.5% had four visits.[4] While a clear improvement is seen in the coverage of ANC attendance, close to 16% of the women who participated in the study did not seek ANC. To ensure that women have full access to ANC in the future, these participants were asked about the reasons for not attending ANC. Nearly 50% of the respondents said that ANC was unnecessary. Other important barriers to ANC included distance to the closest health facility, lack of access to transportation and husband's disapproval. Similar responses were obtained from women living in Hadiya Zone.[2] Unlike in South Soudan, demands for payment at some health facilities and insecurity were not among the reasons discouraging women from attending ANC.[30]

Receiving at least one ANC visit was related to ethnicity, education level, wealth status, women's ability to decide about healthcare, pregnancy related complications, and pregnancy intendedness. These findings are consistent with the results of the global systematic review on the

determinants of ANC conducted by Simkhada et al.[31] Other predictors, which were only significant in univariate analyses, such as maternal age and the size of the household were also found to be important predictors of ANC1 in the systematic review.[31]

The results obtained in our analysis are also in line with past Ethiopian studies.[2,3,32,33] In the study published by Abosse and colleagues, women with a primary education level were more likely to attend ANC than women who were illiterate.[2] Women whose pregnancy was planned and wanted were 76% more likely to use ANC service compared to those who had an unplanned and unwanted pregnancy.[2] In addition to these determinants, Wilunda et al. found that women in the highest wealth quintile had a 3.5-fold increase in the odds of ANC than those in the lowest wealth quintile.[3] The presence of complications during pregnancy was also an important predictor of ANC attendance.[34]

The underutilization of ANC services among women from low socioeconomic status can be partially explained by the costs associated with access to care. These include travel costs as well as out-of-pocket expenses. While MCH services are supposed to be free, several assessments demonstrated that free maternity care is implemented in a minority of facilities.[35] Women therefore have to pay for consultancies, laboratory tests and drugs.[35] Given the financial constraints, women with lower living standards may also have limited access to mass media enabling them to be informed on the benefits of attending ANC.[31] Uneducated women may also have inadequate access to ANC knowledge, thus limiting their access to ANC services.

As shown in our analysis, a woman's ethnic group may also have a significant impact on her ANC attendance. In certain ethnic groups, it might be culturally unacceptable or unnecessary for a pregnant woman to attend ANC. Women from specific ethnic groups may have no autonomy to seek ANC when the husbands or in-laws are culturally seen as the decision makers on care seeking

practices for women.[8] Limited power over healthcare may also affect women's access to family planning and the intendedness of pregnancy.[36]

It is well acknowledged that women who attend several ANC visits are more inclined to deliver in the presence of a skilled birth attendant, seek postnatal care and have better pregnancy outcomes.[12] We therefore assessed the determinants of receiving four or more ANC visits. Education level and wealth status were positively associated with ANC4. Women who were able to take decisions about their health care by themselves or with their partners were more likely to seek four or more visits. Interestingly, a past stillbirth experience was negatively associated with ANC4 attendance. A possible explanation might be that women who suffered a past stillbirth distrust the health care system. Women who had a history of stillbirth were more likely to be aged between 25 and 34 years (50%), uneducated (69%), unemployed (79%) and experienced two or more live birth (88%). Not being educated and unemployed for instance are associated with lower attendance of 4 ANC visits. The majority of the women who reported a past stillbirth were not more likely to experience complication during their last pregnancy, a miscarriage or an abortion. This is however not coherent with past studies that determined that women who experienced a stillbirth in the past were less likely to book late for their first ANC and more likely to attend four visits.[6,31,33] It is important to note that, although not significant, women who experienced a past stillbirth were more likely to attend at least one ANC visit (OR: 1.31 (95% CI: 0.81 – 2.13)). The odds of ANC4 were also still significantly higher for participants who desired their last pregnancy.

In this study, the ownership of mosquito nets was found to be low with 37% of the participants saying that they did not own a bed net during their last pregnancy. Utilization of bed net among women who said that they owned a mosquito net was also relatively low with 55% of the participants reporting always using a net during their last pregnancy. The proportion of households

who owned a mosquito net in this study was lower than the 70% observed in a study conducted within the same study area in 2015 by Birhanu and colleagues from the Jimma University.[19] Beside targeting a different study population, consisting of household heads, the difference in the proportions of households owning a mosquito net between the two studies may result from the fact that the other study followed a recent net distribution to the communities living in the districts. The utilization of ITNs is however quite consistent between the two studies. In a study carried out in 2007 in 531 households of Oromia region, 30% of which were recruited in Jimma Zone, the utilization of mosquito net was also determined to be low among pregnant women (i.e. 59%), despite a bed net ownership of roughly 90%.[37] The fact that this observation was made in 2007 and is yet relatively similar to the one made in our study highlights that the barriers to optimal mosquito net utilization among pregnant women living in this area are to be overcome. Previous studies focusing on the barriers to effective malaria prevention have indicated that perceptions regarding the risk of malaria and the effectiveness of mosquito nets were among the most important reasons for not using a net.[14]

We confirmed the relationship between attending at least one ANC visit and owning and using a mosquito net during last pregnancy. This positive association, which has not been previously assessed in Ethiopia, shows that it is important to ensure that women attend ANC to receive a mosquito net. Given the opportunity that ANC provides in improving the ownership and proper utilization of ITNs, it is also important to ensure that ITNs are always available in health facilities where ANC services are offered. Still, in order to ensure that women have access to ITNs, it is important to first address the barriers to and predictors of ANC1 and ANC4 mentioned above.

With a prevalence of 1.45%, we found that the rate of malaria infection was low in our sample of women who were pregnant in the preceding year. This is consistent with the prevalence

of 2.3% described by Newman et al. in low transmission settings and current national policies explaining why IPTp has not been implemented in Ethiopia.[14,15] Malaria is known to be endemic in the Western and Eastern lowlands of Oromia and not in the Southwest part.[14]

While the relationship between ITN use and risk of malaria has been confirmed in numerous studies, we were not able to find any association between the two, which may have been due to our limited power to observe a difference.[38–40] We also observed that the prevalence of malaria did not vary by whether the house had been sprayed within the year preceding the survey. We however found that the risk of malaria infection changed with age and occupation status. In fact, women aged 25 or above had lower odds of malaria infection than women who were aged between 15 and 18 years. Women who were self-employed were 2.8 times more likely to experience a malaria infection during their last pregnancy. This could be explained by the fact that self-employed women mostly reported "farmer" or "traders" as job status, which may have increased their exposure to mosquito bites compared with women who were housewives or unemployed.

2. Strengths and Limitations

One of the main strengths of our study was the use of a large sample size to assess our associations of interest. While the cross-sectional nature of the data does not allow exploring causal relationships, we established new associations that have not been assessed in the past in this specific area of Ethiopia and reiterate some of the gaps that will need to be overcome to improve maternal health outcomes. We considered a wide range of predicting factors in our analyses and develop a comprehensive wealth index. Residual confounding remains possible, however. For instance, when identifying the determinants of ANC, we did not consider variables relating to husbands' socio-

demographics, women's knowledge of ANC and pregnancy danger signs and media exposure, as highlighted in the conceptual framework.

Knowing that women who delay their first ANC visit may be more at risk of adverse maternal health outcomes[41], it would have also been interesting to also assess the determinants of delayed initiation of ANC visits in our study area, as women tended to delay their first visit to the second trimester. Still, we were able to determine important predictors of receiving four or more ANC visits, which has not been frequently performed in past studies.

Interviewer bias and the limited power to determine additional risk factors of malaria infection during pregnancy are some of the other limitations found in our study. Social desirability bias may have also affected the findings, with women more likely to report attending one ANC visit and sleeping under a bed net. If women who did not attend ANC were more likely to report owning and always using a mosquito net during their last pregnancy, for instance, this might have caused an underestimation of the true associations between ANC attendance and mosquito net ownership and utilization. In regards to the main predictors of ANC attendance that were associated with higher odds of ANC attendance such as education level, wealth status, and pregnancy intendedness, we might have observed biased ORs towards the null, if women who were uneducated, part of the poorest wealth quintile, and did not intend their last pregnancy over-reported their use of ANC.

The chances of recall errors have however been limited by selecting participants who had a birth outcome in the year preceding the survey. Sub-analyses including only the PHCUs that were malarious were not conducted, which may also explain the inability to find additional predictors of malaria in pregnancy.

Finally, women who refused to participate might have been less likely to use ANC services and/or sleep under a mosquito net, and may have been at greater risk of malaria. However, given the high response rate (i.e. 98.5%), this would not likely have substantially changed the estimate of ANC attendance and mosquito net use, and the direction or strength of the associations.

3. Recommendations for Health Extension Workers and Researchers

Through this study, several recommendations can be made to ensure that pregnant women use ANC services and ITNs, and remain protected against malaria. First, HEWs, health development army members, and all other healthcare staff working closely with pregnant women need to be made aware of the potential barriers to the utilization of ANC. Being able to distinguish the users of ANC from the non-users may allow HEWs to target specifically these women during their outreach activities. Although physical barriers and social inequities may also limit the utilization of ANC, health development army members may be able to know exactly which pregnant women to track to ensure that women start attending ANC in the first trimester and using ANC services at their full potential. Finally, health workers could continue to promote husbands' involvement into the healthcare of their wife and baby, and to improve their knowledge of the essential maternal health services and their benefits. As husbands are generally the first ones to know when their wives are pregnant, they can influence their wives to seek ANC early during pregnancy and to receive all four visits and more if needed.[12] This can only occur if husbands understand the importance of ANC and are aware of the suggested timing of ANC visits. Women of reproductive age and pregnant women mostly also received their information from word of mouth from friends, mothers-in-law or through social group.[12] It is therefore important that HEWs and health development army members reach all these groups to improve the uptake of ANC and of other maternal health services.

Researchers also can play an important role in addressing barriers to ANC and ITN ownership and utilization by continuing to identify additional predictors of poor access through quantitative and qualitative assessments with pregnant women, partners, family members, and community and religious leaders. Designing intervention studies to overcome the main behavioral, social, and physical barriers to ANC and ITN utilization should also be emphasized.

Efforts might be required to expand the provision of mosquito nets within ANC services. HEWs and health development army members play an important role in increasing women's knowledge on the importance of always using a mosquito net. It has been shown that women who possess knowledge on the causes, symptoms, prevention and treatment of malaria are not only more likely to use a net but also to ensure that their children sleep under a net.[20,42–44] Health workers can also inform husbands and other family members that mosquito nets are to be used preferably by pregnant women and young children.

Even though the prevalence of malaria in our sample was low, many communities such as the ones in Jimma Zone are characterized as having a low and unstable malaria transmission patterns, thus increasing the tendency for rapid progression to severe malaria and associated consequences among infected individuals.[45] HEWs, nurses and midwives could always make sure to test every woman against malaria for better management and treatment.[14]

Conclusions

In conclusion, data from this cross-sectional survey confirmed that ANC attendance and the ownership and utilization of mosquito nets are low in Jimma Zone. The major factors associated with ANC attendance were education, wealth status, the ability to take decisions regarding the

healthcare, and the intendedness of pregnancy. We also confirm that promoting ITN uptake during ANC services would be of primary importance.

Optimizing the role of community health workers might be the most judicious option to strengthen the uptake of ANC and ITNs in rural communities. Indeed, through contact with trained HEWs in their communities, pregnant women who are less likely to attend ANC and own and use a bed net can be made aware about the consequences associated with the poor utilization of ANC and of malaria in pregnancy.

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Chapter 4: General Conclusions and Recommendations

In 2004, the Health Extension Program (HEP) was introduced by the Ethiopia's Federal Ministry of Health (FMoH) in response to the poor health status found in rural communities. Considered the most important framework for achieving national and international health targets, this program has facilitated the access to a package of essential preventive and curative health services at the village level, through the construction of health posts staffed with trained pairs of health extension workers (HEWs).[1]

HEWs, in partnership with a network of health development army members, play an important role in motivating women to seek care throughout pregnancy and adopt healthy behaviours for themselves and their children.[1] Along with ensuring the prevention, control and treatment of communicable diseases that have a tendency to worsen with pregnancy, HEWs are important for the compilation and transmission of service delivery reports to the upper levels of the health system, where decisions regarding the development and implementation of maternal and child health (MCH) programs can take place.

Despite the implementation of the HEP across Ethiopia, including an emphasis on MCH, the utilization of maternal health services remains less than optimal. Through this thesis, I therefore evaluated the quality of MCH data collected within the HMIS, the antenatal care (ANC) attendance and mosquito net ownership and use, and the prevalence and risk factors of malaria in pregnancy in three district of Jimma Zone, in order to make inferences and give recommendations that will be beneficial for HEWs and other health professionals and stakeholders aiming at improving MCH outcomes in Ethiopia.

Through the first manuscript, I confirmed that the quality of MCH data that has been collected from primary health care units (PHCUs) and forwarded to the Health Management Information System (HMIS) in the past year was generally low. Completeness and timeliness of health post and health centre level reporting were below the limits set by the FMoH. Using MCH indicators and coverage estimates from a community-based cross-sectional survey conducted with women who had a birth outcome in the preceding year in the same PHCUs, I found that the coverage of ANC, skilled birth attendance, and early postnatal care reported in the HMIS were higher than coverage from the survey, with the possibility that these services are being over-reported in the administrative data. An over-representation of the utilization of these essential maternal health services may limit the ability of HMIS workers and supervisors to develop plans and allocate resources for better MCH outcomes.

One important strategy to improve the quality of MCH data collected within the HMIS would be to ensure effective communication processes between HEWs, health centre staff, and HMIS supervisors.[2] As such, supervisors might provide continuous guidance and detailed feedback to HEWs on the quality of their summary reports. Being at the primary level of health data collection, there is an urgent need to better train HEWs regarding data collection, management and utilization. Additional research on the HEWs' perceptions regarding their role in the sustainability of the HMIS would be beneficial. Qualitative research studies may help with that aspect, by giving HEWs and other health centre staff the possibility to express their concerns and perspectives on the ways they can contribute to enhancing the quality of the data gathered within the HMIS.

It is also important to note that barriers other than those relating to the training and knowledge of HEWs and supervisors may explain the poor quality of MCH data in the HMIS. While the introduction of an electronic HMIS has resulted in improvements in the reporting,

monitoring and evaluation of health data, the availability of other essential resources to perform HMIS tasks is still limited. Several PHCUs still have no access to a computer to facilitate the compilation of the data and its use.[3] Belay et al. also noted that HEWs in health posts do not even have access to a calculator to perform basic calculations to assess the use of services in their PHCUs.[3] This can limit their ability to report accurate data to the higher levels of the health system.[3] PHCUs sometime face the unavailability of register forms and tally sheets, which are supposed to be restocked on a regular basis by the district health offices.[3,4] It would be important to overcome these barriers in the future to ultimately build the capacity of the HMIS in informing MCH in Ethiopia.

In the second manuscript of this thesis, I focused on the barriers to and determinants of ANC attendance and insecticide treated net (ITN) ownership and use, and the risk of malaria infection during pregnancy in Jimma Zone, using data from a cross-sectional survey that was conducted with women who had pregnancy outcome in the previous year.

Even though the proportion of women who received one ANC visit was high (84%), less than half of the women attended four ANC visits (47%). In order to improve the coverage of ANC and reach the target of 95% of pregnant women having at least four visits by 2020[1], the main barriers to adequate ANC access need to be addressed. In this study, the main reasons that women reported for not attending ANC were a perceived the lack of necessity and the distance to the health facility. ITN possession and utilization among women who owned a net were also relatively low with estimates of 47% and 55%, respectively. More efforts are therefore needed to improve the coverage of ANC and ITNs. HEWs together with health development army members can hold an important role in ameliorating ANC and ITN coverage through increasing the amount of time they spend conducting home visits. It is also recommended that HEWs and health development army

members seek the participation of husbands, family members, friends and social groups to maximize the use of ANC and ITNs.

To help HEWs and other community health workers target women who are less likely to attend ANC, we identified the non-users through regression analyses. Women who were uneducated and part of a poorest household were less likely to use ANC, highlighting the importance of addressing the social determinants of ANC use in future work. Ethnicity, the intendedness of the pregnancy, and woman's ability to take decisions about her health care were also important predictors of ANC utilization. The fact that women who were exposed to different sources of media reported better ANC attendance highlights the importance of exploring the potential of media in improving access to ANC and other MCH services. This work also indicates the importance of addressing physical accessibility to ANC and improving the knowledge of the women on the importance of attending ANC. We also confirmed the relationship between ANC attendance and the ownership and utilization of mosquito nets, emphasizing again the importance of motivating pregnant women to attend ANC to not only receive an ITN but also to be informed on its appropriate usage.

The prevalence of malaria was low in the study population. However, as shown in the first manuscript, the prevalence of malaria infection in pregnancy from the survey participants is relatively higher than what was reported in the HMIS, meaning that greater attention might need to go towards evaluating trends in malaria infections during pregnancy. HEWs and other ANC workers might also continue to test pregnant women for malaria, as the risks of severe infection and related consequences are higher, given the absence of immunity.

To ensure the collection of high-quality routine health data, the uptake of ANC and mosquito nets, and the prevention and control malaria in pregnancy in rural communities, more support could be going towards strengthening maternal health services, including enhancing the capacity and knowledge of HEWs. Strategies could be put in place to guarantee that all community health workers allocate enough time for the provision of successful home visits and quality health services. Further research may also allow understanding barriers and facilitators from the perspectives of women and their families, HEWs, and other stakeholders in the system. In addition to these points, positive interactions between communities, health workers, health system managers, and researchers will strengthen the contribution that the HEWs, among other health care professionals, can have on the improvement of the health outcomes of mothers, newborns, and children in Ethiopia.

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Appendix A

Table A. 1 Consistency over time ratios in Gomma district, based on an assessment of HMIS data quality for selected MCH indicators, 2013-2015, using WHO data quality report card

	ANC1 ratio	% difference from Gomma ratio	ANC4 ratio	% difference from Gomma ratio	SBA	% difference from Gomma ratio	PNC	% difference from Gomma ratio	DTP1	% difference from Gomma ratio	DTP3	% difference from Gomma ratio
Ratio for Gomma	**0.88**		**0.94**		**1.14**		**2.42**		**0.88**		**0.86**	
Beshasha	0.86	-2.61	0.78	**-16.95**	1.28	**11.99**	2.57	5.94	0.97	**10.91**	1.17	**36.71**
Chami	0.96	8.95	0.86	-7.78	1.25	9.72	2.61	7.66	0.99	**12.82**	0.86	1.05
Chago												
Choche	0.86	2.83	0.90	-3.94	1.08	-4.90	2.50	3.29	0.56	**-35.94**	0.53	**-38.46**
Dhayi	0.75	**-14.28**	0.64	**-31.87**	0.94	**-17.51**	3.02	**24.64**	0.54	**-38.32**	0.59	**-30.53**
Kechene												
Gembe	0.80	-9.07	0.96	2.02	1.03	-9.72	3.34	**37.75**	1.24	**40.47**	1.12	**30.88**
Kedemasa	1.03	**17.57**	0.66	**-29.74**	1.19	4.20	2.34	-3.42	0.86	-2.15	0.67	**-22.14**
Limu Shayi	1.06	**20.86**	1.18	**25.69**	1.30	**14.18**	4.04	**66.52**	0.93	5.44	1.28	**49.07**
Meti	0.62	**-29.47**	1.05	**11.94**	0.84	**-26.79**	2.37	-2.26	0.64	**-27.09**	0.65	**-23.66**
Koticha												
Omo Beko	0.93	5.21	0.69	**-26.23**	1.39	**22.06**	3.98	**64.30**	1.68	**91.26**	0.91	6.52
Yachi	0.93	6.12	0.62	**-33.47**	1.11	-2.71	2.04	**-15.75**	1.25	**42.52**	1.53	**78.21**

Abbreviations: ANC1- antenatal care firs visit, ANC4 – antenatal care fourth visit, SBA – skilled birth attendance, PNC – postnatal care, DTP1 - Diphtheria, Tetanus and Pertussis first dose, DTP3 - Diphtheria, Tetanus and Pertussis third dose

Table A. 2 Consistency over time ratios in Kersa district, based on an assessment of HMIS data quality for selected MCH indicators, 2013-2015, using WHO data quality report card

	ANC1 ratio	% difference from Kersa ratio	ANC4 ratio	% difference from Kersa ratio	SBA ratio	% difference from Kersa ratio	PNC ratio	% difference from Kersa ratio	DTP1 ratio	% difference from Kersa ratio	DTP3 ratio	% difference from Kersa ratio
Ratio for Kersa	**0.99**		**1.24**		**0.93**		**3.70**		**1.07**		**1.11**	
Adere Dika	1.05	5.72	1.10	**-10.84**	0.92	-1.07	6.58	**77.79**	1.19	**11.15**	0.94	**-12.86**
Bale Wajo	1.51	**51.51**	1.34	8.89	1.32	**42.24**	7.05	**90.41**	1.09	2.13	0.87	**-18.68**
Bulbul	0.80	**-19.17**	0.39	**-67.96**	0.70	**-24.46**	4.57	**23.61**	1.11	3.72	1.21	7.75
Kusaye Beru	0.92	-7.93	1.49	**21.11**	0.91	-2.15	8.13	**119.53**	1.01	-5.57	1.14	2.02
Kara Gora	0.60	**-39.45**	0.86	**-30.50**	0.62	**-32.43**	2.57	**-30.36**	0.86	**-20.26**	1.03	-6.20
Kellacha	1.26	**26.81**	2.57	**108.25**	1.21	**30.28**	3.12	**-15.75**	1.43	**33.18**	1.76	**50.46**
Serbo	1.10	**10.74**	1.46	**18.61**	1.04	**11.85**	1.86	**-49.75**	1.26	**17.38**	1.38	**21.39**

Abbreviations: ANC1- antenatal care firs visit, ANC4 – antenatal care fourth visit, SBA – skilled birth attendance, PNC – postnatal care, DTP1 - Diphtheria, Tetanus and Pertussis first dose, DTP3 - Diphtheria, Tetanus and Pertussis third dose

Table A. 3 Consistency over time ratios in Seka Chekorsa district, based on an assessment of HMIS data quality for selected MCH indicators, 2013-2015, using WHO data quality report card

	ANC1 ratio	% difference from SC ratio	ANC4 ratio	% difference from SC ratio	SBA ratio	% difference from SC ratio	PNC ratio	% difference	DTP1 ratio	% difference from SC ratio	DTP3 ratio	% difference from SC ratio
Mean ratio for Seka Chekorsa	**0.96**		**1.03**		**1.05**		**1.66**		**0.96**		**1.01**	
Bake Gudo	1.07	**11.31**	0.94	-8.46	1.04	-0.66	1.70	2.34	0.99	3.32	0.99	-1.68
Buyo Kechema	0.75	**-22.41**	0.99	-3.11	0.91	**-12.58**	1.69	1.56	0.63	**-34.89**	0.54	**-45.93**
Dabo Yaya	1.17	**21.47**	1.03	0.77	1.01	-3.81	2.23	**33.79**	1.18	**22.74**	1.07	6.25
Detu Kersu	0.87	-9.85	1.15	**11.67**	1.06	1.04	1.46	**-12.00**	1.26	**31.67**	1.95	**93.25**
Geta Bake	1.31	**35.58**	1.03	0.389	0.93	**-11.25**	1.46	**-12.36**	1.00	3.84	1.32	**31.05**
Lilu chaa	1.44	**49.27**	1.12	8.94	1.14	8.77	2.23	**33.79**	1.11	**15.47**	1.12	**11.21**
Seka	0.69	**-27.69**	0.91	**-11.77**	1.03	-2.00	1.37	**-17.65**	0.67	**-29.59**	0.81	**-19.74**
Setemma	1.35	**40.04**	1.76	**71.40**	1.11	6.29	1.86	**12.12**	1.05	8.72	1.48	**47.02**
Wokito	0.93	-2.90	0.62	**-39.29**	1.11	6.01	2.04	**22.68**	1.26	**30.52**	1.53	**51.68**

Abbreviations: SC – Seka Chekorsa, ANC1- antenatal care firs visit, ANC4 – antenatal care fourth visit, SBA – skilled birth attendance, PNC – postnatal care, DTP1 - Diphtheria, Tetanus and Pertussis first dose, DTP3 - Diphtheria, Tetanus and Pertussis third dose

Table A. 4 Consistency between antenatal care first visit (ANC1) and diphtheria, tetanus and pertussis first dose (DTP1) for Gomma district, based on an assessment of HMIS data quality for selected MCH indicators, 2014-2015, using WHO data quality report card

	PHCU Ratio	Gomma Ratio	% difference
Beshasha	0.68	0.58	**17.82**
Chami Chago	0.72	0.58	**25.26**
Choche	0.34	0.58	**-41.69**
Dhayi Kechene	0.65	0.58	**12.97**
Gembe	0.79	0.58	**37.89**
Kedemess	0.59	0.58	2.59
Limu Shayi	0.36	0.58	**-37.19**
Meti Koticha	0.47	0.58	**-19.03**
Omo Gurude	0.75	0.58	**30.62**
Yachi	0.64	0.58	**11.07**

Abbreviation: PHCU – primary health care unit

Table A. 5 Overall consistency between official and alternate denominators across the three districts, based on an assessment of HMIS data quality for selected MCH indicators, 2014-2015, using WHO data quality report card

	No. of women making ANC1 visit	Survey estimate (%)	Official denominator of PW (estimates from 2008)	Alternate denominator	Ratio of official to alternate denominator	% of difference between alternate and official denominator
Gomma	4803	90.2	9,625	5324	1.81	**81.0**
Kersa	4887	75.5	7,447	6574	1.15	**15.0**
Seka Chekorsa	7543	85.2	9,371	8852	1.06	6.0

Abbreviations: ANC1 – antenatal care first visit, PW- pregnant women

Table A. 6 Consistency between official and alternate denominators for health centres located in Gomma, based on an assessment of HMIS data quality for selected MCH indicators, 2014-2015, using WHO data quality report card

	No. of women making ANC1 visit	Survey estimate (%)	Official denominator of PW (estimates from 2008)	Alternate denominator	Ratio of official to alternate denominator	% of difference between alternate and official denominators
Beshasha	640	92.4	1243	693	1.79	**79.0**
Chami Chago	512	92.7	786	553	1.42	**42.0**
Choche	677	82.4	1041	822	1.26	**26.0**
Dayi kechene	205	87.1	439	236	1.86	**86.0**
Gembe	597	90.0	919	664	1.38	**38.0**
Kedamess	497	77.5	698	642	1.08	8.0
Limu Shaye	884	90.5	1298	977	1.33	**33.0**
Omo Gurude	221	75.5	2156	293	7.36	**636.0**
Yachi	570	89.2	868	640	1.35	**35.0**

Abbreviations: ANC1 – antenatal care first visit, PW- pregnant women

Table A. 7 Consistency between official and alternate denominators for health centres located in Kersa, based on an assessment of HMIS data quality for selected MCH indicators, 2014-2015, using WHO data quality report card

	No. of women making ANC1 visit	Survey estimate (%)	Official denominator of PW (estimates from 2008)	Alternate denominator	Ratio of official to alternate denominator	% of difference between alternate and official denominator
Adere Dika	577	75.1	761	768	0.99	0.01
Bale wajo	637	48.2	946	1322	0.71	**29.0**
Bulbul	548	78.4	729	699	1.04	4.0
Kallacha	466	81.7	1527	571	2.67	**167.0**
Kara Gora	219	75.8	667	289	2.31	**131.0**
Kusaye	839	77.5	967	1083	0.89	**11.0**
Serbo	1601	84.7	1904	1891	1.001	0.01

Abbreviations: ANC1 – antenatal care first visit, PW- pregnant women

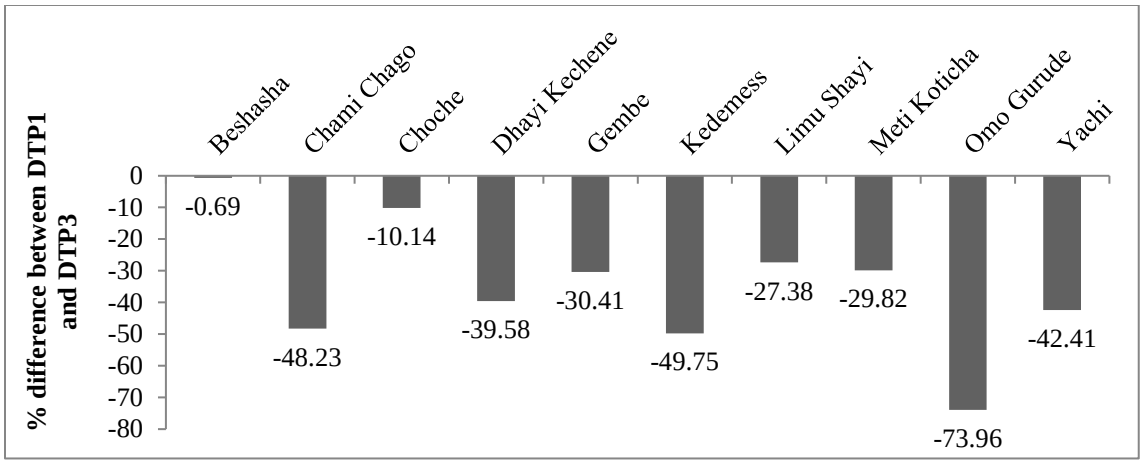
Table A. 8 Consistency between official and alternate denominators for health centres located in Seka Chekorsa, based on an assessment of HMIS data quality for selected MCH indicators, 2014-2015, using WHO data quality report card

	No. of women making ANC1 visit	Survey estimate (%)	Official denominator of PW (estimates from 2008)	Alternate denominator	Ratio of official to alternate denominator	% of difference between alternate and official denominator
Beke Gudo	836	85.7	878	976	0.89	**10.0**
Buyo Kechema	422	91.8	526	460	1.14	**14.0**
Detu	724	82.9	1120	874	1.28	**28.0**
Geta Beka	711	66.8	657	1065	0.62	**38.0**
Lilu chaa	1804	73.0	1787	2472	0.72	**28.0**
Seka	1103	86.0	1245	1283	0.97	3.0
Sentemma	1188	89.4	1306	1329	0.98	1.8
Wekito	755	85.6	1147	882	1.30	3.0

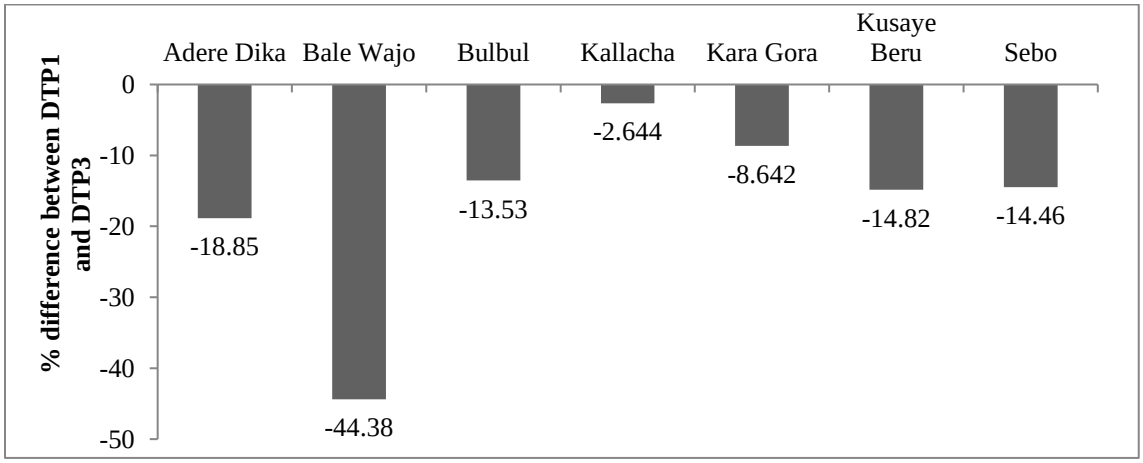
Abbreviations: ANC1 – antenatal care first visit, PW- pregnant women

Figure A. 1 Consistency between the number of diphtheria, pertussis and tetanus (DTP) vaccine first and third doses, based on an assessment of HMIS data quality for selected MCH indicators, 2014-2015, using WHO data quality report card

Gomma



Kersa



Seka Chekorsa

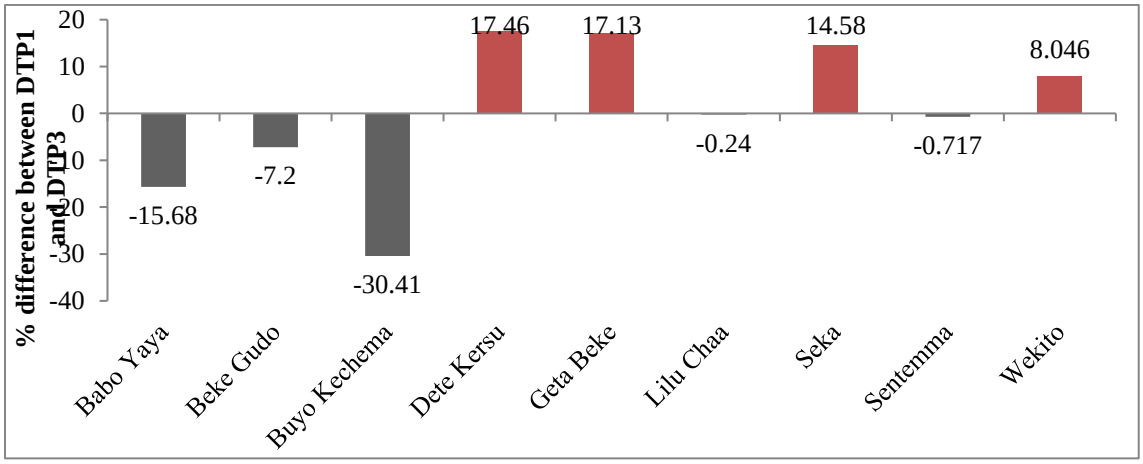
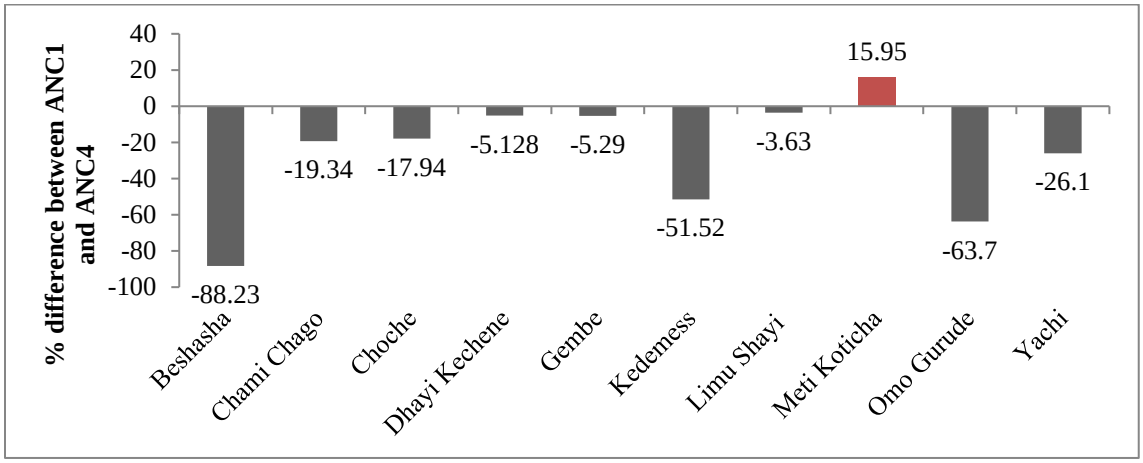
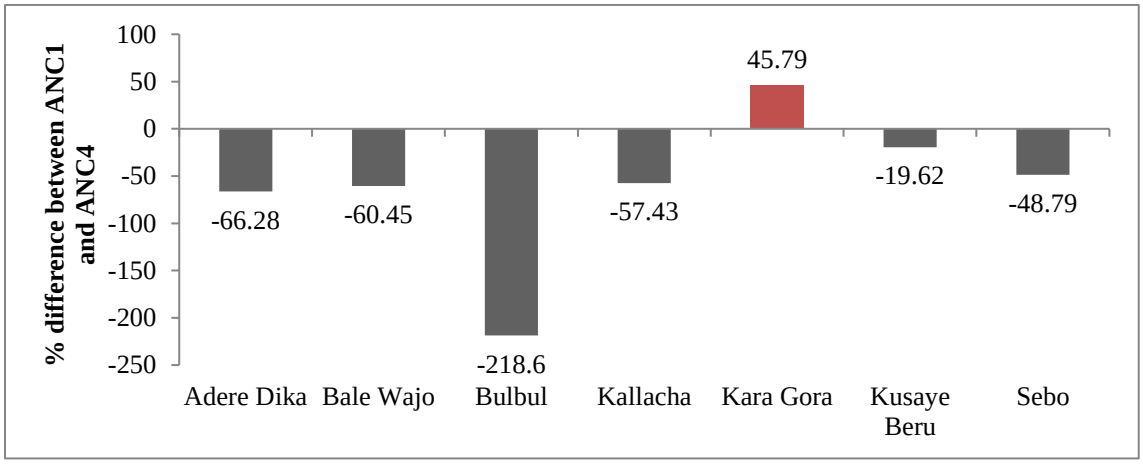


Figure A. 2 Consistency between the numbers of antenatal care (ANC) first and fourth visits, based on an assessment of HMIS data quality for selected MCH indicators, 2014-2015, using WHO data quality report card

Gomma



Kersa



Seka Chekorsa

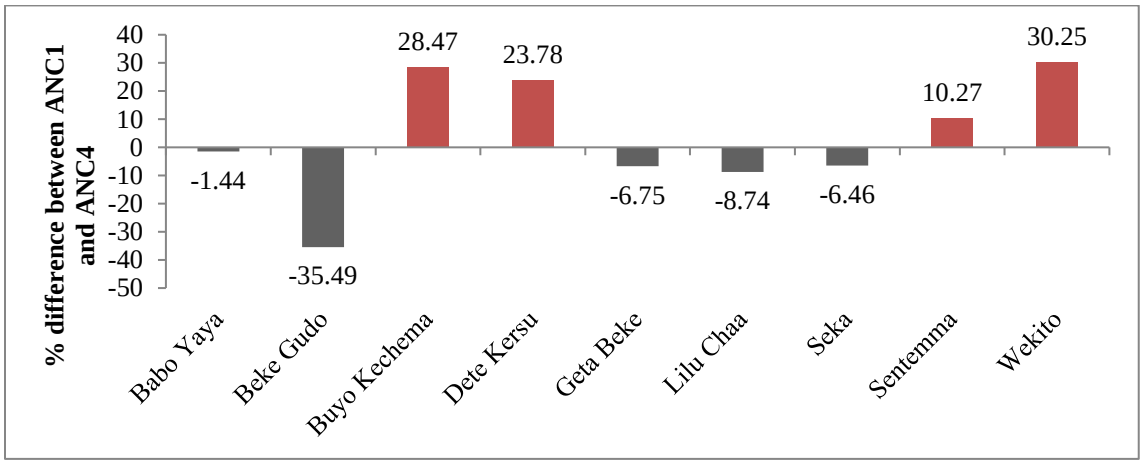
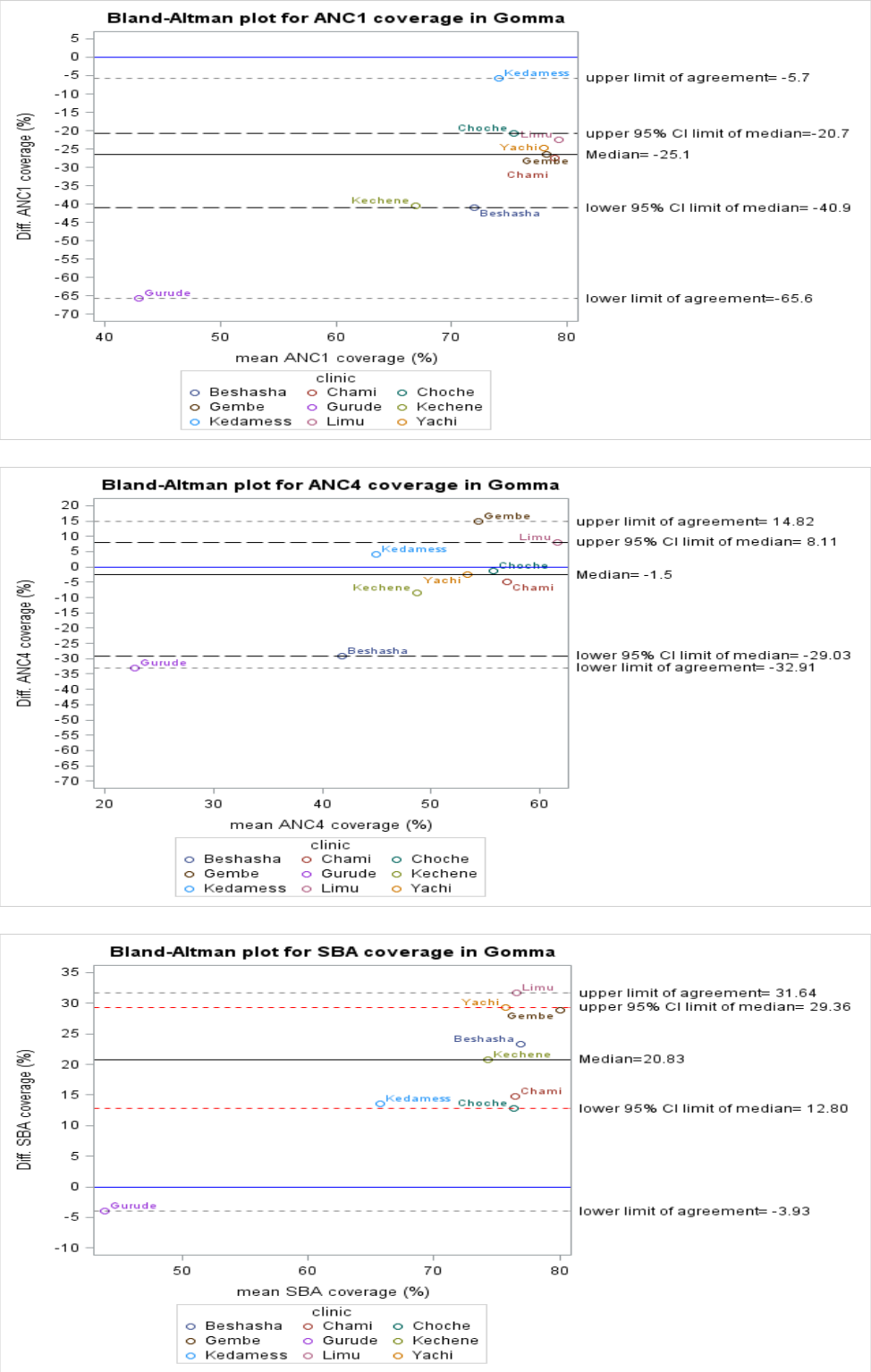
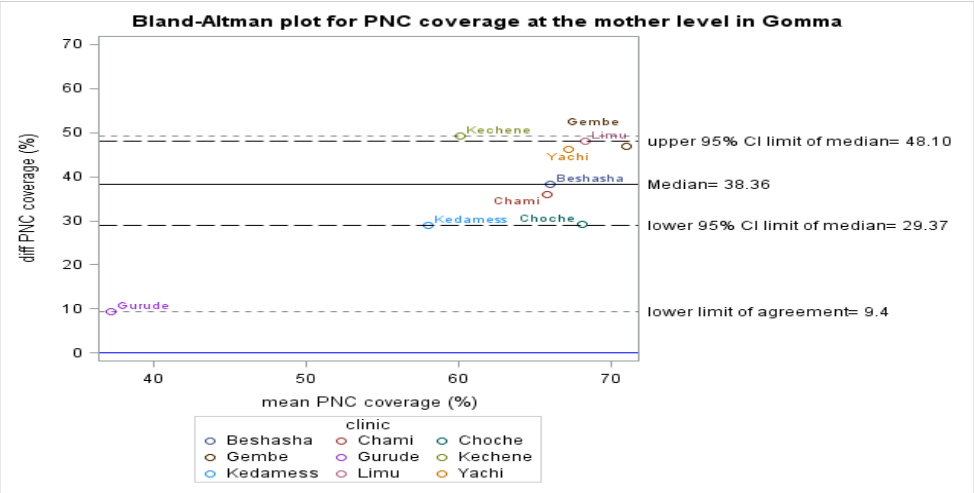
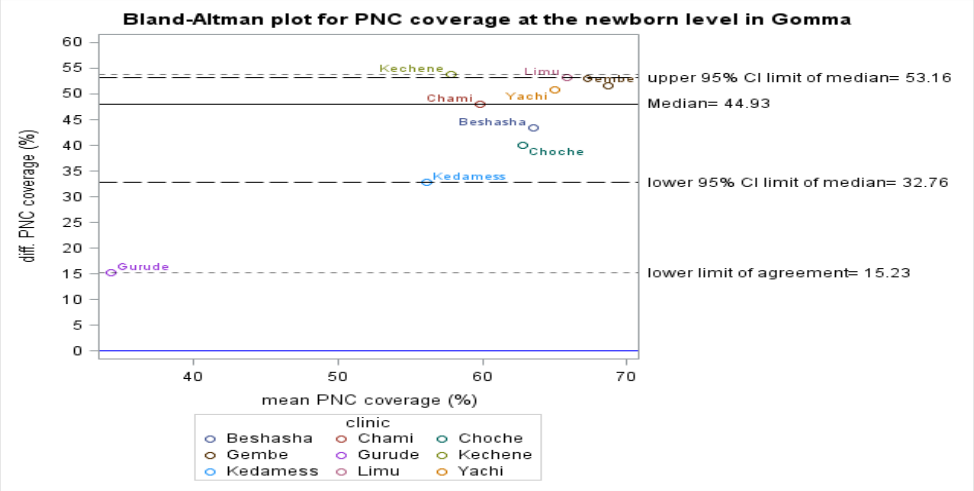


Figure A. 3 Bland-Altman plots for the agreement of maternal and child health indicator coverage estimates between the HMIS and the survey in Gomma




Bland-Altman plot for PNC coverage at the mother level in Gomma
diff PNC coverage (%)
mean PNC coverage (%)
upper 95% CI limit of median= 48.10
Median= 38.36
lower 95% CI limit of median= 29.37
lower limit of agreement= 9.4
clinic
Beshasha
Chami
Choche
Gembe
Gurude
Kechene
Kedamess
Limu
Yachi


Bland-Altman plot for PNC coverage at the newborn level in Gomma
diff. PNC coverage (%)
mean PNC coverage (%)
upper 95% CI limit of median= 53.16
Median= 44.93
lower 95% CI limit of median= 32.76
lower limit of agreement= 15.23
clinic
Beshasha
Chami
Choche
Gembe
Gurude
Kechene
Kedamess
Limu
Yachi

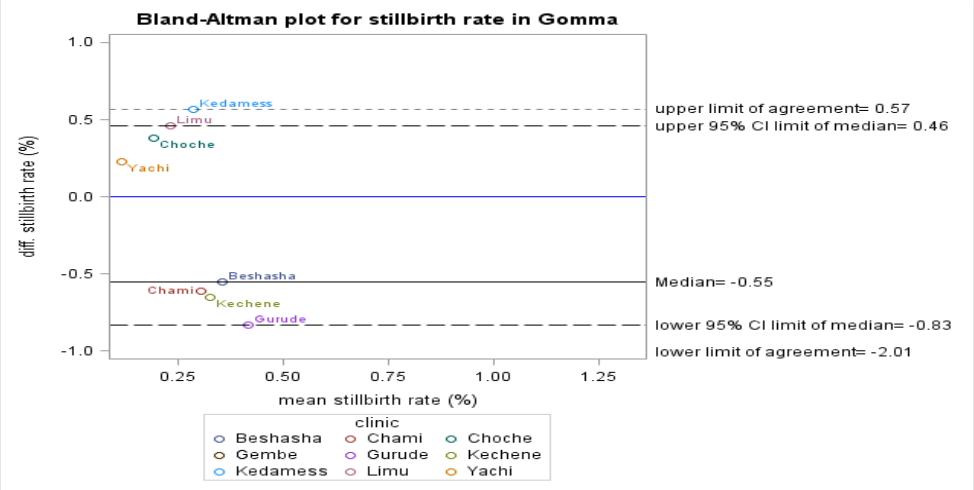
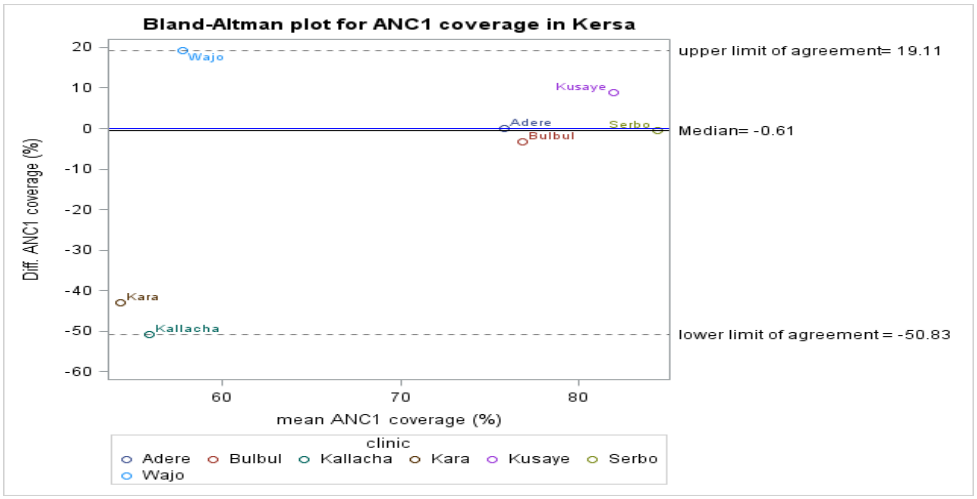
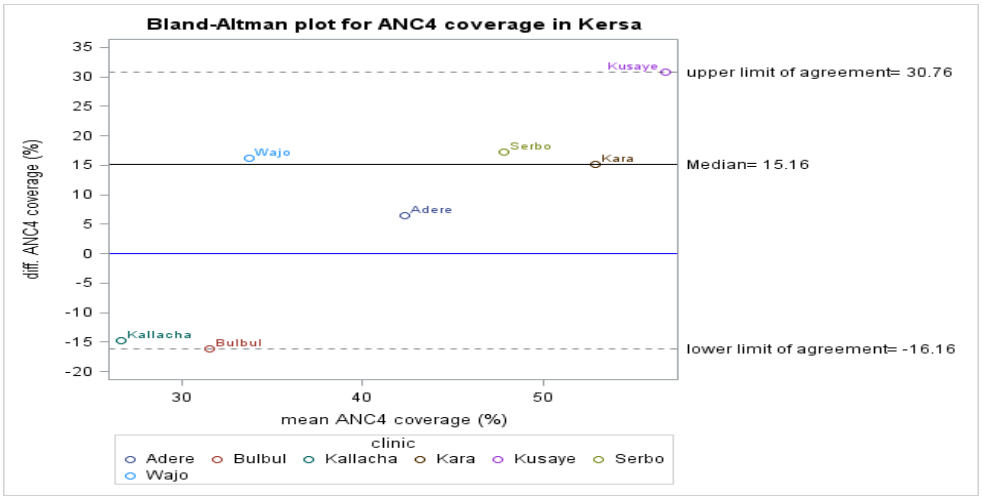
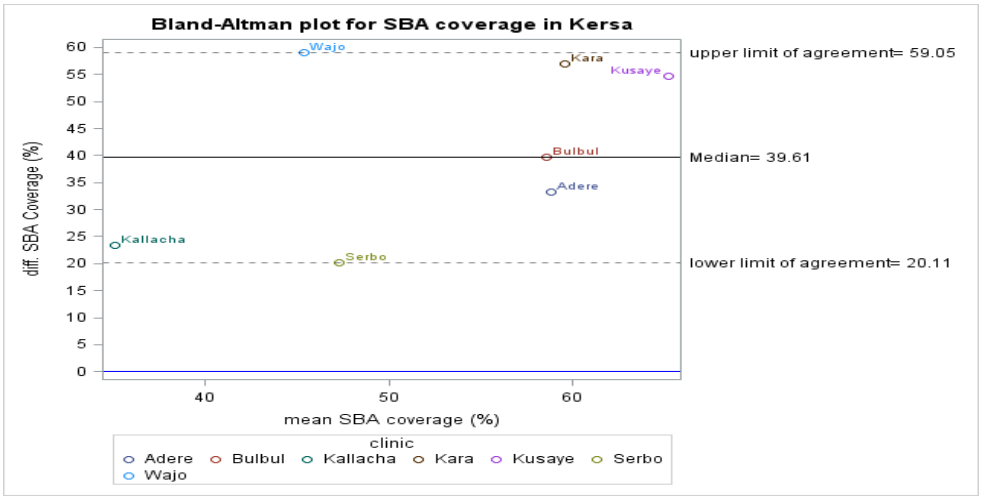
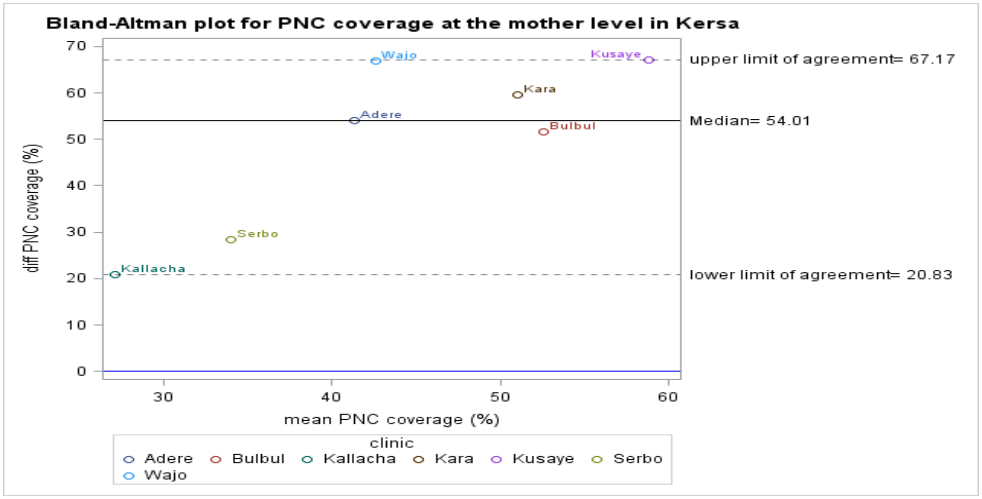

Bland-Altman plot for stillbirth rate in Gomma
diff. stillbirth rate (%)
mean stillbirth rate (%)
upper limit of agreement= 0.57
upper 95% CI limit of median= 0.46
Median= -0.55
lower 95% CI limit of median= -0.83
lower limit of agreement= -2.01
clinic
Beshasha
Chami
Choche
Gembe
Gurude
Kechene
Kedamess
Limu
Yachi

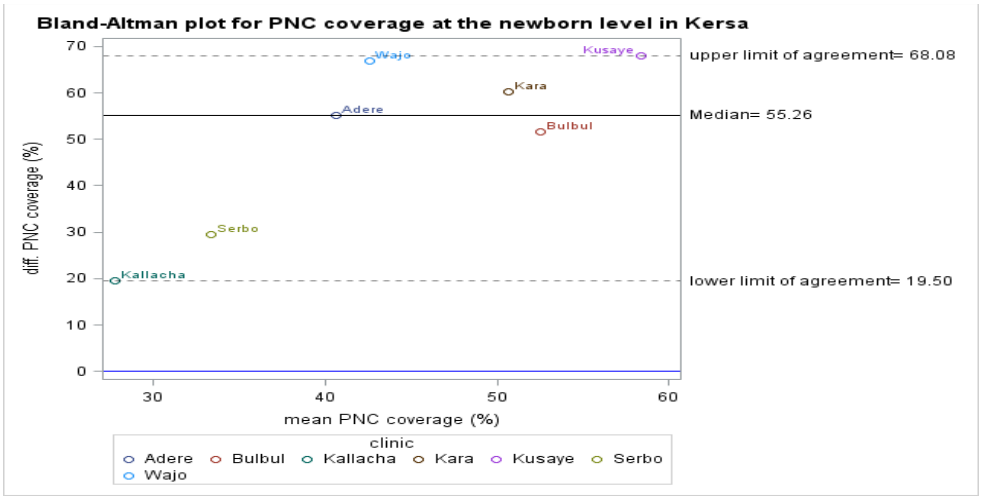
Figure A. 4 Bland-Altman plots for the agreement of maternal and child health indicator coverage estimates between the HMIS and the survey in Kersa








Bland-Altman plot for PNC coverage at the mother level in Kersa
diff PNC coverage (%)
mean PNC coverage (%)
upper limit of agreement= 67.17
Median= 54.01
lower limit of agreement= 20.83
Wajo
Kusaye
Kara
Adere
Bulbul
Serbo
Kallacha
clinic
Adere Bulbul Kallacha Kara Kusaye Serbo Wajo


Bland-Altman plot for PNC coverage at the newborn level in Kersa
diff. PNC coverage (%)
mean PNC coverage (%)
upper limit of agreement= 68.08
Median= 55.26
lower limit of agreement= 19.50
Wajo
Kusaye
Kara
Adere
Bulbul
Serbo
Kallacha
clinic
Adere Bulbul Kallacha Kara Kusaye Serbo Wajo

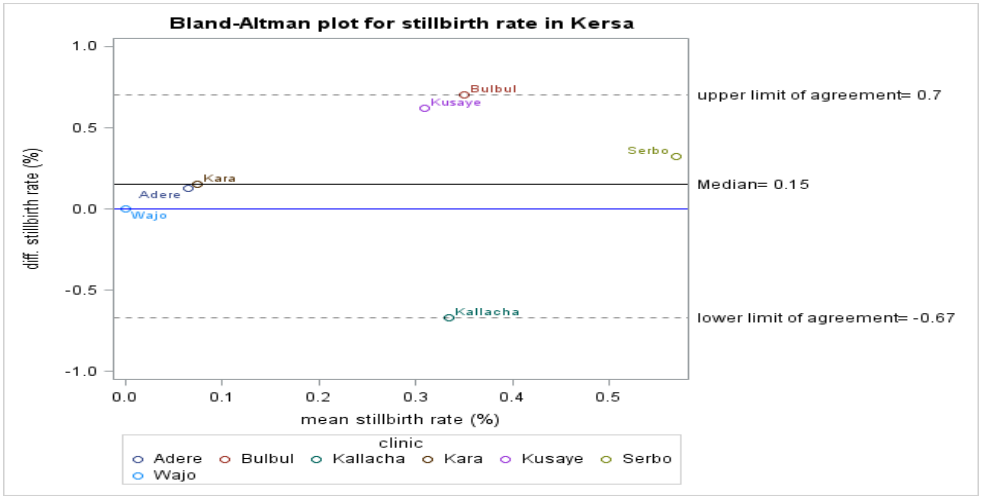
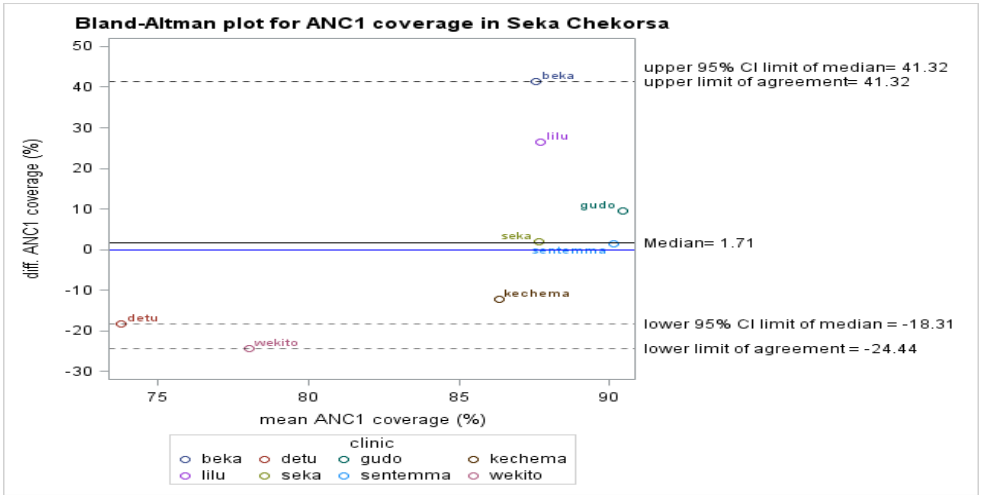
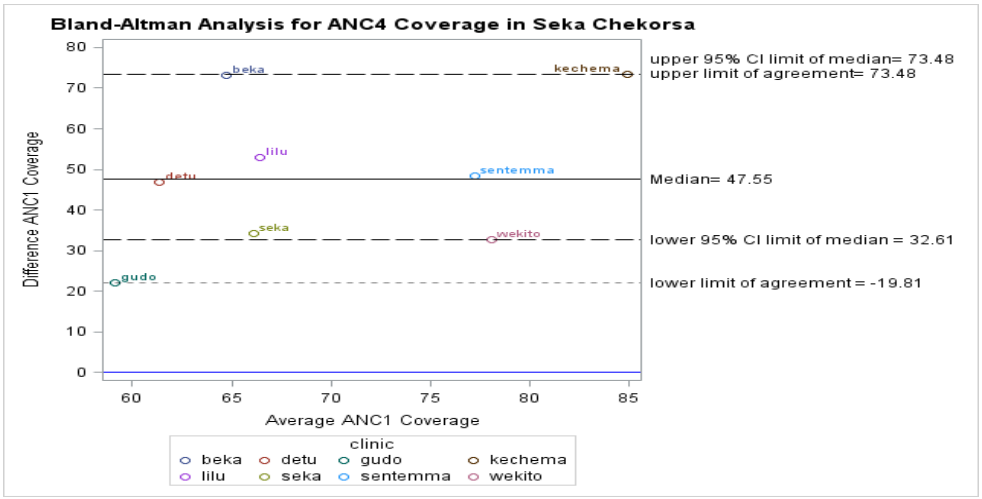
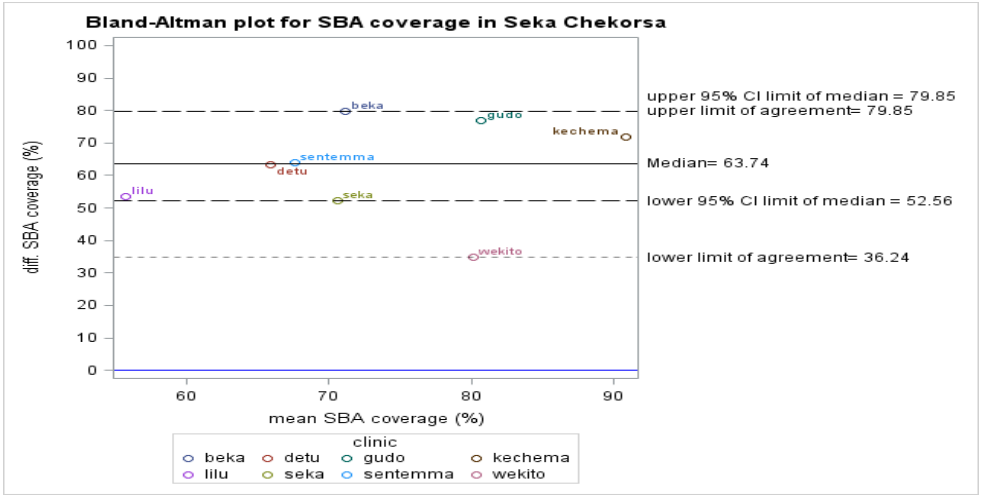
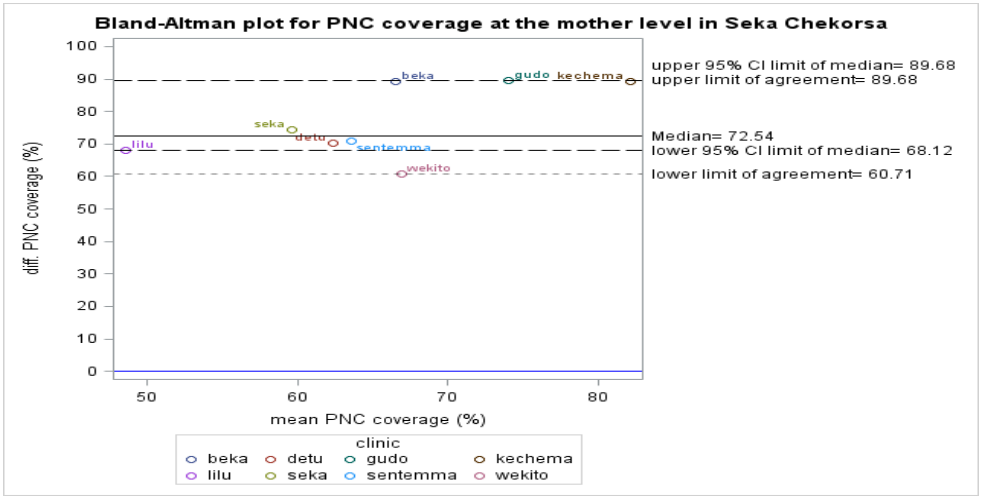

Bland-Altman plot for stillbirth rate in Kersa
diff. stillbirth rate (%)
mean stillbirth rate (%)
upper limit of agreement= 0.7
Median= 0.15
lower limit of agreement= -0.67
Bulbul
Kusaye
Serbo
Kara
Adere
Wajo
Kallacha
clinic
Adere Bulbul Kallacha Kara Kusaye Serbo Wajo

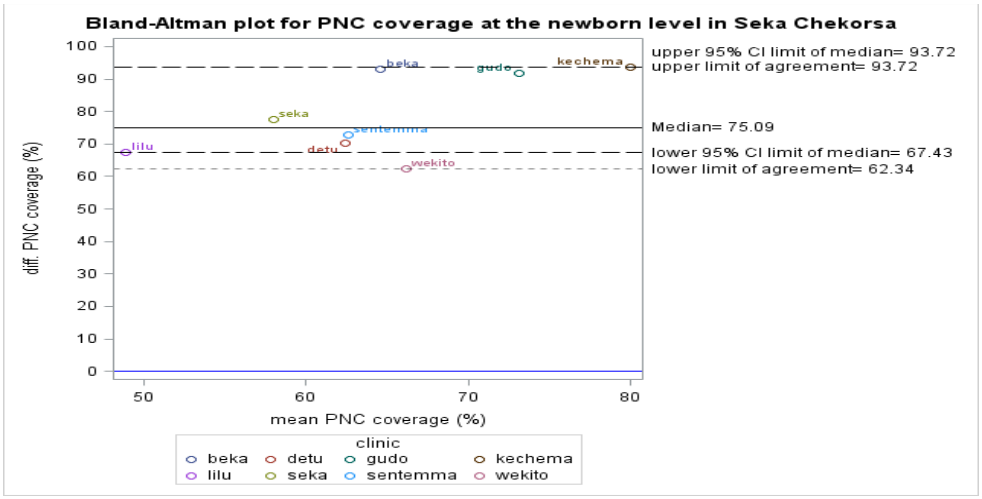
Figure A. 5 Bland-Altman plots for the agreement of maternal and child health indicator coverage estimates between the HMIS and the survey in Seka Chekorsa








Bland-Altman plot for PNC coverage at the mother level in Seka Chekorsa
diff. PNC coverage (%)
mean PNC coverage (%)
upper 95% CI limit of median= 89.68
upper limit of agreement= 89.68
Median= 72.54
lower 95% CI limit of median= 68.12
lower limit of agreement= 60.71
clinic
beka detu gudo kechema
lilu seka sentemma wekito


Bland-Altman plot for PNC coverage at the newborn level in Seka Chekorsa
diff. PNC coverage (%)
mean PNC coverage (%)
upper 95% CI limit of median= 93.72
upper limit of agreement= 93.72
Median= 75.09
lower 95% CI limit of median= 67.43
lower limit of agreement= 62.34
clinic
beka detu gudo kechema
lilu seka sentemma wekito

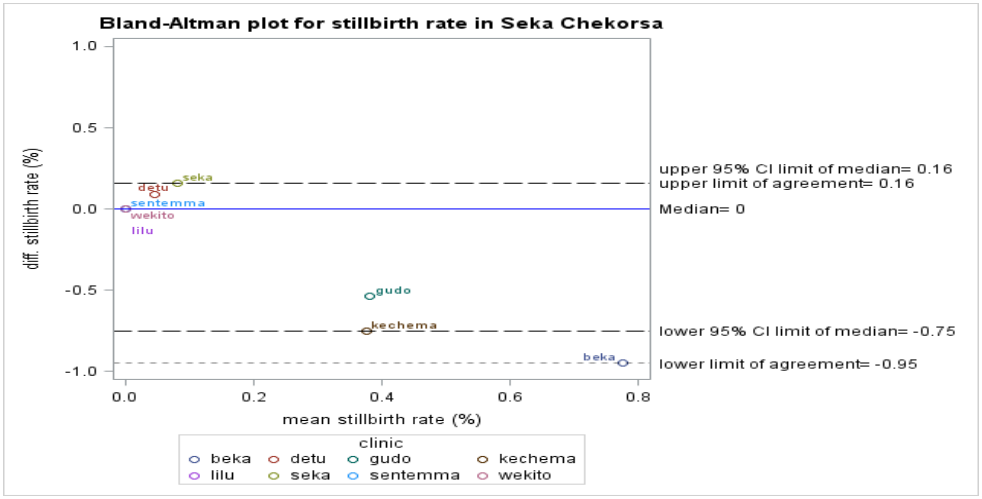
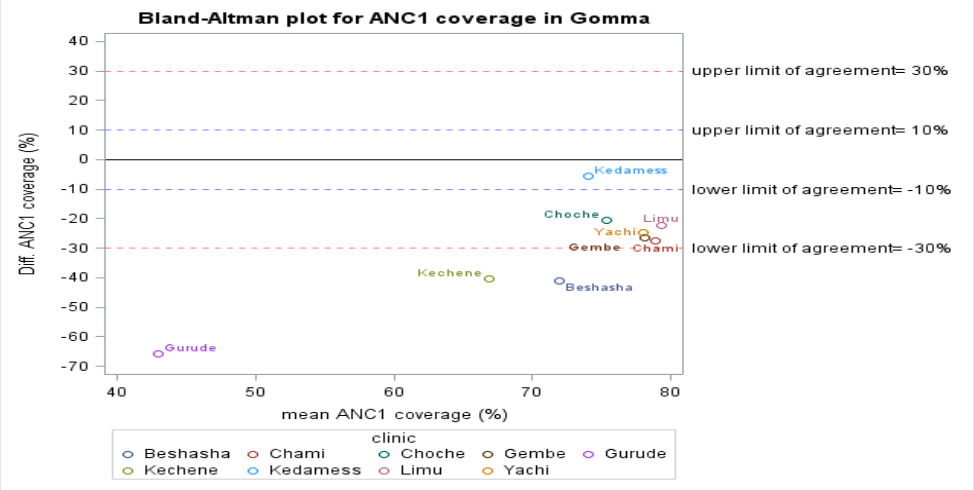
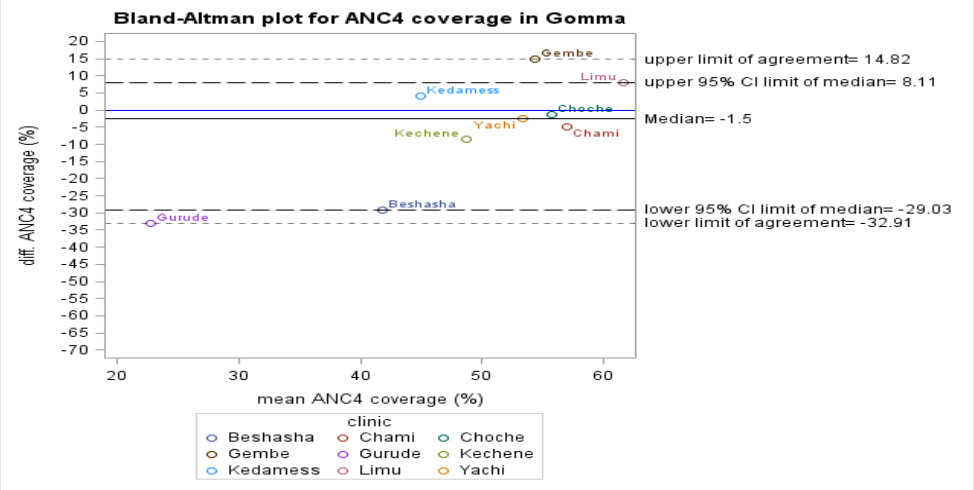
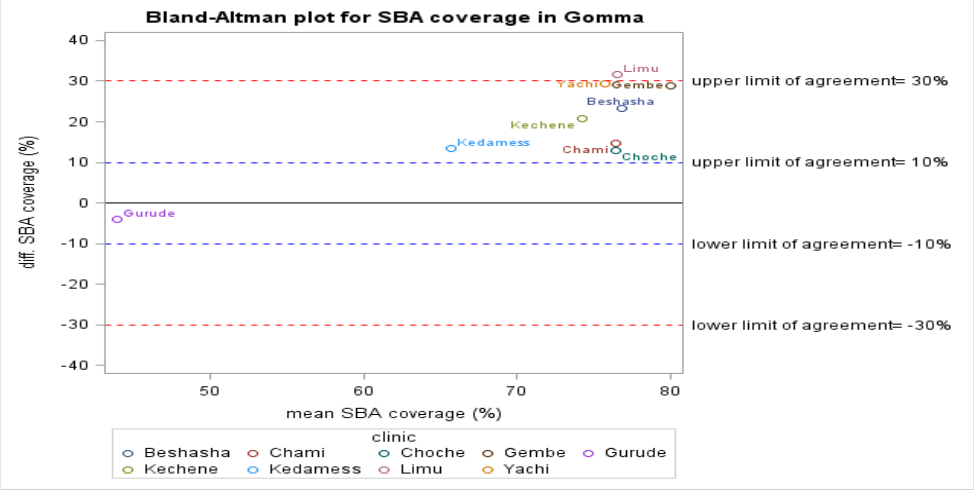
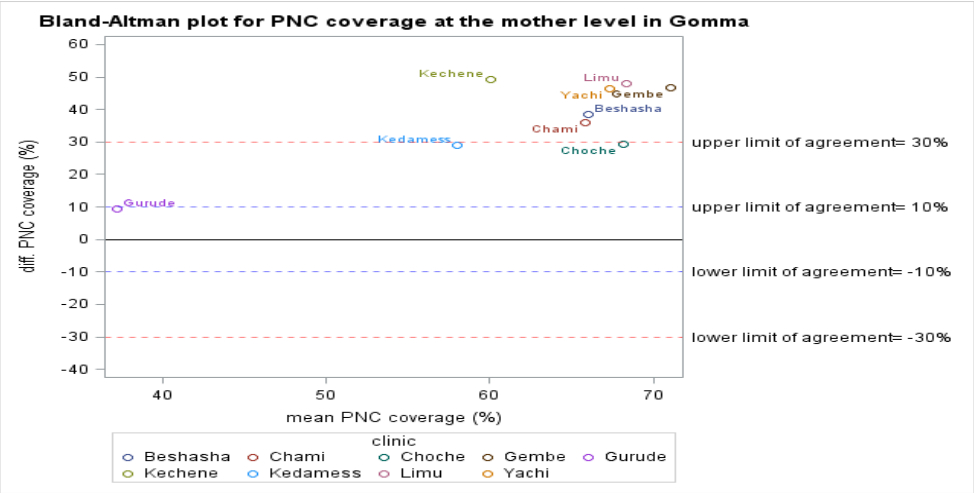

Bland-Altman plot for stillbirth rate in Seka Chekorsa
diff. stillbirth rate (%)
mean stillbirth rate (%)
upper 95% CI limit of median= 0.16
upper limit of agreement= 0.16
Median= 0
lower 95% CI limit of median= -0.75
lower limit of agreement= -0.95
clinic
beka detu gudo kechema
lilu seka sentemma wekito

Figure A. 6 Bland-Altman plots with pre-defined limits of agreement for the concordance between maternal and child health indicator coverage estimates from the HMIS and the survey in Gomma








Bland-Altman plot for PNC coverage at the mother level in Gomma
diff. PNC coverage (%)
mean PNC coverage (%)
Kechene
Limu
Yachi
Gembe
Beshasha
Chami
Kedamess
Choche
Gurude
upper limit of agreement= 30%
upper limit of agreement= 10%
lower limit of agreement= -10%
lower limit of agreement= -30%
clinic
Beshasha
Chami
Choche
Gembe
Gurude
Kechene
Kedamess
Limu
Yachi

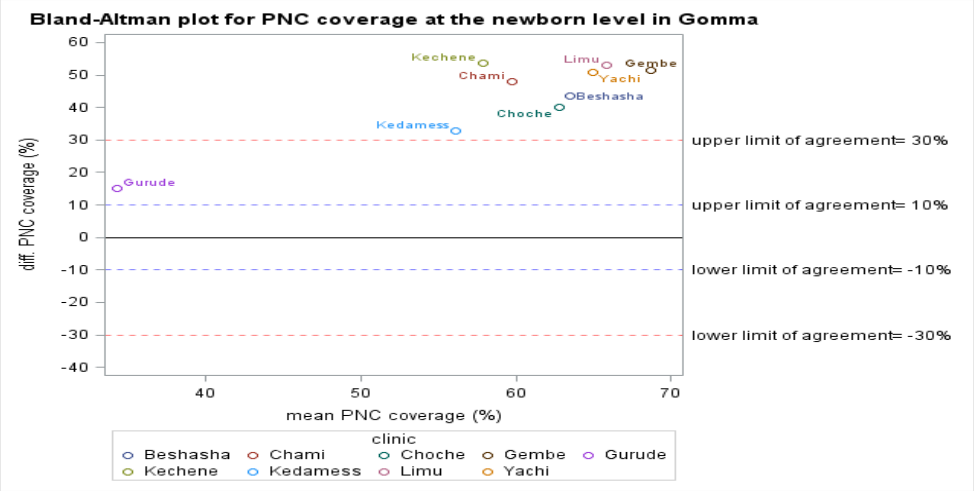
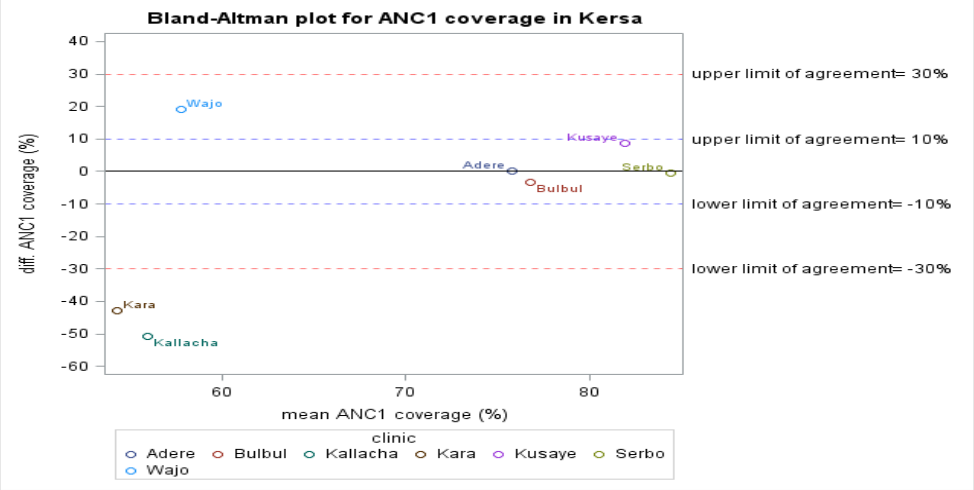
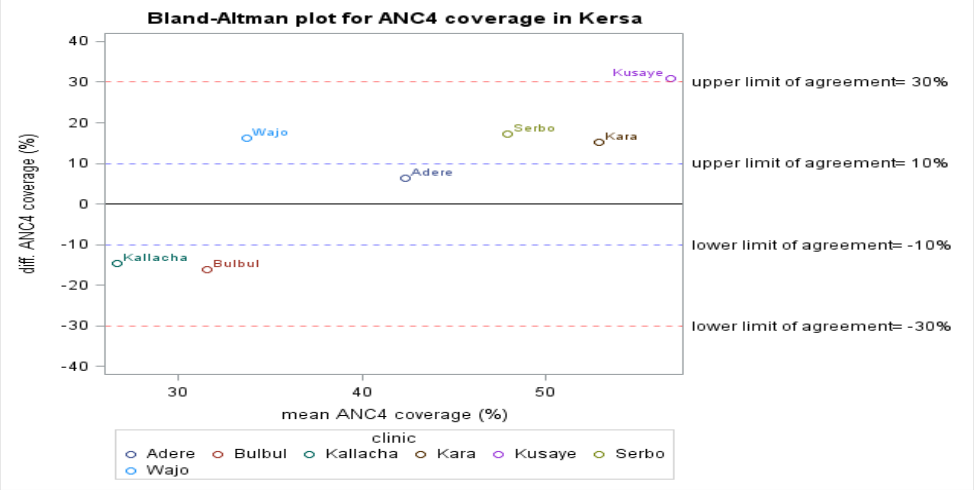
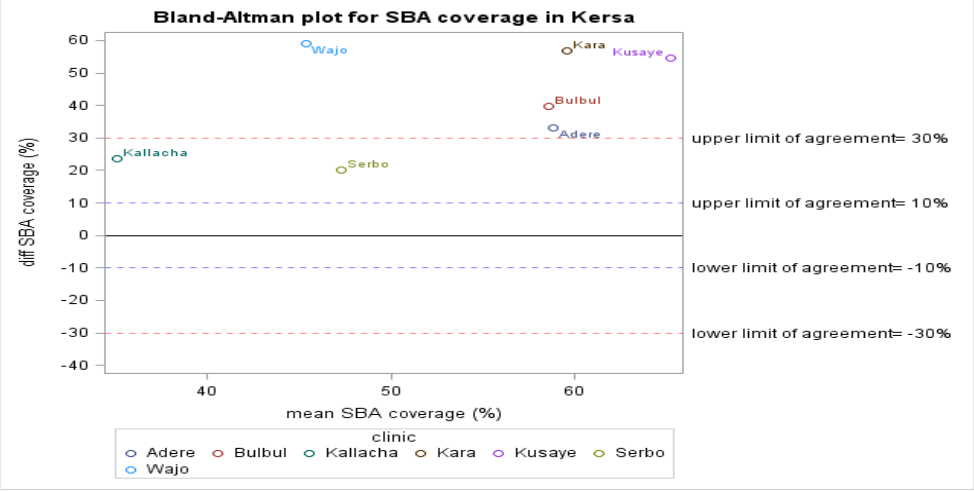
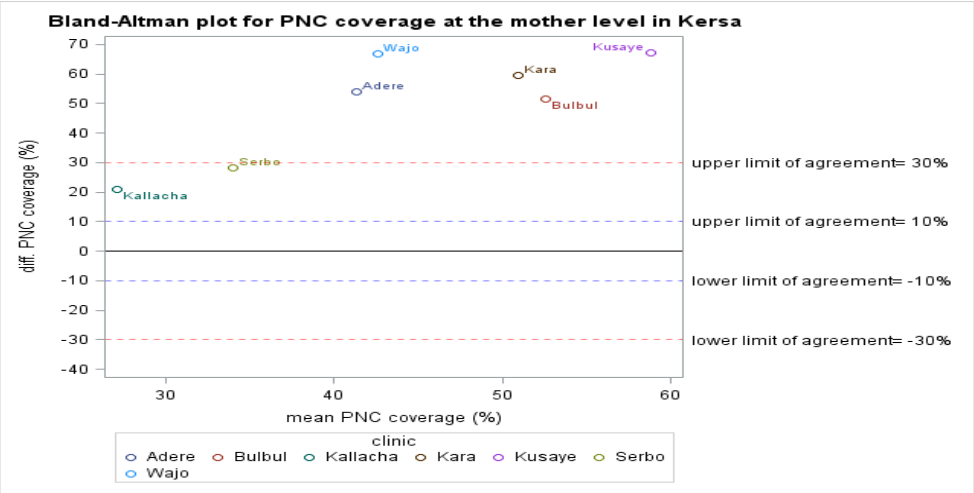

Bland-Altman plot for PNC coverage at the newborn level in Gomma
diff. PNC coverage (%)
mean PNC coverage (%)
Kechene
Limu
Gembe
Yachi
Chami
Beshasha
Choche
Kedamess
Gurude
upper limit of agreement= 30%
upper limit of agreement= 10%
lower limit of agreement= -10%
lower limit of agreement= -30%
clinic
Beshasha
Chami
Choche
Gembe
Gurude
Kechene
Kedamess
Limu
Yachi

Figure A. 7 Bland-Altman plots with pre-defined limits of agreement for the concordance between maternal and child health indicator coverage estimates from the HMIS and the survey in Kersa








Bland-Altman plot for PNC coverage at the mother level in Kersa
diff. PNC coverage (%)
mean PNC coverage (%)
Wajo
Kusaye
Kara
Adere
Bulbul
Serbo
Kallacha
upper limit of agreement= 30%
upper limit of agreement= 10%
lower limit of agreement= -10%
lower limit of agreement= -30%
clinic
Adere Bulbul Kallacha Kara Kusaye Serbo Wajo

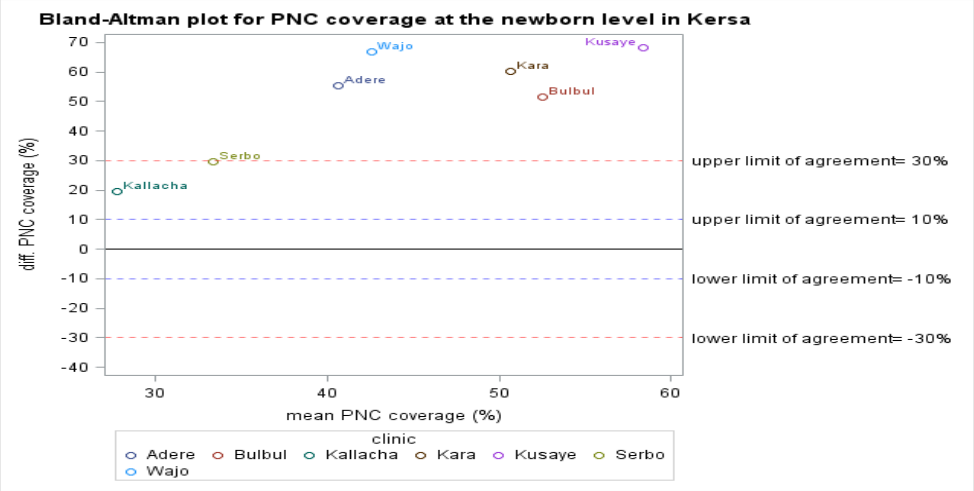
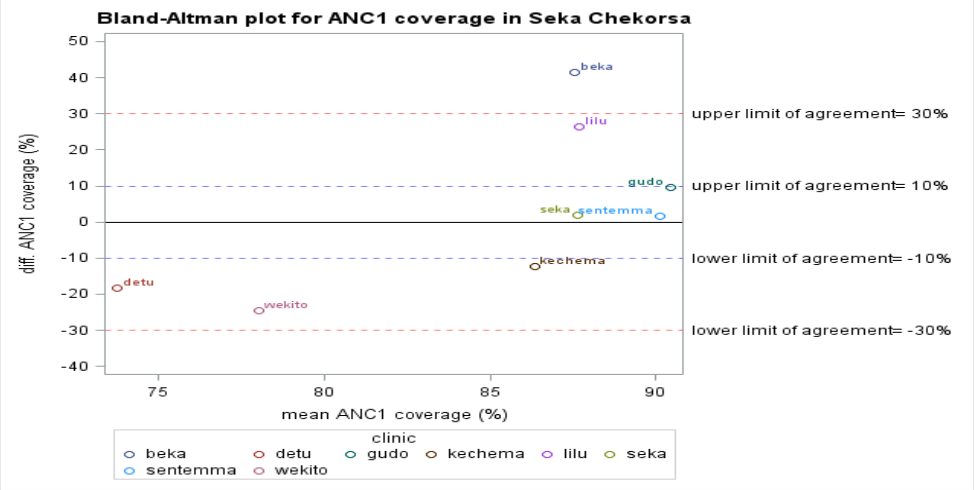
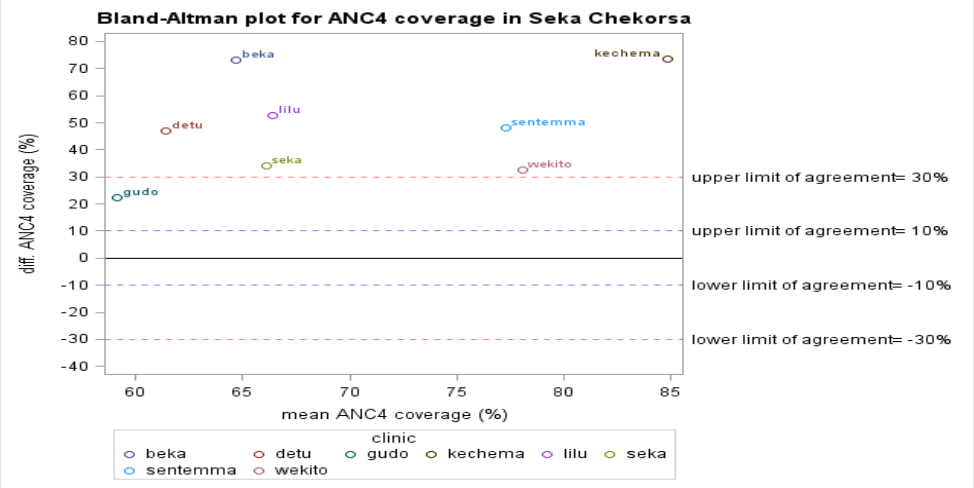
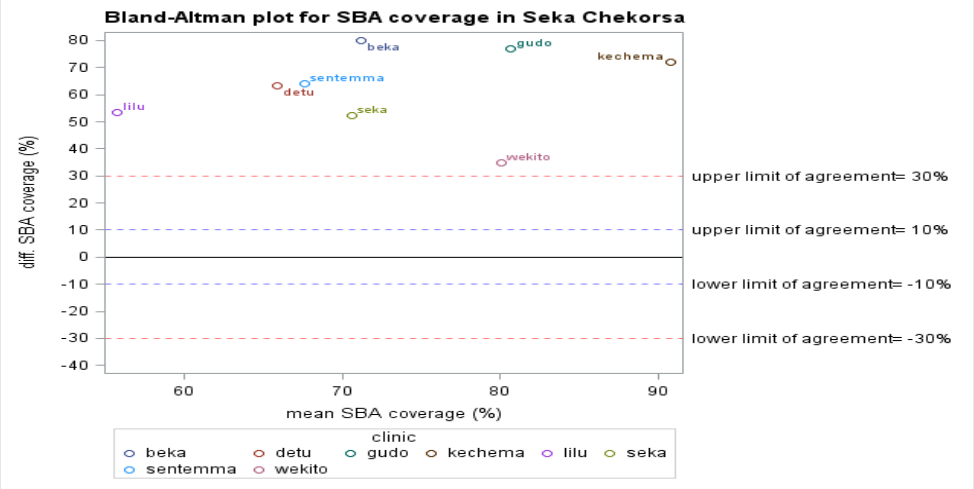
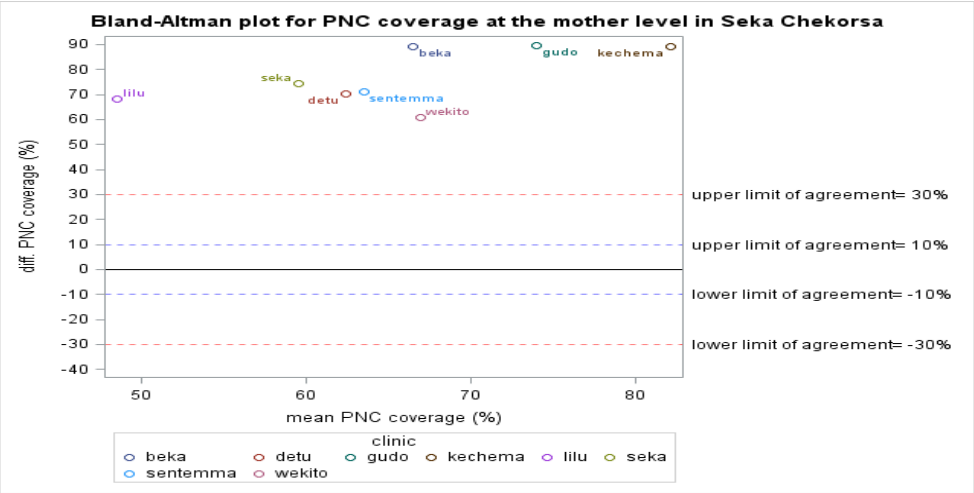

Bland-Altman plot for PNC coverage at the newborn level in Kersa
diff. PNC coverage (%)
mean PNC coverage (%)
Wajo
Kusaye
Kara
Adere
Bulbul
Serbo
Kallacha
upper limit of agreement= 30%
upper limit of agreement= 10%
lower limit of agreement= -10%
lower limit of agreement= -30%
clinic
Adere Bulbul Kallacha Kara Kusaye Serbo Wajo

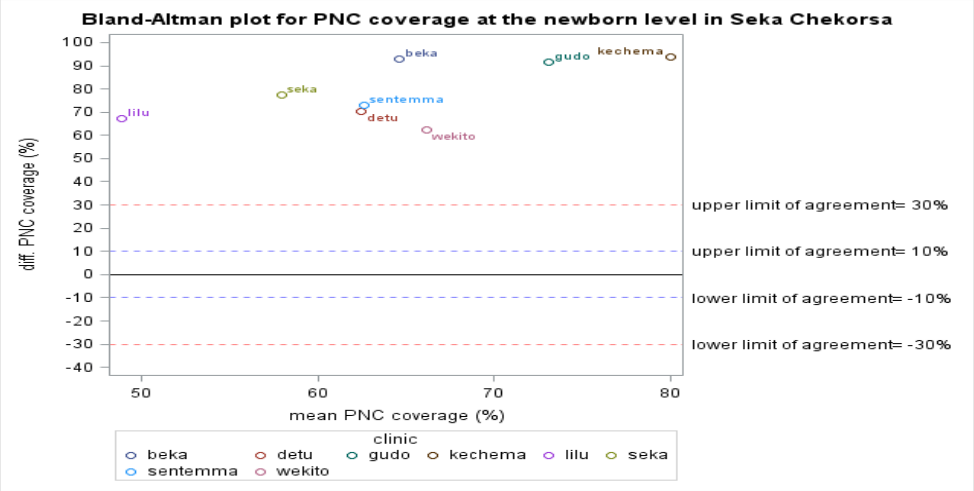
Figure A. 8 Bland-Altman plots with pre-defined limits of agreement for the concordance between maternal and child health indicator coverage estimates from the HMIS and the survey in Seka Chekorsa








Bland-Altman plot for PNC coverage at the mother level in Seka Chekorsa
diff. PNC coverage (%)
mean PNC coverage (%)
beka
gudo
kechema
seka
lilu
detu
sentemma
wekito
upper limit of agreement= 30%
upper limit of agreement= 10%
lower limit of agreement= -10%
lower limit of agreement= -30%
clinic
beka
detu
gudo
kechema
lilu
seka
sentemma
wekito


Bland-Altman plot for PNC coverage at the newborn level in Seka Chekorsa
diff. PNC coverage (%)
mean PNC coverage (%)
beka
gudo
kechema
seka
sentemma
lilu
detu
wekito
upper limit of agreement= 30%
upper limit of agreement= 10%
lower limit of agreement= -10%
lower limit of agreement= -30%
clinic
beka
detu
gudo
kechema
lilu
seka
sentemma
wekito

Appendix B

File Number: H10-15-25C **Date (mm/dd/yyyy):** 11/18/2016

Université d'Ottawa University of Ottawa
Bureau d'éthique et d'intégrité de la recherche Office of Research Ethics and Integrity

Ethics Approval Notice

Health Sciences and Science REB

Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

First Name	Last Name	Affiliation	Role
Manisha	Kulkarni	Medicine / Medicine	Supervisor
Marie-Hélène	Roy-Gagnon	Medicine / Medicine	Co-Supervisor
Mariame	Oumar Ouedraogo	Medicine / Medicine	Student Researcher

File Number: H10-15-25C

Type of Project: Master's Thesis

Title: Assessment of the Malaria Burden and Utilization of Key Malaria and Pregnancy Complications Control Measures among Women in Jimma Zone, Ethiopia

Approval Date (mm/dd/yyyy)	Expiry Date (mm/dd/yyyy)	Approval Type
11/18/2016	11/17/2017	Approved

Special Conditions / Comments:
N/A

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Appendix C

Precision and Power Calculations

Precision and power calculations were performed prior to the analysis to determine whether the fixed sample size of 3,840 women was large enough to address the research objectives.

(a) Antenatal care attendance in Jimma Zone

The sample size formula for a single proportion was used to determine the precision to estimate the proportion of women who attended at least one ANC visit (ANC1) and four visits (ANC4).[1] Considering the proportions of 50.7% for ANC1 and 22.1% for ANC4 reported in the 2016 Ethiopian Demographic Health Survey for Oromia Region[2], a conservative proportion value of 50%, and a design effect of 2[3], the precision around the estimation of ANC1 attendance with our fixed sample size of 3,840 women was estimated as 1.6%. Ranges from 1.3 to 1.6% were obtained for ANC4.

(b) Coverage of mosquito nets in Jimma Zone

The precision or standard error around the estimates of interest (i.e. proportions of pregnant women who owned and used a mosquito net) was determined from the sample size equation for a single proportion. Assuming that 58.5% of pregnant women are part of a household owning a net and 41.7% sleep under a net at night in Oromia region[4] and considering a design effect of 2, as reported in past literature[3], the fixed sample of 3,840 women will provide an estimated precision of 1.57% for both the net ownership and utilization. These precision approximations indicate that the sample size is large enough to detect, with very small variation, similar proportions of women

who own and sleep under a mosquito net. A proportion of 50% is considered the most conservative value and results in a possible precision of 1.59%.

(c) Mosquito nets utilization and risk of malaria infection

The power to detect specific odds ratios of the effect of bed nets on malaria infection was calculated using standard power calculations for logistic regression models.[5] The proportion of pregnant women using a bed net in the Oromia region (i.e. 41.5%) was first used to estimate the standard deviation necessary for the power calculation.[4] Given a marginal malaria prevalence in pregnant women of 2.5%[6], an odds ratio of 0.69 for the effect of mosquito nets possession on malaria infection in children, as reported by Haji et al.[7], a two-sided alpha level of 5%, and a design effect of 2, the power to detect a significant relationship was 24%.

As the effect of bed net possession and utilization on malaria infection risk may differ from one study to another, it is best to estimate a range of power values. Haji and coworkers provided a confidence interval, ranging from 0.56 to 0.85[7], for their odds ratio value, which was then used to estimate a range and resulted in power values fluctuating from approximately 50% to 8% of distinguishing a significant association between mosquito net ownership and utilization during pregnancy and malaria infection. Power calculation adjusting for the correlation among the individual and household covariates included in the regression model should also be taken into account. Considering a fair correlation among the variables (i.e. 0.5), a power of 16% was obtained.

References

1. Charan, J. & Biswas, T. How to calculate sample size for different study designs in medical research? *Indian J. Psychol. Med.* **35,** 121–6 (2013).

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3. Birhanu, Z. *et al.* Access to and use gaps of insecticide-treated nets among communities in Jimma Zone, southwestern Ethiopia: baseline results from malaria education interventions. *BMC Public Health* **15,** 1304 (2015).

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5. Vittinghoff, E., Glidden, D. V., Shiboski, S. C. & McCulloch, C. E. *Regression methods in biostatistics : linear, logistic, survival, and repeated measures models*. (2011). at <https://books.google.ca/books/about/Regression_Methods_in_Biostatistics.html?id=fXC1l1JeqLoC&redir_esc=y>

6. Newman, R. D. *et al.* Burden of Malaria during Pregnancy in Areas of Stable and Unstable Transmission in Ethiopia during a Nonepidemic Year. *J. Infect. Dis.* **187,** 1765–1772 (2003).

7. Haji, Y., Fogarty, A. W. & Deressa, W. Prevalence and associated factors of malaria among febrile children in Ethiopia: A cross-sectional health facility-based study. *Acta Trop.* **155,** 63–70 (2016).

Appendix D

SAS codes for second manuscript modeling

```
*simple model for effect of bed ownership on malaria infection;
proc glimmix data=correction_x;
class PHCU malaria net_own;
model malaria(event='1')= net_own/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*simple model for effect of always using a net on malaria infection;
proc glimmix data=correction_x;
class PHCU malaria net_always ;
model malaria(event='1')= net_always/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*age;
proc glimmix data=correction_x;
class PHCU malaria age;
model malaria(event='1')= age/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;


*occupation;
proc glimmix data=correction_x;
class PHCU malaria employment;
model malaria(event='1')= employment/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*education;
proc glimmix data=correction_x;
class PHCU malaria educ_x;
model malaria(event='1')= educ_x/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*wealth;
proc glimmix data=correction_x;
class PHCU malaria quintile;
model malaria(event='1')= quintile/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*household size;
proc glimmix data=correction_x;
class PHCU malaria size;
model malaria(event='1')= size/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;
```

```
*parity;
proc glimmix data=correction_x;
class PHCU malaria parity;
model malaria(event='1')= parity/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*irs;
proc glimmix data=correction_x;
class PHCU malaria irs;
model malaria(event='1')= irs/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*negative confounding? - Assessed for variables associated both with outcome
and main predictor;
*age;
proc glimmix data=correction_x;
class PHCU malaria net_always age ;
model malaria(event='1')= net_always age/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*occupation;
proc glimmix data=correction_x;
class PHCU malaria net_always employment ;
model malaria(event='1')= net_always employment/ dist=binary link=logit
solution OR;
random intercept/subject=PHCU;
run;

*education;
proc glimmix data=correction_x;
class PHCU malaria net_always educ_x ;
model malaria(event='1')= net_always educ_x/ dist=binary link=logit solution
OR;
random intercept/subject=PHCU;
run;


*interaction - model too complex and proportion too low to assess interaction;
*age;
proc glimmix data=test3 method=RMPL;
class PHCU malaria net_always age_x;
model malaria(event='1')= net_always age_x net_always*age_x/ dist=binary
link=logit solution OR;
random intercept/subject=PHCU;
run;

*employment;
proc glimmix data=test3;
class PHCU malaria net_always employ_x;
model malaria(event='1')= net_always employ_x net_always*employ_x/ dist=binary
link=logit solution OR;
random intercept/subject=PHCU;
run;
```

```
*education;
proc glimmix data=correction_x;
class PHCU malaria net_always educ_x;
model malaria(event='1')= net_always educ_x net_always*educ_x/ dist=binary
link=logit solution OR;
random intercept/subject=PHCU;
run;

*irs;
proc glimmix data=correction_x;
class PHCU malaria net_always irs ;
model malaria(event='1')= net_always irs net_always*irs/ dist=binary
link=logit solution OR;
random intercept/subject=PHCU;
run;


*all variables in one model;
proc glimmix data=correction_x;
class PHCU malaria net_always age employment educ_x quintile size parity irs ;
model malaria(event='1')= net_always age employment educ_x quintile size
parity irs/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

------------------------------------------------------------------------------
------------;
*Association bed net ownership and ANC;

*first multivariate logistic regression model with all variables that had
significant chi-sqaured analysis or were barely significant;
proc glimmix data=merging.final_survey order=formatted;
format anc1 anc1_.;
class PHCU anc1 age educ employment quintile size child dem45;
model bed_own(event='1')=anc1 age educ employment quintile size child dem45/
dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

* simple logisitc regression models;
proc glimmix data=merging.final_survey order=formatted;
format anc1 anc1_.;
class PHCU anc1;
model bed_own(event='1')=anc1/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*effect of age;
proc glimmix data=merging.final_survey;
class PHCU age;
model bed_own(event='1')= age/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

* effect of education;
proc glimmix data=merging.final_survey;
class PHCU educ;
```

```
model bed_own(event='1')= educ/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*effect of wealth;
proc glimmix data=merging.final_survey order=formatted;;
class PHCU quintile;
model bed_own(event='1')= quintile/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*effect of household size;
proc glimmix data=merging.final_survey;
class PHCU size;
model bed_own(event='1')=size/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*effect IRS;
proc glimmix data=merging.final_survey;
class PHCU irs;
model bed_own(event='1')=irs/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*effect district;
proc glimmix data=merging.final_survey;
class PHCU cp17;
model bed_own(event='1')=cp17/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;


*evaluate confounding;
*with age;
proc glimmix data=merging.final_survey order=formatted;
format anc1 anc1_.;
class PHCU anc1 age;
model bed_own(event='1')=anc1 age/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with education;
proc glimmix data=merging.final_survey;
format anc1 anc1_. educ educ.;
class PHCU anc1 educ;
model bed_own(event='1')=anc1 educ/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with wealth;
proc glimmix data=merging.final_survey order=formatted;
format anc1 anc1_. quintile wealth.;
class PHCU anc1 quintile;
model bed_own(event='1')=anc1 quintile/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;
```

```
*with occupation status;
proc glimmix data=merging.final_survey;
format anc1 anc1_.;
class PHCU anc1 employment;
model bed_own(event='1')=anc1 employment/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with household size;
proc glimmix data=merging.final_survey;
format anc1 anc1_.;
class PHCU anc1 size;
model bed_own(event='1')=anc1 size/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with the number of children;
proc glimmix data=merging.final_survey;
format anc1 anc1_.;
class PHCU anc1 child;
model bed_own(event='1')=anc1 child/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with IRS;
proc glimmix data=merging.final_survey;
format anc1 anc1_.;
class PHCU anc1 dem45;
model bed_own(event='1')=anc1 dem45/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*effect modification;
*with age;
proc glimmix data=merging.final_survey order=formatted;
format anc1 anc1_.;
class PHCU anc1 age;
model bed_own(event='1')= anc1|age/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with education;
proc glimmix data=merging.final_survey order=formatted;
format anc1 anc1_. educ educ.;
class PHCU anc1 educ;
model bed_own(event='1')=anc1|educ/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with wealth;
proc glimmix data=merging.final_survey order=formatted;
format anc1 anc1_. quintile wealth.;
class PHCU anc1 quintile;
model bed_own(event='1')=anc1|quintile/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;
```

```
*with occupation status;
proc glimmix data=merging.final_survey;
format anc1 anc1_.;
class PHCU anc1 employment;
model bed_own(event='1')=anc1|employment/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with household size;
proc glimmix data=merging.final_survey;
format anc1 anc1_.;
class PHCU anc1 size;
model bed_own(event='1')=anc1|size/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with the number of children;
proc glimmix data=merging.final_survey;
format anc1 anc1_.;
class PHCU anc1 child;
model bed_own(event='1')=anc1|child/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with IRS;
proc glimmix data=merging.final_survey;
format anc1 anc1_.;
class PHCU anc1 dem45;
model bed_own(event='1')=anc1|dem45/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*singificant interactions included in full model;
proc glimmix data=merging.final_survey order=formatted;
format anc1 anc1_.;
class PHCU anc1 age educ employment quintile size child dem45;
model bed_own(event='1')=anc1 age educ employment quintile size child dem45
anc1*educ anc1*size anc1*child/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run; *no interaction was significant;

*final model;
proc glimmix data=merging.final_survey;
class PHCU anc1 age educ employment quintile size irs;
model bed_own(event='1')=anc1 age educ employment quintile size irs/
dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;



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```

```
* Association bed net utilization and ANC;

*first simple logisitc regression;
proc glimmix data=merging.final_survey order=formatted;
class PHCU anc1;
model net_always(event='1')=anc1/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*effect of age;
proc glimmix data=merging.final_survey order=formatted;
class PHCU age;
model net_always(event='1')=age/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*effect of ethnic group;
proc glimmix data=merging.final_survey order=internal;
class PHCU ethnic;
model net_always(event='1')=ethnic/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*effect of education level;
proc glimmix data=merging.final_survey order=internal;
class PHCU educ;
model net_always(event='1')=educ/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*effect of wealth;
proc glimmix data=merging.final_survey order=internal;
class PHCU quintile;
model net_always(event='1')=quintile/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*effect of irs;
proc glimmix data=merging.final_survey order=internal;
class PHCU irs;
model net_always(event='1')=irs/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*effect of district?;
proc glimmix data=merging.final_survey order=internal;
class PHCU cp17;
model net_always(event='1')=cp17/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*first multivariable logsitic regression;
proc glimmix data=merging.final_survey;
class PHCU anc1 ethnic age educ  quintile irs;
model net_always(event='1')=anc1 ethnic age educ quintile irs/ dist=binary
link=logit solution OR;
random intercept/subject=PHCU;
```

```
run;

*evaluate confounding;
*with age;
proc glimmix data=merging.final_survey;
class PHCU anc1 age;
model net_always(event='1')=anc1 age/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with education;
proc glimmix data=merging.final_survey;
class PHCU anc1 educ;
model net_always(event='1')=anc1 educ/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with ethnic group;
proc glimmix data=merging.final_survey;
class PHCU anc1 ethnic;
model net_always(event='1')=anc1 ethnic/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with wealth;
proc glimmix data=merging.final_survey;
class PHCU anc1 quintile;
model net_always(event='1')=anc1 quintile/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*with irs;
proc glimmix data=merging.final_survey;
class PHCU anc1 irs;
model net_always(event='1')=anc1 irs/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;


*test for effect modification;
*interaction with age;
proc glimmix data=merging.final_survey order=formatted;
class PHCU anc1 age;
model net_always(event='1')=anc1 age anc1*age/ dist=binary link=logit solution
OR;
random intercept/subject=PHCU;
run;

*interaction with ethnicity;
proc glimmix data=merging.final_survey;
class PHCU anc1 ethnic;
model net_always(event='1')=anc1 ethnic anc1*ethnic/ dist=binary link=logit
solution OR;
random intercept/subject=PHCU;
run;

*interaction with education;
```

```
proc glimmix data=merging.final_survey;
class PHCU anc1 educ;
model net_always(event='1')=anc1 educ anc1*educ/ dist=binary link=logit
solution OR;
random intercept/subject=PHCU;
run;

*interaction with wealth;
proc glimmix data=merging.final_survey;
class PHCU anc1 quintile;
model net_always(event='1')=anc1 quintile anc1*quintile/ dist=binary
link=logit solution OR;
random intercept/subject=PHCU;
run;

*interaction with irs;
proc glimmix data=merging.final_survey;
class PHCU anc1 irs;
model net_always(event='1')=anc1 irs anc1*irs/ dist=binary link=logit solution
OR;
random intercept/subject=PHCU;
run;

*interaction with district;
proc glimmix data=merging.final_survey;
class PHCU anc1 cp17;
model net_always(event='1')=anc1 cp17 anc1*cp17/ dist=binary link=logit
solution OR;
random intercept/subject=PHCU;
run;

*final model;
proc glimmix data=merging.final_survey;
class PHCU anc1 age ethnic educ quintile irs;
model net_always(event='1')=anc1 age ethnic educ quintile irs/ dist=binary
link=logit solution OR;
random intercept/subject=PHCU;
run;

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*Determinants of antenatal care - at least one visit;
*simple logistic regression models - adjusted for clustering by PHCU;
*age;
proc glimmix data=merging.final_survey;
class PHCU anc1 age;
model anc1(event='0')=age / dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;
*education - model not converging because of zero value for one of group
(combine secondary with higher level);
proc glimmix data=test;
class PHCU anc1 educ_x;
model anc1(event='0')=educ_x/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
```

```
run;

*ethnic group;
proc glimmix data=merging.final_survey;
class PHCU anc1 ethnic;
model anc1(event='0')=ethnic/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*occupation status;
proc glimmix data=merging.final_survey;
class PHCU anc1 employment;
model anc1(event='0')=employment/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*wealth;
proc glimmix data=merging.final_survey;
class PHCU anc1 quintile;
model anc1(event='0')=quintile/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*decision-making;
proc glimmix data=merging.final_survey;
class PHCU anc1 decision;
model anc1(event='0')=decision/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*household size;
proc glimmix data=merging.final_survey;
class PHCU anc1 size;
model anc1(event='0')=size/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*number of children/HH;
proc glimmix data=merging.final_survey;
class PHCU anc1 child;
model anc1(event='0')=child/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*health problems during pregnancy;
proc glimmix data=merging.final_survey;
class PHCU anc1 problem_preg;
model anc1(event='0')=problem_preg/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*number of livebirth;
proc glimmix data=merging.final_survey;
class PHCU anc1 livebirth;
model anc1(event='0')=livebirth/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;
```

```
*stillbirth;
proc glimmix data=merging.final_survey;
class PHCU anc1 still;
model anc1(event='0')=still/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*pregnancy intention;
proc glimmix data=merging.final_survey;
class PHCU anc1 intention;
model anc1(event='0')=intention/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*number of child-deaths;
proc glimmix data=merging.final_survey;
class PHCU anc1 child_death;
model anc1(event='0')=child_death/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*first multiple logistic regression model (including also variables that had
at least p-value<0.2);
proc glimmix data=test;
class PHCU anc1 age ethnic educ_x employment quintile decision size child
problem_preg livebirth still;
model anc1(event='0')=age ethnic educ_x employment quintile decision size
child problem_preg livebirth still/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*final model;
proc glimmix data=test;
class PHCU anc1 age ethnic educ_x employment quintile decision size child
problem_preg livebirth intention child_death;
model anc1(event='0')=age ethnic educ_x employment quintile decision size
child problem_preg livebirth intention child_death/ dist=binary link=logit
solution OR;
random intercept/subject=PHCU;
run;

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*Determinants of antenatal care - 4 visits;
*simple logisitc regression models;
*age;
proc glimmix data=merging.final_survey;
class PHCU anc4 age;
model anc4(event='1')=age/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*education;
proc glimmix data=merging.final_survey;
class PHCU anc4 educ;
```

```
model anc4(event='1')=educ/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*wealth;
proc glimmix data=merging.final_survey;
class PHCU anc4 quintile;
model anc4(event='1')=quintile/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*decision;
proc glimmix data=merging.final_survey;
class PHCU anc4 decision;
model anc4(event='1')=decision/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*household size;
proc glimmix data=merging.final_survey;
class PHCU anc4 size;
model anc4(event='1')=size/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*children/HH;
proc glimmix data=merging.final_survey;
class PHCU anc4 child;
model anc4(event='1')=child/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*problems during pregnancy;
proc glimmix data=merging.final_survey;
class PHCU anc4 problem_preg;
model anc4(event='1')=problem_preg/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*number of livebirth;
proc glimmix data=merging.final_survey;
class PHCU anc4 livebirth;
model anc4(event='1')=livebirth/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*number of stillbirth;
proc glimmix data=merging.final_survey;
class PHCU anc4 still;
model anc4(event='1')=still/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*pregnancy intention;
proc glimmix data=merging.final_survey;
class PHCU anc4 intention;
model anc4(event='1')=intention/ dist=binary link=logit solution OR;
```

```
random intercept/subject=PHCU;
run;

*include all predictors in model;
proc glimmix data=merging.final_survey initglm;
class PHCU anc4 age educ quintile decision size child problem_preg livebirth
still;
model anc4(event='0')=age educ quintile decision size child problem_preg
livebirth still/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*remove non-significant variables (at p=0.05) - removed age size livebirth;
proc glimmix data=merging.final_survey initglm;
class PHCU anc4 educ quintile decision child problem_preg still;
model anc4(event='0')=educ quintile decision child problem_preg still/
dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*final model;
proc glimmix data=merging.final_survey;
class PHCU anc4 age educ quintile decision size child problem_preg livebirth
still intention;
model anc4(event='1')=age educ quintile decision size child problem_preg
livebirth still intention/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

*stillbirth interacting with other variables?;
proc glimmix data=merging.final_survey;
class PHCU anc4 age still;
model anc4(event='1')= age still/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

proc glimmix data=merging.final_survey;
class PHCU anc4 age still;
model anc4(event='1')= age still age*still/ dist=binary link=logit solution
OR;
random intercept/subject=PHCU;
run;

proc glimmix data=merging.final_survey;
class PHCU anc4 still educ;
model anc4(event='1')= still educ/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

proc glimmix data=correction_x;
class PHCU anc4 still educ_x;
model anc4(event='1')= still educ_x still*educ_x/ dist=binary link=logit
solution OR;
random intercept/subject=PHCU;
run;

proc glimmix data=merging.final_survey;
```

```
class PHCU anc4 still quintile;
model anc4(event='1')= still quintile/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

proc glimmix data=correction_x;
class PHCU anc4 still quintile;
model anc4(event='1')= still quintile still*quintile/ dist=binary link=logit
solution OR;
random intercept/subject=PHCU;
run;

proc glimmix data=merging.final_survey;
class PHCU anc4 still decision;
model anc4(event='1')= still decision/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

proc glimmix data=correction_x;
class PHCU anc4 still decision;
model anc4(event='1')= still decision still*decision/ dist=binary link=logit
solution OR;
random intercept/subject=PHCU;
run;

proc glimmix data=merging.final_survey;
class PHCU anc4 still problem_preg;
model anc4(event='1')= still problem_preg/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

proc glimmix data=correction_x;
class PHCU anc4 still problem_preg;
model anc4(event='1')= still problem_preg still*problem_preg/ dist=binary
link=logit solution OR;
random intercept/subject=PHCU;
run;

proc glimmix data=merging.final_survey;
class PHCU anc4 still intention;
model anc4(event='1')= still intention/ dist=binary link=logit solution OR;
random intercept/subject=PHCU;
run;

proc glimmix data=correction_x;
class PHCU anc4 still intention;
model anc4(event='1')= still intention still*intention/ dist=binary link=logit
solution OR;
random intercept/subject=PHCU;
run;
```